REPUBLIC OF KENYA

LEARNING GUIDE

FOR

ELECTRICAL INSTALLATION

LEVEL 4

TVET CDACC

P.O. BOX 15745-00100

NAIROBI

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Council Secretary/CEO
TVET Curriculum Development, Assessment and Certification Council
P.O. Box 15745–00100
Nairobi, Kenya
Email: info@tvetcdacc.go.ke

FOREWORD

The provision of quality education and training is fundamental to the Government's overall strategy for social economic development. Quality education and training will contribute to achievement of Kenya's development blue print and sustainable development goals. Reforms in education are necessary to align the sector to the provisions of the Constitution of Kenya 2010. This triggered the formulation of the Policy Framework on "Reforming Education and Training in Kenya" (Sessional Paper No. 1 of 2019). A key provision of this policy is the radical change in the design, development and delivery of Technical and Vocational Education and Training (TVET) which is the key to unlocking the country's potential for industrialization. This policy requires that training in TVET be Competency Based, Curriculum development be industry led, certification be based on demonstration of competence and that mode of delivery allows for multiple entry and exit in TVET programs.

The State Department for Vocational and Technical Training (VTT) has a responsibility of facilitating the process of inculcating knowledge, skills and attitudes necessary for catapulting the nation to a globally competitive country, hence the paradigm shift to embrace Competency Based Education and Training (CBET) to address the mismatch between skills acquired through training and skills needed by industry as well as increase the global competitiveness of Kenyan labor force. The Technical and Vocational Education and Training Act No. 29 of 2013 and the Sessional Paper No. 1 of 2019 on Reforming Education and Training in Kenya, emphasizes the need to reform curriculum development, assessment and certification to respond to the unique needs of the industry.

This learning guide has been developed to support the implementation of CBET curriculum in Electrical Installation Level 4 and is intended to guide the trainee through the learning process. It is my conviction that this learning guide will play a critical role towards supporting the development of competent human resource for Electrical Installation sector's growth and sustainable development.

PRINCIPAL SECRETARY, VOCATIONAL AND TECHNICAL TRAINING

MINISTRY OF EDUCATION

PREFACE

Kenya Vision 2030 is anticipated to transform the country into a newly industrializing, "middle-income country providing a high-quality life to all its citizens by the year 2030". The Sustainable Development Goals (SDGs) number four that focuses on inclusive and equitable quality education and promotion of lifelong learning for all, further affirm that education and training is an important driver to economic development for any country. Kenya intends to create a globally competitive and adaptive human resource base to meet the requirements of a rapidly industrializing economy.

TVET CDACC has a responsibility of facilitating the process of inculcating knowledge, skills and attitudes necessary for catapulting the nation to a globally competitive country, hence the paradigm shift to embrace Competency Based Education and Training (CBET) to address the mismatch between skills acquired through training and skills needed by industry as well as increase the global competitiveness of Kenyan labor force. The Technical and Vocational Education and Training Act No. 29 of 2013 and the Sessional Paper No. 1 of 2019 on Reforming Education and Training in Kenya, emphasizes the need to reform curriculum development, assessment and certification to respond to the unique needs of the industry.

To effectively implement CBET curriculum in Electrical Installation Level 4, this learning guide has been designed and organized with clear interactive learning activities for each learning outcome of every unit of learning. The guide further provides information sheet, self-assessment items, tools, equipment, supplies, and materials necessary for the particular learning outcome. This is aimed at imparting the relevant knowledge, requisite skills and the right attitude for work.

I am grateful to the trainers involved in the development of this learning guide.

Prof. CHARLES M. M. ONDIEKI, PhD, FIET (K), Con. Eng Tech.

ACKNOWLEDGEMENT

This learning guide has been designed and developed to support the implementation of Competency Based Education and Training (CBET) curricula in Kenya. The learning guide is intended to support learning by providing practical and theoretical learning activities, simplified content and self-assessment items to guide the trainee in the learning process.

I recognize with appreciation the critical role of trainers in developing this learning guide and ensuring its alignment with National Occupational Standards (OS) and CBET curriculum. I am convinced that this learning guide will support trainees' acquisition of knowledge, skills and right attitude needed for work in Electrical Installation sector.

DR. LAWRENCE GUANTAI M'ITONGA, PhD
COUNCIL SECRETARY/CEO
TVET CDACC

ACRONYMS

CBET	Competence Based Education and Training
NCA	National Construction Authority
NEMA	National Environment Management Authority
OSHA	Occupational Safety and Health Act.

TABLE OF CONTENT

LIST OF TABLES

Background Information

This learning guide will enable the trainee to acquire competencies required by a technician in order to apply algebra, apply coordinate geometry, and carry out mensuration, matrix methods, and vectors.

Layout of the Trainee Guide

Performance standards: These are obtained from the performance criteria statements in the related unit of competency of the Occupational Standards (OS)

Information Sheet: This section covers information relating to the specific learning outcome. This information should include but not limited to meaning of terms, methods, processes/ procedures/ guidelines, Illustrations (photographs, pictures, videos, charts, plans, digital content links, simulations links) and case studies. This section also provides additional information sources relevant to the learning outcome e.g., books, web links

Learning activities: This section covers practical activities related to the Performance Criteria statements, Knowledge in relation to Performance Criteria as given under content in the curriculum Special instructions related to learning activities

Self-Assessment: This section must be related to the Performance Criteria, Required Knowledge and Skills in the Occupational Standards. This section requires the trainee to evaluate their acquisition of skills, knowledge and attitude in relation to the learning outcome. A variety of assessment items such as written and practical tests which emphasizes on the application of knowledge, skills and attitude is recommended

The self-assessment items should be valid, relevant and comprehensive to the level of qualification in the learning outcome

Tools, equipment, materials and supplies: This section should provide for the requirements of the learning outcome in terms of tools, equipment, supplies and materials. The section should be adequate, relevant and comprehensive for the learning outcome.

References: Information sources should be quoted and presented as required in the APA format

The units of learning covered in this learning guide are as presented in the table below:

COMMON COMPETENCIES

Unit of Learning Code	Unit of Learning Title
ENG/OS/EI/CC/01/4	Apply Engineering mathematics
ENG/OS/EI/CC/02/4	Apply Electrical principles
ENG/OS/EI/CC/03/4	Apply workshop processes
ENG/OS/EI/CC/04/4	Prepare and interpret Technical Drawing

CORE COMPETENCIES

Unit of Learning Code	Unit of Learning Title
ENG/OS/EI/CR/01/4	Perform Electrical Installation
ENG/OS/EI/CR/02/4	Perform Testing of Electrical Installation
ENG/OS/EI/CR/03/4	Perform Electrical system breakdown maintenance

CHAPTER 1: ENGINEERING MATHEMATICS

Unit of learning code ENG/OS/EI/CC/01/4

Related Unit of Competency in Occupational Standard: Apply Engineering Mathematics

1.0 Introduction to the unit of learning

This unit describes the competencies required by a technician in order to apply algebra, apply coordinate geometry, and carry out mensuration, matrix methods, and vectors.

1.2 Summary of Learning Outcomes

1. Apply algebra
2. Apply coordinate geometry
3. Carry out mensuration
4. Apply matrix
5. Apply vectors

1.2.1 Learning Outcome 1: Apply algebra

1.2.1.1 1Introduction

This learning outcome specifies the content of competencies on calculations involving indices and logarithms, solving simultaneous equations, solving quadratic equations and applying calculators in solving mathematical problems

1.2.1.2 Performance Standard

1.1 Calculations involving Indices are performed as per the concept

1.2 Calculations involving Logarithms are performed as per the concept

1.3 Scientific calculator is used in solving mathematical problems in line with manufacturer's manual

1.4 Simultaneous equations are performed as per the rules

Quadratic equations are calculated as per the concept

1.2.1.3 Information Sheet

Decimals

The decimal system of numbers is based on the digits 0 to 9. A number such as 64.28 is called a decimal fraction, a decimal point separating the integer part, i.e. 64 from the fractional part, i.e. 0.28.

Terminating and non-terminating(recurring) decimals

A number which can be expressed exactly as a decimal fraction is called a terminating decimal and those which cannot be expressed exactly as a decimal fraction are called non-terminating decimals.

Thus 3/2 = 1.5 is a terminating decimal while 4/3 = 1.3333… is a non-terminating decimal and can be written as $1.\dot{3}$ called 'one point three recurring'

The answer to recurring decimals may be expressed in two ways depending on the accuracy required:

i.) Correct to a number of significant figures, that is, figures which signifies something

ii.) Correct to a number of decimal places, that is, the number of figures after the decimal point. The last digit in the answer is unaltered if the next digit on the right is in the group of numbers 0,1,2,3,4 but is increased by 1if the next digit on the right is in the group of numbers 5,6,7,8,9 i.e. of the next number on the right is 5 and above.

Example: write 7.6183 into two significant figure and also into three decimal places

i) 7.6183 in two significant figures = 7.62

ii) 7.6183 in three decimal places = 7.618

Example 2: write 9.6149 into two significant figures and also into three decimal places

i) 9.6149 in two significant figures = 9.61

ii) 9.6149 in three decimal places = 9.615

Brackets and factorization

When two or more terms in an algebraic expression contain a common factor, then this factor can be shown outside the bracket. For example:(i) $ab + ac = a(b+c)$

(ii) $6px + 2py - 4pz = 2p(3x + y - 2z)$

This process is known as factorization

Example1: remove the brackets and simplify the expression

$(3a + b) + 2(b + c) -4(c + d)$

Solution

$(3a + b) + 2(b + c) -4(c + d) = 3a +b + 2b + 2c - 4c - 4d$

Collecting like terms

$3a + 3b - 2c - 4d$

Example2: remove the brackets and simplify the expression

$2a - [3\{2(4a - 3b) - 5(5a + 2b)\} + 4a]$

Solution:

Removing the inner brackets

$2a - [3\{8a - 2b - 5a - 10b)\} + 4a]$

Collecting like terms together

$2a - [3\{8a - 5a - 2b - 10b\} + 4a]$

$= 2a - [3\{3a - 12b\} + 4a]$

Removing the 'curly' brackets gives:

$2a - [13a - 36b]$

Removing the outer brackets gives:

$2a - 13a + 36b = -11a + 36b$ *or* $36b - 11a$

Example3: factorize: $x^3 + 3x^2 -x - 3$

Solution

$X^3 + 3x^2 - x - 3 = x^2(x + 3) - x - 3$

-1 is a common factor

$x^2(3 + 3) - x - 3 = x^2(x +3) - (x + 3)$

(x – 3) is now a common factor. Thus

$x^2(x +3) - 1(x +3) = (x + 3)\ (x^2 - 1)$

Base and Index

When a number is written as $y = a^x$ then $x = log_a y$

Then a is the base while x is the index. This is index notation of y

Thus since 1000 = 10^3, then 3 = $log_{10}1000$

(a) Logarithm having a base of 10 are called common logarithm and $\log_{10}$ is usually abbreviated to lg.
    The following values may be checked by using a calculator
    Lg 17.9 = 1.2528…., lg 462.7 = 2.6652…., lg 0.0173 = -1.7619

(b) Logarithms having a base of e (where 'e' is a mathematical constant approximately equal to 2.7186) are called hyperbolic, Napierian or natural logarithm and $\log_e$ is usually abbreviated ln
    The following may be checked by using a calculator: ln 3.15 = 1.1474…,
    ln 362.7 = 5. 8935.., ln 0.156 = -1.8578…

Example 1: write the following statements in logarithmic notation

a) $2^3 = 8$
b) $5^{-2} = 1/25$

Solution

a) $Log_2 8 = 3$
b) $Log_5 1/25 = -2$

Law of indices

The following is a summary of law of indices

i.) $a^m \times a^n = a^{(m + n)}$
ii.) $a^m \div a^n = a^{(m - n)}$

iii.) $(a^m)^n = a^{mn}$

iv.) $a^o = 1$

v.) $a^{-n} = 1/a^n$

vi.) $a^{b/c} = {}^c\sqrt{a^b}$

Example 2: evaluate the following

a) $3^2 x\ 3^4 = 3^{(2+4)} = 3^6 = 729$

b) $3^4 \div 3^2 = 3^{(4-2)} = 3^2 = 9$

c) $(3^2)^3 = 3^{2x3} = 3^6 = 729$

d) $3^0 = 1$

e) $3^{-2} = 1/3^2$

f) $36^{1/2} = \sqrt{36} = 6$

Laws of logarithm

a) $log_a(A \times B) = log_a A + log_a B$

b) $log_a (A/B) = log_a A - log_a B$

c) $log_a A^n = nlog_a A$

Example 3: express the following in terms of log a, log b and log c

a) $log\ (ab) = log\ a + log\ b$

b) $log\ (abc) = log\ a + log\ b + log\ c$

c) $log\ (a/b) = log\ a - log\ b$

d) $log\ (a/bc) = log\ a - log\ b - log\ c$

Logarithmic equations

A logarithmic equation is an equation that involves the logarithm of an expression containing a variable.

If $y = a^x$ then $x = \log_a y$ or $\log_a y = x$

Example 4: Solve the following equations:

(a) $\log x=3$ (b) $\log_2 x=3$ (c) $\log_5 x=-2$

Solution

(a) If $\log x=3$ then $\log_{10} x = 3$ and $x=10^3$, i.e. $\boldsymbol{x = 1000}$

(b) If $\log_2 x=3$ then $\boldsymbol{x = 2^3 = 8}$

(c) If $\log_5 x=-2$ then $x=5^{-2} = 1/5^2$

Example 5: Solve the equation:

$\text{Log}\,(x-1) + \log\,(x+1) = 2\log\,(x+2)$

Solution

$\text{Log}\,(x - 1) + \log\,(x + 1) = \log\,(x - 1)(x + 1)$ from the first law of logarithms

$= \log(x^2 - 1)$

$2\log(x + 2) = \log(x + 2)^2 = \log(x^2 + 4x + 4)$

Hence if $\log\,(x^2 - 1) = \log\,(x^2 + 4x + 4)$

Then $(x^2 - 1) = x^2 + 4x + 4$

i.e. $4x + 4 = -1$

$x = -5/4$

Indicial equations

The laws of logarithms may be used to solve certain equations involving powers – **called indicial.**

For example, to solve, say, $3^x = 27$, logarithms to the base of 10 are taken of both sides,

i.e. $\log_{10} 3^x = \log_{10} 27$

and $x \log_{10} 3 = \log_{10} 27$ by the third law of logarithms.

Rearranging gives $x = \log_{10} 27$

$\log_{10} 3$

$= 1.43136\ldots$

0.4771 . . . =3 which may be readily checked.

*(Note, (log 8/ log 2) is **not** equal to log (8/2))*

Example 6: Solve the equation $2^{x+1} = 3^{2x-5}$ correct to 2 decimal places

Solution

Taking logarithms to base 10 of both sides gives:

$\log_{10} 2^{x+1} = \log_{10} 3^{2x-5}$

i.e. $(x+1) \log_{10} 2 = (2x-5) \log_{10} 3$

$x \log_{10} 2 + \log_{10} 2 = 2x \log_{10} 3 - 5 \log_{10} 3$

$x(0.3010)+(0.3010)=2x(0.4771)-5(0.4771)$

i.e. $0.3010x + 0.3010 = 0.9542x - 2.3855$

Hence $2.3855+0.3010=0.9542x - 0.3010x$

$2.6865=0.6532x$

from which $x= 2.6865/0.6532$

=4.11 correct to 2 dps

Conversion of base

$\log_a b = 1/\log_b a$

Example: solve for x given that $log_2 x - 6log_x 2 = 1$

Solution:

$$log_2 x - 6log_x 2 = 1$$

$$log_2 x - \frac{6}{log_2 x} = 1$$

$$\left(log_2 x\right)^{2-6=} log_2 x$$

Let $log_2 x = p$

$\therefore p^2 - 6 = p \; or \; p^2 - p - 6 = 0$

From which $p^2 - 3p + 2p - 6 = 0$

$$p(p - 3) + 2(p - 3) = 0$$

$$(p - 3)(p + 2) = 0, \ p = 3 \ or \ p = - 2$$

But $log_2 x = p \ \therefore log_2 x = 3, \ x = 8 \ or \ 1/4$

Use of calculators

1. Calculator input methods

On a **formula calculator** one types in an expression and then presses 'ENTER' or '=' to evaluate the expression.

Example: 1 + 2 x 3 = 7

1	+	2	x	3	=

On an **immediate execution calculator**, each operation is executed as soon as the next operator is pressed; therefore the **order** of operations in a mathematical expression is not taken into account.

Example: 1+2×3=7 (note that it is necessary to rearrange operands in order to get the correct result)

2	x	3	+	1	=

In **reverse Polish notation** (RPN), also known as **postfix notation,** all operations are entered after the operands on which the operation is performed. Reverse Polish notation is parenthesis-free which usually leads to fewer button presses needed to perform an operation.

Example: 1+2×3=7

1	↵ ENTER	2	↵ ENTER	3	↵ ENTER	+	X

2. Display format

Natural Display (also known as Mathematical Display, Write View, Math Print, and Equation Writer) causes fractions, irrational numbers and other expressions to be displayed as they are written on paper.

Video link on how to use a scientific calculator

Open the link provided below to watch a video demonstrating how to use scientific calculator

https://www.youtube.com/watch?v=QoJN5-afZLY&feature=youtu.be

Reduction of equations

Reduction refers to applying simple rules to a series of equations to change them into a simpler form.

It is also known as simplification.

For example: simplify 2p ÷ 8pq

2p÷8pq means 2p/8pq. This can be reduced by cancelling as in arithmetic

= 2 x p/(8 x p x q) = 1/4q

Example 2: Simplify $a^3b^2c \times ab^3c^5$

Grouping like terms gives: $a^3 \times a \times b^2 \times b^3 \times c \times c^5$

Using the first law of indices gives: $a^{3+1} \times b^{2+3} \times c^{1+5}$

i.e. $a^4 \times b^5 \times c^6 = \boldsymbol{a^4b^5c^6}$

Solution of simultaneous linear equations in two unknowns

Equations which have to be solved together to find the unique values of the unknown quantities, which are true for each of the equations, are called **simultaneous equations**.

Methods of solving simultaneous equations

Two methods are used:

(a) **substitution method**, and (b) **elimination method**

Example1. Solve, by substitution method, the simultaneous equations

$3x - 2y = 12$ ....(1)

$x + 3y = -7$.... (2)

From equation (2), $x = -7-3y$

Substituting for x in equation (1) gives:

$3(-7-3y) -2y=12$

i.e. $-21-9y-2y=12$

$-11y=12+21=33$

Hence $-11y= 33$

$y=-3$

Substituting $y=-3$ *in equation (2) gives:*

$x+3(-3) =-7$

i.e. $x-9=-7$

Hence $x=-7+9=2$

*Thus **x =2 and y = −3** is the solution of the simultaneous equations.*

Example 2: Use an elimination method to solve the simultaneous equations

$3x + 4y = 5$..... (1)

$2x - 5y = -12$..... (2)

solution

If equation (1) is multiplied throughout by 2 and equation (2) by3, then the coefficient of x will be the same in the newly formed equations.

Thus

2×equation (1) gives: 6x+8y =10…….. (3)

3×equation (2) gives: 6x−15y =−36…… (4)

Equation (3) – (minus) equation (4) gives: 0+23y =46

Thus 23 y = 46

y = 2

(Note +8y−−15y=8y+15y=23y and 10−−36=10+36=46. Alternatively, 'change the signs of the bottom line and add'.)

Substituting y=2 in equation (1) gives:

3x+4(2) =5

from which 3x=5−8=−3

and x=−1

Checking in equation (2), left-hand side=2(−1) −5 (2) = −2−10=−12 = right-hand side.

Hence ***x = −1 and y = 2*** *is the solution of the simultaneous equations.*

The elimination method is the most common method of solving simultaneous equations.

Solution of quadratic equations

A **quadratic equation** is one in which the highest power of the variable quantity is 2. For example,

$x^2 - 3x + 1 = 0$ is a quadratic equation.

There are four methods of **solving quadratic equations**

These are:

(i) Factorization method (where possible)

(ii) Completing the square method

(iii) By using the 'quadratic formula'

(iv) Graphical method

Factorization method

Multiplying out $(2x+1)(x-3)$ gives $2x^2 -6x+x-3$, i.e. $2x^2 -5x-3$. The reverse process of moving from $2x^2 -5x-3$ to $(2x+1)(x-3)$ is called **factorizing**.

If the quadratic expression can be factorized this provides the simplest method of solving a quadratic equation.

For example, if $2x^2 -5x-3=0$, then, by factorizing:

solution

(2x+1)(x−3)=0

Hence either (2x+1) = 0 i.e. x = −1/2

or (x−3) = 0 i.e. x = 3

Solving quadratic equations by completing square method

An expression such as x^2 or $(x+2)^2$ or $(x-3)^2$ is called a perfect square.

If $x^2 = 3$ then $x = \pm\sqrt{3}$

If $(x+2)^2 =5$ then $x+2 = \pm\sqrt{5}$ and $x = -2 \pm \sqrt{5}$

If $(x-3)^2 =8$ then $x -3 = \pm\sqrt{8}$, $x = 3 \pm \sqrt{8}$

Hence if a quadratic equation can be rearranged so that one side of the equation is a perfect square and the other side of the equation is a number, then the solution of the equation is readily obtained by taking the square roots of each side

The process of rearranging one side of a quadratic equation into a perfect square before solving is called **'completing the square'**.

The simple procedure here is

a) rearrange the equation so that all terms are on the same side
b) make the coefficient of x^2 be 1 by dividing the quadratic equation by the coefficient of x^2
c) half the coefficient of x, square it and add the value to both sides
d) complete the square and compute for the unknown variable

Example. Solve $2x^2 +5x=3$ by 'completing the square'.

The procedure is as follows:

1. Rearrange the equation so that all terms are on the same side of the equals sign (and the coefficient of the $x2$ term is positive).

Hence $2x^2 +5x-3=0$

2. Make the coefficient of the x^2 term unity. In this case this is achieved by dividing throughout by 2.

Hence

$2x^2/2 + 5x/2 - 3/2 = 0$

$X^2 + 5x/2 - 3/2 = 0$

$$x^2 + \frac{5}{2}x - \frac{3}{2} = 0$$

3. Rearrange the equations so that the x^2 and x terms are on one side of the equals sign and the constant is on the other side.

Hence

$X^2 + 5x/2 = 3/2$

4. Add to both sides of the equation (half the coefficient of x) ^{2}. In this case the coefficient of x is 5/2

. Half the coefficient squared is therefore $(5/4)^2$

Thus

$x^2 + 5/2x + (5/4)^2 = 3/2 + (5/4)^2$

The LHS is now a perfect square, i.e.

$(x + 5/4)^2 = 3/2 + (5/4)^2$

5. Evaluate the RHS. Thus $(x + 5/4)^2 = 3/2 + 25/16 = 24 + 25/16 = 49/16$

6. Taking the square root of both sides of the equation (remembering that the square root of a number gives answer).

   Thus

   $\sqrt{(x + 5/4)^2} = \sqrt{(49/16)}$ i.e. $x + 5/4 = \pm 7/4$

7. Solve the simple equation. Thus

$X = -5/4 \pm 7/4$. ie $x = -5/4 + 7/4 = ½$ or -3

Hence $x = ½$ **or −3** are the roots of the equation $2x^2 + 5x = 3$

Solving quadratic equation by formula

The quadratic formula is $x = -b \pm \sqrt{b^2} - 4ac/2a$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

(This method of solution is 'completing the square)

Where:

a = coefficient of x^2

b = coefficient of x

c = the constant term

Example: Solve $4x^2 + 7x + 2 = 0$ giving the roots correct to 2 decimal places.

Comparing $4x^2 + 7x + 2 = 0$ with $ax^2 + bx + c$ gives $a = 4$, $b = 7$ and $c = 2$.

Hence x = -7 ± √ (49 – 32)/8 = - 0.36 or -1.39

Graphical method

Another method of solving quadratic equation is by graphical method.

1. In this method the quadratic equation given is first rewritten as a quadratic function of y.
2. Then form a table of x values against y
3. Plot the curve and note where the curve cuts the x-axis

- A quadratic equation has two roots if its graph has two x-intercepts
- A quadratic equation has one root it its graph has one x-intercept
- A quadratic equation has no real solutions if its graph has no x-intercepts.

Example:

Solve the equation $x^2 + x - 3 = 0$ by drawing its graph for $-3 \leq x \leq 2$.

Solution:

Rewrite the quadratic equation $x^2 + x - 3 = 0$ as the quadratic function

$y = x^2 + x - 3$

Draw the graph for $y = x^2 + x - 3$ *for* $-3 \leq x \leq 2$.

X	–3	–2	–1	0	1	2
Y	3	–1	–3	–3	–1	3

Table 3

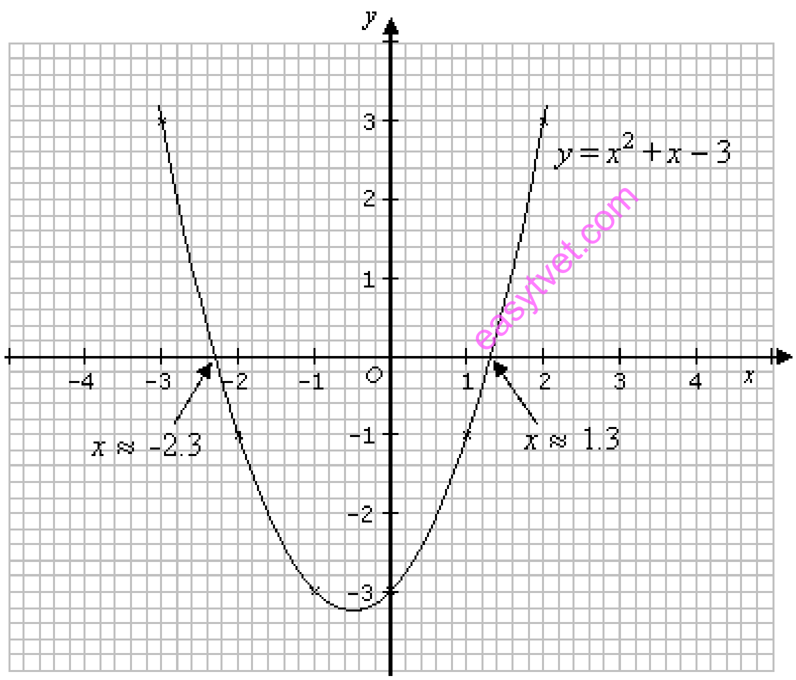


Figure 1.21

The solution for the equation $x^2 + x - 3$ *can be obtained by looking at the points where the graph* $y = x^2 + x - 3$ *cuts the x-axis (i.e.* $y = 0$*).*

The graph $y = x^2 + x - 3$*, cuts the x-axis at* $x = 1.3$ *and* $x = -2.3$

So, the solution for the equation $x^2 + x - 3$ is $x = 1.3$ or $x = -2.3$.

Example

Solve the equation

$x^2 - 3x - 10 = 0$

$x^2 - 3x - 10 = y$

Graph the equation. This could either be done by making a table of values as we have done in previous sections or by a computer or a graphing calculator.

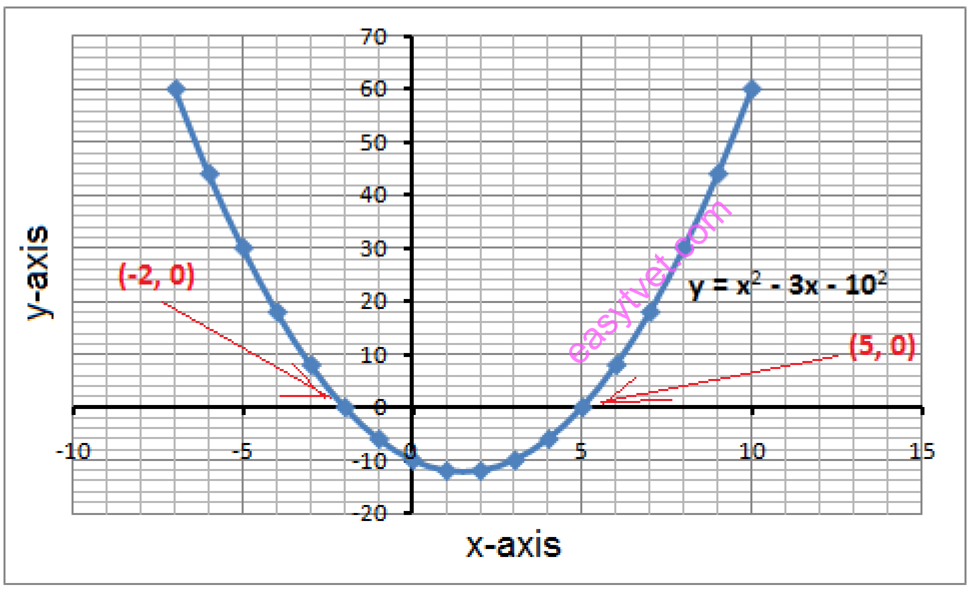


figure 1.22

The parabola cross the x-axis at x = -2 and x = 5. These are the roots of the quadratic equation.

We can compare this solution to the one we would get if we were to solve the quadratic equation by factoring as we've done earlier.

$$x^2 - 3x - 10 = 0$$

$x^2 - 3x - 10 = y$……. factorise

$$(x+2)(x-5) = 0$$

Therefore $x = -2$ or $x = 5$

Open the video link provided to watch more examples on solving quadratic equations graphically https://youtu.be/7GHsJNBwt9E

1.2.1.4 Learning activities

Activity 1: quadratic equation

Key learning activities	**Points of consideration/special instructions**
Introduction learners will be reminded of prior knowledge: substitution, graphs. And roots of quadratics	The trainer will ask prompt questions such as "What does a quadratic look like?" or "How do we know that an equation is a line?" to stimulate thinking.
Posing the Task A problem will be written on a slide of a PowerPoint Presentation and projected onto the screen. Each individual will also be given a paper copy. learners will be encouraged to work in pairs.	learners may be asked to recognize a line and a quadratic in the question.
Anticipated Student Responses R1: May try elimination method.	The trainer will Indicate that you cannot subtract unlike terms Point out that the squaring needs to be re-done Ask the learners

R2: May not square properly R3: May pick the incorrect factors R4: May try trial and error and get tired R5: May graph the line and the curve but fail to draw a conclusion.	to look at the factorising again Ask him to try another method Ask the learners to explain the graph in his own words.
Comparing and Discussing The trainer will look for the most common method and ask one learners to come to the board to explain what s/he did. Then the trainer will ask the learners for another way to solve it. If an individual does not volunteer the trainer will have looked out already for alternatives which s/he will then invite that student up to the board	We will focus on whether the learners can explain the reason for each step in their solution The trainer will encourage each learner to discuss the merits of his solution.
The trainer will summarize what each pair did, what was the most popular method and what the class decided was the best method.	

Table 4

1.2.1.5 Self assessment

Learning outcome 1: apply Algebra

1. simplify: $\frac{7^{-3} \times 3^{4}}{3^{-2} \times 7^{5} \times 5^{2}}$ expressing your answer in index form with positive indices
2. use elimination method to solve the following simultaneous equation

$$3x + 4y = 5$$

$$2x - 5y = - 12$$

3. use substitution method to solve the following simultaneous equations

$$3x - 2y = 13$$

$$2x + 5y =- 4$$

(x=3, y=-2)

4. A craftsman and 4 labourers together earn £ 865 per week, whilst 4 craftsmen and 9 labourers earn £2340 basic per week. Determine the basic weekly wage of a craftsman and a labourer.
5. Give an example of simplifying simple eqations with one unknown
6. Solve the following quadratic equation by factorization method:

   $4x^2 + 8x + 3 = 0$
7. Solve $4x^2 + 7x + 2 = 0$ Using the general formular method and give your answer correct to 2 decimal places
8. Simplify: $log64 - log128 + log32$

9. Evaluate: $\frac{log25-log125+1/2log625}{3log5}$

10. Solve for x: $log_2 x + 6log_x 2 = 5$

11. Use graphical method to solve the equation $x^2 - 3x - 10 = 0$

12. Use the graph of $y = x^2 + x - 6$ $to\ solve$ $x^2 + x - 6 = 0$ (x=2 or -3)

13. Evaluate the following:

    a) Log x^4 – log x^3 = log5x – log 2x [x = 2.5]
    b) Log 2t3 – log t = log 16 + log t [t = 8]

1.2.1.6 Tools, equipment and materials required

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books
- Dice
- Computers with internet connection

1.2.2 Learning outcome 2: Apply Coordinate Geometry

1.2.2.1 Introduction

This learning outcome specifies the content of competencies on forming Cartesian and polar equations, plotting these equations in Cartesian and polar graphs, conversions from Cartesian to polar form and vice versa and finally on how to draw normal and tangents to a given curve.

1.2.2.2 performance standards

2.1 Polar equations are calculated using coordinate geometry

2.2 Graphs of given polar equations are drawn using the Cartesian plane

2.3 Normal and tangents are determined using coordinate geometry

1.2.2.3 information sheet

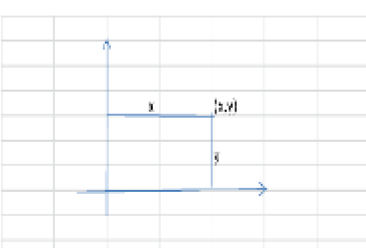
Coordinate system is usually a way of defining a point in space.

There are two ways in which the position of a point in a plane can be represented:

(a) By cartesian co-ordinate i.e. (x,y) and

(b) By polar co-ordinates i.e. (r,ɵ) where r is the radius from a fixed point and ɵ is an angle from a fixed point

Cartesian equation



The Cartesian equation is an equation of a straight line usually written in the form

$$y = ax + c$$

Where a and c are constants (a being gradient of the line)

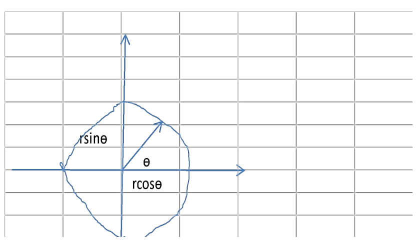
Example: the coordinates of two points A and B are given in the Cartesian plane as (2,6) and (4,1) respectively. Plot these points in a Cartesian plane and hence determine the equation of a line joining the two points.

Solution

Gradient of the line = $\frac{\Delta y}{\Delta x} = \frac{6-1}{2-4} = \frac{-5}{2}$

The Cartesian equation is given by

-5/2 = $\frac{y-1}{x-4}$ **⇒ 2(y – 1) = -5(x – 4) ⇒ 2y – 2 = 20 – 5x, ⇒ y -5x/2 + 11**



Polar equation

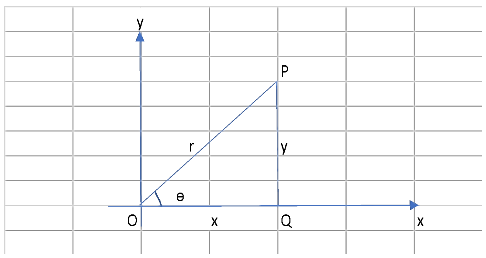
Introduction to Polar Coordinates

Another form of plotting positions in a plane is using polar coordinates. We are used to using rectangular coordinates, or xy-coordinates. Polar coordinates use a graphing system based on circles, and we specify positions using the radius and angle of a point on a circle centered at the origin. We must also know how to convert from rectangular to polar coordinates and from polar coordinates to rectangular.

This video introduces polar coordinates. https://youtu.be/-tZR3ggdoIU

Changing from cartesian into polar co-ordinates

Consider figure… below. If length x and y are known, then the length of r can be obtained by Pythagoras theorem



Since OPQ is a right-angled triangle, $r^2 = x^2 + y^2$ *from which* $r = \sqrt{x^2 + y^2}$

from trigonometric ratios

$$tan ɵ = \frac{y}{x} \therefore ɵ = y/x$$

The angle ɵ may be expressed in degrees or radians and must always be measured from the positive x-axix, i.e. measured from line OQ

Example: change the cartesian co-ordinate (3,4) into polar co-ordinates

Solution

From Pythagoras theorem

$r = \sqrt{3^2 + 4^2} = 5$

By trigonometric ratios

$$ɵ = \frac{4}{3} = 53.13^o \ or \ 0.927 \ radians$$

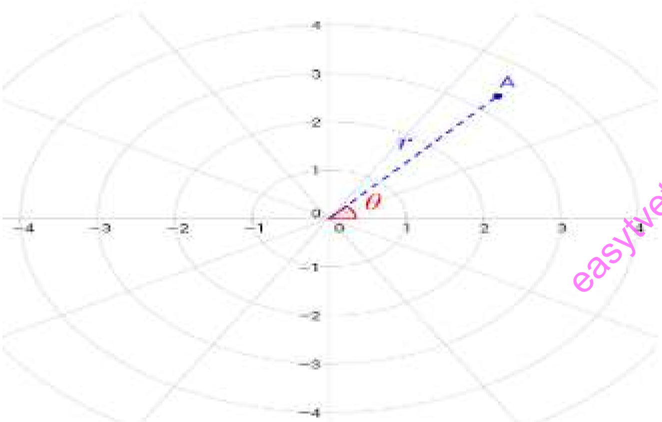
hence (3,4) in cartesian co-ordinate corresponds to (5, 53.13°) or (5, 0.927 rad) in polar co-ordinates.

A polar equation is any equation that describes a relation between *r* and *θ*, where *r* represents the distance from the pole (origin) to a point on a curve, and *θ* represents the counterclockwise angle made by a point on a curve, the pole, and the positive *x*-axis.

Polar curve

A **polar curve** is a shape constructed using the polar coordinate system. Polar curves are defined by points that are a variable distance from the origin (the pole) depending on the angle measured off the positive xx-axis. Polar curves can describe familiar Cartesian shapes such as ellipses as well as some unfamiliar shapes such cardioids and lemniscates.

Each point in the polar coordinate system is given by (r,ɵ) where r is the distance from the pole (origin) to the point, and θ is the counterclockwise angle that is made with the point, pole, and the positive x-axis.



A = (r,ɵ)

Whereas Cartesian curves are useful to describe paths in terms of horizontal and vertical distances, polar curves are more useful to describe paths which are an absolute distance from a certain point.

To convert back and forth between polar and rectangular coordinates, we have the formulas:

$$x = r\cos\theta$$

$$y = r\sin\theta$$

$$r^2 = x^2 + y^2$$

$$tan\theta = \frac{y}{x}$$

NB: one must consider what quadrant the point is when computing ɵ from this identity.

Convert (1, 2) into polar coordinates.

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x=1 and y=2*y*=2. The value of *r* is computed as follows

$$r^2 = x^2 + y^2$$

$$r^2 = 1^2 + 2^2 = 5 \Rightarrow r = \sqrt{5}$$

The value of ɵ is computed as follows:

$$tan\theta = \frac{y}{x} \Rightarrow tan\theta = 2/1$$

$$\theta = 2 = 63.4^o$$

The point is in the first quadrant, so the inverse tangent function gives the correct value of ɵ

the point in polar coordinate is ($\sqrt{5}$, 63.4º)

Convert the following equations into polar form: $4x^2 + 9y^2 = 36$

Solution

Use the identity $x = rcos\theta \ and \ y = rsin\theta$

$\therefore 4r^2cos^2\theta + 9r^2sin^2\theta =$ **36**

$r^2 = \frac{36}{4cos^2 \theta + 9sin^2 \theta} \Rightarrow r = 6/\sqrt{4 + 9sin^2}$

Tangents and normal

A **tangent** to a curve is a line that touches the curve at one point and has the same **slope** as the curve at that point.

A **normal** to a curve is a line **perpendicular** to a tangent to the curve

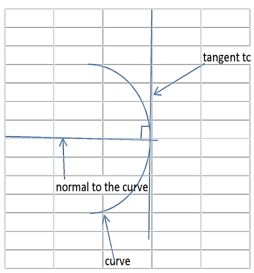


Figure.1.24

The slope of a tangent at any point (x,y) can be found using $\frac{dy}{dx}$

To find the equation of a normal, the condition for two lines with slopes $m_1$and m_2 to be perpendicular

$m_1 \times m_2 = -1$

example: find the equation of a line perpendicular to a line defined by the equation

$y = 2x + 3$ *and passes through a point* $(1, 4\}$

solution

from the equation $y = 2x + 3,\ gradient\ of\ the\ line = 2$

$$for\ two\ perpendicular\ lines,\ the\ products\ of\ their\ gradiets = -\ 1$$

$\therefore 2m_2 = -\ 1,\ from\ which\ m_2 = -\ 1/2$

$$the\ line\ l_2\ whose\ gradient\ is\ -\frac{1}{2}\ also\ passes\ through\ the\ point\ (1, 4)$$

$$\therefore -\frac{1}{2} = \frac{y-4}{x-1}$$

$$y = \frac{9}{2} - \frac{x}{2}$$

Example2: obtain the equation of a line parallel to the line in the above example and passes through the same point (1,4)

Solution

$parallel\ lines\ have\ equal\ gradients,\ therefore\ from\ the\ equation\ y = 2x + 3,\ gragient = 2$

$$since\ the\ line\ passes\ through\ the\ point\ (5, 2) \therefore 2 = \frac{y-2}{x-5}$$

$$from\ which\ y = 2x - 8$$

Applications

Tangent:

1. If we are traveling in a car around a corner and we drive over something slippery on the road (like oil, ice, water or loose gravel) and our car starts to skid, it will continue in a direction **tangent** to the curve.
2. Likewise, if we hold a ball and swing it around in a circular motion then let go, it will fly off in a **tangent** to the circle of motion.

Normal:

1. When you are going fast around a circular track in a car, the force that you feel pushing you outwards is **normal** to the curve of the road. Interestingly, the force that is making you go around that corner is actually directed towards the **center** of the circle, normal to the circle.

2. The spokes of a wheel are placed **normal** to the circular shape of the wheel at each point where the spoke connects with the center

Examples

1. Find the **gradient** of

(i) The tangent (ii) the normal to the curve $y = x^3 - 2x^2 + 5$ at the point (2,5).

$\frac{dy}{dx} = 3x^2 - 4x$, the slope of the tangent is

$m_1 = \frac{\Delta y}{\Delta x}$ at x = 2 ⇒ $3(2)^2 - 4(2) = 4$

The slope of the normal is found from the expression $m_1 \times m_2 = -1$

∴ $m_2 = -1/4$

Find the equation of the (i) tangent and (ii) normal to the curve in the above example

We use $y - y_1 = m(x - x_1)$, with $x_1 = 2$, $y_1 = 5$

(i) The tangent has slope 4, so we have: y – 5 = 4(x – 2) ⇒ y = 4x - 3

(ii) For the normal to the curve, since the tangent has a slope of 4, we have the slope of the normal as $m_2 = -1/4$

so we substitute as follows:

y-5 = -1/4(x – 2) ⇒ y = -1/4x + 11/2

or

x + 4y – 22 =0

1.2.2.4 self-assessment

1. **Find the** gradient of a line AB given the coordinates of A(2,3) and B(1,6)

2. Write the equation of a line that is parallel to the line $2x - 4y = 8$ and passes through the point (3, o)
3. Sketch the graph of $r = 1 + \sin \theta$
4. Find the polar equation of the circle with radius $|a|$ centered = at (a,0)
5. Convert r = 7 to a Cartesian equation
6. Express the given cartesian co-ordinates correct to 2 decimal places in both degrees and radians
    a) (3,5) [(5.83, 59.54°) (5.83, 1.03 rad)]
    b) (6.18,2.35) [(6.61, 20.83°) (6.61, 0.36rad)]
    c) (-2, 4) [(4.47, 116.57°) (4.47, 2.03 rad)]

1.2.2.6 tools equipment and materials

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books
- Dice
- Computers with internet connection

1.2.3 Learning outcome 3: Carry Out Mensuration

1.2.3.1 introduction

This learning outcome specifies competencies on units of measurements, perimeter and areas of regular figures, volume of regular solids, surface area of regular solids, areas of irregular figures and finding areas and volumes using Pappus theorem.

1.2.3.2 performance standards

3.1 Perimeter and areas of figures are obtained

3.2 Volume and of Surface area of solids are obtained

3.3 Area of irregular figures are obtained

3.4 Areas and volumes are obtained using Pappus theorem

1.2.3.3 Information sheet

Mensuration is a branch of mathematics concerned with the determination of lengths, areas and volumes

Units of measurements

Area and volumes are derived from unit lengths of measurement. The SI unit of measuring length is meter (m). Other units of measurements are centimeter (cm), millimeter (mm), decimeter (dm), decameter (Dm), hectometer (Hm) and kilometer (km)

- length is Distance-Span, measured in reference span of 1 unit long line
- area is Surface-Span, measured in reference to span of 1 x 1 square
- volume is Space-Span, measured in reference to span of 1 x 1 x 1 cube

Perimeter and areas of regular figures

Perimeter and area of regular solids

A summary of area and volumes of common regular figures is shown below

Rectangle

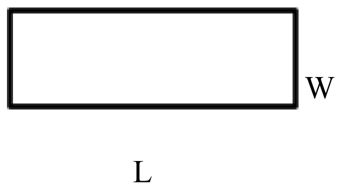


Figure1.2.3.1

⇒ perimeter $p = 2(L + W)$, Area, $A = L \times W$

Circle

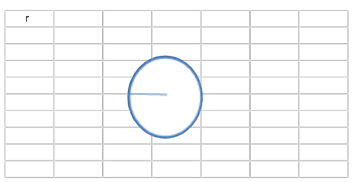


Figure 1.25

Perimeter = πd

Area= πr^2 r^2

Rectangular prism

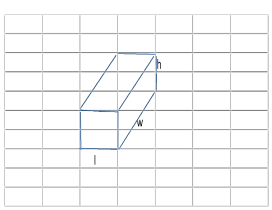
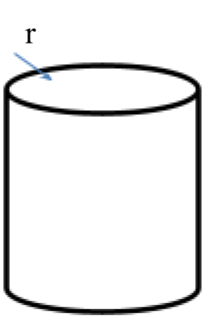


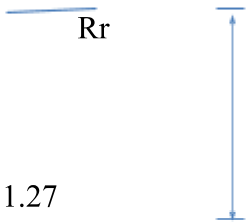
Figure 1.26

Surface . Area = 2(l x w) + 2(l x h) + 2(w x h) square units

Volume = l x w x h cubic units

Cylinder:



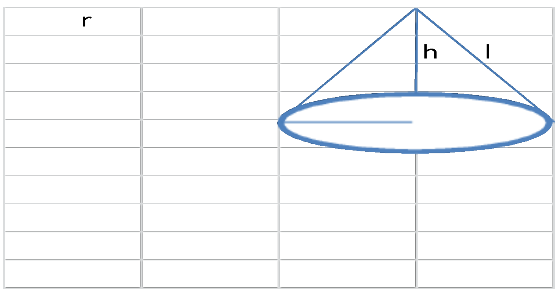


surface Area = $2\pi r^2 + 2\pi rh$ (for closed cylinder)

Volume = $\pi r^2 h$

figure 1.27

Cone



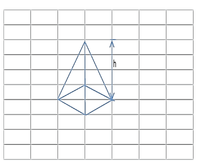
Curved surface Area = πrl

Total surface Area = $\pi rl + \pi r^2$

Volume = $1/3\pi r^2 h$

Pyramid

Total surface area = (sum of areas of triangles forming sides) + (area of base)



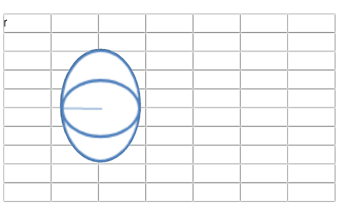
Volume = 1/3 x A x h

Figure 1.28

Where A= area of base

and h= perpendicular height

sphere



Volume = $\frac{4}{3}\pi r^3$

Surface Area = $4\pi r^2$

figure 1.29

Worked problems on volumes and surface areas of regular solids

Problem 1. A water tank is the shape of a rectangular prism having length 2 m, breadth 75 cm and height 50 cm.

Determine the capacity of the tank in (a) m^3 (b) cm^3 (c) litres.

Volume of rectangular prism=l ×b×h

*(a) Volume of tank=2×0.75×0.5=**0.75m³***

(b) 1m3 =106 cm3, hence 0.75m3 =0.75×106 cm3

*=**750 000 cm³***

(c) 1 liter=1000 cm³, hence

750 000 cm3 = 750 000

1000

*liters=**750 liters***

Problem 2. Find the volume and total surface area of a cylinder of length 15 cm and diameter 8 cm.

Volume of cylinder=πr2h

Since diameter=8 cm, then radius r =4 cm

*Hence volume=π ×42 ×15=**754 cm³***

Total surface area (i.e. including the two ends)

= 2πrh + 2πr2

= (2 × π × 4 × 15) + (2 × π × 42)

*= **477.5 cm²***

Problem 3. Determine the volume and total surface area of a cone of radius 5 cm and perpendicular height 12 cm.

Volume of cone = $1/3\pi r^2 h = 1/3 \times \pi \times 5^2 \times 12 =$ ***314.2 cm³***

Total surface area = curved surface area + area of base = $\pi rl + \pi r^2$

Slant height l may be calculated using Pythagoras' theorem

$l = \sqrt{12^2 + 5^2} = 13$ *cm*

Hence total surface area = $(\pi \times 5 \times 13) + (\pi \times 5^2) =$ ***282.7 cm2***

Surface area of irregular figures

To find the area of irregular shapes, the first thing to do is to divide the irregular shape into regular shapes that you can recognize such as triangles, rectangles, circles, squares and so forth...
Then, find the area of these individual shapes and add them up!

Example: find the total surface area of the figure 1.237

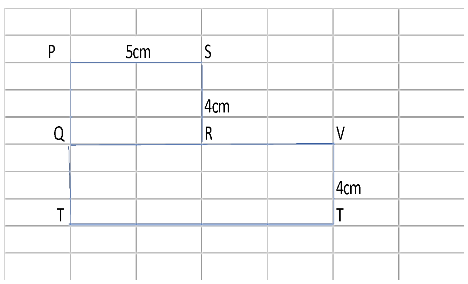


Figure 1.30

Solution

The figure can be divided into two regular figures

1. rectangle PQRS = 5 x 4 = 20cm
2. rectangle QTVW = 10 x 4 = 40cm

   the total area = area of PQRS + QTVW = 20cm + 40cm = 60cm^2

example 2: calculate the total area of the figure 1.238

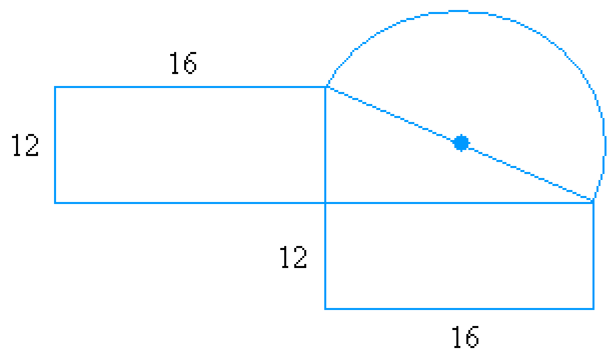


Figure 1.31

The figure above has 4 regular shapes. It has a triangle, two rectangles, and half a circle

Find the area for each of those 4 shapes and add the results

Rectangle

$Area_{rectangle} = length \times width$

$Area_{rectangle} = (12 \times 16)$

$Area_{rectangle} = 192$

Since we have two of the same rectangles, the area is 192 + 192 = 384

Triangle

Notice that the longest side of the rectangle is the base of the triangle and the short side of the rectangle is the height of the triangle

So,

$Area_{triangle} = (base \times height)/2$

$Area_{triangle} = (16 \times 12)/2$

$Area_{triangle} = (192)/2$

$Area_{triangle} = 96$

Circle

To get the area of the half circle, we need to know the diameter

Notice that the diameter is the hypotenuse of a right triangle, so use the Pythagorean Theorem to find the length of the diameter

$c^2 = a^2 + b^2$

$c^2 = 12^2 + 16^2$

$c^2 = 144 + 256$

$c^2 = 400$

$c = \sqrt{400}$

$c = 20$

Therefore, the diameter is 20. Since the diameter is 20, the radius is 10

$Area_{circle} = \pi \times r^2$

$Area_{circle} = 3.14 \times 10^2$

Area $_{circle}$ = 3.14 × 100

Area $_{circle}$ = 314

Since you only have half a circle, you have to multiply the result by 1/2

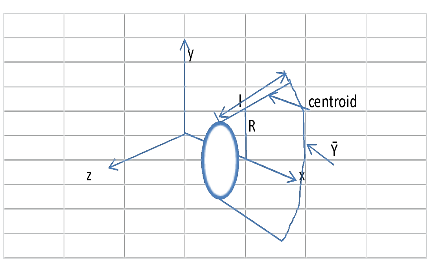
1/2 × 314 = 157

Area of this shape = 384 + 96 + 157 = 637

Areas and volumes using Pappus theorem

Finding surface area using Pappus Theorem

The surface area of an object formed by rotating a curve in an axis = length of the curve multiplied by the centroid during the rotation about the axis



$$A = L(2\pi)\bar{Y}$$

fig 1.32

Pappus theorem for volumes

The second theorem of Pappus states that the volume of revolutions obtained by rotating a lamina F about a non-intersecting axis lying in the same plane is equal to the product of the area A of the lamina F and the distant d travelled by the centroid of F.

V = Ad

Open the link and watch the video on how to calculate the volume of a centroid using pappus theorem.

https://youtu.be/gh5nDadl5F4

1.2.3.4 learning activities

Activity 1

Special instructions	Key learning activities
Learners be provided with a cuboid of larger dimensions and smaller cuboids of unit lengths. The dimensions of the larger cuboid be 30cm by 20cm by 10cm The dimensions of smaller cuboids be 3cm by 2cm by 1cm	• Divide yourselves into groups of three learners • Take the larger box and take the measurements of all the surfaces in centimeters • Calculate the total surface area and volume based on your measurements and let each group write their findings on a piece of paper • Take a small cuboid provided, measure the dimensions and calculate the volume of the small cuboids and note the volume on a piece of paper • Pack the smaller cuboids in the bigger cuboid and count the number of cuboids that completely fills the larger cuboid. • Multiply the volume of the smaller cuboid by the total number of smaller cuboids in the pack. • Compare the result with the initial volume of the bigger cuboid you earlier obtained

Table 5

Activity 2

Figure... shows a field with an irregular shape of which the surface area is to be determined in hectares.

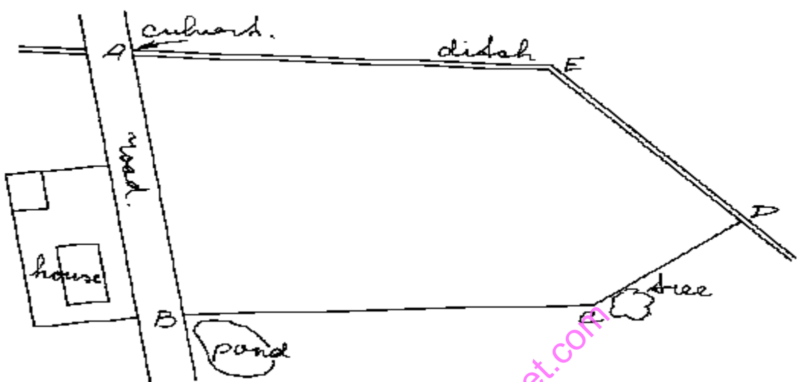


Fig. 1.33

__**Special instruction**__

Learners be provided with measuring tape, marking tools. They are to apply the knowledge acquired in classroom to calculate the area of the field as drawn in the figure in hectares.

__**Key learning activities**__

1. Make a rough sketch of the field indicating the corners of the field (A, B, C, D and E) and the field borders (straight lines).

2. Divide the field, as indicated on the sketch, into areas with regular shapes. In this example, the field can be divided into 3 triangles ABC (base AC and height BB_1), AEC (base AC and height EE_1) and CDE (base EC and height DD_1)

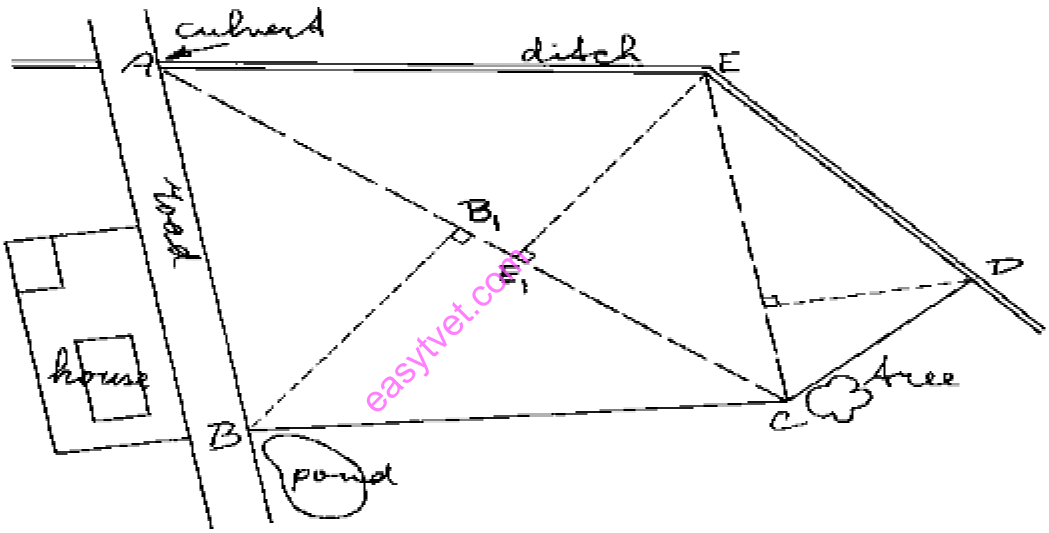


Fig. 1.34

3. Mark, on the field, the corners A, B, C, D and E as indicated in figure.....
4. Set out ranging poles on lines AC (base of triangles ABC and AEC) and EC (base of triangle EDC) and measure the distances of AC and EC.
5. Calculate the surface area of the given field

<u>Measured</u>

Triangle ABC: base = AC = 130 m

height = BB_1 = 55 m

Triangle ACE: base = AC = 130 m

height = EE_1 = 37 m

Triangle CDE: base = EC = 56 m

height = DD_1 = 55 m

Answer

Area = 0,5 x base x height

= 0.5 x 130 m x 55 m = 3 575 m^2

Area = 0.5 x 130 m x 37 m = 2 405 m

Area = 0.5 m x 56 m x 55 m= 1 540 m^2

Field ABCDE:

Area of triangle ABC = 3 575 m^2

Area of triangle ACE = 2 405 m^2

Area of triangle CDE = 1 540 m^2

Total Area = 3 575 m^2 + 2 405 m^2 + 1 540 m^2

= 7 520 m- = 0.752 ha

1.2.3.5 Self-Assessment

1. A water tank in the shape of a regular prism having length 2m, breadth 75cm and height 50cm determine the capacity of the tank in
    a) M^3 (b) cm^3 and (c) litres
2. Find the volume and total surface area of a cylinder of length 15cm and diameter 8cm

3. Calculate the volume and total surface area of the solid prism show in figure. 1.234

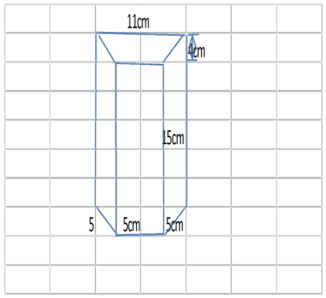


Fig. 1.36.

4. Calculate the total surface area of hemisphere of diameter 5.0cm

1.2.3.6 Tools, equipment and materials required

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books
- Dice
- Computers with internet connection

1.2.4 Learning outcome 4: Apply Matrix

1.2.4.1 introduction

This learning outcome specifies the content of competencies on order of a matrix, addition and subtraction of matrices, determinants, inverse and how to solve simultaneous equation using matrix method.

1.2.4.2 Performance standard

4.1 Determinant and inverse of 2x2 matrix are obtained

4.2 Solutions of simultaneous equations are obtained

4.3 Calculation involving Eigen values and Eigen

1.2.4.3 Information sheet

Definition

A matrix equation is an equation of the form Ax =b, where A is an m x n matrix, b is a vector whose coefficients $x_1, x_2, \ldots, x_n$

Order of a matrix

A matrix consists of rows and columns. Rows are horizontal arrangement while columns are the vertical arrangement.

The number of rows and columns determine the order of a matrix which is given by stating the number of rows followed by the number of columns

Elements of a matrix

Each number or letter in a matrix is called an element of the matrix. Each element can be located in the matrix by stating its position in the row and the column.

For example, given the 2 x 2 matrix $\left(a_{11}\ a_{12}\ a_{21}\ a_{22}\right)$

a_{11} means the element in the first row and first column

a_{12} means the elements in the first row and second column

a_{21} means the elements in the second row and first column

a_{22} means the elements in the second row and second column.

Matrix Operation

Addition and subtraction of matrix

If matrix A = $(a\ b\ c\ d\ )$, B = $(e\ f\ g\ h\ )$ and C =$(i\ j\ k\ l\ )$

Suppose A + B = C, then

a + e = i

b + f = j

c + g = k

d + h = l

Similarly, if A – B = C, then

a – e = i

b – f = j

c – g = k

d – h = l

Multiplication of matrix

Consider matrices, A, B and C given above.

Suppose A x B = C, then

ae + bg = i

af + bh = j

ce + dg = k

cf + dh = l

NB: in matrix multiplication, A x B ≠ B x A unless it is A and B are square matrices

Example1: given matrix A = $(4\ 2\ 6\ 5\ )$ and B = $(2\ 1\ 6\ 3\ )$

Evaluate:

i) A + B
ii) A – B
iii) A x B
iv) B x A

Solution

i) $A + B = (4\ 2\ 6\ 5\ ) + (2\ 1\ 6\ 3\ ) = (6\ 3\ 12\ 8\ )$

ii) $A - B = (4\ 2\ 6\ 5) - (2\ 1\ 6\ 3) = (2\ 1\ 0\ 15)$

iii) $A \times B = (4\ 2\ 6\ 5) \times (2\ 1\ 6\ 3) = (20\ 10\ 42\ 21)$

iv) $B \times A = (2\ 1\ 6\ 3) \times (4\ 2\ 6\ 5) = (14\ 9\ 42\ 27)$

Determinant of 2 x 2 matrixes

Consider matrix A = $(a\ b\ c\ d)$

The determinant of A, denoted by $|A|$ = ad – bc

Singular matrix

A matrix whose determinant is zero is known as singular matrix

Example 2: given matrix M = $(2\ 1\ 4\ 3)$, determine its determinant

Solution

Det of M = $|M| = |2\ 1\ 4\ 3| = 2\text{x}3 - 1\text{x}4 = 2$

Example 3: find the value of p that will make matrix A singular, given that A = $(2p\ 4\ 3\ 1)$

Solution

For A to be singular $|A| = 0$

$\therefore |2p\ 4\ 3\ 1| = 0 \Rightarrow 2p \times 1 - 4 \times 3 = 0$

$\Rightarrow 2p = 12,\ p = 6$

Inverse of 2 x 2 matrixes

The inverse of a 2 x 2 matrix is obtained using the following procedure

1. find the determinant of the matrix, i.e. ad – bc for matrix A given
2. find transpose matrix, i.e. interchange the elements in the leading diagonal and change the signs of elements in the minor diagonal i.e. $(d\ \ -b\ \ -c\ a)$
3. Multiply 2 by the reciprocal of the determinant. i.e. $1/(ad - bc)(d\ \ -b\ \ -c\ a)$ this is the inverse of the matrix A, A^{-1}

Example 4: find the inverse of matrix M in example 2 above.

Solution

$M = (2\ 1\ 4\ 3\ )$, *Det M,* $/M/ = |2\ 1\ 4\ 3\ | = 6 - 4 = 2$

$M^T = (3\ \ -1\ \ -4\ 2\ )\ \ \therefore M^{-1} = ½\ (3\ \ -1\ \ -4\ 2\ ) = (3/2\ \ -1\ \ -2\ 1\ )$

Solution of linear simultaneous equation with 2 unknowns

Procedure

1. Write the simultaneous equation in matrix form
2. Determine the inverse of the matrix equation formed
3. Pre-multiply both sides of the matrix equation by the inverse matrix
4. Compute for the unknown values

Example 5: use the matrix method to solve the following pair of simultaneous equations:

3a + 2b = 12

4a – b = 5

Solution

Forming matrix equation: $\Rightarrow (3\ 2\ 4\ \ -1\ )\left(\frac{a}{b}\right) = \left(\frac{12}{5}\right)$

The inverse of the coefficients matrix is $-\frac{1}{11}(-1\ \ -2\ \ -4\ 3\ )$

Pre-multiply both sides of the matrix equation by the inverse as shown below:

$$-\frac{1}{11}(-1\ \ -2\ \ -4\ 3\ )\ (3\ 2\ 4\ \ -1\ )\left(\frac{a}{b}\right) = -\frac{1}{11}(-1\ \ -2\ \ -4\ 3\ )\left(\frac{12}{5}\right)$$

$$-\frac{1}{11}(-11\ 0\ 0\ \ -11\ )\left(\frac{a}{b}\right) = -\frac{1}{11}\left(\frac{-22}{-33}\right) \Rightarrow \left(\frac{a}{b}\right) = \left(\frac{2}{3}\right),\ \therefore a = 2 \text{ and } b = 3$$

Example 6: Solve the following system of linear equations, using matrix inversion method:

$5x + 2y = 3$

$3x + 2y = 5$.

Solution

The matrix form of the *system is AX = B , where* $A = \begin{bmatrix} 5 & 2 \\ 3 & 2 \end{bmatrix}, X = \begin{bmatrix} x \\ y \end{bmatrix}, B = \begin{bmatrix} 3 \\ 5 \end{bmatrix}$.

We find $|A| = \begin{vmatrix} 5 & 2 \\ 3 & 2 \end{vmatrix}$ *= 10 - 6= 4 ≠ 0. So, A−1 exists and A−1 =* $\frac{1}{4}\begin{bmatrix} 2 & -2 \\ -3 & 5 \end{bmatrix}$.

Then, applying the formula X = A−1B , we get

$$\begin{bmatrix} x \\ y \end{bmatrix} = \frac{1}{4}\begin{bmatrix} 2 & -2 \\ -3 & 5 \end{bmatrix}\begin{bmatrix} 3 \\ 5 \end{bmatrix} = \frac{1}{4}\begin{bmatrix} 6-10 \\ -9+25 \end{bmatrix} = \frac{1}{4}\begin{bmatrix} -4 \\ 16 \end{bmatrix} = \begin{bmatrix} \frac{-4}{4} \\ \frac{16}{4} \end{bmatrix} = \begin{bmatrix} -1 \\ 4 \end{bmatrix}.$$

So the solution is (x = −1, y = 4).

Eigenvalues and eigenvectors

Eigenvalues are numbers associated with a matrix and eigenvectors are special vectors

A matrix A acts on vector x like a factor does with input x and output Ax

Eigenvectors are vectors for which Ax is parallel to x i.e.

$Ax = \lambda x$

In this equation, x is an eigenvector of A and λ is an eigenvalue of A.

An eigenvalue is defined by the characteristic equation:

$|A - \lambda I| = 0$

Where A = the matrix given

λ = eigenvalue

I = identity matrix

An eigenvector is defined by the characteristic equation:

$$(A - \lambda I)x = 0$$

Where x defines the eigenvector in question

Example: find the eigenvalues and the corresponding eigenvectors of the matrix A given as A = (3 1 1 3)

Solution

Characteristic equation defining eigenvalues:

$|A - \lambda I| = 0$

$|3 - \lambda\ 1\ 1\ 3 - \lambda\ | = 0$. $(3 - \lambda)^2 - 1 = 0$, $\lambda^2 - 6\lambda + 8 = 0$ from which

$\lambda = 2$ or $\lambda = 4$

therefore, the eigenvalues are 2 and 4

characteristic equation defining eigenvectors

$$(A - \lambda I)x = 0$$

For $\lambda = 2$

$(3 - 2\ 1\ 1\ 3 - 2\ )\left(\frac{x_1}{x_2}\right) = 0$

$(1\ 1\ 1\ 1\ )\left(\frac{x_1}{x_2}\right) = 0$

$\therefore x_1 + x_2 = 0$ therefore the eigenvector corresponding to $\lambda_1 = 2$ is $V_1 = \left(\frac{-1}{1}\right)$

For $\lambda_2 = 4$

$(3 - 4\ 1\ 1\ 3 - 4\ )\left(\frac{x_1}{x_2}\right) = 0$

$(-\ 1\ 1\ 1\ \ -1\ )\left(\frac{x_1}{x_2}\right) = 0$

$-x_1 + x_2 = 0$ therefore the eigenvector corresponding to $\lambda_2 = 4$ is

$V_2 = \left(\frac{1}{1}\right)$

Application of matrix

Matrix questions are best used as a way to ask several questions about a similar idea when there is a scale involved. They can be used for a variety of reasons, either as a mini-survey on their own, or as a single question type within a larger questionnaire. The closed-ended, predefined answers that apply to a series of questions make Matrix questions great for:

- Customer experience/satisfaction surveys.
- Questions about a subtopic in a larger questionnaire.
- Consolidating many rating-scale questions in a more digestible format.

Customer experience surveys

Matrix questions are commonly used for customer experience surveys. For example, to ask a respondent about their experience on a flight, the rows might ask the respondent about the service, food, or entertainment while the columns ask them to choose a rating response.

Q: Please choose how satisfied you were with your flight experience.

	Very satisfied	Somewhat satisfied	Neutral	Somewhat dissatisfied	Very dissatisfied
In-flight service	✓				
Onboard entertainment				✓	
Wifi connectivity			✓		
Meal options		✓			

Click the link provided to watch video on applying matrix to solve problems in real life situation https://youtu.be/sUFP9TUSZ1s

1.2.4.4 Learning Activities

Activity 1

Special instructions	Key learning activities
trainees be shown examples of matrices and demonstrate how to add and subtract them	• Each trainee to have a paper and a marker • All trainees to write a number of their choice on the paper • Trainees to divide themselves into half using masking tape

	● Create a matrix on both sides of the tape. Trainees to stand in rows and column holding their number signs on either side of the tape ● Trainees not involved in the matrix to add or subtract them ● Trainees to rotate between serving as the number in the matrices and figuring out the sum and differences.

Table 6

Activity 2:

Conduct survey on the quality of training services offered in your institute and tabulate your findings in matrix form. Your rating should be a tick in correspondence with the parameters given [excellent, very good, good, fair, poor, very poor]

Learning Activities	Special instruction
These are the key learning activities a) Syllabus coverage b) Examination pass rate c) Availability of research materials d) gyWi-fi connectivity e) Employability rate of the graduates	The trainee to be provided with a questionnaire to help him/her collect the required data.

Table 7

1.2.4.5 Self-assessment

1. Given matrix $A = (2\ 1\ 4\ 3)$ and $B = (0\ 2\ 6\ 1)$ determine:
   i) A + B
   ii) A –B

iii) 2A + 3B

2. Determine the inverse of the matrix A = $(3\ 5\ 4\ \ -\ 3\ )$
3. Solve the following simultaneous equations using matrix method

   3x + 5y = 7

   4x – 3y = 19
4. Find the value of p for which matrix A is singular given that A = $(2p\ 6\ 8\ 4\ )$
5. Find the eigenvalues and the corresponding eigenvectors of a 2 x 2 matrix if

   A = $(0\ 1\ \ -\ 2\ \ -\ 3\ )$
6. In a system of forces, the relationship between two forces F1 and F2 is given by:

$$5F_1 + 3F_2 + 6 = 0$$

$$3F_1 + 5F_2 + 18 = 0$$

(F1=1.5, F2=-4.5)

1.2.5 Learning outcome 5: Apply Vectors

1.2.5.1Introduction

This learning outcome specifies the content of competencies on vectors and scalar quantities, operations on vectors, obtaining position vectors, resolution of vectors, determining dot and cross products of a vector and operations including gradient, divergence and curl of a vector.

1.2.5.2 Performance standards

5.1 Vectors and scalar quantities are obtained in two dimensions

5.2 ***Operations*** on vectors are performed

5.3 Position of vectors is obtained

5.4 Resolution of vectors is done

5.5 Gradient, Divergence and curl are determined

5.6 Dot and cross products are determined

1.2.5.3 Information sheet

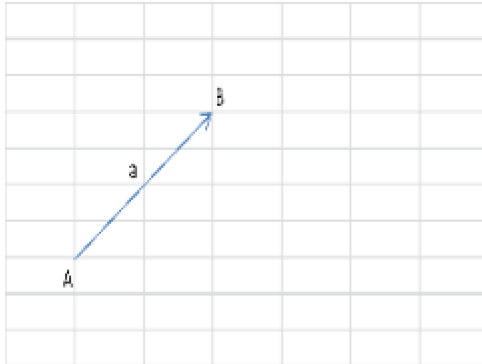
Definitions

Vector: a vector quantity is a quantity that has both magnitude and direction

Scalar: a scalar quantity is a quantity with magnitude only

Vector and scalar in two dimensions

Vectors are represented by a line with an arrow. The line indicates the magnitude of the vector while an arrow indicates the direction of the vector.



The line AB shows that the vector direction is from A to B. magnitude of the vector can be denoted by letter a.

Sometimes vectors are referred to a fixed point, an origin. Such a vector is called a position vector. Consider line OP, referring the position vector of a point P with respect to the origin O. in writing might be presented as $OP\rightarrow$ or just r. the two expressions refer to the same vector

Operation of vectors:

Addition and subtraction

Vectors can be added and subtracted

Graphically, think of adding two vectors together and placing two line segments end-to-end as you maintain distance and direction as in figure….

To add or subtract two vectors together, simply add/subtract together the x components of the two vectors together and the y components together. Vectors may be presented in column, if the coordinates of a point A is given as (1,2) then the column vector will be a = $\binom{1}{2}$

Example 1: given that vector a = $\binom{1}{3}$ and b = $\binom{4}{-1}$, (a) find a + b, (b) a - b

Solution

(a) $a + b = \begin{pmatrix} 1 \\ 3 \end{pmatrix} + \begin{pmatrix} 4 \\ -1 \end{pmatrix} = \begin{pmatrix} 5 \\ 2 \end{pmatrix}$

(b) $a - b = \begin{pmatrix} 1 \\ 3 \end{pmatrix} - \begin{pmatrix} 4 \\ -1 \end{pmatrix} = \begin{pmatrix} -3 \\ 4 \end{pmatrix}$

Multiplying a vector by a scalar

Multiplying a vector by a scalar (a number) maintains the direction of the vector but changes the magnitude of the vector, provided the scalar is positive. If we multiply a vector by a negative scalar, then we will get a vector which points in the opposite direction to the original

Example 2: if a = $\begin{pmatrix} 2 \\ 5 \end{pmatrix}$, b = $\begin{pmatrix} 1 \\ -2 \end{pmatrix}$ and c = $\begin{pmatrix} 3 \\ 4 \end{pmatrix}$ find 2a – b + 3c

Solution: $\Rightarrow 2a = 2\begin{pmatrix} 2 \\ 5 \end{pmatrix}$, $3c = 3\begin{pmatrix} 3 \\ 4 \end{pmatrix}$ $\therefore 2a - b + 3c = 2\begin{pmatrix} 2 \\ 5 \end{pmatrix} - \begin{pmatrix} 1 \\ -2 \end{pmatrix} + 3\begin{pmatrix} 3 \\ 4 \end{pmatrix} = \begin{pmatrix} 4 \\ 10 \end{pmatrix} - \begin{pmatrix} 1 \\ -2 \end{pmatrix} + \begin{pmatrix} 9 \\ 12 \end{pmatrix} = \begin{pmatrix} 12 \\ 24 \end{pmatrix}$

Magnitude of a vector

The *magnitude*, *modulus* or *length* of a vector is calculated using Pythagoras' Theorem.

The magnitude of a vector, **a**, is usually written as $|a|$. For example, given matrix a = $\begin{pmatrix} 4 \\ 3 \end{pmatrix}$ the magnitude of this vector, by Pythagoras is,

$a = \sqrt{4^2 + 3^2} = 25$

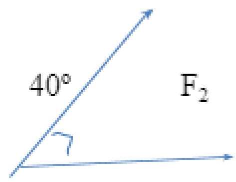
Dot and cross product

If we have any two vectors P and Q, the dot product (scalar product) is given by

$P \cdot Q = |P||Q| \cos\theta$.

Where $|P|$ and $|Q|$ are the magnitudes of P and Q respectively, and θ is the angle between the two vectors

Example 3: find the scalar product of the two force vectors F_1 ==4N and F_2 = 6N at 40° to each other as shown in the diagram



$F_1 \cdot F_2 = |F1|\ |F2| \cos \theta$

$= (4)\ (6) \cos 40° = 18.38$ N

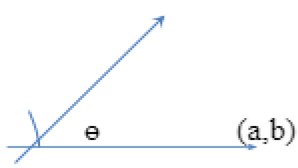
If we have two vectors P and Q defined as:

$P = a\mathbf{i} + b\mathbf{j}$

$Q = c\mathbf{i} + d\mathbf{j}$

Where a, b, c, d are constants; i is the unit vector in the x-direction and j is the unit vector in the y-direction. Then it can be shown that the dot product (scalar product) is given by: $P \cdot Q = ac + bd$

For convenience, let vectors P and Q be as shown on the graph. (P is horizontal)



Simple trigonometry gives us:

$\cos \theta = \frac{c}{|Q|}$, so $c = |Q| \cos \theta$ and $\sin \theta = \frac{d}{|Q|}$, so $d = |Q| \sin \theta$

since P is horizontal, $a = |P|$, $b = 0$

so

$ac + bd = a|Q| \cos \theta + 0 \Rightarrow |P||Q| \cos \theta$

Therefore $P \cdot Q = |P||Q| \cos \theta = as + bd$

Alternative form of the dot product

Find P·Q if P = 6**i** + 5**j** and Q = 2**i** – 8**j**

P·Q = (6i + 5j) · (2i – 8j) = (6 x 2) + (5 x -8) = 12 – 40 = -28

Vector product

Consider vectors P and Q

The cross product of the two vectors is given by P X Q = $|P||Q|$ sin ɵn

Where $|P|$ and $|Q|$ = length of vector P and Q

ɵ = the angle between P and Q

n = unit vector perpendicular to the plane containing a and p and q

Gradient divergent and curl

The gradient of a scalar field

If F(r) = U(x, y, z) is a scalar field, ie a scalar function of position r = [x, y, z] in 3 dimensions, then its gradient at any point is defined in Cartesian co-ordinates by gradF =$i\partial/\partial x$ ∂U /∂xˆi + ∂U /∂yj + ∂U /∂z kˆ

$$\nabla = i\frac{\partial}{\partial x} + j\frac{\partial}{\partial y} + k\frac{\partial}{\partial z}$$

Then Grad F = ∇F

Note ∇F is a vector field

Example: find the gradient function ∇F if f(x,y,z) = $2x^2y^2 + yz - x$

Solution

∇ = (i∂/∂x, j∂/∂y, k∂/∂z)

∇F = (i∂F/∂x, j∂F/∂y, k∂F/∂z)

= $(4xy^2-1)i, (4x^2y + z)j, yk$

Divergent of a vector

Divergent of a vector divF = $\nabla\cdot\vec{F}$

Example: find the divergent of a vector given that F = $(x^2 + y^2, y^2 + z^2, x^2 + z^2)$

Solution

Let $x^2 + y^2 = P$, $y^2 + z^2 = Q$, $x^2 + z^2 = Q$

div$\vec{F}$ **=** $\nabla\cdot\vec{F}$ **=** $\mathbf{P_x + Q_y + R_z} = \{\partial/\partial x, \partial/\partial y, \partial/\partial z\}\{P, Q, R\} = 2x + 2y + 2z = 2(x + y + z)$

Curl of a vector

Mathematically, Curl $\vec{F} = \nabla X\vec{F} = [i\ j\ k\ \partial/\partial x\ \partial/\partial y\ \partial/\partial z\ P\ Q\ R\,]$ = (Ry – Qz, Pz – Rx, Qx – Py)

But $\vec{F} = x^2 + y^2, y^2 + z^2, x^2 + z^2$

P Q R

Curl $\vec{F}$ **= (0 -2z, 0 – 2x, 0 -2y) =(-2z – 2x – 2y)**

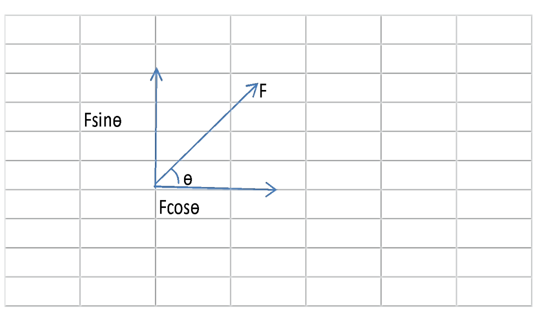
∴ curl $\vec{F}$ **= -2z – 2x – 2y**

Resolution of vectors

A vector can be resolved into two component parts such that the vector addition of the component parts is equal to the original

vector. The two components usually taken are a horizontal component and a vertical component. For the vector shown as ***F*** in

figure, the horizontal component is $F\cos\theta$ and the vertical component is $F\sin\theta$.



Problem 1. A force of 4N is inclined at an angle of 45◦ to a second force of 7N, both forces acting at a point. Find the magnitude of the resultant of these two forces

Horizontal component of force, H = 7 cos 0◦ +4 cos 45◦

*= 7+2.828=***9.828N**

Vertical component of force, V = 7 sin 0◦ +4 sin 45◦

*= 0+2.828=***2.828N**

The magnitude of the resultant of vector addition = $\sqrt{H^2 + V^2} = \sqrt{9.828^2 + 2.828^2}$ = *10.23*

The direction and magnitude of vector addition

= $\tan^{-1}(V/H) = \tan^{-1}(2.828/9.828) = 16.05^o$

Thus, the resultant of the two forces is a single vector of

10.23N at 16.05◦ to the 7N vector.

1.2.5.4 Learning activities

Special instructions	Key learning activities
After introductory lectureLearners will be provided with video link on vectors. They will be required to watch the video and demonstrate their knowledge by posting and responding on a padlet	**These are the key learning activities** • watch the video using the link provided https://youtu.be/xp6ibuI8UuQ • take notes: definition of vectors and scalars, classification of quantities as either vectors or scalars • login the discussion board using the password vectorscalar

	• post your own real life example of how a measurement can be a scalar or a vector situation

Table 8

1.2.5.5 Self-assessment

1. Among the following options, which are scalar-vector pairs…

A. Force – acceleration

B. Pressure – force

C. Displacement – speed

D. Electric current – pressure

2.Two vectors, F1 = 20 N and F2 = 30 N, have direction as shown in the figure below. Determine the resultant of components of vectors in x-axis and y-axis.

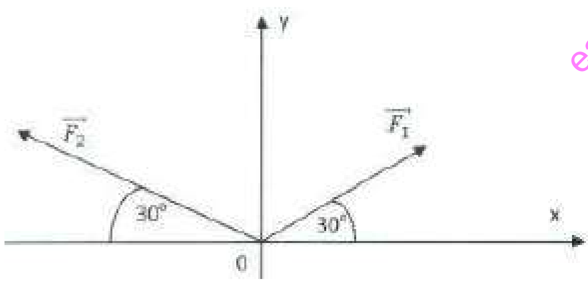


Figure 1.36

3 a mountain climbing expedition establishes a base camp and two intermediate camps, A and B. camp A is 11,200m east of B and 3,200m above base camp. Camp B is 8400m east of and 1700m higher than camp A. Determine the displacement between base camp and camp B.

4. find the dot product of $\vec{u} = [3, 5, 2]$ and $\vec{v} = [-1, 3, 0]$

5. find the scalar product of: $\vec{p} = 10\hat{i} - 4\hat{j} + 7\hat{k}$ and $\vec{q} = -2\hat{i} + \hat{j} + 6\hat{k}$

1.2.5.6 Tools, equipment and materials required

- Scientific Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Graph books
- Dice
- Computers with internet connection

1.2.5.7 RESPONSES TO SELF-ASSESSMENT

Learning outcome 1: Apply Algebra

1. simplify: $\frac{7^{-3} x 3^{4}}{3^{-2} x 7^{5} x 5^{2}}$ expressing your answer in index form with positive indices

   $= 3^6 \text{ x } 5^2/7^8$

2. use elimination method to solve the following simultaneous equation

$$3x + 4y = 5$$

$$2x - 5y = -12$$

   Answer: x = 4, y= 2

3. A craftsman and 4 labourers together earn £ 865 per week, whilst 4 craftsmen and 9 labourers earn £2340 basic per week. Determine the basic weekly wage of a craftsman and a labourer.

   Answer: craftsman = 225, laborers = 160

4. Solve the following quadratic equation by factorization method: $4x^2 + 8x + 3 = 0$

   Answer: x = -1/2 or x = -3/2

5. Solve $4x^2 + 7x + 2 = 0$ Using the general formular method and give your answer correct to 2 decimal places.

   Answer: X = -0.36 or -1.39

6. Simplify: $log64 - log128 + log32$

Answer: 4log2

7. Evaluate: $\frac{log25 - log125 + 1/2log625}{3log5}$

   Answer: 1/3

8. Solve for x: $log_2x + 6log_x2 = 5$

   Answer: x = 4 or x = 8

9. Use graphical method to solve the equation $x^2 - 3x - 10 = 0$

10. Use the graph of $y = x^2 + x - 6$ $to\ solve$ $x^2 + x - 6 = 0$ (x=2 or -3)

11. Evaluate the following:

   c) Log x^4 – log x^3 = log5x – log 2x [x = 2.5]
   d) Log 2t3 – log t = log 16 + log t [t = 8]

Learning outcome 2: apply coordinate geometry

1. **Find the** gradient of a line AB given the coordinates of A(2,3) and B(1,6)

   Answer: $\frac{dy}{dx} = \frac{6-3}{1-2}$ = -3

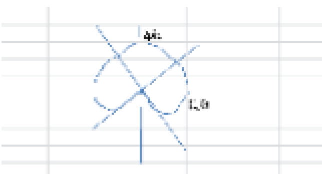
2. Write the equation of a line that is parallel to the line $2x - 4y = 8$ and passes through the point (3,o)

   Answer: $y = 1/2x - 3/2$

3. Sketch the graph of $r = 1 + \sin \theta$

θ	0	π/6	π/4	π/3	π/2	2π/3	3π/4	5π/6	5π/4	3π/2	7π/4
R	1	1.5	1.71	1.87	2	1.87	1.71	1.5	0.29	0	0.29

Table 2



4. Find the polar equation of the circle with radius $|a|$ centered = at (a,0)

   Answer:

   In Cartesian coordinates, the equation of the circle is $(x - a)^2 + y^2 = a^2$ which can be expressed as $(r\cos(\theta) - a)^2 + (r\sin(\theta))^2 = a^2$

   $r^2\cos^2\theta - 2ar\cos\theta + a^2 + r^2\sin^2\theta = a^2$

   $r^2(\cos^2\theta + \sin^2\theta) - 2ar\cos\theta = 0$, but $\sin^2\theta + \cos^2\theta = 1$

   $\therefore r^2 - 2ar\cos\theta = 0 \Rightarrow r(r - 2a\cos\theta) = 0,\ r = 0,\ r - 2a\cos\theta = 0$

   Thus the equation of the circle is $r = 2a\cos\theta$.

5. Convert $r = 7$ to a Cartesian equation

   Answer: $r^2 = 49 \Rightarrow x^2 + y^2 = 49$

6. Express the given cartesian co-ordinates correct to 2 decimal places in both degrees and radians

   d) (3,5) [(5.83, 59.54°) (5.83, 1.03 rad)]

   e) (6.18,2.35) [(6.61, 20.83°) (6.61, 0.36rad)]

   f) (-2, 4) [(4.47, 116.57°) (4.47, 2.03 rad)]

Learning outcome 3: mensuration

1. A water tank in the shape of a regular prism having length 2m, breadth 75cm and height 50cm determine the capacity of the tank in
    b) M^3 (b) cm^3 and (c) litres

    Answer: (a) $0.75m^3$ (b) $750000cm^3$ (c) 750 liters
2. Find the volume and total surface area of a cylinder of length 15cm and diameter 8cm

    Answer: volume = $754cm^3$, surface area = $477cm^2$
3. Calculate the volume and total surface area of the solid prism show in figure. 1.234

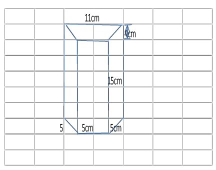


Fig. 1.234.

Answer: volume = $480cm^3$

Surface area = $454cm^2$

4. Calculate the total surface area of hemisphere of diameter 5.0cm

    Answer: surface area = $58.9cm^2$

Learning outcome 4: apply matrix

1. Given matrix A = $(2\ 1\ 4\ 3\ )$ and B = $(0\ 2\ 6\ 1\ )$ determine:
    iv) A + B ⇒ $(2\ 1\ 4\ 3\ ) + (0\ 2\ 6\ 1\ ) = (2\ 3\ 10\ 4\ )$
    v) A –B ⇒ $(2\ 1\ 4\ 3\ )$ - $(0\ 2\ 6\ 1\ ) = (2\ \ -1\ \ -2\ 2\ )$
    vi) 2A + 3B ⇒$2(2\ 1\ 4\ 3\ ) + 3(0\ 2\ 6\ 1\ ) = (4\ 2\ 8\ 6\ ) + (0\ 6\ 18\ 3\ ) = (4\ 8\ 26\ 9\ )$

2. Determine the inverse of the matrix A = $(3\ 5\ 4\ \ -3\ )$

   Answer: $(3/29\ 5/29\ 4/29\ \ -3/29\ )$

3. Solve the following simultaneous equations using matrix method

   3x + 5y = 7

   4x – 3y = 19

   Answer: x = 4, y = 1

4. Find the value of p for which matrix A is singular given that A = $(2p\ 6\ 8\ 4\ )$

   Answer: p = 6

5. Find the eigenvalues and the corresponding eigenvectors of a 2 x 2 matrix if

   A = $(0\ 1\ \ -2\ \ -3\ )$

   Answer: eigenvalues λ = -1 and -2

   Eigenvectors are: $V_1 = \left(\frac{1}{-1}\right)$

   $V_2 = \left(\frac{1}{-2}\right)$

Learning outcome 5: apply vectors

1. Among the following options, which are scalar-vector pairs…

A. Force – acceleration

B. Pressure – force

C. Displacement – speed

D. Electric current – pressure

Solution :

Force = vector, acceleration = vector

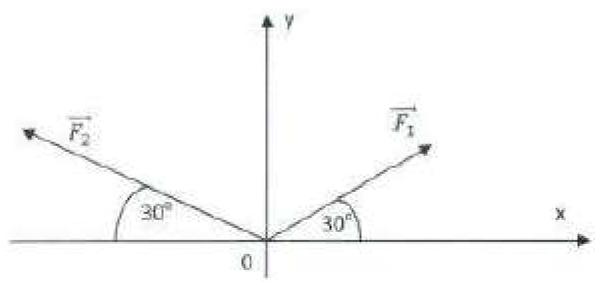
Pressure = scalar, force = vector

Displacement = vector, speed = scalar

Electric current = scalar, pressure = scalar

The correct answer is B.

2.Two vectors, F1 = 20 N and F2 = 30 N, have direction as shown in the figure below. Determine the resultant of components of vectors in x-axis and y-axis.



<u>Solution :</u>

$F1x = F1 \cos 30° = (20)(0.5\sqrt{3}) = 10\sqrt{3}$ Newton (plus sign because points to +x axis)

$F1y = F1 \sin 30° = (20)(0.5) = 10$ Newton (plus sign because point to +y axis)

$F2x = F2 \cos 30° = (30)(0.5\sqrt{3}) = -15\sqrt{3}$ Newton (minus sign because points to -x axis)

$F2y = F2 \sin 30° = (30)(0.5) = 15$ Newton (plus sign because points to +y axis)

The resultant of the x component :

$Fx = F1x + F2x = 10\sqrt{3}\ N – 15\sqrt{3}\ N = -5\sqrt{3}$ Newton

3. a mountain climbing expedition establishes a base camp and two intermediate camps, A and B. camp A is 11,200m east of B and 3,200m above base camp. Camp B is 8400m east of and 1700m higher than camp A. Determine the displacement between base camp and camp B.

Solution

Add vectors in the same direction with "ordinary" addition.

$$x = 11{,}200 \text{ m} + 8{,}400 \text{ m}$$

$$x = 19{,}600 \text{ m}$$

$$y = 3200 \text{ m} + 1700 \text{ m}$$

$$y = 4900 \text{ m}$$

Add vectors at right angles with a combination of pythagorean theorem for magnitude…

$r = \sqrt{(x^2 + y^2)}$

$r = \sqrt{[(19{,}600 \text{ m})^2 + (4{,}900 \text{ m})^2]}$

$r = 20{,}200 \text{ m}$

and tangent for direction.

$$\tan\theta = \frac{y}{x} = \frac{4{,}900 \text{ m}}{19{,}600 \text{ m}}$$

$\theta = 14.0°$

Therefore Camp B is 20,200 m away from base camp at an angle of elevation of 14.0°.

4.find the dot product of: $\hat{u} = [3,5,2]$ and $\hat{v} = [-1,3,0]$

answer: $\vec{u}.\ \vec{v} = u_1v_1 + u_2v_2 + u_3v_3 = 3[-1] + 5[3] + 2[0] = 12$

6. Find the scalar product of: $\vec{p} = 10i - 4j + 7k$ and $\vec{q} = -2i + j + 6k$

Answer: $\vec{p}.\ \vec{q} = u_1v_1 + u_2v_2 + u_3v_3 = 10[-2] + [-4][1] + [7][6] = 18$

1.2.5.7 list of reference

Bird, J. [2005] Engineering Mathematics, 4th Edition

Bird, J. [2006] Higher Engineering Mathematics, 5th Edition

Cook, M. [2005] A-level Core Pure Maths, 2nd Edition

CHAPTER 2: WORKSHOP TECHNOLOGY

Unit of learning code: ENG/CU/EI/CC/03/4/A

Related Unit of Competency in Occupational Standard; Perform Workshop Practices

2.1 Introduction to the unit of learning

This unit covers the competencies required to perform workshop process. Competencies include applying workshop Safety, use of workshop tools and instruments, preparation of workshop for electrical installation, Storage of Electrical tools and materials, troubleshoot and repair/replace workshop tools and equipment

2.2 Summary of Learning Outcomes

1. Apply workshop safety
2. Use of workshop tools, Instruments and equipment
3. Prepare workshop tools and instruments for an Electrical installation
4. Prepare the workshop for an Electrical installation
5. Store Electrical tools and materials
6. Troubleshoot and repair workshop tools and equipment

2.2.1 Learning Outcome 1: Apply Workshop Safety

2.2.1.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required in applying workshop safety. By the end of the lesson the trainee should be able to carry out and do the learning activities given in the learning guide. Also, it is provided with a self-assessment question with responses

All workshops and stores must be under the direct control of a supervisor, who is responsible for ensuring they are maintained and used in a safe and healthy manner. Only those authorized to do so may enter or work in workshops or stores, and must comply with the requirements of the supervisor whilst in that area.

All persons using workshops and stores should apply good housekeeping practices, wear appropriate clothing and footwear, and use the workshop or store only for its intended purpose.

A tidy workplace makes it easier to spot and avoid hazards, and does not interfere with normal work operations. Good housekeeping is fundamental to workshop safety management, and the time allocated to a job must include cleaning up afterwards. This applies to both individual and shared areas.

Personal items, food, drink or cigarettes are not to be taken into workshops and stores, unless a clean work-free area has been set aside for this purpose. Where necessary, lockers should be provided and used.

The store or workshop must be suited to the proposed task. The supervisor shall make the decision as to what tasks are appropriate for each situation.

2.2.1.2 Performance Standard

1. Proper use of PPE is adhered to as per standard operating procedure
2. Workshop rules are followed as per standard operating procedure
3. Proper use of safety equipment are followed as per the manufacturer's recommendations
4. First Aid procedures are adhered to

2.2.1.3 Information Sheet

Learning outcome 1: Apply workshop safety

Apply workshop safety

A Hazard is something with the potential to cause harm; for example, electric tools, working above ground level, wet or uneven floors, rotating parts.

Meaning of PPE (Personal Protective Equipment)

Personal Protective Equipment (PPE) Personal Protective Equipment (PPE) are:

- Gadgets to protect workers from injury or illness caused by having contact with the dangers/hazards in the workplace whether they are chemical, biological, radiation, physical, electrical, mechanical and others.
- It is protective clothing helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury or infection.
- All equipment designed to be worn, or held, to protect against a risk to health and safety.

This includes most types of protective clothing, and equipment such as eye, foot and head protection, safety harnesses, life jackets and high visibility clothing.

The hazards addressed by protective equipment include physical, electrical, heat, chemicals, biohazards, and airborne particulate matter. Protective equipment may be worn for job-related occupational safety and health purposes, as well as for sports and other recreational activities. "Protective clothing" is applied to traditional categories of clothing, and "protective gear" applies to items such as pads, guards, shields, or masks, and others. PPE suits can be similar in appearance to a cleanroom suit.

The purpose of personal protective equipment is to reduce employee exposure to hazards when engineering controls and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

PPE is needed when there are hazards present. PPE has the serious limitation that it does not eliminate the hazard at the source and may result in employees being exposed to the hazard if the equipment fails.

Any item of PPE imposes a barrier between the wearer/user and the working environment. This can create additional strains on the wearer; impair their ability to carry out their work and create significant levels of discomfort. Any of these can discourage wearers from using PPE correctly, therefore placing them at risk of injury, ill-health or, under extreme circumstances, death. Good ergonomic design can help to minimize these barriers and can therefore help to ensure safe and healthy working conditions through the correct use of PPE.

https://en.wikipedia.org/wiki/Occupational_safety_and_health

Care for PPEs

Personal protective equipment should be taken cared as of the other tools and equipment.

1. Wipe your helmets, gloves, safety shoes before keeping it.
2. It should also be cleaned, kept in proper tool rack/ cabinet.
3. It should be stored in dry places so that it will not have mold build-up.
4. Over-all suites should be washed regularly so that perspirations and other dirt will be washed clean.

Standard operating procedure in PPE

This standard operating procedure incorporates the requirements for use of Personal Protective Equipment (PPE) for project staff, co-operators, volunteers, contractors, and those under the project's operational control.

PPE listed in this SOP shall be used to provide protection and safety necessary for those participating in a project activity with PPE requirements. Additional information on the purpose and type of PPE may be available through the SOP for that activity.

Roles and responsibilities

- Projects need to tailor the Roles/Responsibilities based on their staffing level
- Project Manager (PM) is responsible for the overall safety of the project staff and those participating in a project activity and must provide the appropriate PPE for those activities.
- Project Safety Officer (PSO) is responsible for issuing project PPE, for training project staff on the proper use and care of the PPE, and to ensure compliance with this SOP.
- Supervisor is responsible for ensuring project staff and others participating in a project activity are properly wearing their issued PPE. After temporarily issuing the appropriate PPE to non-project personnel, train them on how to use the PPE and retrieve the PPE upon completion of the activity.

- Project Staff is responsible for properly wearing their issued PPE for that activity. They must also properly maintain their issued PPE and when needed request a new PPE to replace worn out or damaged PPE. They will assist the Supervisor when non
- Project people are participating in an activity requiring specific PPE.
- Others participating in the activity must be trained in the proper use of the assigned PPE and wear it properly when directed by project staff.

Training

The PSO or Supervisory staff will train project employees on the use and care of the PPE.

PPE selection

PPE shall be provided, used, and maintained wherever hazards exist (e.g., processing, environmental, chemical, mechanical) or are encountered in a manner capable of causing injury or impairment in the function of any part of the body. Injury can occur though absorption, inhalation, or physical contact with these hazards. The designated PPE person shall set a good example by donning PPE and following Program policy. The following provides guidelines for hazard assessment and PPE selection.

Eye and face protection. Appropriate eye or face protection shall be worn if exposures to potentially injurious hazards exist (e.g., flying particles, liquid chemicals, corrosives, chemical gases, vapors, UV rays). All eyewear shall provide:

- eye and side protection (detachable or permanent)
- protective devices to be worn over prescription eyewear, if needed
- a proper and comfortable fit.

Foot hazards

1. OSHA requires that staff wear protective footwear if the potential for foot injuries exist, including exposure to:
    - compression, squeezing, smashing, falling, or rolling objects
    - electrical hazards
    - slipping
    - chemicals

- temperature extremes
- repeated wetness which may result in fungal infections
- puncturing from objects which may pierce the sole of footwear

2. Engineering and work-practice solutions shall be utilized, including wearing footwear correctly (fully laced, etc.) to receive maximum protection. The Program shall prohibit the use of sandals or open shoes.

Hand and body protection

1. Glove manufacturer specification charts provide guidance in selecting proper PPE. Appropriate hand and body PPE shall be worn when potential hazards exist, including exposure to:
    - Cuts and punctures—severe cuts and lacerations, abrasions or punctures from tools, machines or from handling sharp objects
    - Thermal exposure—caused by extreme cold or heat or hot work
    - Blood borne pathogens—caused by first-aid or clean-up of blood, body fluids, or other infectious agents.
    - Chemical exposure—skin contact from working with chemicals
    - Repetitive motion disorders—caused by computer use or jobs requiring repetitive motion may cause carpal tunnel syndrome
    - entanglement—caused from wearing gloves, clothing, or jewelry near moving equipment
2. Potential engineering and work-practice solutions may include:
    - machine guards—protects against cuts, punctures, abrasion, and chafing
    - job rotation—protects against repetitive motion hazards
    - good housekeeping and clean-up—protects against chemical and blood borne hazards

- workstation design—protects against repetitive motions and provides accident prevention
- evaluating waste prior to handling—aids staff in determining appropriate PPE and process method
- splash guards—protects against chemical contact with skin or eyes

Head protection Head protection (e.g., hard hat) shall be worn if potential for injury from falling objects exist. All head protection shall:

Be used according to manufacturer's instructions

Not be altered in any way include bump caps as an appropriate alternative (if exposure to scalp injuries exist)

Hearing protection Facility staff shall wear hearing protection when exposed to noise levels in excess of 85 dB (A) for an eight-hour time-weighted average.

Respiratory protection Site specific ventilation or exhaust systems are effective engineering control tools.

Workshop safety

The safety in Workshops has been written not only to provide appropriate safety procedures but also to assist trained workshop personnel with the provision of a reference document outlining the general principles of safe working practices relevant to the mechanical engineering aspects. It relates to specific areas where definite safety measures are required for workshop operations

Factories Act and Accident

Various acts relating to accidents are spelt out in workmen's compensation Act-1923. The factories act-1948 and Fatal Accidents Act-1855. These acts describe the regulations for fencing and guarding the dangerous machinery, items and employer's liabilities.

Introduction to workshop safety

A workshop is where you learn to use tools and machines to make things; It can be a dangerous place, so you must learn the safety rules for the workshop.

The safety rules tell you how to dress appropriately and how to behave whilst working with tools that may cause harm. You must never play in the workshop, run around or throw equipment to one another.

Personal safety:

The basic dress rules that you should always follow are:

1. **Proper clothing.**
   You must not wear loose clothes that can be caught in moving machinery. You must wear tight fitting overalls
2. **Proper eye protection.**
   You must always wear goggles to protect your eyes while you are working in the workshop.
3. **Remove tie and jewellery**.
   Ties, watches, rings and other jewellers increase the chance of getting caught by moving machinery. You must remove them before entering the workshop.
4. Cut or secure long hair. Long hair is also dangerous as it may be caught by the machine and pulls you into it.
5. **Proper shoes**. You must not wear sandals or soft shoe inside the workshop as they will not protect your feet from falling objects. A safety shoes (steel-toe shoes) will protect your feet if you accidentally drop something.

   The way you dress in the workshop is very important for your safety, always be sure to wear properly and encourage your friends to do the same.

General workshop safety

It's essential to be aware of and able to foresee the dangers which exist in the workshop and are likely to affect your health and safety.

You should make sure that your workspace is as safe as possible so that few dangers arise.

i) Use the appropriate protective clothing and equipment to minimize the risk of accident

ii) Act in a safe manner at all times.

General Safety Precautions while Working in a Workshop

1. One should not leave the machine ON even after the power is OFF and until it has stopped running completely. Someone else may not notice that the machine is still in motion and be injured.
2. Operator should not talk to other industrial persons when he is operating a machine.
3. One should not oil, clean, adjust or repair any machine while it is running. Stop the machine and lock the power switch in the OFF position.
4. One should not operate any machine unless authorized to do so by the authorize person in the shop.
5. Always check that work and cutting tools on any machine are clamped securely before starting.
6. The floor should be kept clean and clear of metal chips or curls and waste pieces. Put them in the container provided for such things. Scraps and chips or curls may cut through a shoe and injure the foot.
7. Defective guards must be replaced or repaired immediately.
8. One should not operate any machinery when the supervisor or instructor is not in the shop.
9. All set screws should be of flush or recessed type. Projecting set screws are very dangerous because they catch on sleeves or clothing.
10. One should not try to stop the machine with hands or body.
11. Only trained operator should operate machine or switches as far as possible.
12. Always take help for handling long or heavy pieces of material.
13. Always follow safe lifting practices

14. No one should run in the shop at work time.
15. Always keep your body and clothes away from moving machine parts. Get first aid immediately for any injury.
16. Never talk to anyone while operating the machine, nor allow anyone to come near you or the machine.
17. Stop the machine before making measurements or adjustments.
18. Operator should concentrate on the work and must not talk unnecessarily while operating the machines.
19. Never wear necktie, loose sweater, wristwatch, bangles, rings, and loose fitting clothing while working in workshop.
20. Always wear overcoat or apron.
21. Stop machines before attempting to clean it.
22. Make sure that all guards are in their place before starting to operate a machine.
23. Do not attempt to operate a machine until you have received operating instructions.
24. Be thoroughly familiar with the 'stop' button and any emergency stop buttons provided on the machines.
25. Remove burrs, chips and other unwanted materials as soon as possible. They can cause serious cuts.
26. Do not leave loose rags on machines.
27. Wash your hands thoroughly after working to remove oils, abrasive particles, cutting fluid, etc.
28. Report all injuries to the foreman, howsoever small. Cuts and burns should be treated immediately.
29. Keep the work area clean.
30. Keep your mind on the job, be alert, and be ready for any emergency.
31. Always work in proper lighting.
32. On should not lean against the machines.

Concept of accident

It is very difficult to give a definition of the word 'Accident'. However, a generally accepted conception that an accident is a mishap, a disaster that results in some sort of injury, to men, machines or tools and equipment and in general loss to the organization.

The said injury or loss may be of minor or major nature and the accident is termed as non-reportable or reportable. For example, a small cut on the body will be reportable accident in a training workshop. It can be treated by first aid and does not involve any appreciable loss of time, and will not be considered a reportable accident in a production unit.

Causes of accidents

The 98% accidents could be easily avoided provided due precautions are taken well in time. A very familiar slogan goes on to say that accidents do not just happen but are caused due to the failure of one element or the other, and the most unfortunate factor is that the human element is the most pronounced of all which fail.

The common causes which lead to accidents are the following:

1. Unsafe working position.

2. Improper or defective tools or their improper use.

3. Improper acts- which result in violation of safety rules and non-observance of safety precautions.

Causes of accidents

1. Causes due to human beings

a) Carelessness

This is due to overconfidence, loss of interest, fatigue (continuous work without rest), monotony, unnecessary emotion which diverts concentration on the work being done hence resulting to accidents.

b) Ignorance

An operator must understand the users and the function of his machine equipment.

c) Unsuitable clothing in working areas,

Personnel should wear clothing which will provide protection against dangers in areas where they work. That is:

Safety Shoes/boots. They should be a type which provides protection against slippery conditions.

They should be strong enough in the feet to prevent injury from hurting objects e.g. safety boots.

Gloves- They should be worn where there are risks when harming sharp objects whether inside or outside buildings.

Safety glass

- Safety glasses or goggles should be worn where there's likely of danger to the eyes, such as using drills, grinding machines etc.

d) Untidiness

- Keep all passage ways clear and clean.

Circular rods if stepped upon can cause nasty falls.

- Keep the workshop floor free from grease and oils.

2. Contributing causes

a) Unsatisfactory hand tools

E.g. being worn out without handles

- Hammers with loose handles or crippled faces should never be used.
- Chisels with burred heads are dangerous as broken pieces from the edges may fly off and cause injury.
- Files should have tight handles to prevent accidents to the hands.
- Spanners which fit incorrectly will slip and can result I n damaging fingers.
- When drilling always ensure that the work is securely held in a vice or otherwise securely clamped.

b) Unsatisfactory machines

- That is being insufficiently spaced, unguarded, broken, improperly adjusted, insufficiently lubricated and being too small or weak for the job being undertaken.
- So see that all machines are properly guarded, all abrasive wheels are kept in good condition and run at safe speeds.
- Don't attempt to adjust or remove by hand a belt on a rotating shaft.

- don' t allow idle belt to rest on rotating shaft and don' t attempt to oil overhead shafting while it' s in motion.

c) Physical condition of personnel while working

E.g. before lifting equipment ensure that the weight is within your capability to handle. A base that anything used for lifting is serviceable and in good working condition chains, hooks etc.

Should never be overloaded.

Common sources of accidents

The large number of machines in use and an even larger number of parts. This can be regarded as sources of danger and require guarding for protection against accidents.

Some common sources of accident are listed below:

Projecting nips between sets of revolving parts, viz, gears, rolls and friction wheels, etc.

1. Projecting fasteners on revolving parts.

2. Revolving cutting tools, circular saw blades.

3. Revolving drums, crushers, spiked cylinder and armed mixers, etc.

4. Revolving shafts, spindles, bars and tools like drills, reamers, boring bars and chucks, etc.

5. Projecting sharp edges or nips of belt and chain drives viz., belt, pulleys, chains, sprockets and belt fasteners.

6. Reciprocating tools and dies of power presses, drop hammers, and revolving presses, etc.

7. Grinding wheels and stones.

8. Reciprocating knives and saw blades such as cutting and trimming machines and power hack-saws, etc.

9. Revolving drums and cylinders without casing, such as concrete and other mixers.

10. Intermittent feed mechanisms.

11. Projecting nips between various links and mechanisms, like cranks connecting rods, piston rods, rotating wheels and discs, etc.

Common Methods of Protection

The common methods of protection against accidents are the following:

1. Safety by position.

2. Safety by construction.

3. Safety by using interlock guards.gg

4. Safety by using fixed guards.

5. Safety by using automatic guards.

6. Safety by using distance guards.

Safety by construction

When a new machine is designed, it should be ensured that all its dangerous parts are either enclosed in suitable housings or provided with suitable safety guards. For example, the belt drive and motor in a lathe or milling machine are enclosed; the back gears in a lathe are either enclosed or provided with cast iron guards or covers. Lubricating points are provided on the outer surfaces so that the interior parts are not required to be opened every time.

Safety by position

The machine design is in such a way that the dangerous parts are located such that they are always beyond the reach of the operator. The dangerous parts of all the machines should invariably be guarded and undertaking should be made to make them enclosed in the body or housing of the machines.

Safety by using interlock guards

It is a very efficient and sound method of guarding in that the guard cannot be removed and dangerous parts exposed until and unless the machine is totally stopped. Similarly, the machine cannot be started to work unless the guard returns in position and protects the dangerous parts.

An interlocking guard may be mechanical, electrical or some sort of a combination of these. It is essential that it should:

1. Prevent the starting and operation of the machine in case the interlocking device fails.

2. Always acquire its position to guard the dangerous part before the machine can be started.

3. Remain closed in position until the dangerous part is completely at rest.

Safety by using fixed guards

These guards either for man integral part of the machine or are tightly secured to them. They should be made to have rigid construction and should be so placed that any access to the dangerous parts of the machine is totally prevented in the running condition of the machines.

Steel sheets can be advantageously used and they facilitate an easy fabrication of guards and are lighter in weight.

In some cases the fixed guards are made adjustable in order to accommodate different kinds of works or sets of tools. In some cases the fixed guards are provided at a distance from the danger point.

Safety by using distance guards

The principle of a distance guards is that a fencing, enough high, is made of bars, at a suitable distance from the machine such that even if the operative, by chance, extends his hands over it, his fingers, clothes or any part of the body does not reach within the area of dangerous parts. An additional measure of safety, some sort of tripping device is also usually incorporated to stop the machine quickly in case of an accident.

Safety by using automatic guards

The principle of an automatic guard is that its operation is actuated by some moving part of the machine.

It may link that the part will automatically bring the guard in protecting position before the operation of the machine starts. The design of the guard is such that it automatically forces the operative away from the dangerous area of work before the operation starts and does not permit his access to the area again until and unless the machine stops. It may be noted that due to enough time being required for their operation, this type of guards are not suitable for quick-acting and fast-running machines. Their use is largely favored for heavy and slow acting machines like heavy power presses.

Industrial safety

The factory act 1961 states that:

i) Floors steps stairs passages and gang ways must be soundly constructed properly maintained and kept free from obstruction and any substance likely to cause a person to slip.

ii) Hand rails must be provided for stairs.

iii) All ladders must be soundly constructed and properly maintained.

iv) Opening in floors shall, wherever practicable be securely fenced.

Special regulations

The following precautions should be observed

i) Always work never runs

ii) Never throw rubbish on the floor

iii) Keep gang ways and work areas free of metal bars, components, etc.

v) Keep to gangways when moving about never takes short cuts.

vi) If oil water or grease is spilled wipe it up immediately

vii) Wear safety shoes- shoes are available with until slip soles and with metal toe caps to protect the feet from falling objects.

viii) Always check ladders for damage before use.

ix) Always position ladders on firm base at the correct angle.

Aims and objectives

The major objectives of the factory act are;

1. To provide protection to the workers employed in factories against industrial hazards and to ensure safe and better working conditions.

2. It regulates and maintains properly various safety health and welfare activities in the factories.

3. It regulates & maintains working hours of workers, employment of children and adolescents, employment of women, annual leave with wages etc.

The salient features of this act regarding safety are as follows;

1. Fencing of machinery

-Every prime mover like engine or motor, moving part of the machinery is fenced properly.

2. Work on or near the machinery in motion.

Only specially trained workers wearing tight fitting clothes should carry out inspection of any part of the machinery in motion.

3. Employment of young persons on dangerous machines.

No young person should be allowed to work on dangerous machine unless he is properly trained and carefully supervised

4. Hoist and lifts

- Every hoist and lifts should be of god mechanical construction, adequate strength and must be protected by enclosure and fitted with gates.
- Every hoist and lift should be adequately maintained and periodically examined

5. Listing machinery, chains, ropes and lifting tackles

Lifting machines such as cranes, crab, etc should be of good construction, adequate strength should be maintained.

6. Revolving machinery

It should always be ensured that safe working peripheral speed is not exceeded for every revolving machinery.

7. Pressure plants

- The pressure plant should not be operated at a pressure higher than the specified safe working pressure.

8. Floors stairs and means of access to different places

All floors, steps, stairs, passages should of sound construction and free from obstructions

9. Pits sumps, opening in floor etc.

-Every pit, sumps, opening in floor, fixed vessels, tanks etc should be securely covered or fenced.

10. Excessive weights

- No person should be asked to lift carry or move any load so heavily that’s likely to cause him injury.

- Protection of eyes.

➢ **Causes of fire**

A house can easily catch fire from the misuse of appliances and heating equipment to smoking in bedrooms.

However you can take measures to avoid fire in home and ensure the safety of your family. Below are some of the most common causes of house fires, and some tips to take precautions.

1. Cooking equipment

Pots and pans can overheat and cause a fire very easily if the person cooking gets distracted and leaves cooking unattended. Always stay in the room, or ask someone to watch your food, when cooking on hotplates.

2. Heating

Keep portable heaters at least one metre away from anything that could easily catch fire such as furniture, curtains, laundry, clothes and even yourself. If you have a furnace, get it inspected once a year to make sure it is working to safety standards.

3. Smoking in bedrooms

Bedrooms are best to be kept off limits for smoking. A cigarette that is not put out properly can cause a flame, as the butt may stay a lit for a few hours. It could burst into flames if it came into contact with flammable materials, such as furniture.

4. Electrical equipment

An electrical appliance, such as a toaster can start a fire if it is faulty or has a frayed cord. A power point that is overloaded with double adapter plugs can cause a fire from an overuse of electricity. A power point extension cord can also be a fire hazard if not used appropriately. Double check the appliances and power points in your home.

5. Candles

Candles look and smell pretty, but if left unattended they can cause a room to easily burst into flames. Keep candles away from any obviously flammable items such as books and tissue boxes. Always blow a candle out before leaving a room.

6. Curious children

Kids can cause a fire out of curiosity, to see what would happen if they set fire to an object. Keep any matches or lighters out of reach of children, to avoid any curiosity turned disaster. Install a smoke alarm in your child's room and practice a home escape plan with your children and family in case there was a fire.

7. Faulty wiring

Homes with inadequate wiring can cause fires from electrical hazards. Some signs to see if you've bad wiring are:

1. Lights dim if you use another appliance;
2. For an appliance to work, you have to disconnect another;
3. Fuses blow or trip the circuit frequently.

Have a licensed electrician come and inspect you house, or contact your landlord if you have any of the above occurrences.

8. Barbeques

Barbeques are great for an outdoor meal, but should always be used away from the home, tablecloths or any plants and tree branches. Keep BBQs regularly maintained and cleaned with soapy water and clean any removable parts. Check the gas bottle for any leaks before you use it each time.

9. Flammable liquids

If you have any flammable liquids in the home or garage such as petrol, kerosene or methylated spirits, keep them away from heat sources and check the label before storing. Be careful when pouring these liquids.

10. Lighting

Lamp shades and light fittings can build up heat if they are very close to light globes. Check around the house to make sure. Lamp bases can become a hazard if they are able to be knocked over easily, and so should be removed if they are. Check that down lights is insulated from wood panelling or ceiling timbers.

The above tips are a good guide to avoiding a fire in your home. However it's a good idea to protect yourself with adequate home insurance cover to ensure you are covered in the unlikely event a fire were to happen

http://www.cfs.sa.gov.au/site/fire_safety/house_fire_safety/common_causes_of_fire.jsp

Classification of fires

Fire can cause loss of lives, jobs equipment, materials and buildings.

For all practical purposes there are three main classes of fires; A B &C

Class A fires (Solids)

Fires involving ordinary combustible materials such as wood, paper & cloth.

This is one of the most common types of fire because solids are the most common type of fuel and one that is hard to eliminate.

Good housekeeping should help to keep materials like packaging and waste reduced, minimizing risks Water extinguisher is one of the most popular types of extinguishers used class A fire. It can handle most fires involving solids.

The majorities of fires are in this class and can be most effectively extinguished by cooling with water.

Class B fires(liquids)

Fires from flammable liquids such as paraffin, petrol, paint, varnishes, oil and from greases and fats.

Many of the fluids, liquids and chemicals used in workplaces can be flammable or explosive. Like cleaning fluids, solvents, fuels, inks, adhesives and paints.

Make sure you know what flammable liquids are used in your workplace, and carry out a Control of Substances Hazardous to Health' (COSHH) assessment Control of Substances Hazardous to Health assessments are a legal requirement, for any hazardous substances. This about safe storage and use of these substances, keep them in labeled containers and away from sources of ignition. Should a class B fire ignite, foam or powder extinguishers are the best types of extinguishers to attack this type of fire.

Class C fires (gases)

Class C fires are fires involving gases. This could be natural gas, Liquefied petroleum gas (LPG) or other types of gases forming a flammable or explosive atmosphere.

Work with gas is dangerous, and increases fire risk. Keep stored gases in sealed containers in a safe storage area, and ensure that gas work is carried out by competent persons.

While extinguishers can be used on class C gas fires, the only safe method to attack this type of fire is to shut off the gas supply. The best type of extinguisher to put out the fire when the supply of gas is off is a dry powder extinguisher

Fires involving live electrical equipment and wiring. The safest method of extinguishing is to displace the oxygen by projecting a gas or dry powder into the vicinity of the fire.

Class D fires (Metals)

Metals are not often thought of as a combustible material, some types of metal can be, like sodium. Metals are also good conductors, helping a fire spread. All metals will soften and melt at high temperature, which can be a big problem when metal joists and columns are present in a fire as structural elements.

Water can actually act as an accelerate on metal fires, so how would you tackle a class D fire? There are dry powder extinguishers developed to tackle metal fires. The powder inside the extinguisher may vary depending on the type of metal risk it is designed for. Small metal fires can sometimes be smothered with dry earth or sand.

Electrical Fires

This is not strictly a class (class E) of fire, because electricity is more or a source of ignition than a fuel. However, fires in live electrical equipment are an additional hazard. You don't want to be using water, or any other conductor as that could be fatal.

Electrical fires are not given their own full class, as they can fall into any of the classifications. After all it is not the electricity burning but surrounding material that has been set alight by the electric current.

To avoid electric fire;

Making sure electrical equipment and installations are installed correctly, and inspected and maintained, will help to reduce the risk of this type of fire.

Class F (Cooking Fats & Oils)

Deep fat frying and spillages of flammable oils near to heat sources in kitchens can result in a class F fire.

Never leave food or frying equipment unattended during use. The only type of fire extinguisher approved for use on cooking oils and fats is the wet chemical extinguisher. For small class F fires, you could also use a fire blanket.

While you shouldn't use water to attack an electrical fire, you can use other types of fire extinguishers. Like carbon dioxide, and dry powder in low voltage situations. Always turn off the power supply if you can.

In the event of a fire:

The following precautions should be observed at all times.

i) Know the correct fire drill and the positions of fire alarms, firefighting equipment and emergency exits.

ii) Know the correct appliance to use for a particular type of fire and know how to use t.

iii) Don’t bock fire exits.

iv) Don’t use fire appliances for any purpose other than intended.

v) Never smoke in no smoking areas

vi) Always ensure that matches and cigarettes are put out before throwing them away

vii) Avoid spillage of flammable liquids.

Extinguishers and fighting procedures

1) Water type

These are usually operated by striking a plunger to release a gas which pressures the water and forces it out of the nozzle. They are stable only for class-A fires.

- The jet should be directed at the base of the fire and be kept moving across the area of the fire.

2. Chemical foam type

- These may be operated by inverting the extinguisher or by releasing a plunger allowing two solutions to mix and produce foam.
- They are used on class B fires involving flammable liquids.
- The jet is directed with a gentle sweeping movement, allowing the foam to drop down and lie on the Surface of the liquid.
- This smothers the fire by excluding oxygen.

3. Carbon-dioxide (Co_2) type

These are operated by squeezing the discharge lever which allows the liquid co2 to be discharged as a gas. They are used on class c fires where after the current has been switched off the discharge horn is directed straight at the fire.

4. Dry powder pressure type.

This type contains a pressurized as and a dry chemical agent. After the release lever has been operated discharge is controlled by a nozzle at the end of the nose.

These are used on class c fires in the same way as the Co_2 type.

Use of fire extinguishers

Class of fire		Type of fire extinguisher			
		Water	Foam	CO_2	Dry powder
A	Ordinary fires: wood , paper ,cloth	Yes	Yes	No	No
B	Flammable liquids: petrol ,paraffin	No	Yes	Yes	Yes
C	Electrical equipment	No	No	Yes	Yes

Table 1: Uses of fire extinguishers

Fire precautions

Fire is a great danger in a workshop and care must be taken not to start a fire. The main causes of fire are:

1. Careless storage of flammable materials.
2. Careless electrical maintenance.
3. People throwing away cigarettes.

Electrical safety

- Electrical can't be seen we only see the effect due to it.
- Because of this care must be taken when using electricity. There are two main causes of accidents due to electricity.

These are

(i) Carelessness: this arises because of laxity. When electricians have worked for long period they tend to assume the high standards of safety required and start to maintain equipment when it' s live and as a result an accident can easily occur.

(ii) Ignorance and inexperience. Most of the electrical tasks appear very simple when carried out by well-trained electricians. When unqualified personnel attempt to do the same they are usually unable and they leave the tasks uncompleted. This is dangerous to the others. The safety precaution in any electrical installation is to:

i) Prevent electric shock.

ii) Prevent the occurrence of fire due to electrical fires.

Electric shock

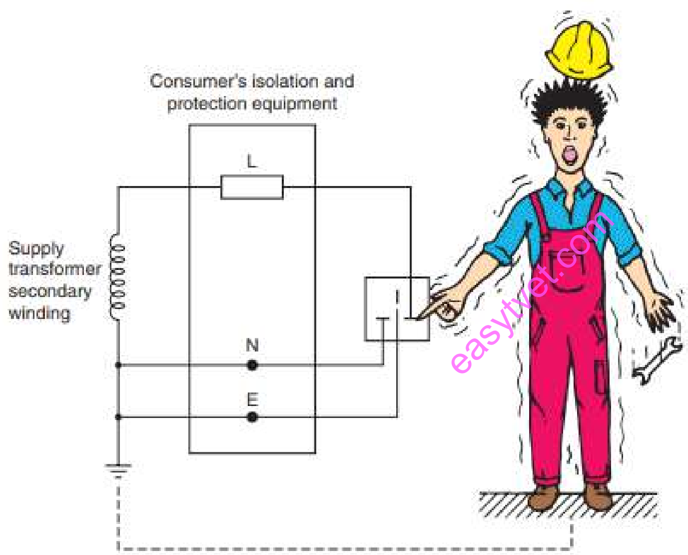


Figure 1:Touching live and earth or live and neutral makes a person part of the electrical circuit and can lead to an electric shock.

- Electric shock occurs when a person becomes part of the electrical circuit.
- One gets electric shock when he or she is in contact with two objects that are at different potentials.
- The person complete the circuit to earth and the current flows through him/or her.

The damage done to the human body will depend on the following factors:

i) Voltage between the two points

ii) The amount of current flowing

ii) The time taken for the current to flow

Also the level or intensity of the shock will depend upon factors, such as age, fitness and the circumstances in which the shock is received. The lethal level is approximately 50 mA, above which muscles contract, the heart flutters and breathing stops. A shock above the 50 mA level is therefore fatal unless the person is quickly separated from the supply. Below 50 mA only an unpleasant tingling sensation may be experienced or you may be thrown across a room, roof or ladder, but the resulting fall may lead to serious injury.

- The methods used to prevent electric shock are;

i) Earthing the metallic and any equipment within the installation

ii) Using all the insulated wiring systems

Treatment of electric shock

If somebody get electric shock, the immediate action should be:

i) Switch off the supply

ii) If necessary start artificial respiration

iii) Seek medical assistance

iv) Treat the burns or injuries.

v) Keep the victim warm.

If the person is in contact with the live conductors then the first thing is to break the contact .care must be taken in order not electrocute yourself.

Try to switch off the supply or to unplug the equipment incase it's a portable tool e.g. a drill. Under no circumstances should you attempt to touch the person. It may be possible to detach the person by pulling or pushing him/her by using insulated object e.g. an insulated cable looped rounded the victims arm or body using a dry wooden pole.

- After the victim is removed from the live contacts provide artificial respiration by using any of the following methods

i) Mouth to mouth

ii) Holger-Nelson

i) Mouth -mouth

- In this method, the patient must be on his back and his mouth should be inspected for any obstructions e.g. false teeth.
- The patient head should be extended by placing one hand on his crown and the other immediately beneath his chin.
- Gently bend his head backwards and then using his both hands, lift his jaw forward.
- Place your lips over the patients' mouth and make a good seal with the thumb and one fore finger of one hand gently close the patient nostrils.
- Take a deep breath and exhale into the patient using little force.
- Watch and feel the patient's chest rise. Remove your lips and let the lungs deflate.
- The above procedure should be repeated twelve times per minute remembering to turn away your head as you don't fill your own lungs with the patients expired air.
- Continue inflation and depletion of the lungs until spontaneous breathing is maintained.

ii) Holger and Neilson.

- The patient should be placed face downwards with the arm overhead, the elbows flexed so that one hand rests on the other in turn.
- Turn the patients head to one side so that the neck rests on his upper most hand. Kneel to one side of the patients head and put the foot of your other leg near his elbow.

- Place your hands on his back just below the shoulder blades and rock forwards with your elbow straight until your arms are approximately vertical, exerting- steady pressure on his chest.
- Grasp the patient's arms just above the elbow and rock backwards raising his arms until tension is felt at the patients shoulder lower his arms.
- The complete cycle should be repeated twelve times a minute.
- This method is practical only when there's no gross injury to the arms shoulder and the ribs.

First aid

Definitions

First aid is the initial assistance or treatment given to a casualty for any injury or sudden illness before the arrival of an ambulance, doctor or other medically qualified person.

A **first aider** is someone who has undergone a training course to administer first aid at work and holds a current first aid certificate.

An **appointed person** is someone who is nominated to take charge when someone is injured or becomes ill, including calling an ambulance if required. The appointed person will also look after the first aid equipment, including re-stocking the first aid box.

First aid

Despite all the safety precautions taken on construction sites to prevent injury to the workforce, accidents do happen and you may be the only other person able to take action to assist a workmate. If you are not a qualified first aider limit your help to obvious common sense assistance and call for help, but do remember that if a workmate's heart or breathing has stopped as a result of an accident he has only minutes to live unless you act quickly.

The Health and Safety (First Aid) Regulations 1981 and relevant approved codes of practice and guidance notes place a duty of care on all employers to provide adequate first aid facilities appropriate to the type of work being undertaken.

The regulations state that:

Employers are under a duty to provide such numbers of suitable persons as is adequate and appropriate in the circumstances for rendering first aid to his employees if they are injured or become ill at work.

For this purpose a person shall not be suitable unless he or she has undergone such training and has such qualifications as the Health and Safety Executive may approve.

This is typical of the way in which the health and safety regulations are written. The regulations and codes of practice do not specify numbers, but set out guidelines in respect of the number of first aiders needed, dependent upon the type of company, the hazards present and the number of people employed.

First aid is the treatment of minor injuries which would otherwise receive no treatment or do not need treatment by a doctor or nurse or In cases where a person will require help from a doctor or nurse, first aid is treatment for the purpose of preserving life and minimizing the consequences of an injury or illness until such help is obtained. A more generally accepted definition of first aid might be as follows: first aid is the

- Initial assistance or treatment given to a casualty for any injury or sudden illness before the arrival of an ambulance, doctor or other medically qualified person.

A first aider is someone who has undergone a training course to administer first aid at work and holds a current first aid certificate. The training course and certification must be approved by the HSE.

- The aims of a first aider are to preserve life, to limit the worsening of the injury or illness and to promote recovery.
- A first aider may also undertake the duties of an appointed person. An appointed person is someone who is nominated to take charge when someone is injured or becomes ill, including calling an ambulance if required.
- The appointed person will also look after the first aid equipment, including re-stocking the first aid box.
- Appointed persons should not attempt to give first aid for which they have not been trained, but should limit their help to obvious common sense assistance and summon professional assistance as required.
- First aid personnel must be available at all times when people are at work, taking into account shift working patterns and providing cover for sickness absences.

Bleeding

If the wound is dirty, rinse it under clean running water. Clean the skin around the wound and apply a plaster, pulling the skin together.

If the bleeding is severe apply direct pressure to reduce the bleeding and raise the limb if possible. Apply a sterile dressing or pad and bandage firmly before obtaining professional advice.

To avoid possible contact with hepatitis or the AIDS virus, when dealing with open wounds, first aiders should avoid contact with fresh blood by wearing plastic or rubber protective gloves, or by allowing the casualty to apply pressure to the bleeding wound.

Burns

Remove heat from the burn to relieve the pain by placing the injured part under clean cold water. Do not remove burnt clothing sticking to the skin.

Do not apply lotions or ointments. Do not break blisters or attempt to remove loose skin. Cover the injured area with a clean dry dressing.

Broken bones

Make the casualty as comfortable as possible by supporting the broken limb either by hand or with padding.

Do not move the casualty unless by remaining in that position he is likely to suffer further injury. Obtain professional help as soon as possible.

Contact with chemicals

Wash the affected area very thoroughly with clean cold water. Remove any contaminated clothing. Cover the affected area with a clean sterile dressing and seek expert advice. It is a wise precaution to treat all chemical substances as possibly harmful; even commonly used substances can be dangerous if contamination is from concentrated solutions.

When handling dangerous substances, it is also good practice to have a neutralizing agent to hand.

Disposal of dangerous substances must not be into the main drains since this can give rise to an environmental hazard, but should be undertaken in accordance with local authority regulations.

Exposure to toxic fumes

Get the casualty into fresh air quickly and encourage deep breathing if conscious. Resuscitate if breathing has stopped. Obtain expert medical advice as fumes may cause irritation of the lungs.

Sprains and bruising

A cold compress can help to relieve swelling and pain. Soak a towel or cloth in cold water, squeeze it out and place it on the injured part. Renew the compress every few minutes.

Breathing stopped

- Remove any restrictions from the face and any vomit, loose or false teeth from the mouth. Loosen tight clothing around the neck, chest and waist.
- To ensure a good airway, lay the casualty on his back and support the shoulders on some padding.
- Tilt the head backwards and open the mouth.
- If the casualty is faintly breathing, lifting the tongue, clearing of the airway may be all that is necessary to restore normal breathing.
- However, if the casualty does not begin to breathe, open your mouth wide and take a deep breath, close the casualty's nose by pinching with your fingers, and, sealing your lips around his mouth, blow into his lungs until the chest rises.
- Remove your mouth and watch the casualty's chest fall.
- Continue this procedure at your natural breathing rate.
- If the mouth is damaged or you have difficulty making a seal around the casualty's mouth, close his mouth and inflate the lungs through his nostrils.
- Give artificial respiration until natural breathing is restored or until professional help arrives.

Heart stopped beating

- This sometimes happens following a severe electric shock. If the casualty's lips are blue, the pupils of his eyes widely dilated and the pulse in his neck cannot be felt, then he may have gone into cardiac arrest.
- Act quickly and lay the casualty on his back.
- Kneel down beside him and place the heel of one hand in the centre of his chest.
- Cover this hand with your other hand and interlace the fingers.
- Straighten your arms and press down on his chest sharply with the heel of your hands and then release the pressure.
- Continue to do this 15 times at the rate of one push per second.
- Check the casualty's pulse. If none is felt, give two breaths of artificial respiration and then a further 15 chest compressions.
- Continue this procedure until the heartbeat is restored and the artificial respiration until normal breathing returns. Pay close attention to the condition of the casualty while giving heart massage.
- When a pulse is restored the blueness around the mouth will quickly go away and you should stop the heart massage. Look carefully at the rate of breathing. When this is also normal, stop giving artificial respiration.
- Treat the casualty for shock; place him in the recovery position and obtain professional help.

Shock

Everyone suffers from shock following an accident. The severity of the shock depends upon the nature and extent of the injury. In cases of severe shock the casualty will become pale and his skin become clammy from sweating. He may feel faint, have blurred vision, feel sick and complain of thirst. Reassure the casualty that everything that needs to be done is being done. Loosen tight clothing and keep him warm and dry until help arrives.

Do not move him unnecessarily or give him anything to drink.

Items of a First-Aid Box

(i) Pair of scissors

(ii) Large size sterilized dressings

(iii) Medium size sterilized dressings

(iv) Small sized sterilized dressings

(v) Large size burn dressings

(vi) Packets of sterilized cotton wool

(vii) Rolled bandages 10 cm wide

(viii) Rolled bandages 5 cm wide

(ix) Bottle (4 oz) of salvolative having the doze and made 1 of administration indicated on label

(xi) Safety pins

(xi) Eye drops

(xii) Adhesive plaster

(xiii) 4 bottle containing $KMnO_4$ crystals, etc.

(xiv) 4 bottle containing a 2% alcoholic solution

(xv) Betadine ointment (50mg)

(xvi) Saframycine ointment (50mg)

(xvii) Dettol

Accident reports

Every accident must be reported to an employer and the details of the accident and treatment given are suitably documented. A first aid Log book or accident book containing first aid treatment record sheets could be used to effectively document accidents which occur in the workplace and the treatment given. Failure to do so may influence the payment of compensation at a later date if an injury leads to permanent disability.

To comply with the Data Protection Regulations, from the all First Aid Treatment Log books or Accident Report books must contain perforated sheets which can be removed after completion and filed away for personal security.

2.2.1.4 Learning Activities

Learning Activity 1

While working in busy production line in textile industry, fire erupts from one of the faulty electrical equipment. The fire gets contained but one of the workers gets minor burns on his left leg. Perform the following to relieve him/her from pain.

1. Cool down the burn. After holding the burn under cool, running water, apply cool, wet compresses until the pain subsides.
2. Remove tight items, such as rings, from the burned area. Be gentle, but move quickly before swelling starts.
3. Avoid breaking blisters. Blisters with fluid protect the area from infection. If a blister breaks, clean the area and gently apply an antibiotic ointment.
4. Apply a moisturizing lotion, such as one with aloevera. After the burned area has been cooled, apply a lotion to provide relief and to keep the area from drying out.
5. Loosely bandage the burn. Use sterile gauze. Avoid fluffy cotton that could shed and get stuck to the healing area. Also avoid putting too much pressure on the burned skin.
6. Take an over-the-counter pain reliever if necessary.
   Consider acetaminophen (Tylenol), ibuprofen (Advil), or naproxen (Aleve).

Learning Activity 2

Objective: to demonstrate skills on how to use a fire extinguisher.

Exercise: Using a fire extinguisher to performs the following tasks.

Instructions: Lit a ***firewood*** fire on ***an open field*** to extinguish in this exercise.

Caution: Fire should be handled with a lot of care and is very dangerous

Procedure

1. Pull the pin (or other motion) to unlock the extinguisher.
2. Aim at the base (bottom) of the fire and stand 6-10 feet away.
3. Squeeze the lever to discharge the agent.

4. Sweep the spray from left to right until the flames are totally extinguished.

2.2.1.5 Self-assessment

1. Hazard may be defined as:
   A. anything that can cause harm
   B. the chance, large or small, of harm actually being done
   C. someone who has the necessary training and expertise to safely carry out an activity
   D. the rules and regulations of the working environment
2. A positive attitude to safety at work:
   A. is the duty of every employer
   B. is the duty of every employee
   C. increases accidents at work
   D. reduces accidents at work
3. The most common cause of accidents at work is:
   A. gloves, boots and hard hats
   B. sprains, strains and trap pains
   C. slips, trips and falls
   D. hook, line and sinker

4. What safety precautions that should be adhered to when giving first aid on a burn?

5. Complete the following table to justify the type of fire extinguisher used for the classes of fires indicated. Use **Yes** or **No**

Class of fire		Type of fire extinguisher			
		Water	Foam	Co_2	Dry powder
A	Ordinary fires: wood , paper ,cloth				
B	Flammable liquids: petrol ,paraffin				

C	Electrical equipment				

6. State the General Safety Precautions while Working in a Workshop
7. John is an electrical technician. Name Personal protective equipment that he may have worn:

2.2.1.6 Tools, Equipment, Supplies and Materials

Tools

- Set of screw drivers
- Pliers
- Phase testers
- Multimeter

Equipment

- PPE –hand gloves, dust coat, dust masks
- Multimeter
- Clamp meter
- Earth electrode resistance meter
- Phase sequence meter
- Computer/smart phone

Materials and supplies

- Stationery
- Cables
- Lubricants
- Service parts

2.2.1.7 References

- IEE regulations

- Organizational procedures manual
- Electrical Installation Maintenance K to 12 – Technology and Livelihood Education Learning Module Republic of the Philippines Department of Education
- Ray_C._Mullin,_Phil_Simmons Electrical_Wiring_Re(z-lib.org)
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2.2.2 Learning Outcome 2: Use of workshop tools, Instruments and equipment

2.2.2.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to properly handle and use workshop tools and equipment. It also specifies the content of competencies in taking care and maintenance of workshop tools, instruments and equipment. The learning outcome must be assessed against as per standard operating procedure.

2.2.2.2 Performance Standard

3.3.2.2.1 ***Workshop tools***, Instruments and equipment are identified as per required installation

3.3.2.2.2 Tools, Instruments and equipment are used as per the manufacture's manuals

3.3.2.2.3 Proper handling of workshop tools, Instruments and equipment as per standard operating procedure

3.3.2.2.4 Care and Maintenance of workshop tools, Instruments and equipment as per standard operating procedure

2.2.2.3 Information Sheet

Classification of workshop tools

A **tool** is a device that can be used to produce an item or accomplish a task, but that is not consumed in the process. It can be considered as extension of the human hand thus increasing speed, power, and accuracy and on the other hands equipment includes any machine powered by electricity.

Hand tools

Hand tools are tools manipulated by hands without using electrical energy such as: puller, hacksaw, pull-push rule, pliers, hammer, and others.

Machine/Power tools

Machine/Power tools are tools manipulated by our hands and with the use of electrical energy such as: electric drill, grinding wheels, vacuum cleaner and others.

Pneumatic tools

Pneumatic tools are tools or instruments activated by air pressure. Pneumatic tools are designed around three basic devices: the air cylinder, the vane motor, and the sprayer.

Hand tools

They include screwdrivers, hammers, pliers, wrenches and pullers.

1. Screwdrivers are used to drive, or turn screws. The common type has a single flat blade for driving screws with slotted heads. The other type has the cross slotted head.

1. Hammers are mostly used tools in the shop. They should be gripped at the end of the handle.

2. Pliers are specified types of adjustable wrenches. The two legs move on a pivot so that items of various sizes can be gripped.

3. Wrenches are used to turn screws, nuts and bolts with hexagonal heads. ―Hexagonal‖ means six-sided. A variety of wrenches are used in the shop.

4. Pullers are used to remove gears and hubs from shafts, bushings from blind holes, and cylinders' liners from the engine blocks.

Machine/Power Tools

Electric drill has an electric motor that drives a chuck. The chuck has jaws that can be opened and then closed to grip a drill kit.

Grinding tool can be either bench-mounted or installed on a pedestal. They may either have a grinding wheel, view wheel, or two grinding wheel

3. Vacuum cleaner is used for cleaning the floor and car interiors after service.

Pneumatic tools

Pneumatic Torque Wrench. This wrench uses compressed air to quickly and powerfully turn nuts, bolts, and other objects.

Air chisel uses reciprocating motion to drive a cutting hammering tool. An air hammer drives a chisel to cut off a nut that has frozen to a stud. It can be used with a variety of tools-cutters and punches to do many jobs.

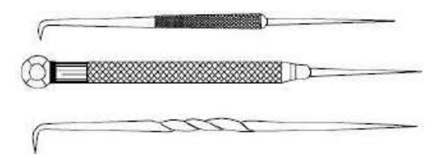
Air drill is lighter than a comparable electric drill. Repeatedly stalling or overloading does not damage or overheat the air drill.

Air racket uses the sockets and attachments from a standard socket set.

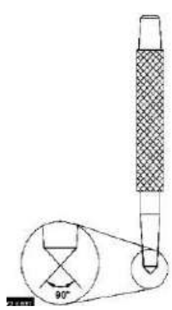
5. Pneumatic floor jack uses compressed air to flow into the jack cylinder and causes the ram to extend and raise the vehicle.

Marking tools

a) Marking out Tools are used to mark the given measurement on the surface of the work piece. a) Scriber



b) Dot punch



c) Center punch

d) Hermaphrodite caliper

Dividers

f) Try square

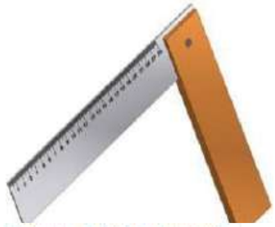
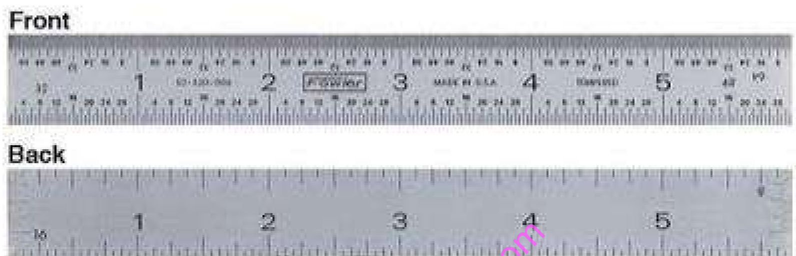


Figure SEQ Figure * ARABIC 7: Try square

g) Steel rule



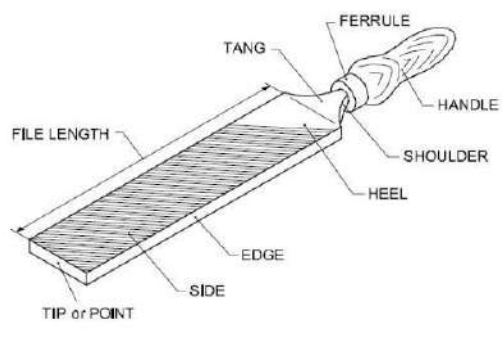
h) Scribing block

i) V-blocks

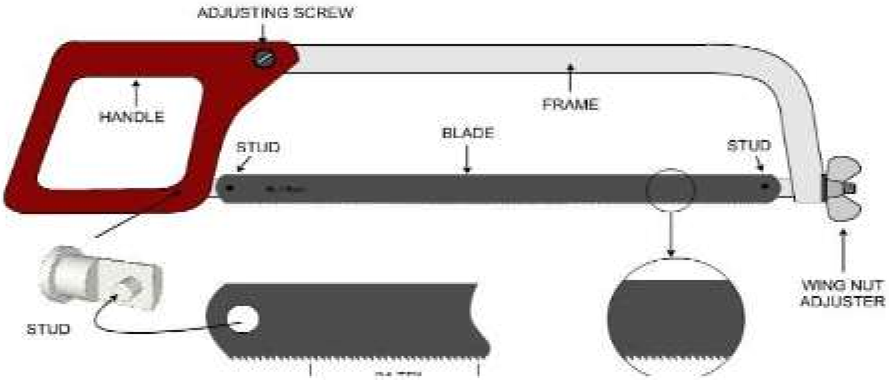
Cutting tools

- Files
- Hacksaw
- Chisel
- Scraper

a) File



b) Hacksaw



Chisel

Parts of a chisel

Ferrule: The ferrule is the brass or iron extension of the blade that attaches to the handle

Handle: A chisel handle can be made of hard timber materials such as beech, oak, hickory or ash.

Holding tools

- Vices
- Clamps
- Pliers

Striking tools

- Hammers
- Mallets

Tightening tools

Spanners

Uses of workshop tools, Instruments and equipment

Good quality, sharp tools are important to any craftsman, they enable learned skills to be used to the best advantage.

The basic tools required by anyone in the electro technical industry are those used for stripping and connecting conductors.

Basic electrical tools, equipment, and their uses include:

Pliers

Pliers are available in different types, shape, and sizes. They are also available in both insulated and uninsulated handles. An insulated handle should be used when working on or near hot wires. It is also used for cutting big and small wires.

Figure 13: Pliers

Diagonal Cutting Pliers

Figure 14: Diagonal Cutting Pliers

Diagonal cutting pliers, sometimes called side snips or dikes, are used to cut wires. They are specially designed with a cutting edge that goes down to the tip of the jaws, allowing you to get into tight areas to trim wires. Some types can also have a built-in voltage detector to sense live wires. You can also find combination tools that include wire-stripping slots built into the handles.

Drawing Wire/ Tape

Figure 15: Drawing Wire/ Tape

A Drawing Wire/ Tape is used to pull stranded or solid wire conductors through metal or PVC conduit. Cable lube is available to assist you in pulling the wires through the conduit. A fish tape can also be helpful when you are pulling cables through wall cavities.

This is a tool used when making wiring improvements, such as adding or extending circuits.

Voltmeter or Multimeter

Figure 16: Voltmeter or Multimeter

A voltmeter is used to read voltage levels and verify that circuits are "live" or off. Unlike a circuit tester, this tool gives you reading on how much voltage is being carried. More sophisticated forms of the tool are known as multimeters, and they can not only read voltage levels but also amperage, resistance, and DC voltage and amperage. They do, however, require practice to learn how to use them properly.

Wire Crimpers

Figure 17:Wire Crimpers

Wire crimpers are used to crimp lugs or connection terminals onto wires. This tool is not often used for routine circuit repairs, but it has many uses when working with appliances or electronics. Many types can also be used to strip wire insulation.

Screw Drivers

A screwdriver comes in various sizes and with several tip shapes. Screwdrivers used by electricians should have insulated handles. Using a screwdriver for a particular job, the width of the screwdriver tip should match the width of the screw slot.

Figure 18: Screw drivers

Drilling Equipment

Drilling equipment is needed to make holes in building structure passages of conduits and wires.

Figure 19: Driller

Sawing and Cutting

Tools Saws commonly used by electricians include the crosscut, keyhole, and hacksaw.

Figure 20: Hack saw

Soldering Equipment

In doing electric wiring splices and taps (connections made to wire) should be soldered, unless you use solderless connectors. Typical equipments available for soldering are shown below.

Figure 21: Soldering equipment

Hammers

Hammers are used with chisels and for nailing and fitting. Below are examples of carpenter's claw hammer, lineman's hammer, and machinist's ball-peen hammer

Figure 22: Hammers

Measuring Tools

To measure wire length and other items, the electrician finds considerable use for measuring tools such as the extension or zigzag rule, push-pull rule and a steel tape as shown below.

Figure 23: Folding rule

Tape measure

Figure 24:Tape measure

A standard is used for all kinds of field measurements, such as setting heights for switches and outlets, centering lighting fixture boxes, and marking surfaces for cutouts.

Spirit level

A small level, such as a torpedo level, fits easily in a tool pouch and is used to make sure your work is level and plumb. A great installation starts with level boxes and straight switch and outlet covers.

A torpedo level should be part of every homeowner's standard toolkit; it will have plenty of uses beyond electrical work.

Figure 25:Tape measure

Flashlight

Electrical repair and improvement work involves a lot of dark places, from attics and basements, to wall and ceiling cavities, to the insides of electrical boxes. A tactical flashlight is needed as much for safety as it is for convenience. A couple of hand flashlights and a headlamp are good additions to an electrician's toolbox.

Figure 26: Utility Knife

Utility Knife

A utility knife, or *box cutter,* is handy for cutting sheathing from non-metallic (Romex) cable, to cut off electrical tape, and to open cardboard boxes.

Figure 27: Utility Knife

Voltage Testers

A voltage tester, as the name suggests, is used for testing the presence of voltage in a circuit. A voltage tester has a neon bulb with two wires attached to its bottom. This is used to test the flow of current in a wire. A good voltage tester is rated for up to 500 V. in the old days, Phase Tester also were used for this purpose.

Wire Strippers

Figure 29: Wire Strippers

Another essential electrical specialty tool for homeowners is a good pair of wire strippers. Wire strippers are used to cut and strip insulation from electrical wires. A wire stripper tool has a row of gauged holes for stripping wires of different sizes, and it usually includes cutting jaws for trimming the wire ends.

Along with a voltage tester, this is perhaps the most important specialty electrical tool you can own. It makes sense to invest in a good set of wire strippers, as it will serve many functions.

Other tools and equipment include:

- Bending machine
- Stock and die

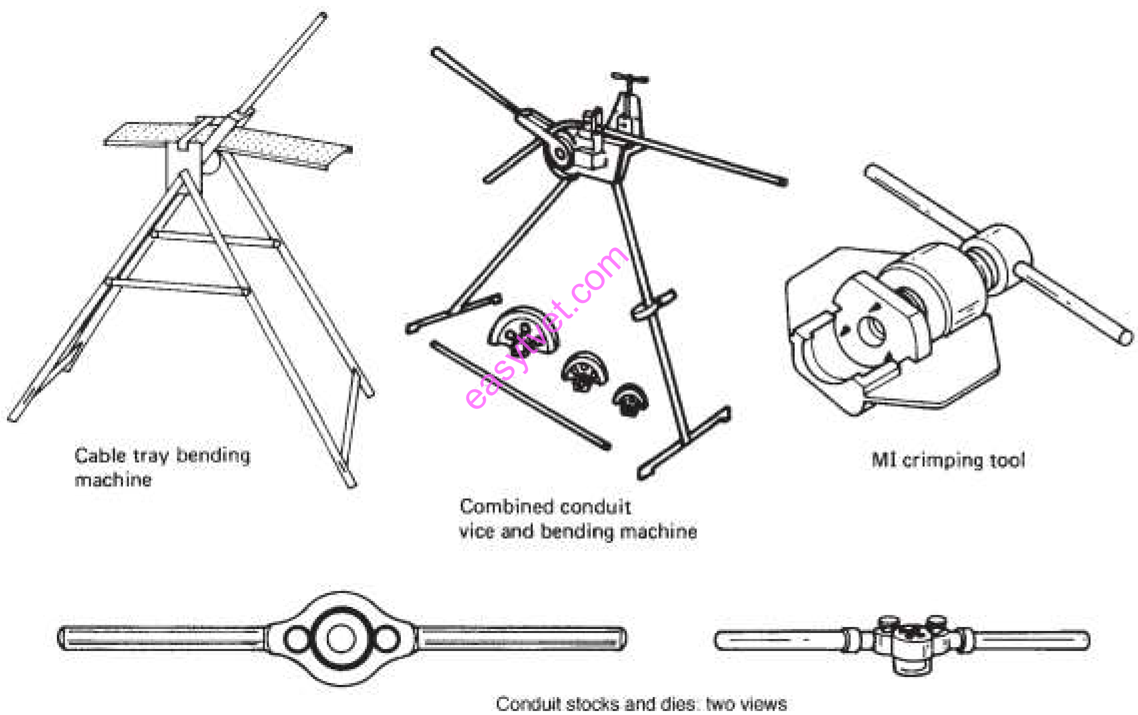


Figure 30: Some special tools required by an electrician engaged in industrial installations

Maintenance of electrical tools and equipment

To ensure that your electric tools work when you need them, you must take proper care of them. A good routine of maintenance for your tools is one thing that you can do to make sure that the tool you need is working when you need it.

1. **Clean out the Dust**. To make sure that your electric tools are ready to go when you are, keep them clean and free of dust. Spend some time to clean out the dust every once in a while on your tools while they are inactive in storage.

2. **Check the Cords**. Look for tear/cut insulator on the power cords on your electric tools. This will ensure that your electric tool can get the power that it needs to function without an accident.

3. **Use the right tool correctly**. Use tools correctly and for their intended purposes. Follow the safety directions and operating procedures recommended by the manufacturer. When working on a circuit, use approved tools with insulated handles.


4**. Protect your Tools**. Keep tools and cords away from heat, oil, and sharp objects. These hazards can damage insulation. If a tool or cord heats up, stop using it. Report the condition to a supervisor or instructor immediately.


5. **Use double-insulated tools:** Portable electrical tools are classified by the number of insulation barriers between the electrical conductors in the tool and the worker.

6. **Storing Your Tools:** Keep your electric tools stored in their original cases and containers. This will keep them free of dust and dirt while they are not being used.

Maintenance of power equipment

- Keep Power tools Clean.
- Dust and grime can bring your power tools to a grinding halt if left unchecked over time.
- Store Power tools correctly.
- Inspect for Wear or Damage.

- Lubricate Moving Parts.
- Keep Batteries in Shape.

Safety rules for hand tools

- Always use the correct tool for the job in hand and use it properly and sensibly
- Always keep tools clean and sharp
- Always keep tools in a toolbox and secure safety rules for power tools
- Always check that the casing is not damaged
- Always check that the cable is not damaged
- Always check that the plug top is not damaged
- Always check that no coloured conductors are showing anywhere on the flexible cord

Keep power tools clean

Dust and grime can bring your power tools to a grinding halt if left unchecked over time. Wipe them clean with a rag after every job has been completed and then store them. Deep clean periodically by using a damp cloth. Get into exhausts and intakes and other hard-to-clean areas with lightly oiled cotton swabs or other slender tools.

Store power tools correctly

Keep your power tools protected from dust, moisture and other adverse conditions by storing them properly after use. Keep them in their original cases if possible, or tuck them away in storage drawers or tool chests, preferably in a garage or basement with a moderately controlled climate. This not only protects them, it also keeps them organized so you can easily find the tool you need when you need it.

Inspect for wear or damage

Periodically inspect power tools for any signs of wear or damage. Pay special attention to power cords. If you see frayed insulation or exposed wires, have the cord repaired or replaced immediately by a professional, unless you have the expertise to do it yourself. Damaged power cords can potentially lead to injury from electric shock or can cause a fire. Also, check the cord's prongs to see if they are bent or loose. If any are, repair or replace.

Lubricate moving parts

Keep moving parts lubricated for premium performance. Not only does it keep the mechanics of a tool running smoothly, it also decreases the chance of rust developing. While common machine oil is a good choice, consult your owner's manual to see if the manufacturer recommends or requires a specific type of oil.

Keep batteries in shape

Cordless, battery-powered tools are convenient and portable and have become very popular for contractors and homeowners alike. To keep them running efficiently and effectively, it is essential for their batteries to be maintained.

Batteries remain working at peak level by fully charging and then fully discharging their power once every couple of weeks. Don't let batteries sit unused for extended periods of time. Try to use batteries once every two weeks.

Care for batteries by cleaning contacts with cotton swabs and alcohol. Store batteries you won't be using for a while in a dry, clean place away from excessive heat.

2.2.2.4 Learning activities

Learning Activity 1

Directions: Inside the tools box are hand, pneumatic, and power tools. Identify and write them in their corresponding column provided below.

	Air chisel Hammer Air racket Air drill Electric drill Vacuum cleaner

	Grinding wheels Wrenches Screwdrivers pullers	
Hand tools		Pneumatic tools
1.	1.	1.
2.	2.	2.
3.	3.	3.
4.	4.	4.

Instruction:

In a specific tool cabinet and a tool rack assigned to you, arrange and store tools and equipment accordingly.

Procedure:

1. Classify the tools and equipment according to their types.
2. Arrange the tools by their types in the shelves/racks.
3. Place equipment in designated places or location.

Assessment: The teacher will assess you based on the performance criteria listed below

PERFORMANCE CRITERIA	PERFORMANCE LEVEL		
	YES	NO	NA
1. Classified the tools and equipment according to their types.			

<table>
<tr><td colspan="2">2. Arranged the tools by their types in the shelves/racks.</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">3. Placed equipment in designated places or location.</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Overall Performance</td><td>Competent</td><td></td><td></td><td></td></tr>
<tr><td>Not yet competent</td><td></td><td></td><td></td></tr>
</table>

Learning Activity 2

Let us determine how much you already know about usage of tools and instruments. Take this exercise

Exercise: Demonstrate skills on how to use stock and die correctly when making threads on steel conduit.

Procedure

i. Ensure the round section steel conduit is vertical in the vice (at 90 degrees).
ii. Place the die on the round section steel conduit, keeping it parallel with the vice.
iii. Add a little pressure and turn the stock in a clockwise direction.
iv. The first couple of 'turns' of the die are critical.
v. If the stock is not parallel to the vice, a drunken thread will result. Stop once the die begins to cut the first couple of threads and check that the stock is still parallel to the vice.
vi. Continue to rotate the stock in a clockwise direction.
vii. Once the thread has been started, for every clockwise rotation, rotate the stock in an anticlockwise direction, for half a turn.
viii. This clears away any steel chippings, from the die.
ix. Thread cutting can continue until the correct length is been achieved.
x. Remove the stock and die from the thread by rotating it in an anticlockwise direction, effectively unscrewing it from the steel.

xi. Untighten the centre adjusting screw and then tighten the two outer adjusting screws. Run the die down the thread a second time, as this will finish the thread accurately.

2.2.2.5 Self-Assessment

1. Pliers, cutters, a knife and a range of screwdrivers are the tools required in the electro technical industry for:

   A. Erecting conduit
   B. Assembling tray
   C. Stripping and connecting conductors
   D. Terminating an mi cable

2. Always wear PPE when in the shop, even when tools are not being used.

   A. True

   B. False

2. Grace is an electrical technician who manages an electrical workshop. outline the safety rules to be adhered to while using hand tools.

3. Tools are supposed to be maintained and taken care of. State how a technician can maintain and take care of power equipment.

4. Properly insulated electrical tools contribute to safety adherence in electrical works. Explain the essence of using properly insulated tools in electrical works.

2.2.2.6 Tools, Equipment, Supplies and Materials

Tools

Set of screw drivers

Pliers

Phase testers

Multimeters

Equipment

PPE –hand gloves, dust coat, dust masks

Clamp meter

Earth electrode resistance meter

Phase sequence meter

Materials and supplies

Stationery

Cables

Lubricants

Service parts

2.2.2.7 References

1. IEE regulations
2. Organizational Procedures Manual
3. Electrical Installation Maintenance K To 12 – Technology and Livelihood Education Learning Module Republic of The Philippines Department of Education
4. Ray C. Mullin, Phil Simmons Electrical Wiring Re(Z-Lib.Org)
5. Brian Scaddan Ieng; MII (Elec) Electrical Insta(Z-Lib.Org)
6. https://projects.truevalue.com/maintenance_and_repair/basic_maintenance/proper_tool_maintenance.aspx

2.2.3 Learning Outcome 3: Prepare workshop tools and instruments for an Electrical installation

2.2.3.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to perform Issuing of required tools and instruments, check Functionality of tools and instruments and calibration of workshop instruments.

2.2.3.2 Performance Standard

1. List of required tools and instruments is prepared per the required installation
2. Issuing of required tools and instruments is performed as per standard operating procedure
3. Functionality of tools and instruments is checked in line with the standard operating procedure
4. Calibration of workshop instruments are performed as per the standard operating procedure

2.2.3.3 Information Sheet

Instruments for an Electrical practical

Wires Strippers

Professional electricians regularly strip the plastic coating on wires to expose the copper and make customized connections with other wiring or components. This essential electrical maintenance tool comes in a variety of models and types.

Fish Tape

Fish tape is one of many popular electrician tools. It’s used to run wiring between gang boxes (or other electrical components) through conduit piping. Fish tape is housed in a retractable coil and can be fed through installed conduit piping. Once the end of the fish tape appears on the opposite side, wiring can be hooked to the tape and the tape can be retracted—pulling the wire along the conduit.

Fishing Rods

Fishing rods are essential electrician tools when installing wire through walls, below carpets, or above ceilings. Rods are typically fiberglass and include hooks on the end for easy manoeuvring.

Terminal Block

These modular, insulated devices assist electricians when grouping multiple wires together. They're used to connect wiring to a ground or connect electrical switches and outlets to mains.

Voltage Tester

To safely perform electrical work, electrical power must be cut off in key sections of the property (usually via the circuit breaker). A hand held voltage tester allows electricians to test outlets for power, so they know when they're safe to work on. Electricians also use this tool to confirm power has been restored.

Reaming Bit

An installing new conduit (or replacing old ones) means connecting different segments of piping together to create a wiring route between electrical components. A reaming bit attaches to an electric drill and widens the opening on one end of the piping, allowing it to connect to another segment of piping and complete a secure conduit.

Conduit Bender

When determining a wiring route, electricians often run wiring along the corner of the wall or in other mostly hidden areas. Conduit benders are electrician tools used to curve conduit piping to accommodate these routes and ensure the conduits remain non-intrusive and efficiently placed in the customer's home.

Splicing Connector

These plastic clips help electricians make quick connections with multiple pieces of wire. They can be used with multiple cables, including device wires, telephone cables, and electrical cables.

Flashlights

For an electrician, working in the dark is a potential hazard of the job. Keep essential electrician tools, like flashlights and other various work lights, handy and within reach.

Issuing and confirmation of tools and instruments before and after practical

You can specify tools on job plans and work orders to indicate which tools are needed to perform a task. In the Stocked Tools application, you can issue tools to those work orders to indicate that the tools are dispatched for use with the right job

Testing of practical tools and Instruments

While planning for a practical, one needs to be sure that the tools are in the right order. Some of the things to consider while testing tools are:

1. Making sure that they are working as expected.
2. They can give accurate, measurement.
3. Screw drivers are not blunt.
4. Stripping tools are available.

Functionality of tools

To check the functionality of tools and equipment, Equipment Inspections is necessary.

- Equipment inspections will be performed by both the operators and maintenance.
- Inspections can and will happen: daily, weekly, monthly, quarterly, semiannually, and annually.
- Developing and training operators in the proper techniques for machine inspection.
- The weekly/monthly/quarterly lubrication and preventive maintenance schedules are necessary to assure machine reliability, and safety.
- Master copy of each inspection will be located in the Maintenance Supervisor's Equipment Files.

Document Control

The Document control falls under three categories:

- retaining

- updating
- and deleting document
- Retaining documents means to collect all useful information of the specific items and store them in a logical manner.
- Information includes drawings, operator's manuals, maintenance /service manuals, and equipment inspection documents.

Calibration and service of equipment

Calibration, in its most basic form, is the measuring of an instrument against a standard. As instruments become more complicated, successfully identifying and applying best practices can reduce business expenses and improve organizational capabilities.

What is Calibration?

Calibration is the comparison of a measurement device (an unknown) against an equal or better standard. A standard in a measurement is considered the reference; it is the one in the comparison taken to be the more correct of the two.

Calibration finds out how far the unknown is from the standard. A "typical" commercial calibration uses the manufacturer's calibration procedure and is performed with a reference standard at least four times more accurate than the instrument under test.

Purpose of a calibration

There are three main reasons for having instruments calibrated:

1. To ensure readings from an instrument are consistent with other measurements.

2. To determine the accuracy of the instrument readings.

3. To establish the reliability of the instrument i.e. that it can be trusted.

https://www.mgnewell.com/wp-content/uploads/2016/05/Purpose-of-Calibration.pdf

Classification of non-functional and functional tools

Tools are very useful to us in our homes especially to our job. But tools that are no longer functional may cause harm.

A. Make an inventory of functional and non-functional tools in your shop.

B. Classify your tools according to is function.

Method of identifying non-functional/faulty tools and equipment

1. Visual inspection. It refers to the visual observation of an expert on the appearance of the tools and equipment.
2. Functionality. Vibration or extra noise from the operation means problems on parts and accessories started to develop.
3. Performance. When there is something wrong with the performance of either hand tools or equipment they need an immediate repair or maintenance.
4. Power supply (for electrically operated only). Failure to meet the required power supply, malfunction will occurs in the part of hand tools or equipment.
5. Person’s involved. It refers to the technical person who has the knowledge and skills about the technology.

2.2.3.4 Learning Activities

Learning Activity 1

Exercise

Objective: To be able to understand and perform how to make requisition of supplies, materials, and tools for a specific job/ Issuing of required tools and instruments

Task: Make a requisition of material you require to carry out the project in learning activity 2

Learning Activity 2: Project

Project plan in making an extension cord

Introduction

You might be wondering why there are several projects which are not completely done. Well, there are several reasons why this happens.

It might be out of budget or not properly planned. So, this Lesson will help you achieve the desired quality project.

A project plan is necessary before undertaking any project because it serves as your guide in accomplishing an activity.

It will give you an idea what needs to be done, how much to spend and what procedures to undertake. A well prepared project plan saves time and cost of materials.

Below is a sample project plan of an extension cord. This format can also be used in preparing a plan for other projects in the future.

Project Plan - (Making an extension cord)

Name of Student: __________________________ Year & level:__________________

Name of Project: Extension Cord

Assembly Date Started: ___________________ Date Finished: __________________

Objective:

a) Demonstrate how to make an extension cord.

b) Observe safety measures while doing the project.

c) Demonstrate tools selection for a specific practical.

Materials Needed

- Flat Cord
- Male Plug
- Eyelet wire connectors
- Convenience Outlet

Tools and Equipment Needed:		Quantity	Remarks
1.	Standard/Flat Screw Driver		
2.	Philips Screw Driver		
3.	Long Nose Pliers		
4.	Side Cutting Pliers		
5.	Electrician's knife/ Pocket knife		
6.	Continuity Tester or Multi-tester		

Procedure:

1. Prepare the plan.

2. Gather all necessary materials, tools and equipment needed.

3. Insert cord into the male plug, split the cord wires about 8 centimeters long.

4. Remove insulation of both wires 1 centimeter long with a pocket knife as if sharpening a pencil. Be careful not to cut any strand.

5. Scrape bare wire with the back of the knife until shiny. Twist the wire stands.

6. Tie the underwriter's knot.

7. Make a loop on terminal wires and connect the wires to the screw of the male plug. The loop should go with the thread clockwise direction.

8. Split the cord wires at the other end about 4 centimeters long, then follow procedure no. 4.

9. Connect the wires to the connectors.

10. Open the convenience outlet then remove the screw.

11. Insert the wire connectors to the screws, tighten it and return the cover.

12. Check the continuity and test the extension cord.

2.2.3.5 Self-Assessment

1. An instrument used to measure the amount of electrical current in a circuit.

   A. Voltmeter
   B. Ammeter
   C. Micrometer
   D. Ohmmeter

2. A pocket sized tool used to test the line wire or circuit if there is current in it.

   A. Phase Tester
   B. Wire gauge
   C. Ruler
   D. Pull-push rule

3. A measuring tool used to measure the length of an object in centimeter and inches.

A. Test light
B. Wire gauge
C. Ruler
D. Pull-push rule

4. It is used to measure the diameter of wires/conductors. It can measure small and big sizes of wires and cables.

A. Voltmeter
B. Ammeter
C. Micrometer
D. Ohmmeter

5. It is used to measure the voltage, resistance and current of a circuit. It connected in parallel or series with the circuit depending on what to measure.

A. Avometer or multimeter
B. Micrometer
C. Ohmmeter
D. Ammeter

2.2.3.6 Tools, Equipment, Supplies and Materials

Tools

- Standard/Flat Screw Driver
- Philips Screw Driver
- Long Nose Pliers
- Side Cutting Pliers
- Electrician's knife/ Pocket knife
- Continuity Tester or Multi-tester
- Set of screw drivers
- Pliers
- Phase testers

Equipment

- PPE –hand gloves, dust coat, dust masks
- Multimeters
- Clamp meter
- Earth electrode resistance meter
- Phase sequence meter

Materials and supplies

- Borrower's Slip/ Form
- Stationery
- Cables
- Lubricants
- Service parts

2.2.3.7 References

- IEE regulations
- Organizational procedures manual
- Electrical Installation Maintenance K to 12 – Technology and Livelihood Education
  Learning Module
  Republic of the Philippines DEPARTMENT OF EDUCATION
- Ray C. Mullin, Phil Simmons] Electrical Wiring Re(z-lib.org)
- [Brian Scaddan IEng; MIIE_(elec)] Electrical insta(z-lib.org)

2.2.4 Learning outcome 4: Store electrical tools and materials

2.2.4.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required in the management of tools. That is storage of tools, cleaning of tools and waste management in workshops.

2.2.4.2 Performance Standard

1. Tools are checked against the issuing list as standard operating procedures
2. Tools are stored as per the standard operating procedure
3. Tools are cleaned as per the workshop standard operating procedure
4. Waste materials are disposed as per the EHS

2.2.4.3 Information Sheet

Essential Electrician Tools

Wire Strippers

Professional electricians regularly strip the plastic coating on wires to expose the copper and make customized connections with other wiring or components. This essential electrical maintenance tool comes in a variety of models and types.

Fish Tape

Fish tape is one of many popular electrician tools. It's used to run wiring between gang boxes (or other electrical components) through conduit piping. Fish tape is housed in a retractable coil and can be fed through installed conduit piping. Once the end of the fish tape appears on the opposite side, wiring can be hooked to the tape and the tape can be retracted—pulling the wire along the conduit.

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Splicing Connector

These plastic clips help electricians make quick connections with multiple pieces of wire. They can be used with multiple cables, including device wires, telephone cables, and electrical cables.

Flashlights

For an electrician, working in the dark is a potential hazard of the job. Keep essential electrician tools, like flashlights and other various work lights, handy and within reach.

Electrical measuring equipment

Electrical instruments are classified according to the electrical quantity or the measured characteristics. It is also classified according to the type of test function, according to the current that can be measured by them.

Ammeter

An ammeter is an instrument which is used to measure the electric current in amperes in a branch of an electric circuit. In order to measure the current it must flow through the ammeter, so the ammeter must be placed in series with the measured branch and it must have very low resistance so that the alteration of the current can be avoided which is measured. Instruments which is used to measure smaller currents are micro-ammeter. The ammeter is connected in series to the device which is to be measured because objects in series have the same current.

Types of ammeter

Moving iron ammeter

In a moving iron, ammeter can measure the AC and DC; it has an iron piece instead of the spring and pointer system of the galvanometer. The iron will act by the magnetic field created in the coil.

Zero centre ammeters

Zero centre ammeters are used where the voltage needs to be monitored in two directions and they are used along with a battery. In this the charging of battery deflects the needle in one direction and discharging of the battery deflects the battery in the other.

Galvanometer

Galvanometer was the first type of ammeter, it is used to detect and measure electric current. It is an analogue electromechanical transducer which makes a rotary deflection in response to the electric current flowing through the coil. A galvanometer can read direct current flow, the magnetic field created as current flows through a coil acts on a spring, which will move the needle indicator.

Shunt

A shunt can be used in ammeters to measure large currents, shunt acts as a resistor the known quantity of resistance is used to obtain an accurate reading. Digital ammeters use analog to digital converter to measure the current across the shunt.

Clamp meter

Clamp meters are used to measure the current flowing through a conductor; AC clamp meters have a current transformer in it. With the help of the current transformer the reading will be taken. There are two types of clamp meters AC clamp meter which is used to measure the AC and the DC clamp meter which is used to measure the DC.

Voltmeter

The voltmeter can be considered as a kind of galvanometer, which can be used to measure the voltage potential of an electrical circuit or the potential difference between two points. A voltmeter can also be considered as an ammeter they also measure the current, voltage is only measured when the current is transmitted in a circuit through resistance. Voltmeters are capable to measure the current, voltage and resistance. Voltmeters are also termed as high resistance ammeters they can also measure DC and AC. A voltmeter can measure the change in voltage by two points in an electrical circuit and they are connected in parallel with the portion of the circuit on which the measurement is made. Voltmeters must have high resistance so that it won't have any effect on the current or voltage associated with the circuit.

Types of voltmeter

Digital voltmeter

Digital voltmeters can measure the AC and DC voltages and it displays the result in converted digital form with decimal point and polarity. It can provide accurate details about the current draw and current continuity and this will help the users to troubleshoot erratic loads.

What are the advantages of digital voltmeter?

- Outputs are accurate without any error
- Readings are taken quickly
- Versatile and accurate
- Less power consumption
- Portable instrument

Electrostatic voltmeter

These voltmeters are instruments that can accurately measure the voltage without any charge transfer. Whereas conventional voltmeter needs charge transfer to the voltmeter and it will lead to loading and adjustment of the source voltage. The main advantage of an electrostatic voltmeter is that it can do the surface potential measurement on any type of material without any physical contact.

Ohmmeter

An ohmmeter is an instrument that is used to measure the resistance and they can measure the value of resistance accurately. According to their measurement and construction, these instruments are classified into the series type and shunt type ohmmeter. It can be used to check the continuity of the electrical circuits and components. Series type ohmmeters are used to measure the high resistance values while the shunt type is used to measure low resistance values.

Potentiometer

Potentiometer is instruments that can be used to measure the unknown voltage. The known voltage will be supplied from a standard cell or any other known voltage reference source. Potentiometer measurement has high accuracy because the measurement is done by the comparison method and the obtained result is not by the deflection of the pointer. Potentiometer can be used to compare the E.M.F of the two cells, it can be used to determine the E.M.F of a cell, it can be used to determine the internal resistance of a cell and to calibrate the voltmeter and ammeter.

Wattmeter

Watt-meters are used to measure power; these instruments are similar in design and construction of an ammeter. It can be used to measure the average electric power in watts. Wattmeter has two coils they are current and pressure coil. Wattmeter can be used to measure the gain in amplifiers, bandwidth in filters.

Multi-meter

Multi-meters can be used to make various electrical measurements; they can be used to measure AC and DC voltage, AC and DC current, and resistance. It is known as multi-meter because it can do the functions of various meters such as voltmeter, ammeter, and ohm-meter. Multi-meters can also be used to check the continuity. Multi-meters are of two types they are analog and digital multi-meter analog multi-meter has an analog scale and they are less accurate, while the digital multi-meter and the reading are in digital and they are more accurate.

Issuing and confirmation of tools and instruments before and after practical

You can specify tools on job plans and work orders to indicate which tools are needed to perform a task. In the Stocked Tools application, you can issue tools to those work orders to indicate that the tools are dispatched for use with the right job

Testing of practical tools and Instruments

While planning for a practical, one needs to be sure that the tools are in the right order. Some of the things to consider while testing tools are:

1. making sure that they are working as expected
2. they can give accurate ,measurement
3. Screw drivers are not blunt
4. Stripping tools are.

Why Maintain Inventory of Tools and Equipment

The most significant point to think at the start of your career is to acquire branded tools.

They must be made out of high-quality steel and manufactured for precision. Special consideration is given to balance so that the tool/equipment will be properly maintained and prevent loses.

Since the technician must work with his tools daily, regular inventory of tools/equipment is very significant.

The initial cost of a minimum number of tools is high but there is accompanying warranty guarantees satisfaction and many years of service.

It is better, in the long run, to start with a few cautiously selected tools that will take care of your most common needs and then slowly build-up to a complete set.

It is sometimes hard to identify and memorize the huge number of tools and equipment in the workshop, maintaining the inventory record is of great value.

For better equipment inventory management:

- Know what you have.
- Track how it is used.
- Right asset, right place, right time.
- Don't spend more – spend smarter.
- Fix things before they break.
- Find underlying issues.
- Buy the best.
- Use the right **equipment** inventory system.

Maintaining and Storing Tools & Equipment

An important aspect of any business is the maintenance and storage of tools and equipment.

The investment in tools and equipment is a significant part of the overhead expenses in any operation.

Proper selection and maintenance of equipment are important factors in managing business. Selecting the proper tool for the job and using the tool properly will increase efficiency and reduce maintenance problems.

Purchase tools, which are well-made and suited to the intended use. Commercial usage may entail more heavy duty demands on equipment.

Hand tools:

1. Clean dirt and debris from tools after each use.
2. Oil metal parts to prevent rust.
3. Lightly sand rough wooden handles and apply linseed oil.
4. Repair loose handles.
5. Sharpen blades of cutting tools.
6. Store tools in a clean dry storage area.
7. Protect surfaces of cutting tools in storage.

Power tools:

1. Read and follow the maintenance schedule in the owner's manual for each piece of power equipment.
2. Change the oil.
3. Clean the air filter.
4. Lubricate moving parts.
5. Sharpen dull blades or replace worn blades according to the owner's manual.
6. Replace spark plugs.
7. Drain oil and gasoline before long-term storage.

8. Check electric cords and connections on electric-powered tools.

9. Store tools in a clean dry storage area.

Equipment:

1. Store equipment in a clean dry storage area.

2. Rinse and clean spray equipment after each use.

3. Clean spreaders and check wheel-driven gears.

4. Clean carts and wheelbarrows after use.

Figure 31: Sample Proper Arrangement and storage of tools and equipment

A lubricant is a substance introduced to lessen friction between moving surfaces. It may also transport external particles. The property of reducing friction is known as lubricity.

Types and Kinds of Cleaning Solvents

Solvent is a component of a solution that dissolves solute and is usually present in large proportion or amount. It can be classified as polar and nonpolar.

Polar solvents are solvents which dissolve/are soluble in water; while nonpolar solvents are solvents which do not dissolve/are insoluble in water. Solvents are usually used for cleaning in workshops.

They are water, gasoline, kerosene, thinner and detergent soap. The table below shows the kinds of cleaning solvent based on their solubility in water.

Cleaning Solvents	Solubility in Water	Polar	Nonpolar
a. water	soluble	x	
b. gasoline	insoluble		x
c. kerosene	insoluble		x
d. thinner	insoluble		x
e. detergent soap	soluble	x	

Table 2: Shows the kinds of cleaning solvent based on their solubility in water

Uses of Cleaning Solvents

Cleaning Solvents	Uses
Gasoline	Wash greasy tools/ equipment.
Kerosene	Remove dust, grease oil, paint, etc.
Thinner	Remove spilled paint on the floor, walls and tools.
Water	Wash dust in the floor, walls, etc.
Detergent Soap and water	Wash/clean benches, tables, cabinets, etc.

Waste Disposal

Waste is any substance which is discarded after primary use, or is worthless, defective and of no use. A by-product by contrast is a joint product of relatively minor economic value.

Waste management (or **waste disposal**) includes the activities and actions required to manage waste from its inception to its final disposal. This includes the collection, transport, treatment and disposal of waste, together with monitoring and regulation of the waste management process.

Waste disposal methods

Recycling

Recycling refers to both the direct **reuse** of used products (e.g. used clothing and functioning parts removed from used vehicles) and **material recycling**, that is the recovery of raw materials from waste (e.g. production of new glass from fragments, the melting of scrap iron and the production of recycled building materials from construction waste). **Down cycling** refers to the transformation of waste to materials of lower quality than the initially used material.

Incineration

Combustible waste from households and waste wood that is not suitable for recycling undergo thermal treatment in waste incineration plants or waste wood furnaces. The heat released in the process **is used to generate electricity and heat buildings**. Waste with a high calorific value and low level of pollutant contamination can be used in industrial plants, e.g. cement plants, as an alternative to fossil fuels. Waste that is contaminated with organic pollutants undergoes separate thermal treatment (e.g. in hazardous waste incineration plants). Incinerators must have a flue gas treatment system. The requirements for flue gas treatment and the incineration system are based on the nature of the waste.

Chemical-physical and biological treatment

The objective of both chemical-physical and biological treatment is to enable **the removal of pollutants from waste** or its **safe land filling**. Waste water and polluted excavated material are typical of the types of waste that are managed in this way. Following chemical-physical treatment, the pollutants can be disposed of in concentrated form in facilities suitable for this purpose.

Landfills

Residues from waste incineration or waste that is not suitable for material recycling or thermal treatment are deposited in landfills that are compliant with the legal requirements. If the waste does not fulfil the requirements for land filling, it must be pre-treated

Collection and logistics

The waste management sector involves many different specialised actors. Their tasks include the collection of waste at source (industry, commerce and households) in suitable transport containers, its intermediate storage and handover to waste disposal operations. The treatment of waste is often based on a cascade of specialised plants. In all cases, **smooth logistics** are a precondition for the efficient management of waste. In the case of hazardous waste, in accordance with the Ordinance on Movements of Waste, the handover must be **documented**.

Correct Disposal of Waste Material

The Controlled Waste Regulations 1998 tell us that we have “a Duty of Care” to handle, recover and dispose of waste responsibly

The Environmental Protection (Duty of Care) Regulations 1991 tell us that any business has a duty to ensure that any waste produced is handled safely and in accordance with the law.

Your company is responsible for the waste that it produces even after handling it over to another party such as a Skip Hire company.

If such a third party mishandles your waste or disposes of it irresponsibly then it is the responsibility of the company you work for, not the Skip Hire company.

The duty of care under the new Regulations has no 'time limit' and extends until the waste has either been finally and properly disposed of or fully recovered.

If a material has hazardous properties, it may need to be dealt with as 'Special Waste'. Containers may be classified as 'Special Waste' if they contain residues of hazardous or dangerous substances.

If the residue is 'Special' then the whole container is Special Waste. Do not burn scrap cable on site, re-cycle it through a scrap metal merchant.

Electro technical companies produce very little waste material and even smaller amounts of 'Special Waste'. Most electrical contractors deal with waste by buying in the expertise and building in these costs to the total cost of a contract.

However, this method still requires individuals to sort any waste responsibly by placing it in the appropriate skip or container.

To comply with the Waste Regulations:

- Make sure waste is transferred only to 'authorized' companies as per the law.
- Make sure that the waste being taken is accompanied by the proper paperwork called 'waste transfer notes'
- Label waste skips and waste containers so that it is clear to everyone what type of waste is going into which skip or container
- Minimise the waste that you produce and do not leave it behind when a job is completed for someone else to clear away. As the producer of any waste, you are responsible for it. Remember there is no time limit on the Duty of Care for waste materials

Waste management

Waste management is the collection, transport, processing or disposal, managing and monitoring of waste materials.

The term usually relates to materials produced by human activity, and the process is generally undertaken to reduce their effect on health, the environment or aesthetics.

Waste management is a distinct practice from resource recovery which focuses on delaying the rate of consumption of natural resources.

The management of wastes treats all materials as a single class, whether solid, liquid, gaseous or radioactive substances, and tried to reduce the harmful environmental impacts of each through different methods.

Waste management practices differ for developed and developing nations, for urban and rural areas, and for residential and industrial producers.

Management for non-hazardous waste residential and institutional waste in metropolitan areas is usually the responsibility of local government authorities, while management for non-hazardous commercial and industrial waste is usually the responsibility of the generator.

2.2.4.4 Learning Activities

Learning Activity 1

Procedure in Arranging and Storing Tools and Equipment

Instruction:

In a specific tool cabinet and a tool rack assigned to you, arrange and store tools and equipment accordingly.

PERFORMANCE CRITERIA	PERFORMANCE LEVEL		
	YES	NO	NA

1. Were the tools/equipment placed in their respective location and accessible for use when needed?				
2. Were the tools arranged according to their types?				
3. Were the tools and equipment ready before performing the task?				
4. Were the equipment placed in their proper location and arranged according to their types?				
Overall Performance	Competent			
(Competent if all the tasks are completed correctly)	Not yet competent			

Procedure:

1. Classify the tools and equipment according to their types.

2. Arrange the tools by their types in the shelves/racks.

3. Place equipment in designated places or location.

Assessment: The teacher will assess you based on the performance criteria listed below.

Learning Activity 2: Procedure in Cleaning Tools and Work Area

Instructions: Bring cleaning solvents, rags and brooms, washing pan, electric fan and safety apparel. Clean tools and work area.

Procedure:

A. Tools

1. Wear protective clothing and goggles.
2. Gather the tools to be cleaned in the designated area for cleaning.
3. Classify the tools to be cleaned according to how dirty they are.
4. Measure and pour enough amount of cleaning solvent to the washing pan.
5. Submerge the tools in the washing pan.
6. Use paint brush to remove the dirt from the tools.
7. Get the tools from the washing pan and wipe them with rags until dry.
8. Clean and keep all materials used for cleaning.

B. Work Area

1. Wear protective clothing and goggles.
2. If there is dirt on the floor such as paint, used oil, grease, rust, etc., remove it first using the appropriate cleaning solvent.
3. Use the broom in cleaning the remaining dirt in the work area and an electric fan to facilitate the drying of the floor.

Assessment:

The teacher will assess the students based on the performance criteria listed below.

<table>
<tr><td colspan="2" rowspan="2">PERFORMANCE CRITERIA</td><td colspan="3">PERFORMANCE LEVEL</td></tr>
<tr><td>YES</td><td>NO</td><td>NA</td></tr>
<tr><td colspan="2">1. Were protective clothing and goggles worn at all times?</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">2. Were tools and equipment free of dust, grease, oil and other substances?</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">3. Was the work area dry, free of dust, grease and other substances?</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">4. Were excess cleaning substances cleaned and kept in proper places?</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Overall Performance
(Competent if all the tasks are completed correctly)</td><td>Competent</td><td></td><td></td><td></td></tr>
<tr><td>Not yet competent</td><td></td><td></td><td></td></tr>
</table>

2.2.4.5 Self-Assessment

1. Pliers, cutters, a knife and a range of screwdrivers are the tools required in the electro technical industry for:
   A. Erecting conduit
   B. Assembling tray
   C. Stripping and connecting conductors
   D. Terminating an mi cable

2. An example of 'Special Waste' is:

A. sheets of asbestos

B. old fibre-glass roof insulation

C. old fluorescent tubes

D. part coils of PVC insulated cables

3. Special Waste must be disposed of:

A. in the general site skips

B. in the general site skip by someone designated to have a 'duty of care'

C. at the 'Household Waste' re-cycling centre

D. by an 'authorised company' using a system of waste transfer notes'

4. Put a (✓) after each word if the solvent is polar and (X) if it is nonpolar**.**

1. water (   )
2. kerosene ( )
3. detergent soap (   )
4. gasoline ( )
5. thinner ( )

5. The table below show cleaning solvents for tools and equipment. Complete the table .

Cleaning solvents	Uses
Gasoline	
Kerosene	
Thinner	
Water	
Detergent Soap and Water	

2.2.4.6 Tools, Equipment, Supplies and Materials

Tools

- Set of screw drivers
- Pliers
- Phase testers
- Multimeter

Equipment

- PPE –hand gloves, dust coat, dust masks
- Multimeter
- Clamp meter
- Earth electrode resistance meter

Phase sequence meter

Materials and supplies

- Stationery
- Cables
- Lubricants
- Service parts

2.2.4.7 References

- IEE regulations
- Organizational procedures manual

- Electrical Installation Maintenance K to 12 – Technology and Livelihood Education Learning Module
  Republic of the Philippines DEPARTMENT OF EDUCATION
- Ray_C._Mullin,_Phil_Simmons]_Electrical_Wiring_Re(z-lib.org
- [Brian_Scaddan_IEng;_MIIE_(elec)]_Electrical_insta(z-lib.org)

2.2.5 Learning Outcome 5: troubleshoot and repair/replace workshop tools and equipment

2.2.5.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to identify, diagnose, repair/ replace faulty tools and finally and testing the functionality of the tools after repair.
The level of troubleshooting most often performed on tools and equipment hardware is exchanging *Field Replaceable Units* (*FRU*s). The cost of using a technician to diagnose the problem further, and repair it, can quickly exceed the cost of the new replacement unit.

2.2.5.2 Performance Standard

1. Faulty tools are identified as per their expected functionality
2. Faulty equipment are diagnosed in line with the fault diagnosis procedures
3. Repair/Replace faulty components as per standard operating procedure
4. Repaired/Replaced tool and equipment are tested as per the expected functionality

2.2.5.3 Information Sheet

Meaning of troubleshooting

Troubleshooting is the first step in the heavy **equipment repair** process in making a repair action and returning the **equipment** into service.

Electrical Troubleshooting can be hazardous. Ensure you take the proper precautions. Electricity has long been recognized as a serious workplace hazard, exposing employees to electric shock, electrocution, burns, fires and explosions.

Meaning of troubleshooting

Troubleshooting is a form of problem solving, often applied to repair failed products or processes on a machine or a system. It is a logical, systematic search for the source of a problem in order to solve it, and make the product or process operational again. Troubleshooting is needed to identify the symptoms. Determining the most likely cause is a process of elimination eliminating potential causes of a problem. Finally, troubleshooting requires confirmation that the solution restores the product or process to its working state.

In general, troubleshooting is the identification or diagnosis of "trouble" in the management flow of a system caused by a failure of some kind. The problem is initially described as symptoms of malfunction, and troubleshooting is the process of determining and remedying the causes of these symptoms.

Common faults in Electrical equipment

Fault-finding for electronic/electrical equipment is a skill that is neither an art nor a science, but an engineering discipline in its own right. Effective fault-finding requires:

- A good general knowledge of electricity and electronics.
- Specialized knowledge of the faulty equipment.
- Suitable test equipment.
- Experience in using such test equipment.
- The ability to formulate a procedure for isolating a fault.
- The availability of service sheets and other guides.

Common Problems

An electrical fault is the deviation of voltages and currents from nominal values or states. Under normal operating conditions, power system equipment or lines carry normal voltages and currents which results in safer operation of the system.

But when a fault occurs, it causes excessively high currents to flow which causes damage to equipment and devices. Fault detection and analysis are necessary to select or design suitable switchgear equipment, electromechanical relays, circuit breakers, and other protection devices.

Symmetrical faults

These are very severe faults and occur infrequently in the power systems. These are also called balanced faults and are of two types namely line to line to ground (L-L-L-G) and line to line (L-L-L).

2. Unsymmetrical faults

These are very common and less severe than symmetrical faults. There are mainly three types namely line to ground (L-G), line to line (L-L), and double line to ground (LL-G) faults.

Fault diagnosis procedure

Here are six key points to consider

Collect the Evidence

All the evidence collected must be relevant to the problem in hand. If one is in doubt as to whether anything is relevant, then include it. Reject it afterwards at the first opportunity if it clearly is not relevant. The quantity of information collected is unimportant, what matters are that all information collected is relevant. Observe the system running, if you consider it safe to do so. Use all your senses: smell (burning), hearing (vibration), touch (temperature), sight (for unusual conditions). Refer to any relevant documentation.

Analyse the Evidence

Consider all the evidence collected and, if possible, reject any which after further careful consideration is not relevant. Study the hard core of relevant evidence and – through the process of careful, logical thinking –diagnose the likely fault or at least the area or region of the fault.

Locate the Fault

In a sense this is a continuation of the process of ‘analyses. The areas or regions are systematically reduced in size until a specific part can be identified as being faulty. For example, if a door bell does not ring when it should; it is only by means of a systematic approach that one determines that the bell itself is faulty.

Determination and Removal of the Cause

If the cause of a fault is not removed, the fault will recur even though the fault has been rectified. For instance, a flat bicycle tyre might be the result of a puncture (the fault) in the inner tube. If the puncture is repaired (i.e. the fault is removed) this will not be of much use if the cause of the puncture in the first place is not determined and appropriate action taken. The cause of the puncture may be a nail which has penetrated the outer cover. This must be removed

Rectification of the Fault

This may be a simple task, as in the case referred to above, or it may be a much bigger one. Whatever is the case, it is a specific task based on earlier findings.

Check the System

It is important to ensure that the machine, equipment or system is functioning normally after the cause of the fault and the fault itself has been dealt with. In the case of the puncture, it is easy to confirm that the cause of the fault – and the fault itself – has indeed been dealt with satisfactorily, assuming that the tyre remains inflated. With more sophisticated equipment or systems it may necessary to 'fine-tune' the system in order to return it to optimum working conditions.

Repair/Replace of components in Electrical equipment

Any electronic instrument or piece of equipment can be considered as a system. A system can be defined as "anything formed of component parts connected together to make a regular and complete whole".

An instrument or piece of equipment can have subsystems made in blocks to perform specific functions. These subsystems are made up of electronic circuits, which are forms of electronic/electrical or electromechanical component parts. The failure of a component in equipment may lead to the failure of the system. Failure is said to be the inability of a system to perform its required function. The need for continuous performance of equipment requires that it is given regular maintenance. It is, therefore imperative that the meaning of maintenance is well understood.

Maintenance

This is all the activities carried out on an equipment in terms of proper installation, good servicing, routine checks, repairs and replacement of faulty parts in order for such equipment to operate at it maximum output throughout its useful life. An equipment or instrument is considered to have failed when under any of these conditions:

a) when it becomes completely inoperative

b) when it is still in operation but unable to perform the required function any longer

c) When it becomes unsafe for its continued use.

Maintenance of tools and equipment in electrical workshop

Preventive Maintenance

This is the practice or arrangement whereby a piece of equipment or instrument are regularly checked, oiled, greased or cleaned according to manufacturer's specification for effective performance. This maintenance method is normally carried out at a specified time of a year and in that case the entire working system is shut down. Fund is normally provided to ensure that spare parts and some other materials meant for such maintenance are provided. The essence of this form of maintenance is to ensure that the equipment does not break down and thus performs to specification.

Corrective Maintenance

This method is applied to equipment that has failed and thus broken down due to either improper operations or a defective part. It is concerned with the detection, location and repairs of faults as they occur. This requires a good understanding of system fault location methods in addition to an understanding of overall system and circuit operation.

Types of Maintenance

There are five different types of maintenance and these are as follows:

3. Fixed Time Maintenance

This is servicing of equipment periodically at regular intervals. The particular maintenance requirements will probably vary with the level of service. For example the requirements for 12 monthly services will be different for those for 3 monthly.

2. **Condition Based Maintenance**

This type of maintenance requires the use of human senses to know when it is needed. In the cause of operating an equipment one may see signs of smoking, electrical sparks, feel for excessive heated, smells for signs of burning and some others. The condition at which the equipment is will necessitate that it should be opened up immediately for maintenance. This act will assist in preventing further damage. Some more complex systems have sensing devices built in to them, and alarm systems to detect variation from the norm.

3. **Opportunity Based Maintenance**

This is carried out when an equipment is opened up for repairs and this opportunity is used to do any other maintenance tasks which are due in the near future, such as routine servicing and the replacement of any parts which are at the end of their useful life. Also, the opportunity can be used to replace a broken part which had occurred before opening the equipment but had no effect in its operation.

4. **Design Out Maintenance**

This maintenance type is used on equipment which has a part that is failing regularly due to an apparent design weakness. It may be possible to upgrade the weak part and effectively change the design for the better. If a particular part is not available one may be able to change the design to allow a more common part to be used. In spectrophotometry, for example, it may be possible to modify a simple car headlamp bulb to enable it to function as a tungsten source.

5**. Operate To Failure Maintenance**

These are cases whereby equipment is not given general routine care but it is allowed to fail before any other maintenance is attempted. This is widely used on electronic equipment which normally is not just taken to a mechanic for servicing while still functional. They are only opened up when they have broken down. This means that equipment is operated to failure before it is opened up for maintenance.

Troubleshooting Hazards

Troubleshooting can introduce many new safety concerns especially when inspecting equipment that is energized. Testing often requires the troubleshooter to temporarily connect test instruments to "live" terminals, which may involve opening enclosures or cabinets that normally are locked or bolted closed to protect workers.

This introduces two main hazards:

1. Shock Hazard. If you were to contact live equipment with your body or a tool you are holding the current flowing through your body could cause severe injury, burns, and even death.

2. Flash Hazard. If you are in the vicinity of equipment that fails and causes an electric arc, the flash, heat and shrapnel caused by the arc can also be life threatening.

Fault Condition Reporting

While repairs are under way it is sometimes necessary to hand over the work or the equipment to someone else. If this is to work efficiently you must be able to pass on all relevant information. This is also important to ensure the safety of all personnel while the system is not in its usual operating condition.

The steps involved are:

1. Document all changes to normal operational line-up either in the log or, if the system is in use, on forms supplied for this purpose. You should also make notes in your personal journal.

2. Set out work schedules in accordance with safe practices and nominated company procedures.

This may require you to document all notifications given to relevant persons together with Authority to Carry Out Running Repairs, Work Permits, Clearance Certificates, Tags(Danger and Out of Service, etc.) Locks and Sentinels in operation or other applicable special precautions.

3. Highlight any special precautions or fallback procedures relating to operation of running equipment.

4. Prepare a concise report on the current status of the repair being undertaken including personnel involved, equipment or tooling obtained, equipment or tooling ordered or required, parts availability, strip-down status of the machine and estimated completion time.

5. Pass on findings in regard to component condition or potential weaknesses found during dismantling and other information necessary for the person taking over to make informed decisions.

6. Where practical, carry out a tour of inspection with the new person of the affected plant, pointing out areas of concern and activities under way.

7. Ensure they have understood you and have a clear picture of the situation and its implications.

Calibration and service of equipment

Calibration, in its most basic form, is the measuring of an instrument against a standard. As instruments become more complicated, successfully identifying and applying best practices can reduce business expenses and improve organizational capabilities.

What is Calibration?

Calibration is the comparison of a measurement device (an unknown) against an equal or better standard. A standard in a measurement is considered the reference; it is the one in the comparison taken to be the more correct of the two.

Calibration finds out how far the unknown is from the standard. A "typical" commercial calibration uses the manufacturer's calibration procedure and is performed with a reference standard at least four times more accurate than the instrument under test.

Purpose of a calibration

There are three main reasons for having instruments calibrated:

1. To ensure readings from an instrument are consistent with other measurements.

2. To determine the accuracy of the instrument readings.

3. To establish the reliability of the instrument i.e. that it can be trusted.

Calibration, zeroing and care of instruments

Precise calibration of instruments is usually well outside the province of the electrician, and would normally be carried out by the manufacturer or a local service representative.

A check, however, can be made by the user to determine whether calibration is necessary by comparing readings with an instrument known to be accurate, or by measurement of known values of voltage, resistance, etc.

It may be the case that readings are incorrect simply because the instrument is not zeroed before use, or because the internal battery needs replacing.

Most modern instruments have battery condition indication, and of course this should never be ignored. Always adjust any selection switches to the off position after testing.

Too many instrument fuses are blown when, for example, a multimeter is inadvertently left on the ohms range and then used to check for mains voltage. The following set procedure may seem rather basic but should ensure trouble-free testing:

1. Check test leads for obvious defects.
2. Zero the instrument.
3. Select the correct range for the values anticipated. If in doubt, choose the highest range and gradually drop down.
4. Make a record of the test results, if necessary.
5. When a zero reading is expected and occurs (or, in the case of insulation resistance, an infinite reading), make a quick check on the test leads just to ensure that they are not open-circuited.
6. Return switches/selectors to the off position.
7. Replace instrument and leads in carrying case.

Safe use of electrical equipment

When one is using electrical equipment such as drills, saws, sanders, etc. on site or in a workshop, great care must be taken to ensure that the tools are in good condition and that the cables supplying them are not damaged in any way and are adequate for the job they have to do.

Any connections of cables must be carried out by a competent person using approved tools and equipment. For work on building sites, tools using a voltage lower than usual (110 V instead of 230 V) are recommended.

All current-using and current-carrying apparatus used on sites must be inspected and checked at regular intervals. A 3-month period is recommended, but the user should always check before use that all electrical apparatus is in good condition.

Ensure that all cables exposed to mechanical damage are well protected.

https://www.mgnewell.com/wp-content/uploads/2016/05/Purpose-of-Calibration.pdf

Classification of non-functional and functional tools

Tools are very useful to us in our homes especially to our job. But tools that are no longer functional may cause harm.

A. Make an inventory of functional and non-functional tools in your shop.

B. Classify your tools according to is function.

Method of identifying non-functional/faulty tools and equipment

7. Visual inspection. It refers to the visual observation of an expert on the appearance of the tools and equipment.
8. Functionality. Vibration or extra noise from the operation means problems on parts and accessories started to develop.
9. Performance. When there is something wrong with the performance of either hand tools or equipment they need an immediate repair or maintenance.
10. Power supply (for electrically operated only). Failure to meet the required power supply, malfunction will occurs in the part of hand tools or equipment.

11. Person’s involved. It refers to the technical person who has the knowledge and skills about the technology.

2.2.5.4 Learning activities

Learning Activity1

Let us determine how much you already know about checking conditions of tools and equipment. Take this test.

Instruction: Read each statement and identify what is being described. Choose your answer inside the circle and write them in the space provided before each number.

Hand tools
Pneumatic floor jack screwdrivers
Wrenches
Personal Protective Equipment(PPE)
Pullers
Vacuum cleaner
Air drill
Pneumatic torque wrench
Machine /power tools

____________1. Uses compressed air to flow into the jack cylinder and causes the ram to extend and raise the vehicle.

____________2. These are tools manipulated by our hands without using electrical energy.

___________3. Are used to drive, or turn screws. The common type has a single flat blade for driving screws with slotted heads. The other type has the cross slotted head.

____________4. A tool used to turn screws, nuts and bolts with hexagonal heads. ―Hexagonal‖ means six-sided. A variety of wrenches are used in the shop.

____________5. A tool used to remove gears and hubs from shafts, bushings from blind holes, and cylinders' liners from the engine blocks.

_____________6. This is used for cleaning the floor and car interiors after service.

_____________7. This is lighter than a comparable electric drill. Repeatedly stalling or overloading does not damage or overheat the air drill.

_____________8. A gadget that protects workers from injury or illness caused by having contact with the dangers/hazards in the workplace, Used by linemen to remove insulation of wire and cables in low and high voltage transmission lines.

____________9. This wrench uses compressed air to quickly and powerfully turn nuts, bolts, and other objects.

___________10. These are tools manipulated by our hands and with the use of electrical energy

Learning Activity 2

Let us determine how much you already know about selecting measuring tools and instruments. Take this test.

Instruction: Match the electrical measuring tools and instruments in Column A to their descriptions in Column B. Write the letter of your answer in the space provided before each number.

Column A	Column B
_____1. 	A. Voltmeter
_____2. 	B. Volt-ohmmeter
_____3. 	C. Micrometer
_____4. 	D. Clamp Ammeter
_____5. 	E. Wire gauge

2.2.5.5 Self-Assessment

1. What is troubleshooting?

2. Explain the following two hazards that can arise in faulty equipment
    i. **Shock Hazard**.
    ii. **Flash Hazard**.
3. List the three main reasons for having instruments calibrated:

4. Explain the following Methods of identifying non-functional/faulty tools and equipment

2.2.5.6 Tools, Equipment, Supplies and Materials

Tools

Phase tester

Screw drivers

Equipment

- PPE
- Oscilloscope
- Multimeter

Supplies and Materials

Insulation tape

2.2.5.7 References

1. IEE regulations
2. Organizational procedures manual
3. Electrical Installation Maintenance K to 12 – Technology and Livelihood Education Learning Module Republic of the Philippines DEPARTMENT OF EDUCATION
4. Ray C. Mullin, Phil_Simmons Electrical Wiring Re(z-lib.org)
5. Brian Scaddan IEng; MII (elec) Electrical insta(z-lib.org)
6. https://www.mgnewell.com/wp-content/uploads/2016/05/Purpose-of-Calibration.pdf

2.2.5.6 Responses on Self-Assessment

2.2.5.6.1 Responses on Self-Assessment: Learning outcome 1

1. A
2. D
3. C
4. **Remove heat from the burn to relieve the pain by placing the injured part under clean cold water. Do not remove burnt clothing sticking to the skin.**
   Do not apply lotions or ointments.
   Do not break blisters or attempt to remove loose skin. Cover the injured area with a clean dry dressing.
5.

Class of fire		Type of fire extinguisher			
		Water	Foam	Co_2	Dry powder
A	Ordinary fires: wood , paper ,cloth	**Yes**	**Yes**	**No**	**No**
B	Flammable liquids: petrol ,paraffin	**No**	**Yes**	**Yes**	**Yes**
C	Electrical equipment	**No**	**No**	**Yes**	**Yes**

6. One should not leave the machine ON even after the power is OFF and until it has stopped running completely. Someone else may not notice that the machine is still in motion and be injured.

- Operator should not talk to other industrial persons when he is operating a machine.
- One should not oil, clean, adjust or repair any machine while it is running. Stop the machine and lock the power switch in the OFF position.
- One should not operate any machine unless authorized to do so by the authorize person in the shop.

- Always check that work and cutting tools on any machine are clamped securely before starting.
- The floor should be kept clean and clear of metal chips or curls and waste pieces. Put them in the container provided for such things. Scraps and chips or curls may cut through a shoe and injure the foot.
- Defective guards must be replaced or repaired immediately.
- One should not operate any machinery when the supervisor or instructor is not in the shop.
- All set screws should be of flush or recessed type. Projecting set screws are very dangerous because they catch on sleeves or clothing.
- One should not try to stop the machine with hands or body.
- Only trained operator should operate machine or switches as far as possible.
- Always take help for handling long or heavy pieces of material.
- Always follow safe lifting practices
- No one should run in the shop at work time.
- Always keep your body and clothes away from moving machine parts. Get first aid immediately for any injury.
- Never talk to anyone while operating the machine, nor allow anyone to come near you or the machine.
- Stop the machine before making measurements or adjustments.
- Operator should concentrate on the work and must not talk unnecessarily while operating the machines.
- Never wear necktie, loose sweater, wristwatch, bangles, rings, and loose fitting clothing while working in workshop.
- Always wear overcoat or apron.
- Stop machines before attempting to clean it.
- Make sure that all guards are in their place before starting to operate a machine.
- Do not attempt to operate a machine until you have received operating instructions.
- Be thoroughly familiar with the 'stop' button and any emergency stop buttons provided on the machines.

- Remove burrs, chips and other unwanted materials as soon as possible. They can cause serious cuts.
- Do not leave loose rags on machines.
- Wash your hands thoroughly after working to remove oils, abrasive particles, cutting fluid, etc.
- Report all injuries to the foreman, howsoever small. Cuts and burns should be treated immediately.
- Keep the work area clean.
- Keep your mind on the job, be alert, and be ready for any emergency.
- Always work in proper lighting.
- On should not lean against the machines.

7. Personal protective equipment:

· **Safety goggles**

· **Safety shoes**

· **Safety helmet**

· **Safety gloves**

· **Safety shoes**

· **Safety belt**

Learning Activity 1

Hand tools	Powers	Pneumatic tools
Screw drivers	Grinding wheels	Air racket

Wrenches	Vacuum cleaner	Air drill
Pullers	Electric drill	Air chisel
Hammers		

2.2.5.6.2 Responses on Self-Assessment: Learning outcome 2

1. C

2. A

3. Always use the correct tool for the job in hand and use it properly and sensibly
   - Always keep tools clean and sharp
   - Always keep tools in a toolbox and secure safety rules for power tools
   - Always check that the casing is not damaged
   - Always check that the cable is not damaged
   - Always check that the plug top is not damaged
   - Always check that no coloured conductors are showing anywhere on the flexible cord

4. **Keep Power tools Clean.**

   Dust and grime can bring your power tools to a grinding halt if left unchecked over time.

   Store Power tools correctly.

   Inspect for Wear or Damage.

   Lubricate Moving Parts.

   Keep Batteries in Shape.

4\. **Better electrical hand tools, such as wire cutters and linesman pliers, have insulated handles to help guard against shock**

2.2.5.6.3 Responses on Self-Assessment: Learning Outcome 3

1. B
2. A
3. D
4. C
5. A

2.2.5.6.4 Responses on Self-assessment: learning outcome 4

1. C
2. A
3. D

4. Put a (✓) after each word if the solvent is polar and (X) if it is nonpolar.

1. water (✓)
2. kerosene (X)
3. detergent soap (✓)
4. gasoline (X)
5. thinner (X)

5. The table below show cleaning solvents for tools and equipment. Complete the table .

Cleaning solvents	Uses
Gasoline	**Wash greasy tools/equipment**
Kerosene	**Remove dust, grease oil paint, etc**
Thinner	**Remove spilled paint on floor, walls and tools**
Water	**Wash dust in the floor, walls, etc**
Detergent Soap and Water	**Wash/ clean benches, tables, cabinets,etc**

Learning activity 1: learning outcome 5

1. Pneumatic floor jack
2. Hand tools
3. Screw drivers
4. Wrench
5. Puller

6. Vacuum cleaner
7. Air drill
8. Personal Protective Equipment (PPE)
9. Pneumatic Torque Wrench
10. Machine/Power tools

Learning activity 2: Learning outcome 5

Answer

1. C
2. E
3. A
4. B
5. D

2.2.5.6.5 Responses on Self-assessment: Learning outcome 5

1. **Troubleshooting is the first step in the heavy equipment repair process in making a repair action and returning the equipment into service.**

2.
   i. **Shock Hazard**. If you were to contact live equipment with your body or a tool you are holding the current flowing through your body could cause severe injury, burns, and even death.
   ii. **Flash Hazard**. If you are in the vicinity of equipment that fails and causes an electric arc, the flash, heat and shrapnel caused by the arc can also be life threatening.

3.
   i. **To ensure readings from an instrument are consistent with other measurements.**

ii. **To determine the accuracy of the instrument readings.**

iii. **To establish the reliability of the instrument i.e. that it can be trusted.**

4.

i. **Visual inspection.** It refers to the visual observation of an expert on the appearance of the tools and equipment.

ii. **Functionality.** Vibration or extra noise from the operation means problems on parts and accessories started to develop.

iii. **Performance.** When there is something wrong with the performance of either hand tools or equipment they need an immediate repair or maintenance.

iv. **Power supply** (for electrically operated only). Failure to meet the required power supply, malfunction will occurs in the part of hand tools or equipment.

v. **Person's involved**. It refers to the technical person who has the knowledge and skills about the technology.

CHAPTER 3: ELECTRICAL PRINCIPLES

Unit of learning code: ENG/CU/EI/CC/02/4/A.

Related Unit of Competency in Occupational Standard: **Apply Electrical Principles Skills.**

3.1 Introduction to the unit of learning

This unit describes the competencies required by a technician in order to apply a wide range of Electrical principles in their work. Which includes; Basic Electrical quantities, D.C and A.C circuits in electrical installation, electrical machines, earthing in Electrical installations, capacitance and inductance

3.2 Summary of Learning Outcomes

1. Basic Electrical quantities
2. D.C and A.C circuits in electrical installation
3. Electrical machines
4. Earthing in Electrical installations
5. Capacitance and inductance

3.2.1 Learning Outcome 1: Basic Electrical Quantities

3.2.1.1 Introduction to the learning outcome

To apply basic Electrical quantities correctly one requires the ability to understand the SI units of Electrical quantities. Stated, Calculate and relates the quantities in Ohm's law.

3.2.1.2 Performance Standard.

- Basic SI units in Electrical are identified as established standards.
- Quantities of Charge, force, work and power are identified as per established standards.
- Perform calculations involving electrical quantities i.e., Current, Resistance and voltage as per established standards.

3.2.1.3 Information Sheet

Definition of terms.

SI unit

The system of units used in engineering and science is the Système Internationale d'Unités (International system of units), usually abbreviated to SI units, and is based on the metric system. This was introduced in 1960 and is now adopted by the majority of countries as the official system of measurement.

Quantity Unit

Length metre, m

Mass kilogram, kg

Time second, s

Electric current ampere, A

Thermodynamic temperature kelvin, K

Luminous intensity candela, cd

Amount of substance mole,

Charge

The unit of charge is the coulomb∗ (C), where one coulomb is one ampere second (1coulomb = 6.24×1018 electrons). The coulomb is defined as the quantity of electricity which flows past a given point in an electric which flows past a given point in an electric circuit when a current of one ampere∗ is maintained for one second. Thus, charge, in coulombs Q =It where I is the current in amperes and t is the time in seconds

Force

The unit of force is the newton∗ (N), where one newton is one-kilogram meters per second squared. The newton is defined as the force which, when applied to a mass of one kilogram, gives I t an acceleration of one meter per second squared. Thus force, newton's, F=ma where m is the mass in kilograms and a is the acceleration in meters per second squared. Gravitational force or weight is mg, where g = 9.81 m/s2.

Work

The unit of work or energy is the joule∗ (J), where one joule is one newton meter. The joule is defined as the work done or energy transferred when a force of one newton is exerted through a distance of one metre in the direction of the force. Thus, work done on a body, in joules, W=Fs Where F is the force in newton's and s is the distance in metres moved by the body in the direction of the force. Energy is the capacity for doing work.

Power

The unit of power is the watt∗ (W), where one watt is one joule per second. Power is defined as the rate of doing work or transferring energy. Thus, power, in watts P= Wt Where W is the work done or energy transferred, in joules, and t is the time, in seconds. Thus, energy, in joules W =Pt.

Resistance and conductance

The unit of electric resistance is the ohm (Ω), where one ohm is one volt per ampere. It is defined as the resistance between two points in a conductor when a constant electric potential of one volt applied at the two points produces a current flow of one ampere in the conductor. Thus, resistance, in ohms $R= VI$ where V is the potential difference across the two points, in volts, and I is the current flowing between the two points, in amperes. The reciprocal of resistance is called conductance and is measured in Siemens (S), named after the German inventor and industrialist Ernst Siemen∗ conductance, in Siemens $G=1R$ where R is the resistance in ohms.

Electrical power and energy

When a direct current of I amperes is flowing in an electric circuit and the voltage across the circuit is V volts, the power, in watts $P=VI$

Electrical energy =Power×time

=VIt joules

Although the unit of energy is the joule, when dealing with large amounts of energy, the unit used is the kilowatt hour (kWh) where

1 kWh = 1000 watt hour

= 1000× 3600 watt seconds or joules

= 3 600 000 J

1.2.1.4 Learning Activities.

1. Identified basic SI units in Electrical as per established standards

2. Identified quantities of charge, force, work and power as per established standards

3. Performed calculations involving Electrical quantities i.e resistance, current and voltage as per established standards.

1.2.1.5 Self-Assessment

1. If a current of 5A flows for 2 minutes, find the quantity of electricity transferred.

2. Find the force acting vertically downwards on a mass of 200 g attached to a wire

3. A portable machine requires a force of 200 N to move it. How much work is done if the Machine is moved 20 m and what average power is utilized if the movement takes 25 s?

4.: A source e.m.f. of 5V supplies a current of 3A for 10 minutes. How much energy is Provided in this time?

5. What is a derived unit?

6. A mass of 1000 kg is raised through a height of 10 m in 20 s. What is

(a) the work done and (b) the power developed?

1.2.1.6 Tools, Equipment, Supplies and Materials

- Scientific Calculators
- Ohmmeter
- Voltmeter
- Ammeter

1.2.1.7 References

- John Bird (2017) Electrical and Electronics Principles Technology fifth Edition
- John Bird(2017) Electrical and Electronics Principles Technology sixth Edition

1.2.1.8 Responses to Self-Assessment

Problem 1. If a current of 5 A flows for 2 minutes, find the quantity of electricity transferred.

Quantity of electricity Q = It coulombs

I = 5 A, t = 2 × 60 = 120 s

Hence Q= 5 × 120 = 600 C

Problem 2. Find the force acting vertically downwards on a mass of 200 g attached to a wire.

Mass=200 g=0.2 kg and acceleration due to gravity,

g =9.81 m/s2

Force acting downwards

= weight

= mass × acceleration

= 0.2 kg× 9.81m/s2

= 1.962 N

Problem 3. A portable machine requires a force of 200 N to move it. How much work is done if the machine is moved 20 m and what average power is utilized if the movement takes 25 s?

Work done = force× distance

= 200 N× 20m

= 4 000 Nm or 4 kJ

Power = work done/ time taken

= 4000 J/ 25 s

= 160 J/s = 160W

Problem 4. A source e.m.f. of 5V supplies a current of 3A for 10 minutes. How much energy is provided in this time? Energy = power ×time, and power =voltage ×current.

Hence

= VIt = 5 × 3 × (10× 60) = 9000Ws or J = 9 kJ

Problem5. Derived SI units _use combinations of basic units and there are many of them. Two examples are:

Velocity – metres per second (m/s)

Acceleration – metres per second squared (m/s2)

Problem 6. A mass of 1000 kg is raised through a height of 10 m in 20 s. What is (a) the work done and (b) the power developed?

(a) Work done = force× distance and force
 = mass × acceleration Hence,
 Work done = (1000 kg× 9.81m/s2) × (10m) = 98 100 Nm = 98.1 kNm or 98.1 kJ

(b) Power = work done/time taken
 = 98 100 J/20 s
 = 4905 J/s
 = 4905W or 4.905 kW

3.2.2 Learning Outcome 2: D.C And A.C Circuits In Electrical Installation

3.2.3.1 Introduction to the learning outcome

To apply DC and AC circuits in an Electrical Installation one is required to understand the Meaning of terms Conductors and insulators, Ohm's law Resistance variation, Resistors and color coding.

AC and DC circuits

- R-L, R-C, R-L-C circuits
- Series
- Parallel
- Parallel and series
- Parallel resonance and Q-factor
- Power factor improvement
- AC and DC network theorems e.g Kirchhoff's laws

3.2.3.2 Performance Standard

- Theory of conductors and insulators is determined as per established procedures
- Ohm's law is performed as per established procedures
- Calculations involving resistor connection is performed as per established procedures

- Colour coding for fixed resistors is performed as per established standards
- Calculations involving parallel and series circuits are performed as per established standards
- Calculations involving R-L-C circuits are performed as per established standards
- Calculations involving DC and AC circuits. Network theorems are performed. E.g., Kirchhoff's laws,
- Conversion of AC to DC and DC to AC are performed as per established standards
- Parallel resonance and Q-factor are determined as per established standards

o Power factor improvement is performed as per established standards

3.2.3.3 Information Sheet

Meaning of term;

A conductor is a material having a low resistance which allows electric current to flow in it. All metals are conductors and some examples include copper, aluminium, brass, platinum, silver, gold and carbon.

An insulator is a material having a high resistance which does not allow electric current to flow in it. Some examples of insulators include plastic, rubber, glass, porcelain, air, paper, cork, mica, ceramics and certain oils.

Ohm's law states that the current I flowing in a circuit is directly proportional to the applied voltage V and inversely proportional to the resistance R, provided the temperature remains constant. Thus, I = VR or V = IR or R = V/I

Example

The current flowing through a resistor is 0.8 A when a p.d. of 20V is applied. Determine the value of the resistance. From Ohm's law, resistance R= V/I

= 20/0.8

= 200/8

=25Ω

Colour	Significant figures	Multiplier	Tolerance
Silver	–	10^{-2}	±10%
Gold	–	10^{-1}	±5%
Black	0	1	–
Brown	1	10	±1%
Red	2	10^2	±2%
Orange	3	10^3	–
Yellow	4	10^4	–
Green	5	10^5	±0.5%
Blue	6	10^6	±0.25%
Violet	7	10^7	±0.1%
Grey	8	10^8	–
White	9	10^9	–
None	–	–	±20%

Resistor colour coding and ohmic values

(a) Colour code for fixed resistors

The colour code for fixed resistors is given in Table(i) For a four-band fixed resistor (i.e., resistance values with two significant figures): yellow-violet orange-red indicates 47 k with a tolerance of ±2%

(Note that the first band is the one nearest the end of the resistor.) (ii) For a five-band fixed resistor (i.e., resistance values with three significant figures): red-yellow white-orange-brown indicates 249 k with a tolerance of ±1% (Note that the fifth band is 1.5 to 2 times wider than the other bands.)

(b) Letter and digit code for resistors

Another way of indicating the value of resistors is the letter and digit code shown in Table 5.2.

Resistance value	Marked as
0.47 Ω	R47
1 Ω	1R0
4.7 Ω	4R7
47 Ω	47R
100 Ω	100R
1 kΩ	1K0
10 kΩ	10K
10 MΩ	10 M

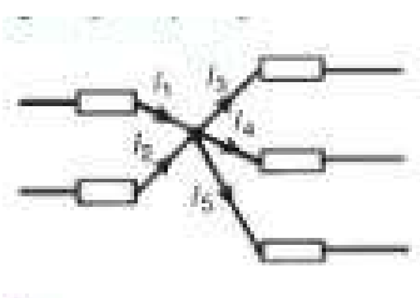
Tolerance is indicated as follows =±1%, G=±2%,J =±5%, K =±10% and M =±20%.Thus, for example,

R33M = 0.33 ± 20%

4R7K = 4.7 ± 10%

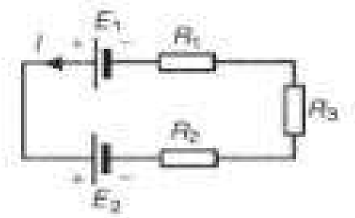
390RJ = 390 ± 5%

Kirchhoff's laws



Kirchhoff's laws state:

(a) Current Law. At any junction in an electric circuit the total current flowing towards that junction is equal to the total current flowing away from the junction, i.e. I =0 Thus, referring to Fig. Below I1+I2 =I3 +I4 +I5 or I1+I2 −I3 −I4 −I5 =0



(b) Voltage Law. In any closed loop in a network, the algebraic sum of the voltage drops (i.e. products of current and resistance) taken around the loop is equal to the resultant e.m.f. acting in that loop Thus, referring to Fig. Below

$E1 - E2 = IR1 + IR2 + IR3$

(Note that if current flows away from the positive terminal of a source, that source is considered by convention to be positive. Thus, moving anticlockwise around the loop of Fig. 15.2, E1 is positive and E2 is negative.)

Series AC Circuit

R–L series a.c. circuit

In an a.c. circuit containing inductance L and resistance R, the applied voltage V is the phasor sum of VR and VL, and thus the current I lags the applied voltage V by an angle lying between 0◦ and 90◦ (depending on the values of VR and VL), shown as angle φ. In any a.c. series circuit the current is common to each component and is thus taken as the reference phasor.

Figure 15.6

From the phasor diagram of Fig. 15.6, the **'voltage triangle'** is derived.

For the R–L circuit:

$$V = \sqrt{V_R^2 + V_L^2} \quad \text{(by Pythagoras' theorem)}$$

and

$$\tan\phi = \frac{V_L}{V_R} \quad \text{(by trigonometric ratios)}$$

In an a.c. circuit, the ratio applied voltage V to current I is called the **impedance**, Z, i.e.

$$Z = \frac{V}{I}\ \Omega$$

If each side of the voltage triangle in Fig. 15.6 is divided by current I then the **'impedance triangle'** is derived.

For the R–L circuit: $Z = \sqrt{R^2 + X_L^2}$

$$\tan\phi = \frac{X_L}{R}$$

$$\sin\phi = \frac{X_L}{Z}$$

and

$$\cos\phi = \frac{R}{Z}$$

From the voltage triangle of Fig. 15.6, supply voltage

$$V = \sqrt{12^2 + 5^2}$$

i.e. $$V = 13\,V$$

(Note that in a.c. circuits, the supply voltage is **not** the arithmetic sum of the p.d.s across components. It is, in fact, the **phasor sum**.)

$$\tan\phi = \frac{V_L}{V_R} = \frac{5}{12}$$

from which, circuit phase angle

$$\phi = \tan^{-1}\left(\frac{5}{12}\right) = 22.62^\circ \text{ lagging}$$

('Lagging' infers that the current is 'behind' the voltage, since phasors revolve anticlockwise.)

Example1. In a series R–L circuit the p.d. across the resistance R is 12V and the p.d. across the inductance L is 5V. Find the supply voltage and the phase angle between current and voltage

If each side of the voltage triangle in Fig. 15.10 is divided by current I then the 'impedance triangle' is derived.

For the R–C circuit: $Z = \sqrt{R^2 + X_C^2}$

$$\tan\alpha = \frac{X_C}{R} \quad \sin\alpha = \frac{X_C}{Z} \quad \text{and} \quad \cos\alpha = \frac{R}{Z}$$

R–C series a.c. circuit

In an a.c. series circuit containing capacitance C and resistance R, the applied voltage V is the phasor sum of VR and VC and thus the current I leads the applied voltage V by an angle lying between 0◦ and 90◦ (depending on the values of VR and VC), shown as angle α

From the phasor diagram, the 'voltage triangle' is derived.

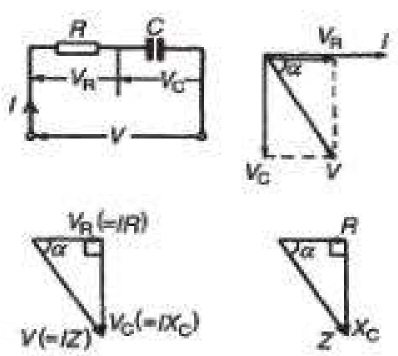
For the $R-C$ circuit:

$$V = \sqrt{V_R^2 + V_C^2} \quad \text{(by Pythagoras' theorem)}$$

and

$$\tan \alpha = \frac{V_C}{V_R} \quad \text{(by trigonometric ratios)}$$

As stated in Section 15.4, in an a.c. circuit, the ratio of applied voltage V to current I is called the **impedance** Z, i.e. $Z = V/I\ \Omega$



Example 1

A resistor of 25Ω is connected in series with a capacitor of 45µF. Calculate (a) the Impedance and (b) the current taken from a 240 V, 50 Hz supply. Find also the phase angle between the supply voltage and the current.

$R = 25\,\Omega$, $C = 45\,\mu F = 45 \times 10^{-6}\,F$, $V = 240\,V$ and $f = 50\,Hz$. The circuit diagram is as shown in Fig. 15.10

Capacitive reactance,

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(50)(45 \times 10^{-6})} = 70.74\,\Omega$$

(a) Impedance $Z = \sqrt{R^2 + X_C^2} = \sqrt{25^2 + 70.74^2}$

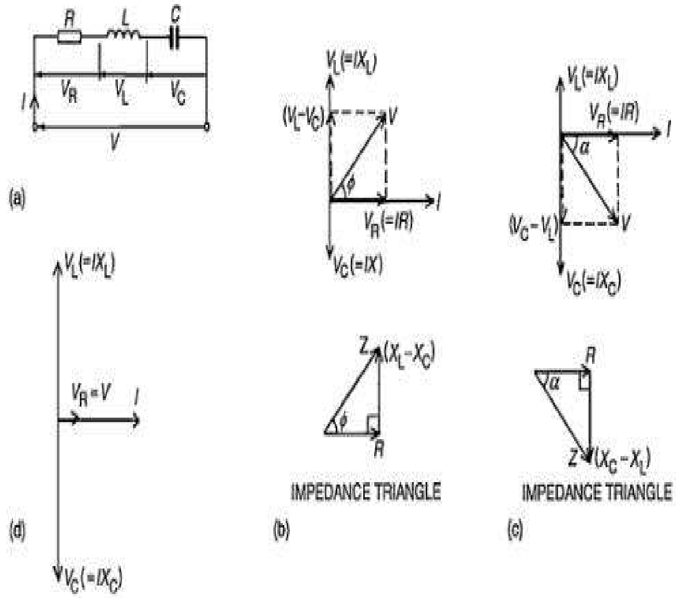
$= \mathbf{75.03\,\Omega}$

(b) Current $I = V/Z = 240/75.03 = \mathbf{3.20\,A}$

Phase angle between the supply voltage and current, $\alpha = \tan^{-1}(X_C/R)$ hence

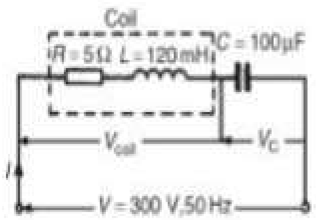
$$\alpha = \tan^{-1}\left(\frac{70.74}{25}\right) = \mathbf{70.54^\circ\ leading}$$

('Leading' infers that the current is 'ahead' of the voltage, since phasors revolve anticlockwise.)



R–L–C series a.c. circuit

In an a.c. series circuit containing resistance R, inductance L and capacitance C, the applied voltage V is the phasor sum of VR, VL and VC. VL and VC are anti-phase, i.e. displaced by 180◦, and there are three phasor diagrams possible – each depending on the relative values of VL and V



$$_L - X_C)^2$$

When $X_C > X_L$ (Fig. 15.12(c)):

$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$

and $$\tan \alpha = \frac{X_C - X_L}{R}$$

When $X_L = X_C$ (Fig. 15.12(d)), the applied voltage V and the current I are in phase. This effect is called **series**

Example 1

A coil of resistance 5 and inductance 120 mH in series with a 100μF capacitor is connected to a 300 V, 50Hz supply. Calculate (a) the current flowing, (b) the phase difference between the supply voltage and current,(c) the voltage across the coil and (d) the voltage across the capacitor.

This ratio is a measure of the quality of a circuit (as a resonator or tuning device) and is called the **Q-factor**. Hence

$$\text{Q-factor} = \frac{V_L}{V} = \frac{IX_L}{IR} = \frac{X_L}{R} = \frac{2\pi f_r L}{R}$$

Alternatively,

$$\text{Q-factor} = \frac{V_C}{V} = \frac{IX_C}{IR} = \frac{X_C}{R} = \frac{1}{2\pi f_r CR}$$

At resonance

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

i.e.

$$2\pi f_r = \frac{1}{\sqrt{LC}}$$

Hence

$$\text{Q-factor} = \frac{2\pi f_r L}{R} = \frac{1}{\sqrt{LC}}\left(\frac{L}{R}\right) = \frac{1}{R}\sqrt{\frac{L}{C}}$$

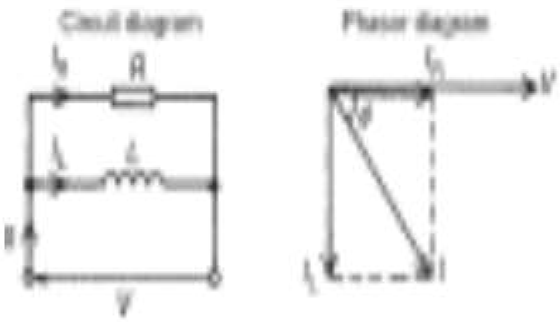
Q-factor

At resonance, if R is small compared with XL and XC, it is possible for VL and VC to have voltages many times greater than the supply voltage .Voltage magnification at resonance= voltage across L (or C)supply voltage V .This ratio is a measure of the quality of a circuit (as a resonator or tuning device) and is called the Q-factor. Hence

PARALLEL CIRCUIT

R-L ac circuit

In the two-branch parallel circuit containing resistance R and inductance L,the current flowing in the resistance, IR, is in-phase with the supply voltage V and the current flowing in the inductance, IL, lags the supply voltage by 90◦. The supply current I is the phasor sum of IR and IL and thus the current I lags the applied voltage V by an angle lying between 0◦ and 90◦ (depending on the values of IR and IL), shown as angle φ in the phasor diagram.



From the phasor diagram: $I = \sqrt{I_R^2 + I_L^2}$ (by Pythagoras' theorem) where

$$I_R = \frac{V}{R} \text{ and } I_L = \frac{V}{X_L}$$

$$\tan\phi = \frac{I_L}{I_R},\ \sin\phi = \frac{I_L}{I} \text{ and } \cos\phi = \frac{I_R}{I}$$

(by trigonometric ratios)

$$\text{Circuit impedance, } Z = \frac{V}{I}$$

EXAMPLE1

A 20_ resistor is connected in parallel with an inductance of 2.387mH across a 60V, 1 kHz supply. Calculate (a) the current in each branch, (b) the supply current, (c) the circuit phase angle, (d) the circuit impedance and (e) the power consumed.

The circuit and phasor diagrams are as shown in Fig. 16.1

(a) Current flowing in the resistor,

$$I_R = \frac{V}{R} = \frac{60}{20} = 3\,\text{A}$$

Current flowing in the inductance,

$$I_L = \frac{V}{X_L} = \frac{V}{2\pi f L}$$

$$= \frac{60}{2\pi(1000)(2.387 \times 10^{-3})} = 4\,\text{A}$$

(b) From the phasor diagram, supply current,

$$I = \sqrt{I_R^2 + I_L^2} = \sqrt{3^2 + 4^2} = 5\,\text{A}$$

(c) Circuit phase angle,

$$\phi = \tan^{-1}\frac{I_L}{I_R} = \tan^{-1}\frac{4}{3} = 53.13^\circ \text{ lagging}$$

(d) Circuit impedance,

$$Z = \frac{V}{I} = \frac{60}{5} = 12\,\Omega$$

(e) Power consumed

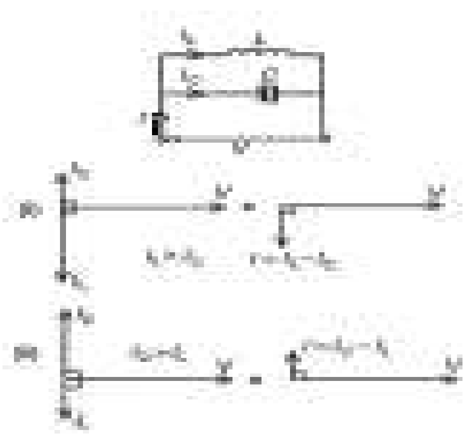
$$P = VI\cos\phi = (60)(5)(\cos 53.13^\circ)$$

$$= 180\,\text{W}$$

(Alternatively, power consumed, $P = I_R^2 R = (3)^2(20) = 180\,\text{W}$)

L-C ac circuit

In the two-branch parallel circuit containing inductance L and capacitance C, IL lags V by 900 and IC leads V by 900.



Theoretically there are three phasor diagrams possible—each depending on the relative values of I_L and I_C:

(i) $I_L > I_C$ (giving a supply current, $I = I_L - I_C$ lagging V by 90°)

(ii) $I_C > I_L$ (giving a supply current, $I = I_C - I_L$ leading V by 90°)

(iii) $I_L = I_C$ (giving a supply current, $I = 0$)

The latter condition is not possible in practice due to circuit resistance inevitably being present (as in the circuit described in Section 16.5).

For the *L–C* parallel circuit,

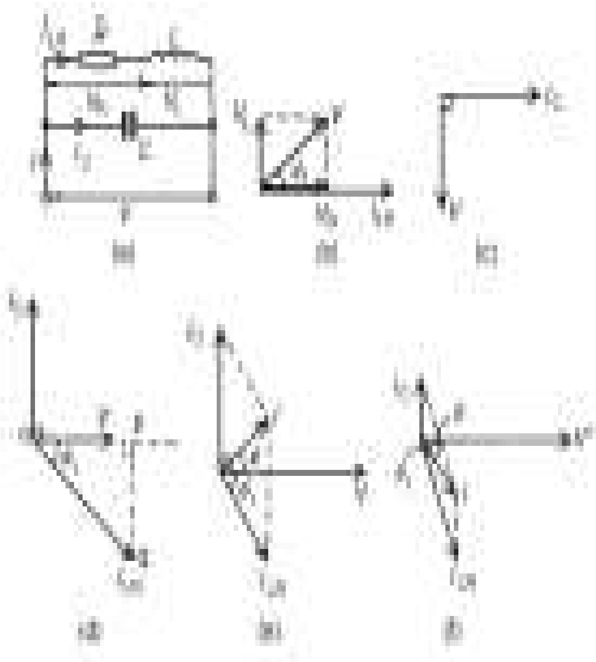
$$I_L = \frac{V}{X_L} \quad I_C = \frac{V}{X_C}$$

I = phasor difference between I_L and I_C

and $Z = \frac{V}{I}$

LR-C ac circuit

In the two-branch circuit containing capacitance C in parallel with inductance L and resistance R in series (such as a coil)shown in Fig(a),the phasor diagram for the LR branch alone is shown in Fig.(b) and the phasor diagram for the C branch is shown alone in Fig. (c). Rotating each and superimposing on one another gives the complete phasor diagram shown in Fig(d).



The current I_{LR} of Fig. 16.5(d) may be resolved into horizontal and vertical components. The horizontal component, shown as op is $I_{LR}\cos\phi_1$ and the vertical component, shown as pq is $I_{LR}\sin\phi_1$. There are three possible conditions for this circuit:

(i) $I_C > I_{LR}\sin\phi_1$ (giving a supply current I leading V by angle ϕ—as shown in Fig. 16.5(e))

(ii) $I_{LR}\sin\phi > I_C$ (giving I lagging V by angle ϕ—as shown in Fig. 16.5(f))

(iii) $I_C = I_{LR}\sin\phi_1$ (this is called **parallel resonance**, see Section 16.6)

There are two methods of finding the phasor sum of currents I_{LR} and I_C in Fig. 16.5(e) and (f). These are: (i) by a scaled phasor diagram, or (ii) by resolving each current into their '**in-phase**' (i.e. horizontal) and '**quadrature**' (i.e. vertical) **components**, as demonstrated in Problems 6 and 7. With reference to the phasor diagrams of Fig. 16.5:

Impedance of LR branch, $Z_{LR} = \sqrt{R^2 + X_L^2}$

Current, $I_{LR} = \dfrac{V}{Z_{LR}}$ and $I_C = \dfrac{V}{X_C}$

Supply current

I = phasor sum of I_{LR} and I_C (by drawing)

$$= \sqrt{(I_{LR}\cos\phi_1)^2 + (I_{LR}\sin\phi_1 \sim I_C)^2}$$

(by calculation)

where ~ means 'the difference between'.

$$\text{Circuit impedance } Z = \frac{V}{I}$$

$$\tan\phi_1 = \frac{V_L}{V_R} = \frac{X_L}{R}$$

$$\sin\phi_1 = \frac{X_L}{Z_{LR}} \quad \text{and} \quad \cos\phi_1 = \frac{R}{Z_{LR}}$$

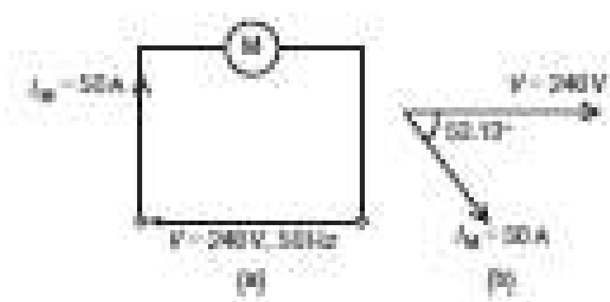
$$\tan\phi = \frac{I_{LR}\sin\phi_1 \sim I_C}{I_{LR}\cos\phi_1} \quad \text{and} \quad \cos\phi = \frac{I_{LR}\cos\phi_1}{I}$$

POWER IMPROVEMENT

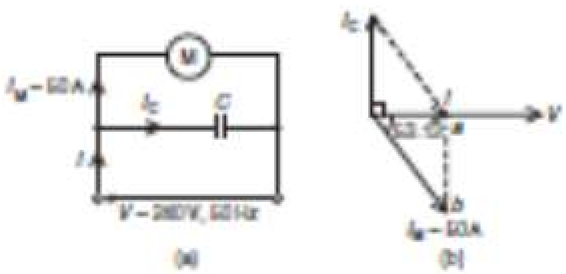
In any a.c. circuit, power factor $=\cos\varphi$, where φ is the phase angle between supply current and supply voltage. Industrial loads such as a.c. motors are essentially inductive (i.e. R–L) and may have a low power factor. For example, let a motor take a current of 50A at a power factor of 0.6 lagging from a 240V, 50Hz supply, as shown in the circuit diagram of Fig(a).

If power factor = 0.6 lagging, then: $\cos\varphi = 0.6$ lagging

Hence, phase angle, $\varphi = \cos^{-1} 0.6 = 53.13^\circ$ lagging, Lagging means that I lags V , and the phasor diagram is as shown in Fig(b).



How can this power factor of 0.6 be 'improved' or 'corrected' to, say, unity? Unity power factor means: $\cos\varphi = 1$ from which, $\varphi = 0$ So how can the circuit of Fig(a) be modified so that the circuit phase angle is changed from53.13∘ to 0∘? The answer is to connect a capacitor in parallel with the motor as shown in Fig(a).



When a capacitor is connected in parallel with the inductive load, it takes a current shown as IC. In the phasor diagram of Fig(b), current IC is shown leading the voltage V by 90∘.The supply current in Fig(a) is shown as I and is now the phasor sum of IM and IC In the phasor diagram of Fig(b), current I is shown as the phasor sum of IM and IC and is in phase with V , i.e. the circuit phase angle is 0∘, which means that the power factor is cos 0∘= 1

Thus, by connecting a capacitor in parallel with the motor, the power factor has been improved from 0.6 lagging to unity.

From right-angle triangles,cos 53.13∘ = adjacent/hypotenuse

= I/50

from which, supply current, I = 50 cos 53.13∘

= 30A

Before the capacitor was connected, the supply current was 50A. Now it is 30 A.

Herein lies the advantage of power factor improvement– the supply current has been reduced. When power factor is improved, the supply current is reduced, the supply system has lower losses (i.e. Lower I 2R losses) and therefore cheaper running costs.

3.2.3.4 Learning Activities

Determined theory of conductors and insulators as per established procedures

- Performed Ohms law as per established procedures

- Performed calculations involving resistor connection as per established procedures
- Performed color coding for fixed resistors as per established standards
- Performed calculations involving parallel and series circuits as per established standards
- Performed calculations involving R-L-C circuits as per established standards
- Performed calculations involving DC and AC circuits. Network theorems . E.g. Kirchoff's laws,
- Performed conversion of AC to DC and DC to AC as per established standards
- Determined parallel resonance and Q-factor as per established standards
- Performed power factor improvement as per established standards

3.2.3.5 Self-Assessment

1. Define the following terms;

I. A conductor

II. An insulator.

2. State ;

I. Kirchhoff's laws

II. Ohm's law.

3. What is Q-factor

4. A resistor of 25Ω is connected in series with a capacitor of 45μF. Calculate (a) the Impedance and (b) the current taken from a 240 V, 50 Hz supply. Find also the phase angle between the supply voltage and the current.

5. In a series R–L circuit the p.d. across the resistance R is 12V and the p.d. across the inductance L is 5V. Find the supply voltage and the phase angle between current and voltage

3.2.2.6 Tools, Equipment, Supplies and Material

- Scientific calculators
- Ohmeter
- Resistors
- Conductor

3.2.2.7 References

- John Bird(2017) Electrical and Electronics Principles Technology fifth Edition
- John Bird(2017) Electrical and Electronics Principles Technology sixth Edition
- Watkins, A.J, Kitcher C (2009) Electrical Installation calculations Basic Eighth Elsevier Ltd
- Stokes,J Handbook of Electrical Installation Practice Fourth Edition Blackwell Science Ltd

3.2.2.8 Response To Self-Assessment.

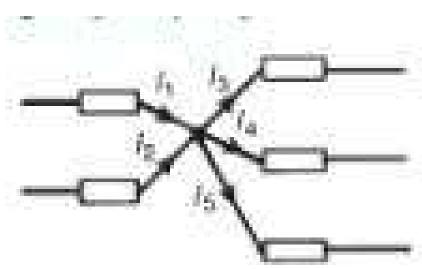
II. A conductor is a material having a low resistance which allows electric current to flow in it. All metals are conductors and some examples include copper, aluminum, brass, platinum, silver, gold and carbon.

III. An insulator is a material having a high resistance which does not allow electric current to flow in it. Some examples of insulators include plastic, rubber, glass, porcelain, air, paper, cork, mica, ceramics and certain oils.

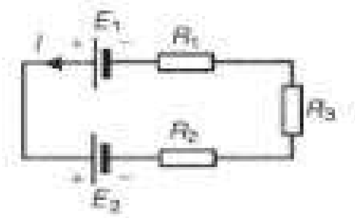
2. Kirchhoff's laws state:

(a) Current Law. At any junction in an electric circuit the total current flowing towards that junction is equal to the total current flowing away from the junction, i.e. $I = 0$ Thus, referring to Fig. Below $I_1 + I_2 = I_3 + I_4 + I_5$ or $I_1 + I_2 - I_3 - I_4 - I_5 = 0$

(b) Voltage Law. In any closed loop in a network, the algebraic sum of the voltage drops (i.e. products of current and resistance) taken around the loop is equal to the resultant e.m.f. acting in that loop Thus, referring to Fig. Below



$E_1 - E_2 = IR_1 + IR_2 + IR_3$



Ohm's law states that the current I flowing in a circuit is directly proportional to the applied voltage V and inversely proportional to the resistance R, provided the temperature remains constant. Thus, I = VR or V = IR or R = V/I

3.Q-factor. At resonance, if R is small compared with XL and XC, it is possible for VL and VC to have voltages many times greater than the supply voltage .Voltage magnification at resonance= voltage across L (or C)supply voltage V .This ratio is a measure of the quality of a circuit (as a resonator or tuning device) and is called the Q-factor.

4. A resistor of 25Ω is connected in series with a capacitor of 45μF. Calculate (a) the Impedance and (b) the current taken from a 240 V, 50 Hz supply. Find also the phase angle between the supply voltage and the current.

$R = 25\,\Omega$, $C = 45\,\mu F = 45 \times 10^{-6}\,F$, $V = 240\,V$ and $f = 50\,Hz$. The circuit diagram is as shown in Fig. 15.10

Capacitive reactance,

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi (50)(45 \times 10^{-6})} = 70.74\,\Omega$$

(a) Impedance $Z = \sqrt{R^2 + X_C^2} = \sqrt{25^2 + 70.74^2}$
$= \mathbf{75.03\,\Omega}$

(b) Current $I = V/Z = 240/75.03 = \mathbf{3.20\,A}$

Phase angle between the supply voltage and current, $\alpha = \tan^{-1}(X_C/R)$ hence

$$\alpha = \tan^{-1}\left(\frac{70.74}{25}\right) = \mathbf{70.54^\circ\ leading}$$

('Leading' infers that the current is 'ahead' of the voltage, since phasors revolve anticlockwise.)

5. In a series R–L circuit the p.d. across the resistance R is 12V and the p.d. across the inductance L is 5V. Find the supply voltage and the phase angle between current and voltage

From the voltage triangle of Fig. 15.6, supply voltage

$$V = \sqrt{12^2 + 5^2}$$

i.e. $\quad \mathbf{V = 13\,V}$

(Note that in a.c. circuits, the supply voltage is **not** the arithmetic sum of the p.d.s across components. It is, in fact, the **phasor sum**.)

$$\tan\phi = \frac{V_L}{V_R} = \frac{5}{12}$$

from which, circuit phase angle

$$\phi = \tan^{-1}\left(\frac{5}{12}\right) = \mathbf{22.62^\circ\ lagging}$$

('Lagging' infers that the current is 'behind' the voltage, since phasors revolve anticlockwise.)

3.2.3 Learning Outcome 3: Electrical Machines

3.2.3.1 Introduction to the learning outcome

To operate Electrical machines correctly one is required to have knowledge on Single phase Electrical machines, DC single phase motors and generators, AC Single phase motors and generators, Single phase transformers, Application of AC and DC machines, Motor starter, DC Motor speed control

3.2.3.2 Performance Standard

- Types of single-phase electrical machines are identified as per established standards
- Calculations involving single phase AC and DC Motors are performed per established standards
- Types of single-phase transformers are identified as per established standards
- Calculations involving single AC and DC transformers are performed as per established standards
- Types of single-phase generators are identified as per established standards
- Motor starting methods are identified as per established procedure
- DC motor speed control is established as per standard operating procedures

3.2.3.3 Information Sheet

DC Generators

D.c generators are classified according to the method of their field excitation. These groupings are:

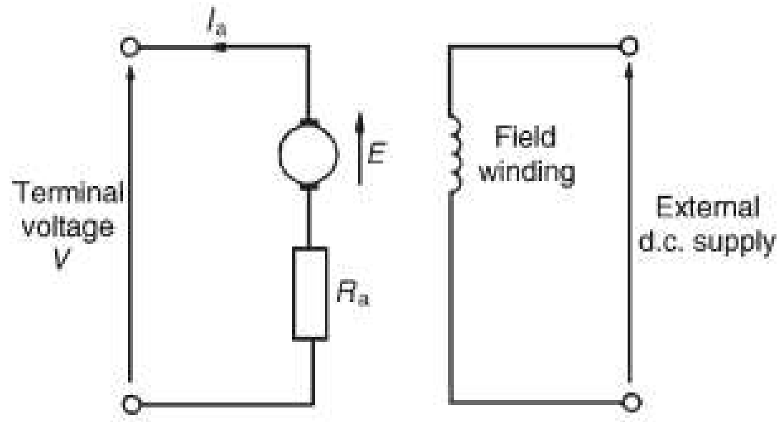
(i) Separately excited generators, where the field winding is connected to a source of supply other than the armature of its own machine.

(ii) Self-excited generators, where the field winding receives its supply from the armature of its own machine, and which are sub-divided into (a) shunt, (b) series and (c) compound wound generators.

Types of DC Generators

(a) Separately excited generator

A typical separately-excited generator circuit is shown below. When a load is connected across the armature terminals, a load current Ia will flow. The terminal voltage will fall from its open-circuit e.m.f. E due to a volt drop caused by current flowing through the armature resistance, shown as Ra i.e. terminal voltage, $V = E - IaRa$ or generated e.m.f., $E = V + IaRa$



EXAMPLE

Determine the terminal voltage of a generator which develops an e.m.f. of 200V and has an armature current of 30A on load. Assume the armature resistance is 0.30, terminal voltage,

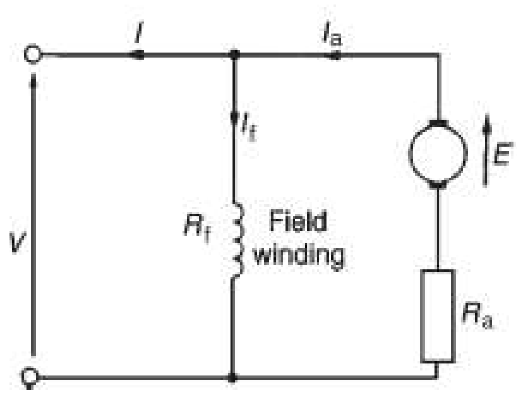
V = $E - Ia\ Ra$

= 200−(30)(0.30)

= 200−9 = 191volts

(b) Shunt-wound generator

In a shunt-wound generator the field winding is connected in parallel with the armature, The field winding has a relatively high resistance and therefore the current carried is only a fraction of the armature current.



Terminal voltage, V=E−IaRa or generated e.m.f., E=V+IaRa

Ia =If +I from Kirchhoff's current law, where

Ia = armature current, If = field current (=V/Rf) and

I = load current

EXAMPLE

A shunt generator supplies a 20Kw load at 200V through cables of resistance, R = 100m_. If the field winding resistance, Rf = 50_ and the armature resistance, Ra = 40m_, determine (a) the terminal voltage and(b) the e.m.f. generated in the armature.

(a)The circuit is shown below

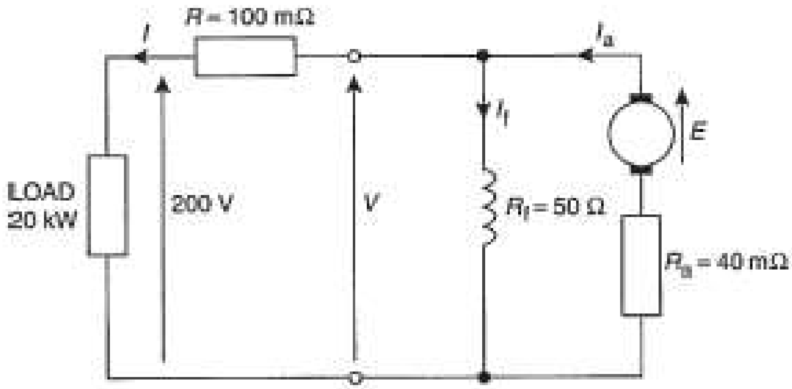
Load current, I = 20000watts/200volts

= 100A

Volt drop in the cables to the load

=IR = (100) (100×10−3) = 10V

Hence terminal voltage=200+10=210volts



(b) Armature current $I_a = I_f + I$

Field current, $I_f = \dfrac{V}{R_f} = \dfrac{210}{50} = 4.2\,\text{A}$

Hence $I_a = I_f + I = 4.2 + 100 = 104.2\,\text{A}$

Generated e.m.f. $\boldsymbol{E} = V + I_a R_a$

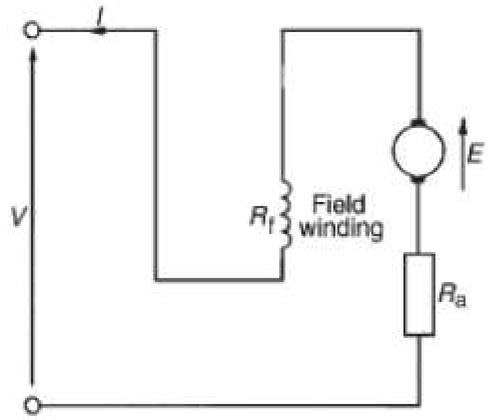
$$= 210 + (104.2)(40 \times 10^{-3})$$

$$= 210 + 4.168$$

$$= \mathbf{214.17\ volts}$$

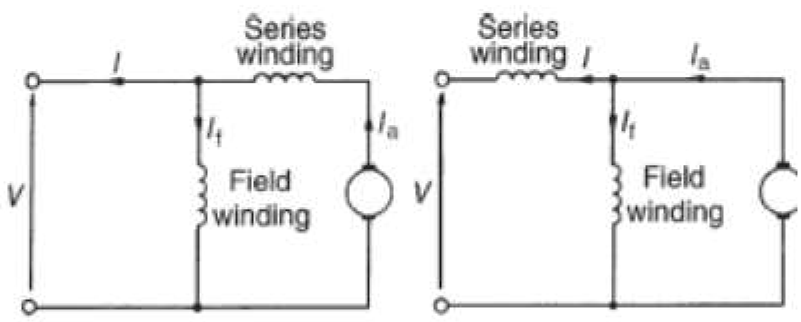
(c) Series-wound generator

In the series-wound generator the field winding is connected in series with the armature, as shown below



[d]. Compound-wound generator

In the compound-wound generator two methods of connection are used, both having a mixture of shunt and series windings, designed to combine the advantages of each. (a) shows what is termed a long shunt compound generator, (b) shows short-shunt compound generator. The latter is the most generally used form of d.c. generator.

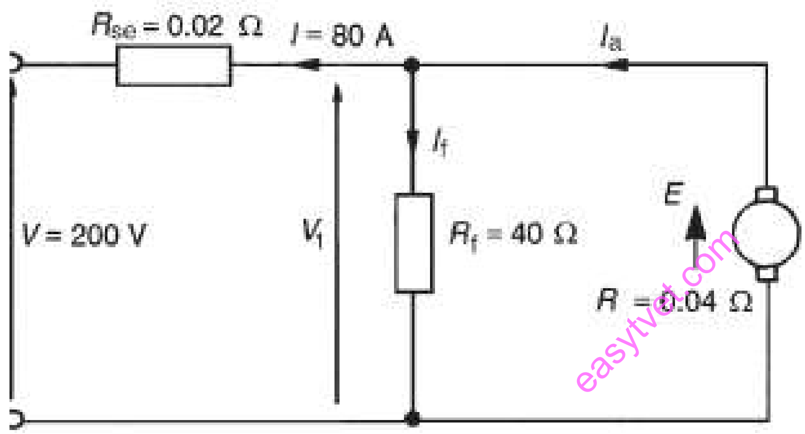


EXAMPLE

A short-shunt compound generator supplies 80A at 200V. If the field resistance, Rf = 40_, the series resistance, RSe = 0.02_ and the armature resistance, Ra = 0.04_, determine the e.m.f. generated.

Volt drop in series winding = IRSe = (80/)(0.02)

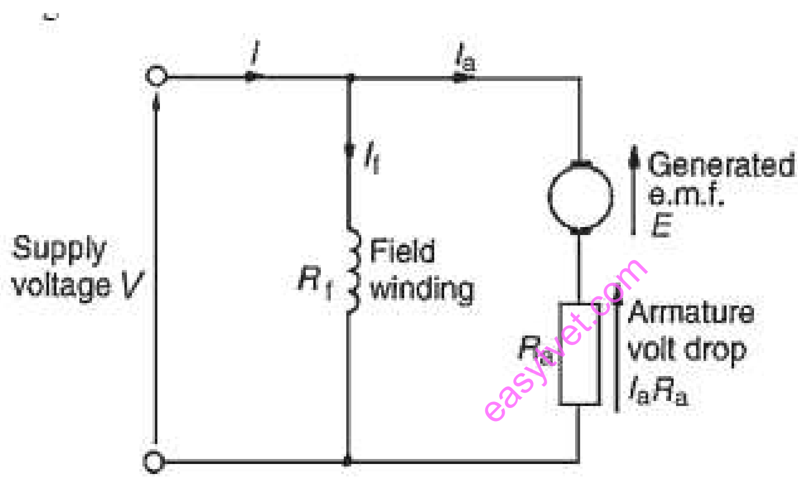
= 1.6V



TYPES OF DC MOTORS

(a) Shunt-wound motor

In the shunt-wound motor the field winding is in parallel with the armature across the supply, as shown in the figure below



Supply voltage, V=E+IaRa or generated e.m.f., E= V−IaRa

Supply current, I=Ia+If from Kirchhoff's current law

EXAMPLE

A 240V shunt motor takes a total current of 30A. If the field winding resistance Rf = 150_ and the armature resistance Ra = 0.4_, determine (a) the current in the armature and (b) the back e.m.f.

= 28.4A

(a) Field current $I_f = \frac{V}{R_f} = \frac{240}{150} = 1.6\,\text{A}$

Supply current $I = I_a + I_f$

Hence armature current, $I_a = I - I_f = 30 - 1.6$

$= \mathbf{28.4\,A}$

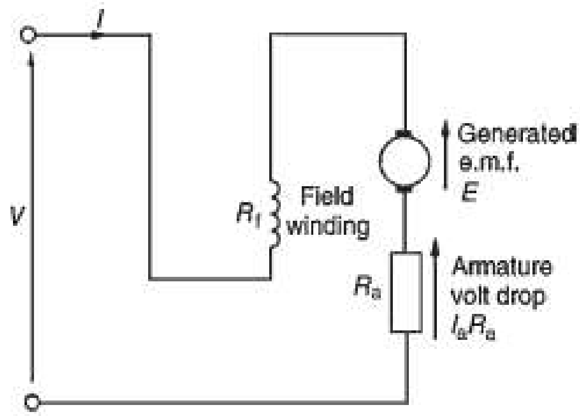
(b) Back e.m.f.

$E = V - I_a R_a = 240 - (28.4)(0.4) = \mathbf{228.64\ volts}$

(b) Series-wound motor

In the series-wound motor the field winding is in series with the armature across the supply, as shown below.

Supply voltage $V=E+I(Ra+Rf)$ *or generated e.m.f.* $E=V-I(Ra+Rf)$



(c) Compound-wound motor

There are two types of compound-wound motor:

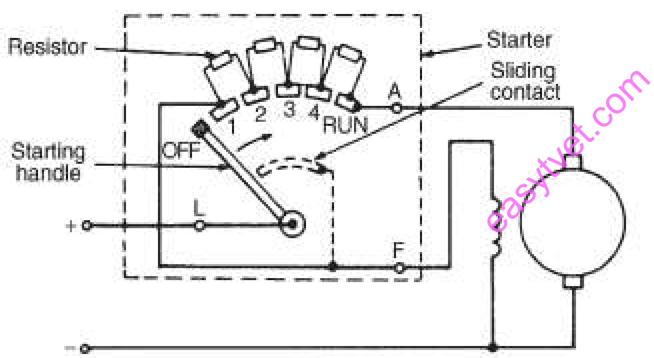
(i) Cumulative compound, in which the series winding is so connected that the field due to it assists that due to the shunt winding.

(ii) Differential compound, in which the series winding is so connected that the field due to it opposes that due to the shunt winding.

DC MOTOR STOTOR

If a d.c. motor whose armature is stationary is switched directly to its supply voltage, it is likely that the fuses protecting the motor will burn out. This is because the armature resistance is small, frequently being less than one ohm. Thus, additional resistance must be added to the armature circuit at the instant of closing the switch to start the motor.As the speed of the motor increases, the armature conductors are cutting flux and a generated voltage, acting in opposition to the applied voltage, is produced, which limits the flow of armature current. Thus the value of the additional armature resistance can then be reduced.

When at normal running speed, the generated e.m.f. is such that no additional resistance is required in the armature circuit. To achieve this varying resistance in the armature circuit on starting, a d.c. motor starter is used, as shown in Fig below



The starting handle is moved slowly in a clockwise direction to start the motor. For a shunt-wound motor, the field winding is connected to stud 1 or to L via a sliding contact on the starting handle, to give maximum field current, hence maximum flux, hence maximum torque on starting, since T ∝Ia .A similar arrangement without the field connection is used for series motors

SPEED CONTROL OF DC MOTORS

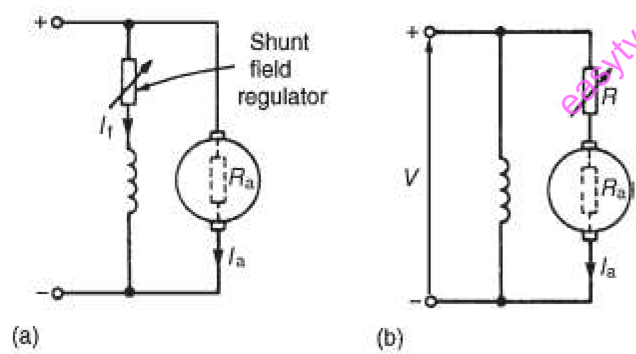
Shunt-wound motors

The speed of a shunt-wound d .c. motor, n, is proportional to

$V - IaRa$

Φ

The speed is varied either by varying the value of flux, or by varying the value of Ra. The former is achieved by using a variable resistor in series with the field winding, as shown in Fig below and such a resistor is called the shunt field regulator



As the value of resistance of the shunt field regulator is increased, the value of the field current, If, is decreased. This results in a decrease in the value of flux, , and hence an increase in the speed, since n∝1/. Thus only speeds above that given without a shunt field regulator can be obtained by this method. Speeds below those given by

$V - IaRa/\Phi$

are obtained by increasing the resistance in the armature circuit, where

n∝

$V - Ia(Ra+R)/\Phi$

Since resistor R is in series with the armature, it carries the full armature current and results in large power loss in large motors where a considerable speed reduction is required for long periods.

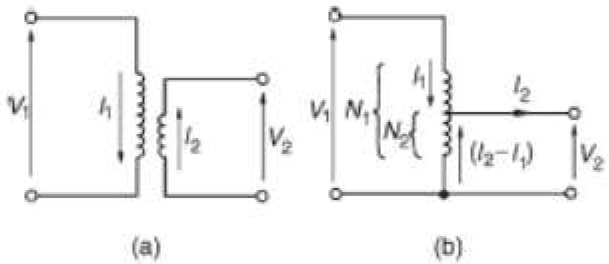
These methods of speed control are demonstrated in the following worked problem.

TRANSFOMER

An auto transformer is a transformer which has part of its winding common to the primary and secondary

Circuits. Fig(a) shows the circuit for a double wound transformer and Fig(b) that for an auto transformer. The latter shows that the secondary is actually part of the primary, the current in the secondary being ($I2-I1$). Since the current is less in this section,the cross-sectional area of the winding can be reduced,

which reduces the amount of material necessary.



3.2.3.4 Learning Activities

- Identified types of single-phase electrical machines as per established standards
- performed Calculations involving single phase AC and DC Motors per established standards
- Identified types of single phase transformers as per established standards
- performed calculations involving single AC and DC transformers as per established standards
- Identified types of single phase generators as per established standards
- Identified Motor starting methods as per established procedure
- Established DC motor speed control as per standard operating procedures

3.2.3.5 Self-Assessment

2. What is s shunt field regulator in speed control of DC motor

.

3. Name and explain two types of a DC generator.

4. Determine the terminal voltage of a generator which develops an e.m.f. of 200V and has an armature current of 30A on load. Assume the armature resistance is 0.30 , terminal voltage,

4. Name types of a DC motors

5. A 240V shunt motor takes a total current of 30A. If the field winding resistance Rf = 150_ and the armature resistance Ra = 0.4_, determine (a) the current in the armature and (b) the back e.m.f.= 28.4A

3.2.3.6. Tools, Equipment, Supplies and Materials

- Scientific calculators
- Motor
- Generator
- Transformer

3.2.3.7 References

John Bird(2017) Electrical and Electronics Principles Technology fifth Edition o John Bird(2017) Electrical and Electronics Principles Technology sixth Edition

o Watkins, A.J, Kitcher C (2009) Electrical Installation calculations Basic Eighth Elsevier Ltd

o Linsley, T, (2011), Basic Electrical Installation Work Sixth Edition

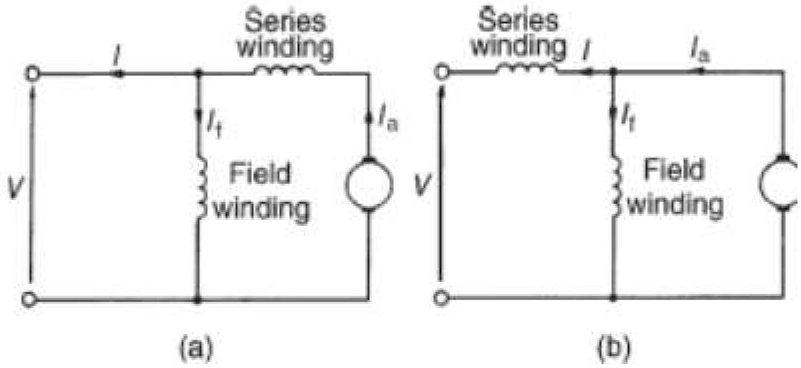
o Kitcher, K,(2008) Practical Guide to Inspection, Testing and Certification of Electrical Installations First Edition Elsevier Ltd

3.2.3.8 Response To Self-Assessment

2. The speed is varied either by varying the value of flux, , or by varying the value of Ra. The former is achieved by using a variable resistor in series with the field winding, such a resistor is called the shunt field regulator

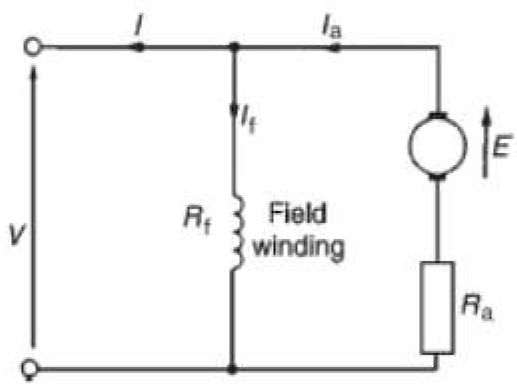
3. **([a) Compound-wound generators**

In the compound-wound generator two methods of connection are used, both having a mixture of shunt and series windings, designed to combine the advantages of each.(a) shows what is termed a long shunt compound generator,(b) shows short-shunt compound generator. The latter is the most generally used form of d.c. generator



. (b) **Shunt-wound generator**

In a shunt-wound generator the field winding is connected in parallel with the armature, The field winding has a relatively high resistance and therefore the current carried is only a fraction of the armature current.



4. Determine the terminal voltage of a generator which develops an e.m.f. of 200V and has an armature current of 30A on load. Assume the armature resistance is 0.30 , terminal voltage,

V = E − Ia Ra

= 200−(30)(0.30)

= 200−9 = 191volts.

4. Types of DC motors

i. Shunt-wound motor

ii. Series-wound motor

iii. Compound-wound motor

5. A 240V shunt motor takes a total current of 30A. If the field winding resistance Rf = 150_ and the armature resistance Ra = 0.4_, determine (a) the current in the armature and (b) the back e.m.f.= 28.4A

(a) Field current $I_f = \frac{V}{R_f} = \frac{240}{150} = 1.6\,A$

Supply current $I = I_a + I_f$

Hence armature current, $I_a = I - I_f = 30 - 1.6$

$= \mathbf{28.4\,A}$

(b) Back e.m.f.

$E = V - I_a R_a = 240 - (28.4)(0.4) = \mathbf{228.64\ volts}$

3.2.4 Learning Outcome 4: Earthing in Electrical Installations

3.2.4.1 Introduction to the learning outcome

To apply earthing in Electrical Installations trainee is required to understand

Meaning of earthing, Terms in earthing, earthing systems, earthing points in electrical installation,

IEE regulations and Factors to consider in selecting an earthing system

3.2.4.2 Performance Standard

- Earthing types are identified as per established standards
- Earthing systems are identified as per established procedures
- Tests to determine the earthing system are performed as per established standards
- Test on an earthing system is performed in line with the IEE regulations

3.2.4.3 Information Sheet

Earthed Systems

Definition of terms

- Static Charge: The electricity generated when two dissimilar substances come into contact. Conveyer belts are active producers of static electricity.

- Switching Surge: A transient wave of voltage in an electric circuit caused by the operation of a switching device interrupting load current or fault current.

- Transient Overvoltage: The temporary overvoltage of short duration associated with the operation of the switching device, a fault, a lightning stroke, or during arcing earth faults on the unearthed system.

- System: An earthed system consists of all interconnected earthing connections in a specific power system and is defined by its isolation from adjacent earthing systems. The isolation is provided by transformers primary and secondary windings that are coupled only by magnetic means. Thus, the system boundary is defined by the lack of a physical connection that is either metallic or through a significantly high impedance. The limits and boundaries of earthing systems

In the earthed systems, at least one conductor or point (usually the middle wire or neutral point of generators or transformers) is intentionally earthed, either solidly or through an impedance. The earthed systems have multiple advantages:

- Greater safety;
- No excessive system over voltages that can occur on unearthed systems during arcing, resonant, or near - resonant earth faults; and
- Easier detection and location of faults when they occur.

Purpose of System Earthing

System earthing or intentional connection of a phase or neutral conductor to earth is for the purpose of controlling the voltage to earth within predictable limits. It also provides for a flow of current that will allow detection of an undesired connection between the system conductors and the earth, and which may initiate the operation of automatic devices to remove the source of voltage from conductors with such undesired connections to earth. The American NEC prescribes certain system earthing connections that must be made to be in compliance with the code. The control of voltage to earth limits the voltage stress on the insulation of conductors so that insulation performance can be predicted more readily. The control of voltage also allows for the reduction of shock hazard to any living body who might come in contact with the live conductors.

Methods of System Neutral Earthing

The earthing of the system can be done by either solid earthing or earthing through an impedance (reactive or resistive or earth - fault neutralizer)

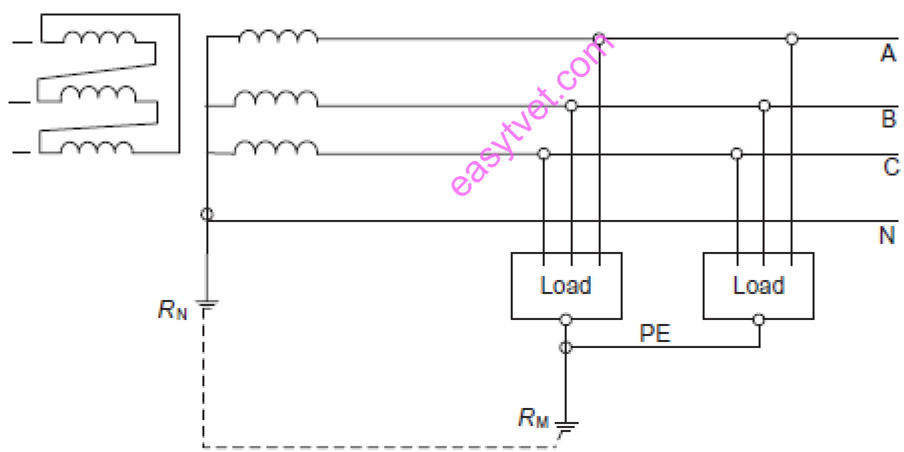
Solid Earthed: The neutral point is connected directly through an adequate earth connection in which no impedance is intentionally inserted. The direct neutral earthing is either distributed or non-distributed.

Reactance Earthed: The neutral point is earthed through impedance, the principle element of which is an inductive reactance.

TT Earthing System

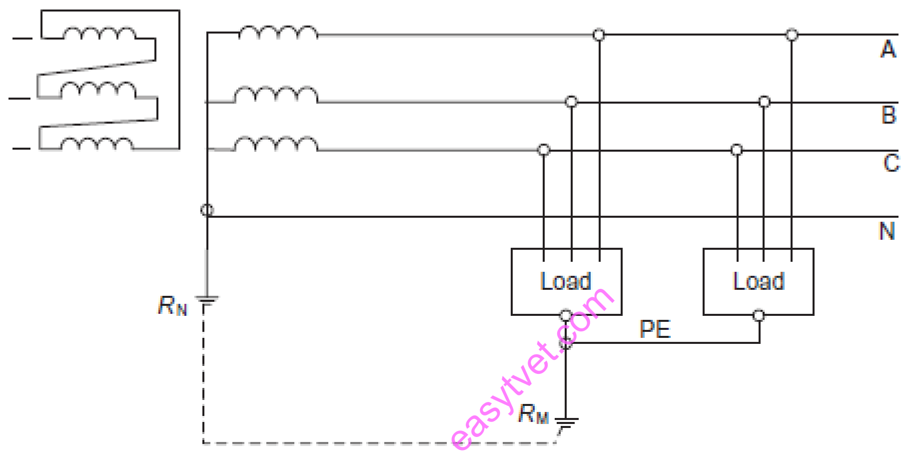
In this system, the neutral is directly earthed as it is denoted by the first letter“ T ” and the exposed conductive parts of the loads are directly earthed via a conductor of PE individually or altogether as it is denoted by the second letter “ T ”

The earth of both neutral conductor and protective conductor may or may not be interconnected or combined. On the other hand, all exposed conductive parts protected by the same protective device should be connected to the same earth.



TN Earthing System

This system has directly earthed neutral, which is denoted by the first letter" T " while the exposed conductive parts of the loads are connected via a PE conductor to the neutral conductor.



3.2.4.4 Learning Activities

- Identified earthing types as per established standards
- Identified earthing systems identified as per established procedures
- Identified tests to determine the earthing system performed as per established standards

- Performed test on an earthing system in line with the IEE regulations

3.2.4.5 Self-Assessment

1. What is a system
2. State three advantages of earthed system
3. Name methods of system neutral earthing
4. What is TN earthed

3.2.4.6 Tools, Equipment, Supplies and Materials

Electrical installation tool kit

Multimeter/AVO meter

Wattmeter

Insulation resistance tester

Clamp meter

3.2.4.7 References

- John Bird (2017) Electrical and Electronics Principles Technology fifth Edition
- John Bird (2017) Electrical and Electronics Principles Technology sixth Edition
- Kitcher, K, (2008) Practical Guide to Inspection, Testing and Certification of Electrical Installations First Edition Elsevier Ltd

3.2.4.8 Response To Self-Assessment

1. System: An earthed system consists of all interconnected earthing connections in a specific power system and is defined by its isolation from adjacent earthing systems. The isolation is provided by transformers primary and secondary windings that are coupled only by magnetic means. Thus, the system boundary is defined by the lack of a physical connection that is either metallic or through a significantly high impedance. The limits and boundaries of earthing systems

2.

Greater safety.

•No excessive system over voltages that can occur on unearthed systems during arcing, resonant, or near - resonant earth faults

•Easier detection and location of faults when they occur.

3.

- Solid Earthed
- Reactance Earthed

4. This system has directly earthed neutral, which is denoted by the first letter “T ” while the exposed conductive parts of the loads are connected via a PE conductor to the neutral conductor.

3.2.5 Learning Outcome 5: Capacitance and Inductance

3.2.5.1 Introduction to the learning outcome

To apply capacitance and inductance one is required to understand; Meaning of electrostatic field, Sources of electrostatic field, Electric field strength and capacitance, Electric flux density, Permittivity, Types capacitors, Magnetic circuits and Magnetic fields.

3.2.5.2 Performance Standard

- Sources of Electrostatic fields are identified as established procedures
- Dielectric materials are identified as per the established standards
- Calculations involving capacitor parameters are performed as per established standards
- Types of capacitors are identified as per established standards
- Concept of charge and electrostatic field is established as per established standards
- Calculations involving capacitors are performed as per established standards
- Concept of magnetic circuits is identified as per established procedure

Parameters

- Calculations involving inductors are performed as per the established procedures

3.2.5.3 Information Sheet

Electrostatic field

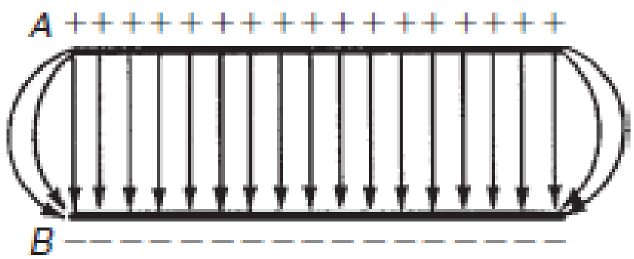
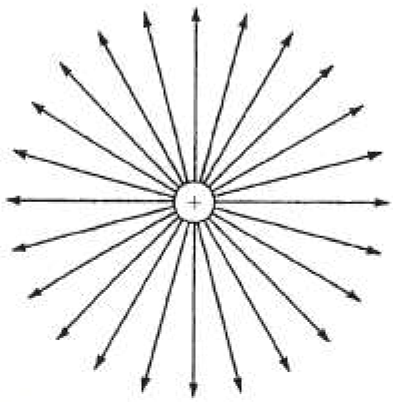
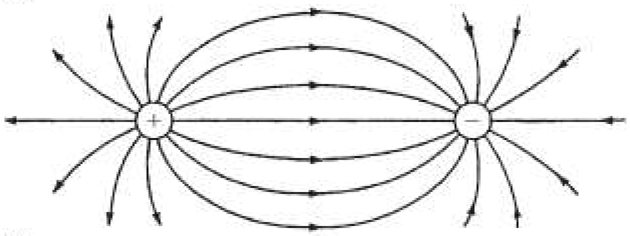


Fig. above represents two parallel metal plates, A and B, charged to different potentials. If an electron that has a negative charge is placed between the plates, a force will act on the electron tending to push it away from the negative plate B towards the positive plate, A. Similarly, a positive charge would be acted on by a force tending to move it towards the negative plate. Any region such as that shown between the plates in Fig. above, in which an electric charge experiences a force, is called an electrostatic field. The direction of the field is defined as that of the force acting on a positive charge placed in the field. the direction of the force is from the positive plate to the negative plate. Such a field may be represented in magnitude and direction by lines of electric force drawn between the charged surfaces. The closeness of the lines is an indication of the field strength. Whenever a p.d. is established between two points, an electric field will always exist.



(a)



(b)

Fig(a) above shows a typical field pattern for an isolated point charge, and Fig(b) shows the field pattern for adjacent charges of opposite polarity. Electric lines of force (often called electric flux lines) are continuous and start and finish on point charges; also, the lines cannot cross each other. When a charged body is placed close to an uncharged body, an induced charge of opposite sign appears on the surface of the uncharged body. This is because lines of force from the charged body terminate on its surface.

The concept of field lines or lines of force is used to illustrate the properties of an electric field. However,

it should be remembered that they are only aids to the imagination.

The force of attraction or repulsion between two electrically charged bodies is proportional to the magnitude of their charges and inversely proportional to the square of the distance separating them, i.e.

force $\propto \boldsymbol{q_1 q_2/d^2}$

Capacitors

Every system of electrical conductors possesses capacitance. For example, there is capacitance between the conductors of overhead transmission lines and also between the wires of a telephone cable. In these examples the capacitance is undesirable but has to be accepted, minimized or compensated for. There are other situations where capacitance is a desirable property.

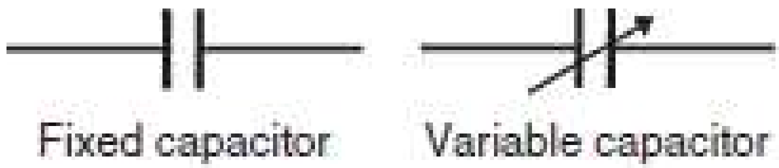
Devices specially constructed to possess capacitance are called capacitors (or condensers, as they used to be called). In its simplest form a capacitor consists of two plates which are separated by an insulating material known as a dielectric. A capacitor has the ability to store a quantity of static electricity.

The symbols for a fixed capacitor and a variable capacitor used in electrical circuit diagrams are shown below

The ***charge Q*** stored in a capacitor is given by:

$\boldsymbol{Q = I \times t}$ ***coulombs***

where I is the current in amperes and t the time in seconds.



(a) $C = 4\mu F = 4 \times 10^{-6} F$ and
$Q = 5 mC = 5 \times 10^{-3} C$

Since $C = \frac{Q}{V}$ then $V = \frac{Q}{C} = \frac{5 \times 10^{-3}}{4 \times 10^{-6}}$

$$= \frac{5 \times 10^{6}}{4 \times 10^{3}} = \frac{5000}{4}$$

Hence p.d. $V = 1250 V$ or $1.25 kV$

(b) $C = 50 pF = 50 \times 10^{-12} F$ and

$V = 2 kV = 2000 V$

$$Q = CV = 50 \times 10^{-12} \times 2000$$

$$= \frac{5 \times 2}{10^{8}} = 0.1 \times 10^{-6}$$

Hence, charge $Q = 0.1 \mu C$

Example

(a) Determine the p.d. across a 4Mf capacitor when charged with 5mC. (b) Find the charge on a 50 pF capacitor when the voltage applied to it is 2kV

Dielectric material

For a parallel plate capacitor, as shown below. experiments show that capacitance C is proportional to

the area A of a plate, inversely proportional to the plate spacing d (i.e., the dielectric thickness) and depends on the nature of the dielectric:

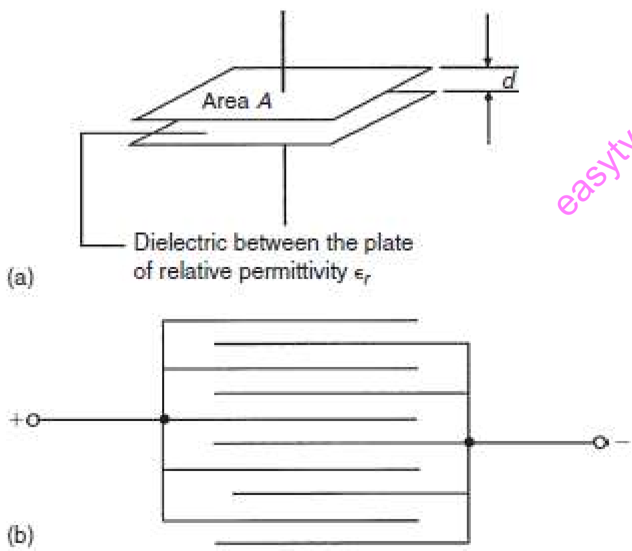
Capacitance, $$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \text{ farads}$$

Where $\varepsilon_0 = 8.85 \times 10^{-12}$F/m (constant)

ε_r = relative permittivity

A = area of one of the plates, in m^2, and

d = thickness of dielectric in m



Another method used to increase the capacitance is to interleave several plates as shown in Fig.(b).

Ten plates are shown, forming nine capacitors with a capacitance nine times that of one pair of plates.

If such an arrangement has n plates then capacitance $C \propto (n-1)$. Thus capacitance

$$C = \frac{\varepsilon_0 \varepsilon_r A(n-1)}{d} \text{ farads}$$

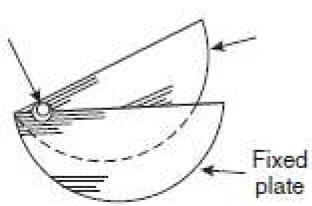
The maximum amount of field strength that a dielectric can withstand is called the dielectric strength of the material. Dielectric strength,

$$E_m = \frac{V_m}{d}$$

Types of Capacitors

1. Variable air capacitors. These usually consist of two sets of metal plates (such as aluminium), one

fixed, the other variable. The set of moving plates rotate on a spindle as shown by the end view of

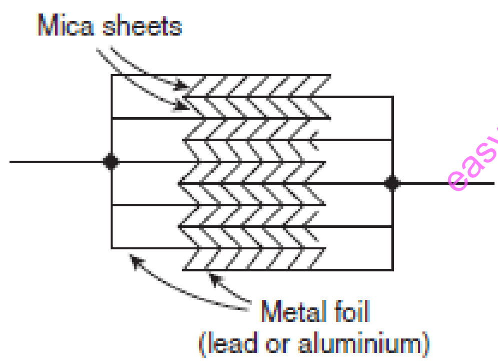


As the moving plates are rotated through half a revolution, the meshing, and therefore the capacitance,

Varies from a minimum to a maximum value. Variable air capacitors are used in radio and electronic circuits where very low losses are required, or where a variable capacitance is needed. The maximum

Value of such capacitors is between 500Pf and 1000pF.

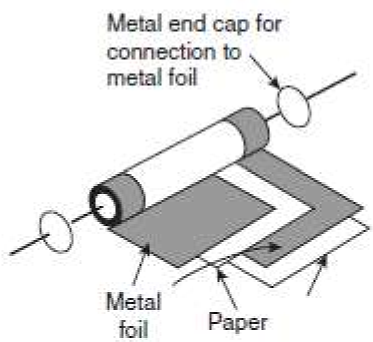
2. Mica capacitors. A typical older type construction is shown below



Usually, the whole capacitor is impregnated with wax and placed in a Bakelite case. Mica is easily

obtained in thin sheets and is a good insulator. However, mica is expensive and is not used in capacitors above about 0.2μF. A modified form of mica capacitor is the silvered mica type. The mica is coated on both sides with a thin layer of silver which forms the plates. Capacitance is stable and less likely to change with age. Such capacitors have a constant capacitance with change of temperature, a high working voltage rating and along service life and are used in high frequency circuits with fixed values of capacitance up to about 1000pF.

3. Paper capacitors. A typical paper capacitor is shown in Fig. below where the length of the roll Corresponds to the capacitance required.



The whole is usually impregnated with oil or wax to exclude moisture, and then placed in a plastic or aluminium container for protection. Paper capacitors are made in various working voltages up to about 150kV and are used where loss is not very important. The maximum value of this type of capacitor is between 500pF and 10μF.Disadvantages of paper capacitors include variation in capacitance with temperature change and a shorter service life than most other types of capacitor

5. Plastic capacitors. Some plastic materials such as polystyrene and Teflon can be used as dielectrics.

Construction is similar to the paper capacitor, but using a plastic film instead of paper. Plastic capacitors operate well under conditions of high temperature, provide a precise value of capacitance,

a very long service life and high reliability

6. Titanium oxide capacitors have a very high capacitance with a small physical size when used at a low temperature.

7. Electrolytic capacitors. Construction is similar to the paper capacitor, with aluminium foil used for the

Plates and with a thick absorbent material, such as paper, impregnated with an electrolyte (ammonium

borate) separating the plates. The finished capacitor is usually assembled in an aluminium container

and hermetically sealed. Its operation depends on the formation of a thin aluminium oxide layer on the

positive plate by electrolytic action when a suitable direct potential is maintained between the plates.

This oxide layer is very thin and forms the dielectric. (The absorbent paper between the plates is a

conductor and does not act as a dielectric.) Such capacitors must always be used on d.c. and must

be connected with the correct polarity; if this is not done the capacitor will be destroyed since the oxide layer will be destroyed. Electrolytic capacitors are manufactured with working voltage from 6V to 600V, although accuracy is generally not very high. These capacitors possess a much larger capacitance than other types of capacitors of similar dimensions due to the oxide film being only a few microns thick.

The fact that they can be used only on d.c. supplies limit their usefulness.

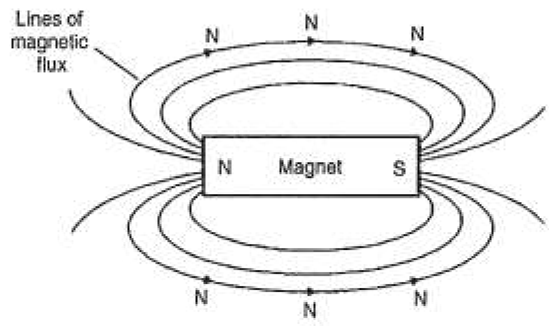
MAGNETIC CIRCUIT

Magnetic field

A permanent magnet is a piece of ferromagnetic material (such as iron, nickel or cobalt) which has properties of attracting other pieces of these materials. A permanent magnet will position itself in a north and south direction when freely suspended. The north-seeking end of the magnet is called the North Pole, N, and the south-seeking end the South Pole, the area around a magnet is called the magnetic field and it is in this area that the effects of the magnetic force produced by the magnet can be detected.

A magnetic field cannot be seen, felt, smelt or heard and therefore is difficult to represent. Michael Faraday suggested that the magnetic field could be represented pictorially, by imagining the field to consist of lines of magnetic flux, which enables investigation of the distribution and density of the field to be carried out.

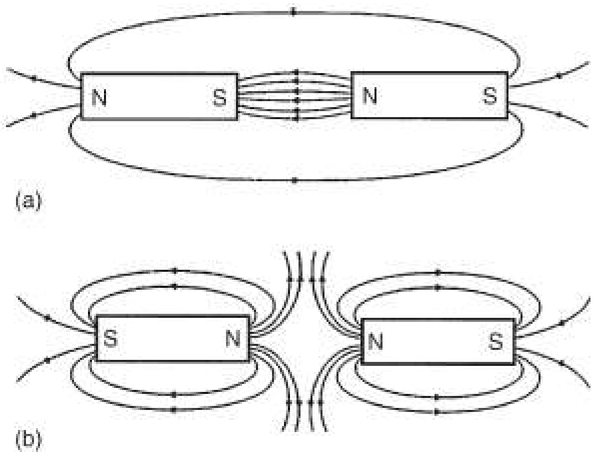
The distribution of a magnetic field can be investigated by using some iron filings. A bar magnet is placed on a flat surface covered by, say, cardboard, upon which is sprinkled some iron filings. If the cardboard is gently tapped the filings will assume a pattern similar to that shown below. If a number of magnets of different strength are used, it is found that the stronger the field the



Closer are the lines of magnetic flux and vice versa. Thus, a magnetic field has the property of exerting a force, demonstrated in this case by causing the iron filings to move into the pattern shown. The strength of the magnetic field decreases as we move away from the magnet. It should be realized, of course, that the magnetic field is three-dimensional in its effect, and not acting in one plane as appears to be the case in this experiment. If a compass is placed in the magnetic field in various positions, the direction of the lines of flux may be determined by noting the direction of the compass pointer.

The direction of a magnetic field at any point is taken as that in which the north-seeking pole of a compass needle points when suspended in the field. The direction of a line of flux is from the north pole to the south pole on the outside of the magnet and is then assumed to continue through the magnet back to the point at which it emerged at the north pole. Thus, such lines of flux always form complete closed loops or paths, they never intersect and always have a definite direction.

The laws of magnetic attraction and repulsion can be demonstrated by using two bar magnets. In fig. below with unlike poles adjacent, attraction takes place



Lines of flux are imagined to contract and the magnets try to pull together. The magnetic field is strongest in between the two magnets, shown by the lines of flux being close together. In Fig (b), with similar poles adjacent (i.e. two north poles), repulsion occurs, i.e. the two north poles try to push each other apart, since magnetic flux lines running side by side in the same direction repel.

7.3 Magnetic

Magnetic Flux and flux density

Magnetic flux is the amount of magnetic field (or the number of lines of force) produced by magnetic source. The symbol for magnetic flux is Φ

The unit of magnetic flux is the weber∗, Wb.

Magnetic flux density is the amount of flux passing through a defined area that is perpendicular to the direction of the flux:

Magnetic flux density = magnetic flux

area

The symbol for magnetic flux density is B. The unit of magnetic flux density is the tesla∗, where

1 T = 1Wb/m2. Hence $B = \Phi/A$ tesla where A(m2) is the area

Magnetomotive Force and Magnetic Field Strength

Magnetomotive force (m.m.f.) is the cause of the existence of a magnetic flux in a magnetic circuit, m.m.f. $F_m = NI$ amperes where N is the number of conductors (or turns) and I is the current in amperes. The unit of m.m.f is sometimes expressed as 'ampere-turns'. However, since 'turns 'have no dimensions, the SI unit of m.m.f. is the ampere.

Magnetic field strength (or magnetizing force),

$H = NI/l$ ampere per metre where l is the mean length of the flux path in metres.

Thus m.m.f. = NI = Hl amperes

Inductors

A component called an inductor is used when the property of inductance is required in a circuit. The basic form of an inductor is simply a coil of wire. Factors which affect the inductance of an inductor include:

(i) The number of turns of wire – the more turns the higher the inductance

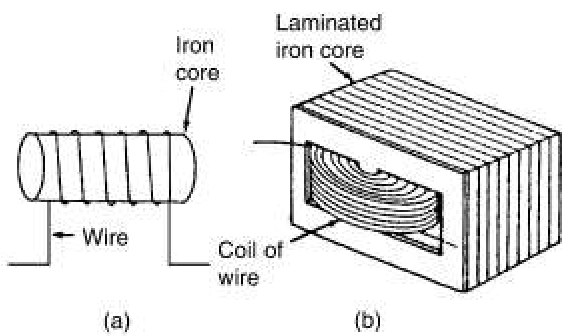
(ii) The cross-sectional area of the coil of wire – the greater the cross-sectional area the higher the inductance

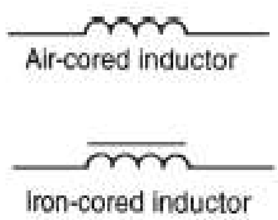
(iii) The presence of a magnetic core – when the coil is wound on an iron core the same current sets up a more concentrated magnetic field and the inductance is increased

(iv) The way the turns are arranged – a short, thick coil of wire has a higher inductance than a long, thin one.

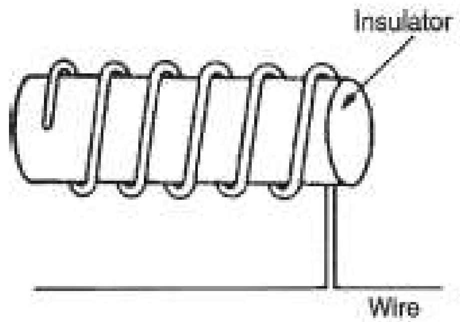
Two examples of practical inductors are shown below and the standard electrical circuit diagram

Symbols for air-cored and iron-cored inductors.





An iron-cored inductor is often called a choke since, when used in a.c. circuits, it has a choking effect, limiting the current flowing through it.Inductance is often undesirable in a circuit. To reduce inductance to a minimum the wire may be bent back on itself, as shown below, so that the magnetizing effect of one conductor is neutralized by that of the adjacent conductor. The wire may be coiled around an insulator, as shown, without increasing the inductance. Standard resistors may be non-inductively wound in this manner.



Example

A flux of 25mWb links with a1500 turn coil when a current of 3A passes through the coil. Calculate

(a) The inductance of the coil,

(b) The energy stored in the magnetic field and

(c) The average e.m.f. induced if the current falls to zero in 150ms.

(a) **Inductance,**

$$L = \frac{N\Phi}{I} = \frac{(1500)(25 \times 10^{-3})}{3} = \mathbf{12.5\,H}$$

(b) **Energy stored,**

$$W = \frac{1}{2}LI^2 = \frac{1}{2}(12.5)(3)^2 = \mathbf{56.25\,J}$$

(c) **Induced e.m.f.,**

$$E = -L\frac{dI}{dt} = -(12.5)\left(\frac{3-0}{150 \times 10^{-3}}\right)$$
$$= \mathbf{-250\,V}$$

(Alternatively,

$$E = -N\frac{d\Phi}{dt}$$
$$= -(1500)\left(\frac{25 \times 10^{-3}}{150 \times 10^{-3}}\right)$$
$$= \mathbf{-250\,V}$$

since if the current falls to zero so does the flux.)

3.2.5.4 Learning Activities

1. Identified sources of Electrostatic fields as established procedures
2. identified dielectric materials as per the established standards
3. performed calculations involving capacitor parameters as per established standards
4. identified types of capacitors as per established standards
5. established concept of charge and electrostatic field as per established standards
6. performed Calculations involving capacitors as per established standards
7. identified concept of magnetic circuits as per established procedure

Parameters

- performed calculations involving inductors as per established procedures.

1.2.5.5 Self-Assessment

1. what is a capacitor
2. Draw the symbols of fixed and variable capacitors
3. Differentiate between magnetic flux and magnetic flux density
4. What are the factors affecting inductance of an inductor?
5. Name five types of a capacitor

1.2.5.6 Tools, Equipment, Supplies and Materials

- Scientific calculator
- Capacitor
- Dielectric materials
- Inductor
- magnets

1.2.5.7 References

John Bird(2017) Electrical and Electronics Principles Technology fifth Edition

John Bird(2017) Electrical and Electronics Principles Technology sixth Edition

Watkins, A.J, Kitcher C (2009) Electrical Installation calculations Basic Eighth Elsevier Ltd

3.2.5.8 Response To Self-Assessment

1. Devices specially constructed to possess capacitance are called capacitors (or condensers, as they used to be called). In its simplest form a capacitor consists of two plates which are separated by an insulating material known as a dielectric. A capacitor has the ability to store a quantity of static electricity.

2.

3. Magnetic flux is the amount of magnetic field (or the number of lines of force) produced by magnetic source. The symbol for magnetic flux is Φ

The unit of magnetic flux is the weber∗, Wb.

Magnetic flux density is the amount of flux passing through a defined area that is perpendicular to the direction of the flux:

Magnetic flux density = magnetic flux

Area

The symbol for magnetic flux density is B. The unit of magnetic flux density is the tesla∗, T, where

1 T = 1Wb/m2. Hence

B = Φ/A tesla where A (m2) is the area

4.

(i) The number of turns of wire – the more turns the higher the inductance
(ii) The cross-sectional area of the coil of wire – the greater the cross-sectional area the higher the inductance

(iii) The presence of a magnetic core – when the coil is wound on an iron core the same current sets up a more concentrated magnetic field and the inductance is increased

(iv) The way the turns are arranged – a short, thick coil of wire has a higher inductance than a long, thin one.

5. Types of capacitors

- Variable air capacitor
- Mica capacitor
- Paper capacitor
- Plastic capacitor
- Ceramic capacitor

CHAPTER 4: TECHNICAL DRAWING

Unit of learning code: ENG/CU/EI/CC/04/4/A.

Related Unit of Competency in Occupational Standard: Prepare and interpret Technical Drawings.

4.1 Introduction to the unit of learning

This unit covers the competencies required to prepare and interpret technical drawings. It involves competencies to select, use and maintain drawing equipment and materials. It also involves producing plain geometry drawings, solid geometry drawings, orthographic drawings of components and Electrical drawings.

4.2 Summary of Learning Outcomes

1. Use and maintenance of drawing equipment and materials
2. Produce plane geometry drawings
3. Produce solid geometry drawings.
4. Produce and orthographic drawings
5. Produce Electrical drawings

4.2.1 Learning Outcome 1: Use and Maintenance of Drawing Equipment and Materials

4.2.1.1 Introduction to the learning outcome

To use and maintain drawing equipment and materials one is required to identify and care the equipment and materials as per the manufacturer's instructions and work place procedures and also use personal protective Equipment (PPEs)

4.2.1.2 Performance Standard.

1. Drawing equipment are identified and gathered according to task requirements
2. Drawing equipment are identified and gathered according to task requirements
3. Drawing equipment are used and maintained as per manufactures instructions
4. Drawing materials are used as per workplace procedures
5. Waste materials are disposed in accordance with workplace procedures and environmental legislations
6. Personal Protective Equipment is used according to occupational safety and health regulations

4.2.1.3 Information Sheet

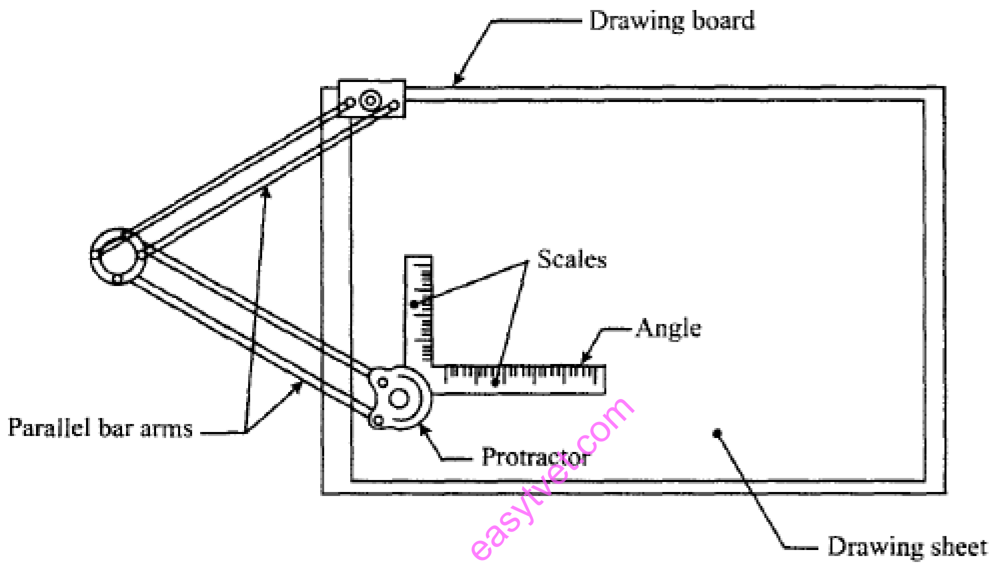
Drawing instruments

Drawing board

Until recently drawing boards used are made of well-seasoned softwood of about 25 mm thick with a working edge for T-square. Nowadays mini-draughters are used instead of T-squares which can be fixed on any board. The standard size of board depends on the size of drawing sheet size required.

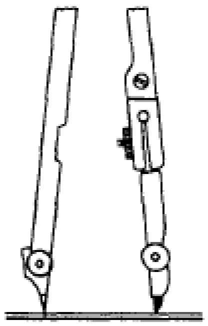
Mini-Draughter

Mini-draughter consists of an angle formed by two arms with scales marked and rigidly hinged to each other. It combines the functions of T-square, set-squares, scales and protractor. It is used for drawing horizontal, vertical and inclined lines, parallel and perpendicular lines and for measuring lines and angles

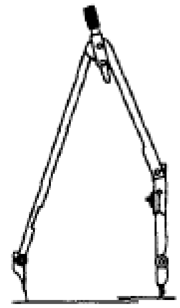


Instrument box

1. Compasses, Dividers and Inking pens. What is important is the position of the pencil lead with respect to the tip of the compass. It should be at least I mm above as shown below because the tip goes into the board for grip by 1 mm.



Sharpening and position of compass lead



Position of the lead leg to draw larger circles

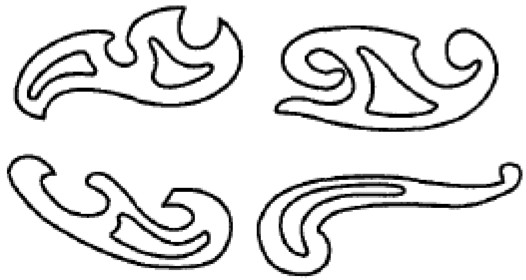
Set of Scales

Scales are used to make drawing of the objects to proportionate size desired. These are made of Wood, steel or plastic. BIS recommends eight set-scales in plastic/cardboard with designations.

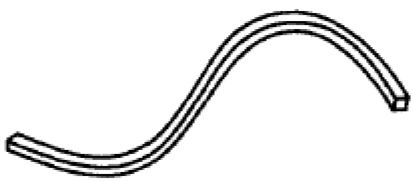
French Cures

French curves are available in different shapes shown below. First a series of points are plotted along

the desired path and then the most suitable curve is made along the edge of the curve. A flexible curve consists of a lead bar inside rubber which bends conveniently to draw a smooth curve through any set of points.



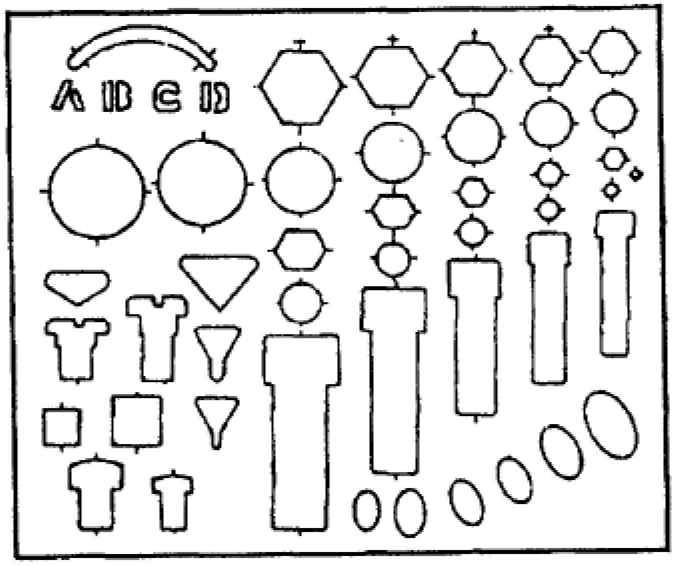
(a) French curves



(b) Flexible curve

Templates

These are aids used for drawing small features such as circles, arcs, triangular, square and other shapes and symbols used in various science and engineering fields.



Pencils

Pencils with leads of different degrees of hardness or grades are available in the market. The hardness or softness of the lead is indicated by 3H, 2H, H, HB, B, 2B, 3B, etc. The grade HB denotes medium hardness ofl ead used for general purpose. The hardness increases as the value of the numeral before the letter H increases. The lead becomes softer, as the value of the numeral before B increases.

HB- Soft grade for Border lines, lettering and free sketching

H- Medium grade for Visible outlines, visible edges and boundary lines

2H - Hard grade for construction lines, dimension lines, leader lines, extension lines, Centre lines, hatching lines and hidden lines.

Proper care and maintenance.

It is essential to take proper care of the drafting tools, materials, and equipment. Below are some tips to properly use and take care of them.

a) Avoid dropping your tools and equipment.
b) Never use measuring tools in cutting paper
c) Wipe off the surface and edges of triangles and T-squares.
d) Sharpen and store your pencils properly after use
e) Find or create and organizer where you can hang your measuring tools.
f) Have a separate container for making tools.
g) Keep your drawing sheets in a plastic tube to protect them from a dust and dirt.
h) Never lend or borrow drafting tools and materials if may.

4.2.1.4 Learning Activities

1. Identified and gathered drawing equipment according to task requirements.
2. Identified and gathered drawing materials according to task requirements
3. Used and maintained drawing equipment as per manufacturer's instructions
4. Used drawing materials as per Workplace procedures
5. Disposed waste materials in accordance with workplace procedures and environment legislations.
6. Used personal protective equipment according to occupational safety and health regulation

4.2.1.5 Self-Assessment

1.3 Name and give uses of Five drawing instruments.

1.4 What are the proper care and maintenance of drawing instruments.

4.2.1.6 Tools, Equipment, Supplies and Materials

a. Drawing room

b. Drawing instruments e.g., T-squares, set squares, drawing sets
c. Drawing tables
d. Pencils, papers, erasers
e. Masking tapes

4.2.1.7 References

K.Venkata Reddy Engineering Drawing 2nd Edition

S.K Bhattacharya Electrical Engineering Drawing 2nd Edition

Kenneth Morling Geometric and Engineering Drawing 3rd Edition.

4.2.1.8 Response for Self-assessment

1

i. Divider-used to equally divide a line or space by trials and error.
ii. Protractor-It is a semi-circular tool used to measure or layout angle/arc.
iii. Compass- draws large arcs and circles in pencil or pen point.
iv. T-square-guides in drawing parallel horizontal lines
v. French curve-it is used as a guide in drawing irregular curved lines.

2

a. Avoid dropping your tools and equipment
b. Never use measuring tools in cutting paper
c. Wipe off the surface and edges of triangles and T-squares.
d. Sharpen and store your pencils properly after use
e. Find or create and organizer where you can hang your measuring tools.

4.2.2 Learning Outcome 2: Produce Plane Geometry Drawings

4.2.2.1 Introduction to the learning outcome

To produce plane geometry drawing one is required to understand; types of lines in drawings, Construction of geometric forms, Construction of different angles, Measurement of different angles and Bisection of different angles and lines

4.2.2.2 Performance Standard

1. Different types of lines used in drawing and their meanings are identified according to standard drawing conventions Different types of geometric forms are constructed according to standard conventions
2. Different types of angles are constructed according to principles of geometry
3. Different types of angles are measured using appropriate measuring tools
4. Angles are bisected according to standard conventions
5. Freehand sketching of different types of geometric forms, tools, equipment, diagrams is conducted

4.2.2.3 Information Sheet

Plane geometry is the geometry of figures that are two-dimensional, i.e., figures that have only length and breadth. There are an endless number of plane figures but we will concern ourselves only with the more common ones – the triangle, the quadrilateral and the better-known Polygons

Definition of terms

Geometry –the shape of the object, represented as views from various angles.

Dimensions-the size of part, expressed in accepted unit

Material-represents what the component is made from.

Finish- specifies the surface quality.

Types of lines.

- Continuous thick line

This line is used to display the outline and edges of the main drawing, does with a pencil soften than HB.

- Continuous thin line

This line is basically used for dimension, extension, projection and leader line. A harder pencil should be used, such as a 2H pencil.

- Continuous thin line free hand line

This line is used to show short break or irregular boundaries.

- Continuous thin zigzag line

This line is used to show long break.

- Dashed line

This line is used to shown hidden edges of the main object

- Chain thin line long dotted

This line is used to represent the centre line for circles and arcs

- Chain thin with thick ends

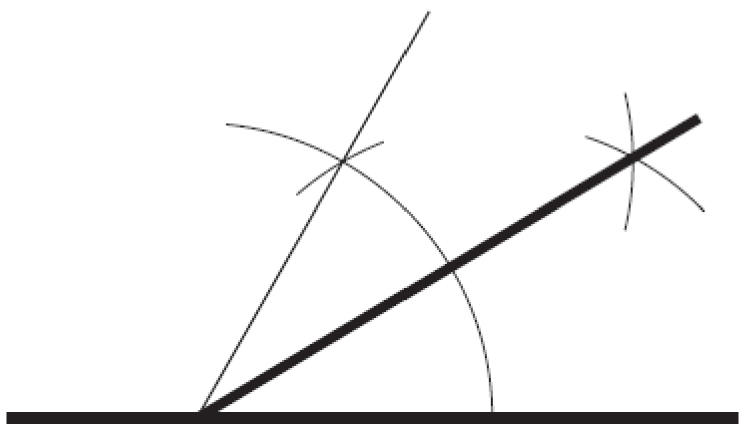
This line is used to represent the location of a cutting plane

- Long thin dashed and double short dashed lines

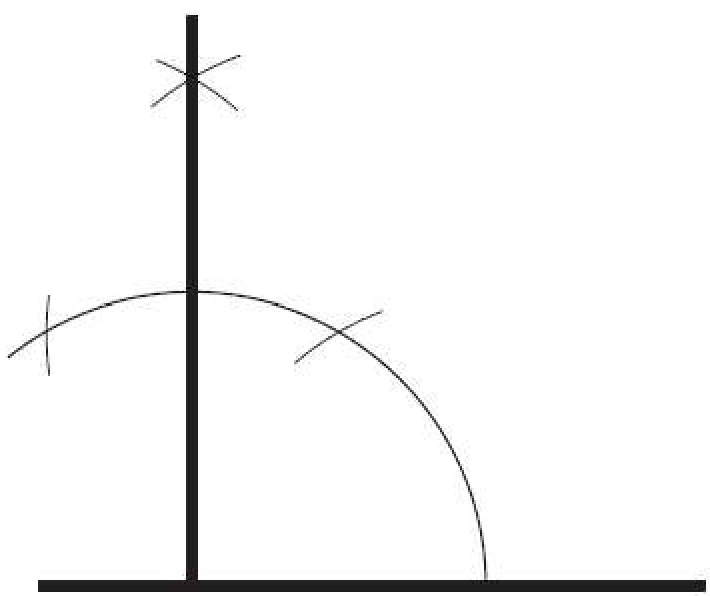
This line is located in front of cutting planes, outlines of adjacent parts, censorial lines, and to state centre of gravity.

Types of Angles

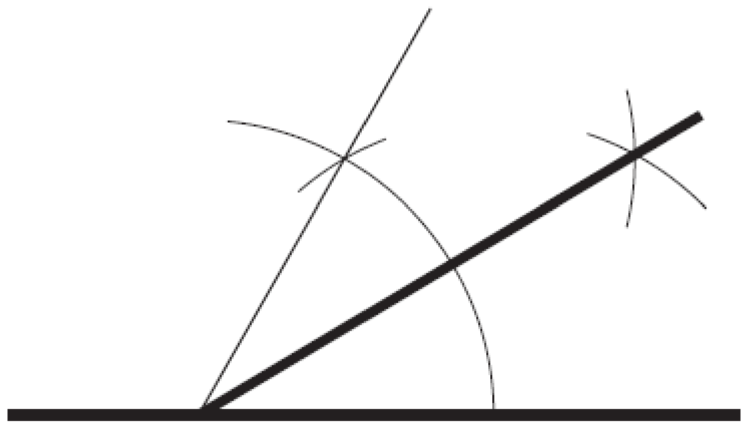
To construct 600



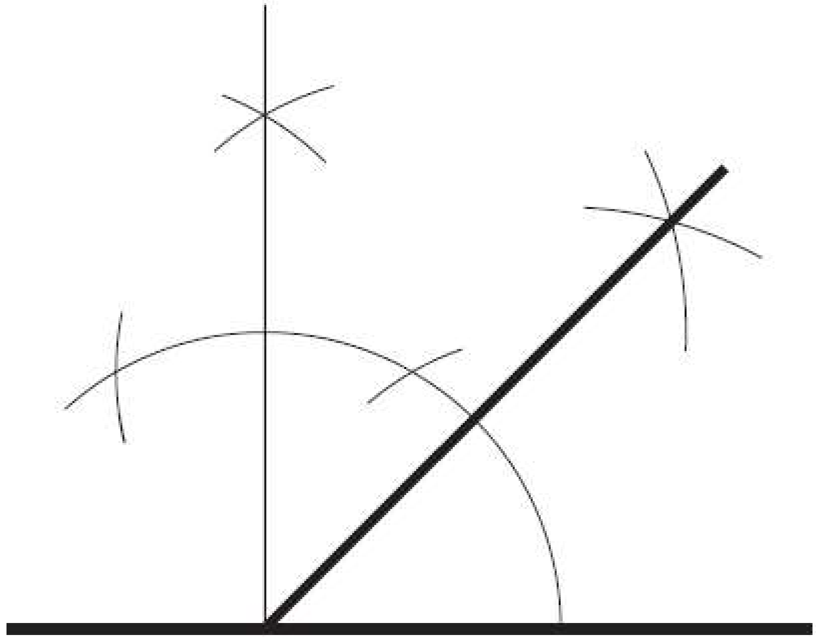
To construct 90^0



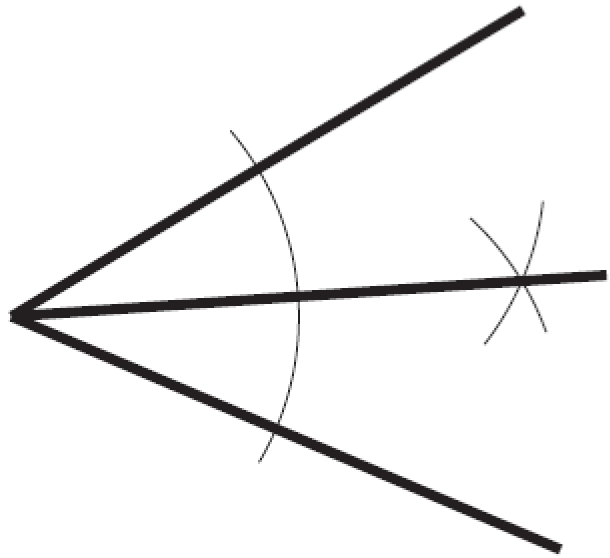
To construct 30^0



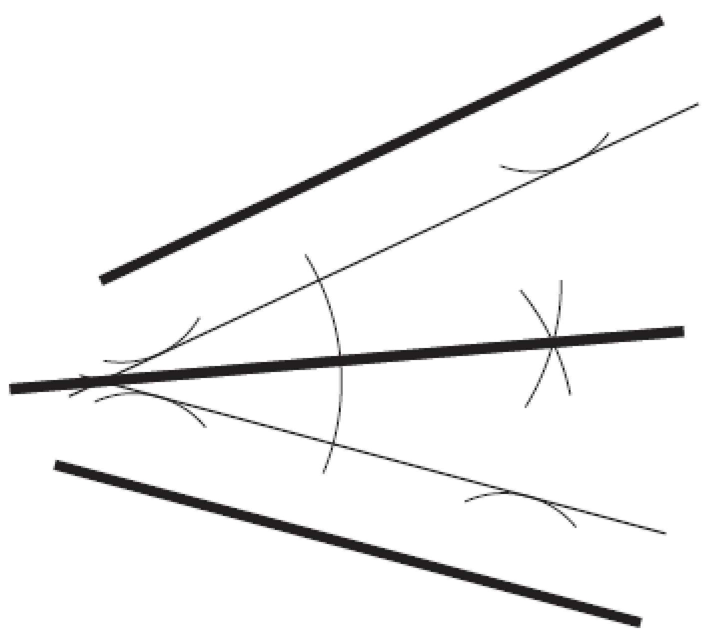
To construct 45^0



To bisect an angle



To bisect an angle formed by two converging lines



4.2.2.4 Learning Activities

1. Identified different types of lines used in drawing and their meanings according to standard drawing conventions Constructed different types of geometric forms according to standard conventions
2. Constructed different types of angles according to principles of geometry
3. Measured different types of angles using appropriate measuring tools
4. Bisected angles according to standard conventions

4.2.2.5 Self-Assessment

1. Name any five types of lines
2. Bisect 300 angle
3. Construct a parallel line

4.2.2.6 Tools, Equipment, Supplies and Materials

- Drawing room
- Drawing instruments e.g., T-squares, set squares, drawing sets
- Drawing tables
- Pencils, papers, erasers
- Masking tapes

4.2.2.7 References

K.Venkata Reddy Engineering Drawing 2nd Edition

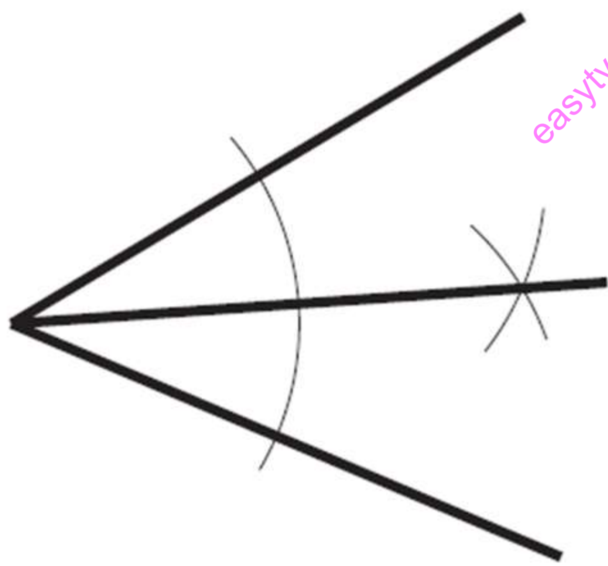
S.K Bhattacharya Electrical Engineering Drawing 2nd Edition

4.2.2.8 Response to Self-Assessment

1. Types of lines

- Continuous thick line
- Continuous thin line
- Dashed line
- Chain thin line long dotted
- Chain thin with thick ends

2.



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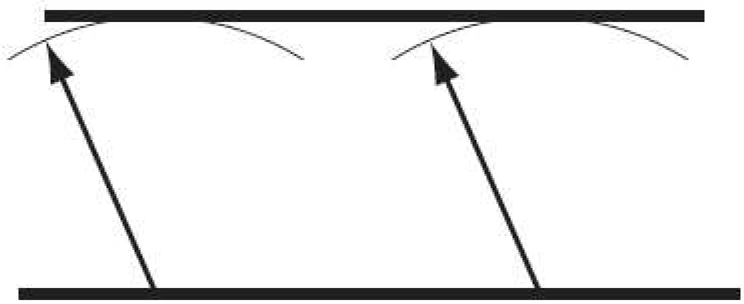


4.2.3 Learning Outcome 3: Produce Solid Geometry Drawings

4.2.3.1 Introduction to the learning outcome

To produce solid geometry drawings, one is required to understand; Interpretation of sketches and drawings of patterns, Sectioning of solids and Development and interpenetrations of solids.

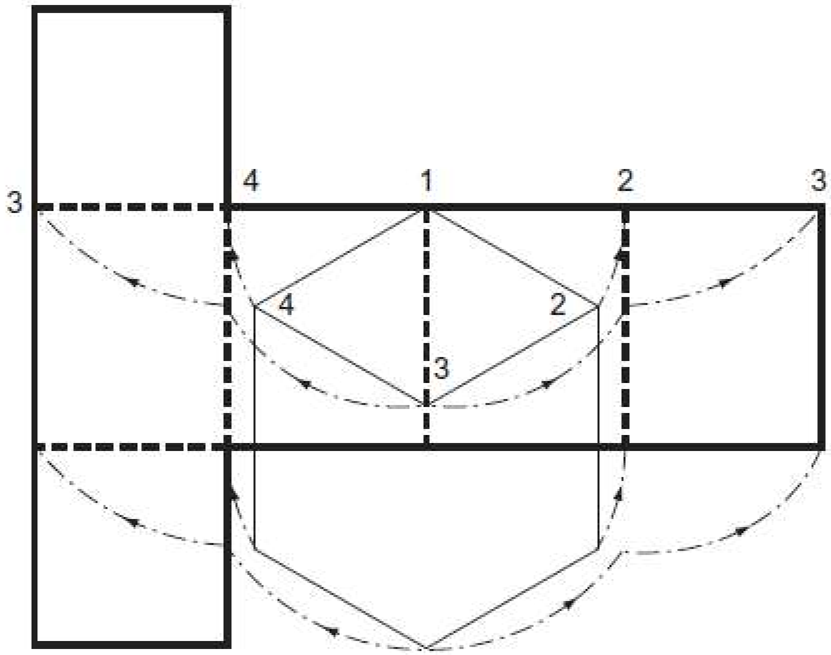
4.2.3.2 Performance Standard

1. Drawings of patterns are interpreted according to standard conventions
2. Patterns are developed in accordance with standard conventions
3. Patterns are assembled as per standard conventions
4. Pattern assembly is interpreted as per standard conventions.

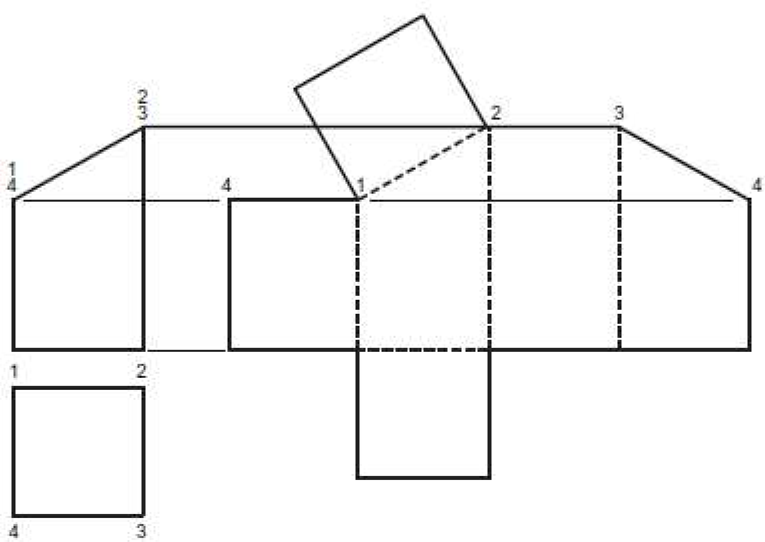
4.2.3.3 Information Sheet

Prism

The prism below shows how a square prism is unfolded and its development obtained. Note that where there are corners in the undeveloped solid, these are shown as dotted lines in the development.



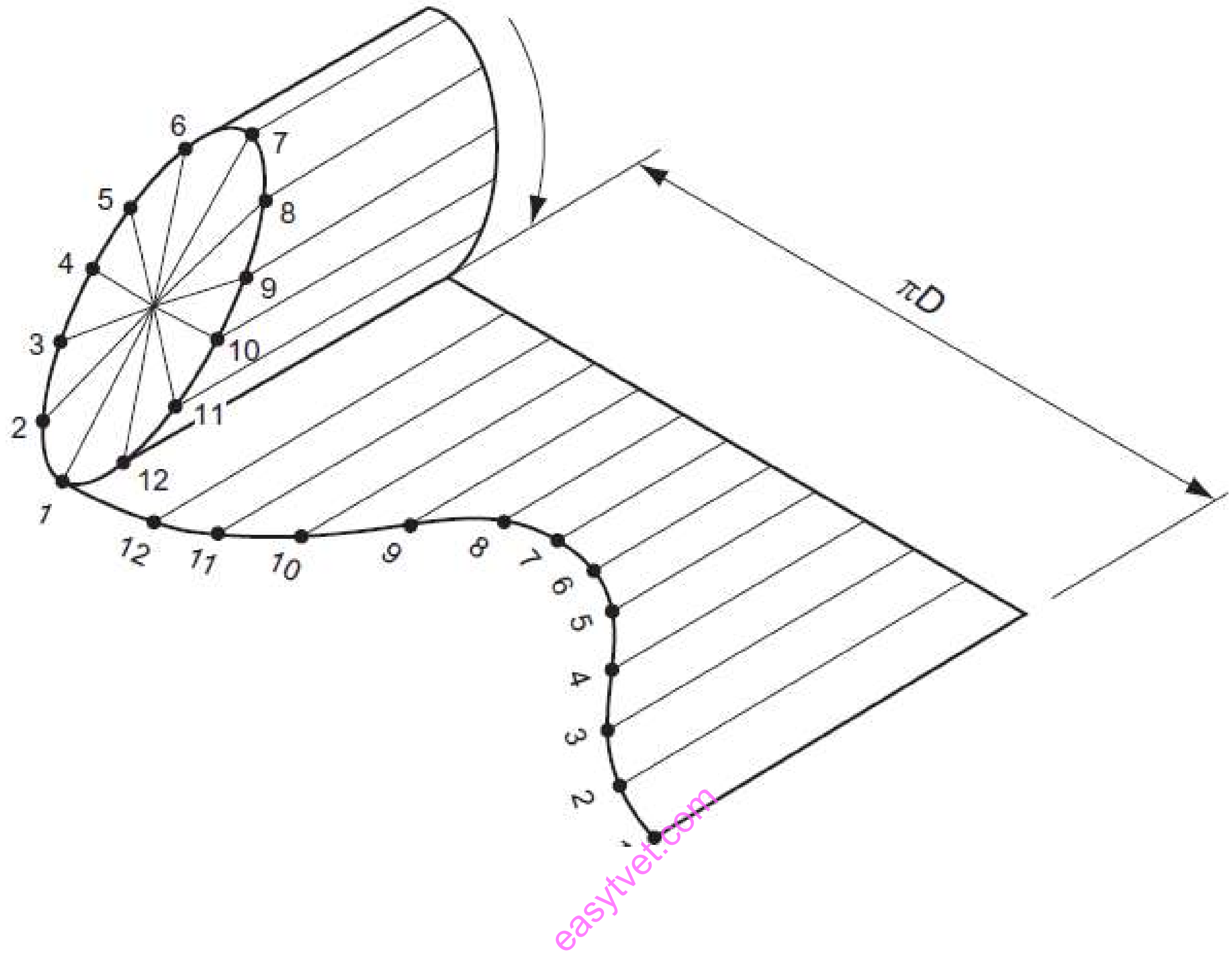
To develop a square prism with an oblique top.



Cylinders

If you painted the curved surface of a cylinder and, while the paint was wet, placed the cylinder on a flat surface and then rolled it once, the pattern that the paint left on the flat surface would be the development of the curved surface of the cylinder.

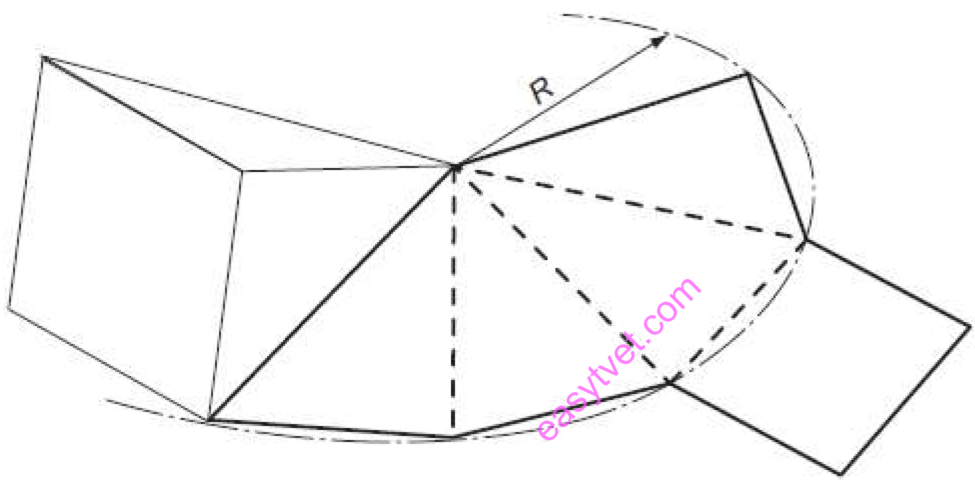
Figure below shows the shape that would evolve if the cylinder was cut obliquely at one end. The length of the development would be πD , the circumference. The oblique face has been divided into 12 equal parts and numbered. You can see where each number will touch the flat surface as the cylinder is rolled.



Pictorial view of the development of a cylinder.

Pyramids

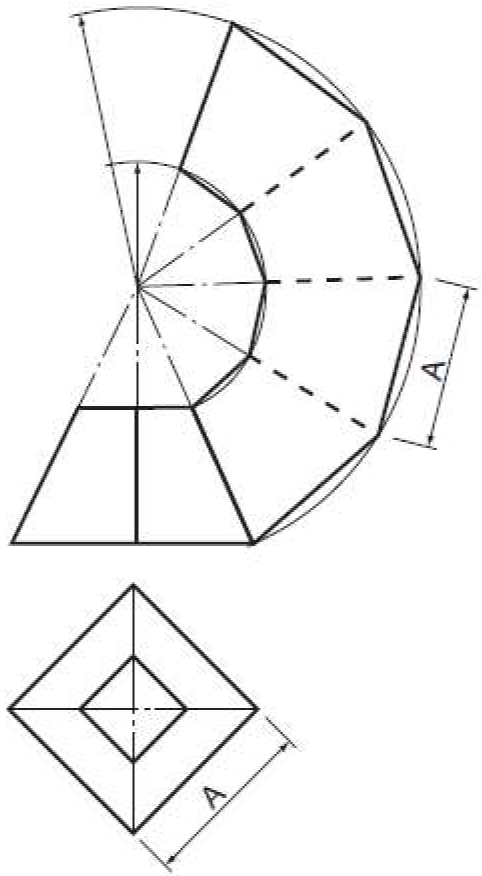
Figure below shows how the development of a pyramid is found. If a pyramid is tipped over so that it lies on one of its sides and is then rolled so that each of its sides touches in turn, the development is traced out. The development is formed within a circle whose radius is equal to the true length of one of the corners of the pyramid



R = True length of a corner of the pyramid

To develop the sides of the frustum of a square pyramid

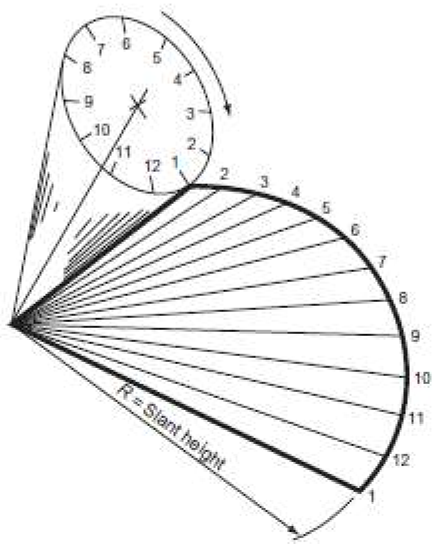
The true length of a corner of the pyramid can be seen in the FE. An arc is drawn, radius equal to this true length, centre the apex of the pyramid. A second arc is drawn, radius equal to the distance from the apex of the cone to the beginning of the frustum, centre the apex of the cone. The width of one side of the pyramid, measured at the base, is measured on the plan and this is stepped round the larger arc four times



Cones

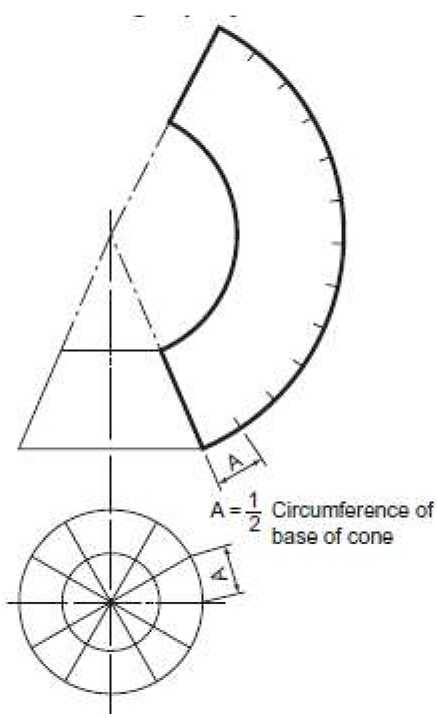
Figure below shows how if a cone is tipped over and then rolled it will trace out its development. The development forms a sector of a circle whose radius is equal to the slant height of the cone. The length of the arc of the sector is equal to the circumference of the base of the cone. If the base of the cone is divided into 12 equal sectors that are numbered from 1 to 12,

the points where the numbers touch the flat surface as the cone is rolled can be seen.



To develop the frustum of a cone.

The plan and elevation of the cone are shown below. The plan is divided into 12 equal sectors. The arc shown as dimension A is 1/12 of the circumference of the base of the cone.



4.2.3.4 Learning Activities

- Interpreted drawings of patterns according to standard conventions
- Developed patterns in accordance with standard conventions
- Assembled patterns as per standard conventions
- Interpreted pattern assembly as per standard conventions.

4.2.3.5 Self-Assessment

1. Develop the frustum of a cone that has been cut oblique
2. Develop the sides of a hexagonal frustum if the top has been cut obliquely

4.2.3.6 Tools, Equipment, Supplies and Materials

- Drawing room
- Drawing instruments e.g., T-squares, set squares, drawing sets
- Drawing tables
- Pencils, papers, erasers
- Masking tapes

4.2.3.7 References

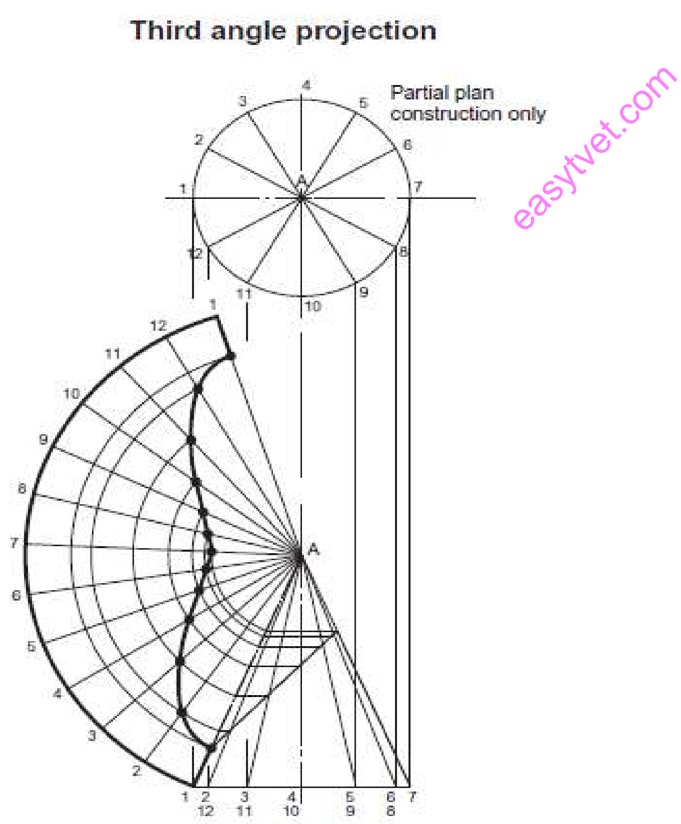
K.Venkata Reddy Engineering Drawing 2nd Edition

S.K Bhattacharya Electrical Engineering Drawing 2nd Edition

Kenneth Morling Geometric and Engineering Drawing 3rd Edition

4.2.3.8 Response to self-assessment

1.



4.2.4 Learning Outcome 4: Produce Orthographic Drawings

4.2.5.1 Introduction to the learning outcome

To produce orthographic drawings, one is required to understand; Meaning of pictorial and orthographic drawings, meaning of symbols and abbreviations, Drawing and interpretation of orthographic elevations, Dimensioning of orthographic elevations, Sectioning of views and Assembly drawing.

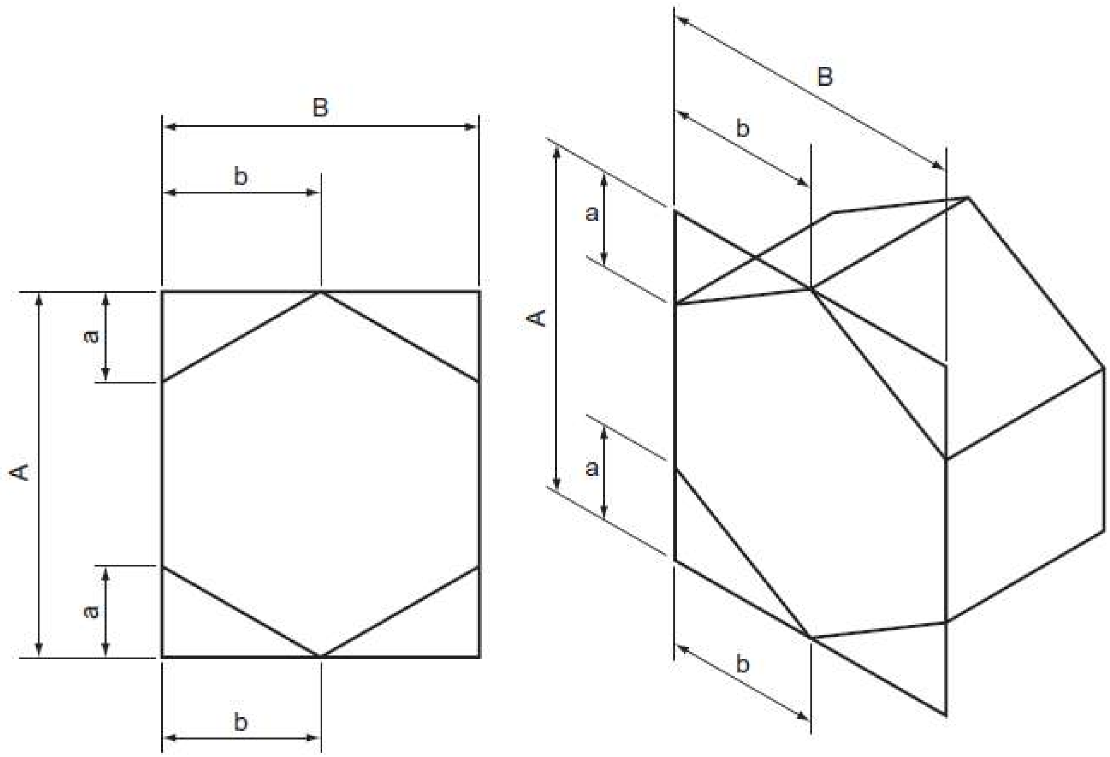
4.2.5.2 Performance Standard

1. Symbols and abbreviations are identified and their meaning interpreted according to standard drawing conventions
2. First and third angle orthographic drawings are produced and interpreted in accordance with the standard conventions
3. Orthographic elevations are dimensioned in accordance with standard conventions
4. Isometric drawings are produced and interpreted in accordance with standard conventions
5. Assembly drawing is produced and interpreted in line with the operating standards

4.2.5.3 Information Sheet

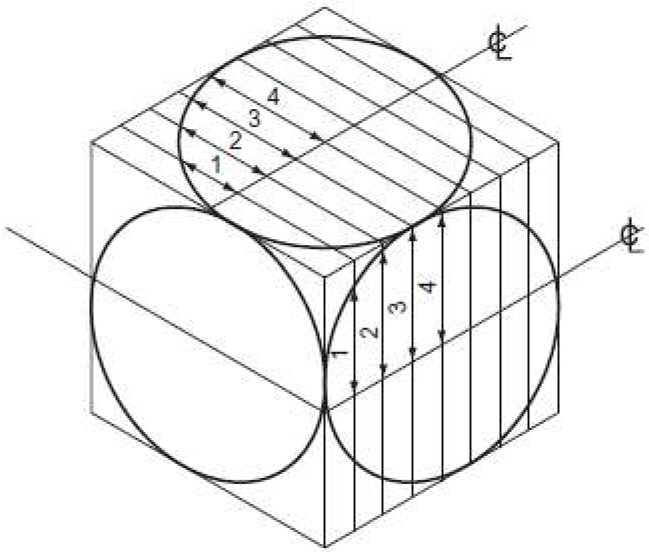
Engineering drawings are always drawn in orthographic projection. For the presentation of detailed drawings, this system has been found to be far superior to all others. The system has, however, the disadvantage of being very difficult to understand by people not trained in its usage. It is always essential that an engineer be able to communicate his ideas to anybody, particularly people who are not engineers, and it is therefore an advantage to be able to draw using a system of projection that is more easily understood. There are many systems of projection and this book deals with three: isometric, oblique and orthographic projections. Isometric and oblique projections present the more pictorial view of an object.

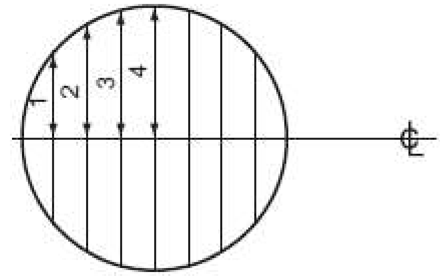
An isometric drawing of a regular hexagonal prism.



Circles and Curves Drawn in Isometric Projection

All of the faces of a cube are square. If a cube is drawn in isometric projection, each square side becomes a rhombus. If a circle is drawn on the face of a cube, the circle will change shape when the cube is drawn in isometric projection. Figure below shows how to plot the new shape of the circle.



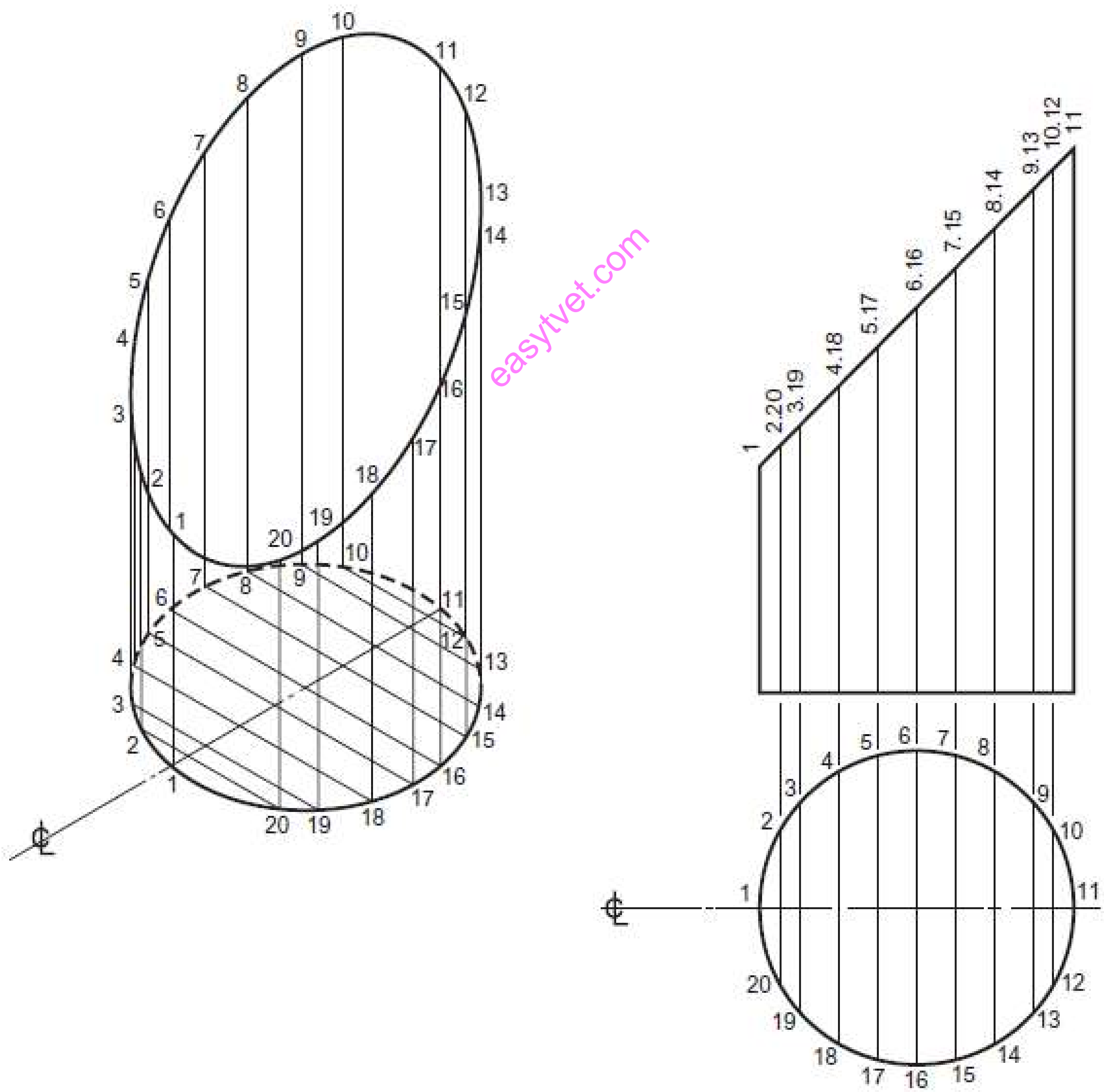


The circle is first drawn as a plane figure, and is then divided into an even number of equal strips. The face of the cube is then divided into the same number of equal strips. Centre lines are added and the measurement from the centre line of the circle to the point where strip 1 crosses the circle is transferred from the plane drawing to the isometric drawing with a pair of dividers. This measurement is applied above and below the centre line. This process is repeated for strips 2, 3, etc.

The points that have been plotted should then be carefully joined together with a neat freehand curve.

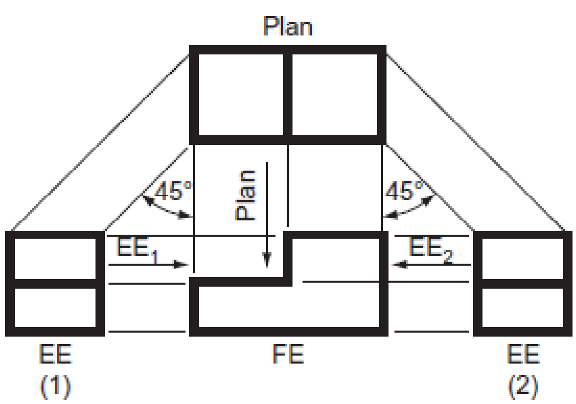
Cylinder cut obliquely.

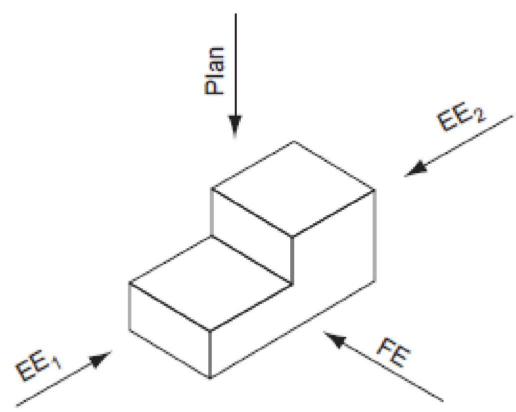
Figure below shows a cylinder cut at 45 °. Two views of the cylinder have to be drawn: a plan view and an elevation. The plan view is divided into strips and the positions of these strips are projected onto the elevation. The base of the cylinder is drawn in isometric projection in the usual way. Points1 to 20, where the strips cross the circle, are projected vertically upwards and the height of the cylinder, measured from the base with dividers is transferred for each point in turn from the elevation to the isometric view. These points are then carefully joined together with a neat freehand curve.



Third angle orthographic projection

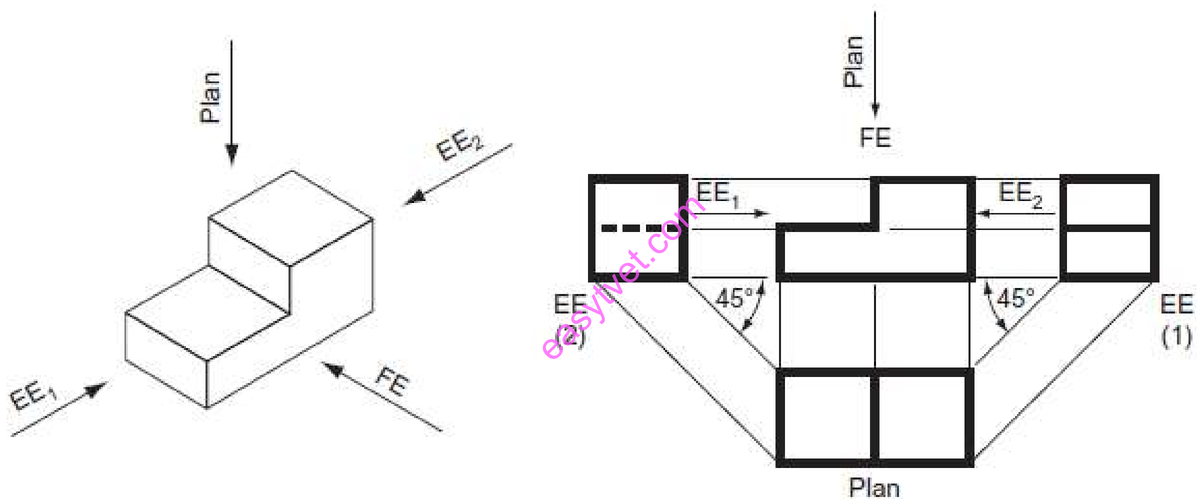
Figure below shows the same shaped block drawn in third angle projection. First draw the view obtained by looking along the arrow marked FE. This gives you the FE. Now look along the arrow marked EE 1 (which points from the left) and draw what you see to the left of the FE. This gives you an EE. Now look along the arrow marked EE 2 (which points from the right) and draw what you see to the right of the FE. This gives you another EE. Now look down onto the block, along the arrow marked ‘ plan ’ and draw what you see above the FE. This gives the plan and its exact position is determined by drawing lines from one of the EE at 45 ° .Note that with third angle projection, what you see from the left you draw on the left, what you see from the right you draw on the right and what you see from above you draw above.





First angle orthographic projection

Figure below shows the same block drawn in first angle projection. Again, first draw the view obtained by looking along the arrow marked FE. This gives the FE. Now look along the arrow marked EE 1 (which points from the left) and draw what you see to the right of the FE. This gives you an EE. Now look along the arrow marked EE 2 (which points from the right) and draw what you see to the left of the FE. This gives you another EE. Now look down on the block, along the arrow marked ‘ plan ’ and draw what you see below the FE. This gives the plan and its exact position is determined by drawing lines from one of the EE at 45 °.



4.2.5.4 Learning Activities

1. Identified symbols and abbreviations and their meaning interpreted according to standard drawing conventions
2. Produced first and third angle orthographic drawings and interpreted in accordance with the standard conventions
3. Dimensioned orthographic elevations in accordance with standard conventions
4. Produced isometric drawings and interpreted in accordance with standard conventions
5. Produced and interpreted assembly drawing in line with the operating standards

4.2.5.5 Self-Assessment

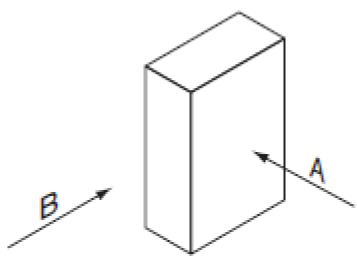
1. Figure below shows the following views of a rectangular prism, drawn in first angle projection with the prism tilted at 45 ° in the FE.

A FE looking along arrow A.

An EE looking along arrow B.

A plan.

An AP showing the cross-sectional shape of the prism.



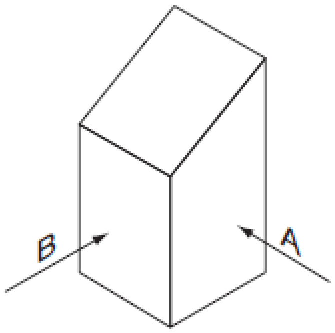
2. Figure below shows the following views of a square prism drawn in third angle projection. The top of the prism has been cut obliquely at 30 °.

A FE looking along arrow A .

An EE looking along arrow B .

A plan.

An AP projected from the FE at 30 ° .



4.2.5.6 Tools, Equipment, Supplies and Materials

- Drawing room
- Drawing instruments e.g. T-squares, set squares, drawing sets
- Drawing tables
- Pencils, papers, erasers

Masking tapes

4.2.5.7 References

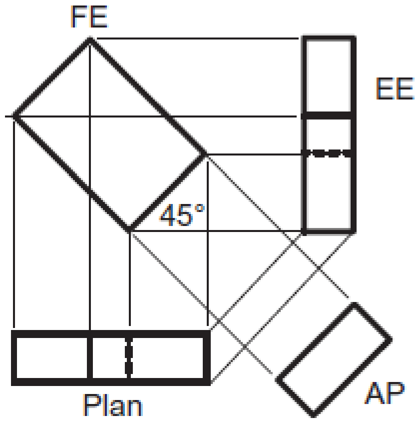
K.Venkata Reddy Engineering Drawing 2nd Edition

S.K Bhattacharya Electrical Engineering Drawing 2nd Edition

4.2.5.8 Response to self-assessment

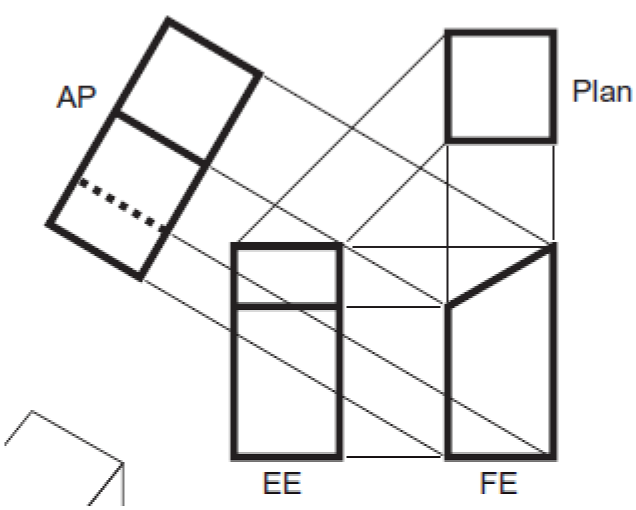
1.7

First angle projection



1.8

Third angle projection



4.2.5 Learning Outcome 5: Produce Electrical Drawings

4.2.5.1 Introduction to the learning outcome

To Produce Electrical drawings, one is required to have knowledge on; Electrical symbols and abbreviations, meaning of electrical drawings, drawing of electrical diagrams and Interpretation of electrical drawings.

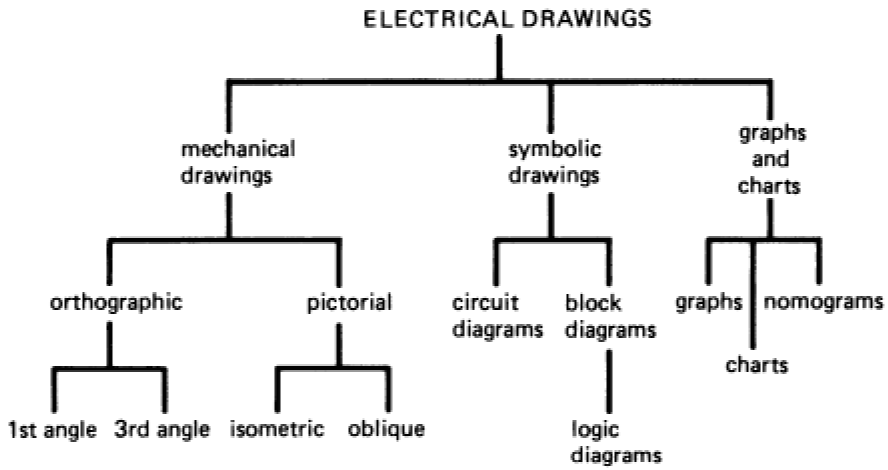
4.2.5.2 Performance Standard

1. Electrical symbols and abbreviations are identified and their meaning interpreted according to BS 3939
2. Electrical diagrams and drawings are developed as per established standards
3. Electrical drawings are produced in accordance with BS 3939
4. Electrical drawings and diagrams are interpreted as per established standards

4.2.5.3 Information Sheet

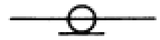
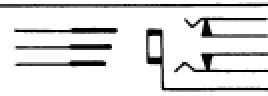
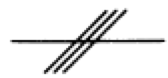
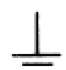
Types of Electrical drawing

Many kinds of drawing are used in electrical engineering in order to record different categories of information. Technicians and technician engineers may have to produce only some of these types of drawing, but they will need to understand all of them, and be able to extract information from them. Circuit diagrams show the way in which the components in an electrical or electronic system are connected together. When reading or drawing circuit diagrams it is important to remember two points.

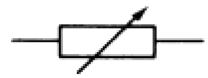
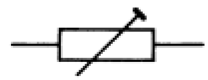
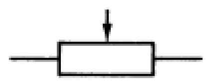
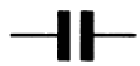


(l) The symbol used to represent each component depends only on its function, and has no relation to its shape, size or electrical rating. (2) The symbols are placed on the drawing to make the diagram as clear and easy to follow as possible. Their position bears no relationship to the layout of the components in the corresponding equipment. In view of the increase in international trade in electrical apparatus it is important to adhere wherever possible to internationally standard methods of drawing circuit diagrams. This is because much British equipment is exported all over the world, and in particular electronic apparatus may be made in one country, sold in another, and require servicing in a third. Unfortunately there is not complete uniformity in the component symbols used in all countries but the various national standards are steadily being brought into agreement with the international standards recommended by the International Electro-technic Commission set up for this purpose. The British standard for symbols is BS 3939: Symbols for electronics and electrical diagrams.

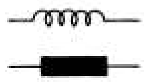
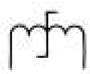
Symbols for connection and connectors

conductors crossing, no connection		1
conductors connected		2
coaxial pair		3
plug and socket		4
three-pole concentric plug and break-jack		5
fuse	 preferred  alternative	6
group of three conductors		7
normally closed link		8
earth		9
frame or chassis		10

Symbols for resistors and capacitors.

Component	*Symbol*	*Ref.*
basic resistor		R 1
permitted alternative		R 2
variable resistor		R 3
variable resistor — preset		R 4
voltage divider with moving contact		R 5
capacitor		C 6
polarised electrolytic capacitor		C 7
variable capacitor		C 8

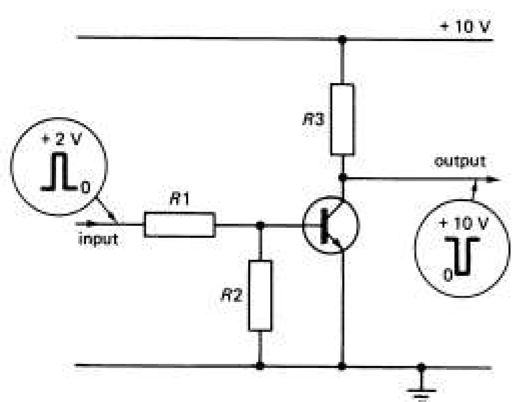
Symbols for inductors and transformers

Component	Symbol	Ref.
basic symbol for winding of inductor or transformer		L 1
alternative, non-preferred		L 2
inductor with ferromagnetic core		L 3
two-winding transformer		T 4
variable inductor, preset with ferromagnetic core		L 5
inductor with saturable core		L 6
three-phase power transformer star-delta connection		T 7

DRAWING CIRCUIT DIAGRAMS

Although some circuit diagrams are prepared as a re~rd of a particular product, the majority are in: tended as working drawings. These will be used for manufacturing the equipment they describe, commissioning, or maintaining it. The main purpose, then, of the drawing is to communicate to the reader the details of the circuit and the way in which it functions. Consequently, when preparing the diagram a very important factor is the clarity with which it shows the circuit's function. This must be given priority over a symmetrical appearance or a uniform spacing of symbols through the drawing. The following points help to make the drawing easy to read. (1) The main signal path should run from left to right. Inmost electronic equipment one or more inputs and outputs can be identified and this layout is easy to implement. It becomes more difficult with some electrical drawings; and power-station diagrams, for example, are often drawn with the main busbars near the top of the drawing and the various feeds in and out drawn at right angles, that is, vertically up and down the diagram. (2) D.C. power supply lines should be drawn horizontal, the most positive line being at the top of the page and the rest in order of their potential, the most negative being at the bottom. Where only one supply line is used this is sometimes drawn above the earth line even when negative to it. For a small diagram involving linear signals this procedure is acceptable, although not always easy to follow

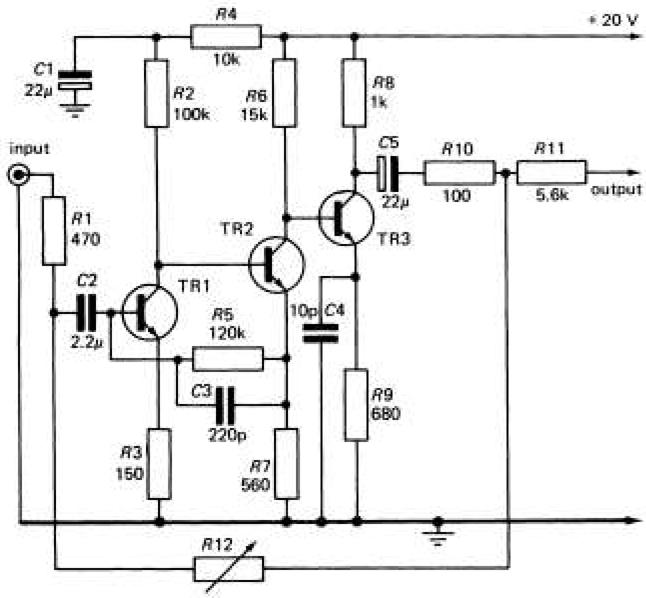
Transistor pulse amplifier



However, with pulse or digital circuits it becomes extremely confusing when fault-finding with an oscilloscope. This is because oscilloscopes are always built so that a positive-going signal moves the beam upwards. Thus in figure above, with no input signal the transistor base is at the same potential (earth) as the emitter and so the collector current is very small and the collector rises to the same potential as the supply line, + 10 V. A positive-going signal, if the resistors are properly chosen, will drive the base into conduction and saturate the transistor, causing it to conduct fully so that the collector voltage falls to near earth potential. The two waveforms show the signal which would be observed on an oscilloscope connected to input and output. It is much easier to relate these signals and their polarities if the positive line is at the top of the drawing, as shown, than if it were drawn below the earth line. On many maintenance manuals for apparatus concerned with pulse waveforms, for example television receivers and oscilloscopes, the wave forms to be expected at key points in the circuit are shown by the inset drawings. These are always drawn with a positive upwards convention to agree with the manner in which oscilloscopes deflect.

EXAMPLES OF CIRCUIT DIAGRAMS

Circuit diagram for a tape recorder Figure below shows a three-stage directly coupled amplifier which forms the first section of the recording chain for a tape-recorder. Since there are no inter-stage capacitors the stages are connected directly from collector to base and to simplify the layout each transistor is drawn higher on the page than the previous one. As there is a single amplifying signal path the input is on the left and the output on the right.



Circuit diagram for X-deflection amplifier of an oscilloscope

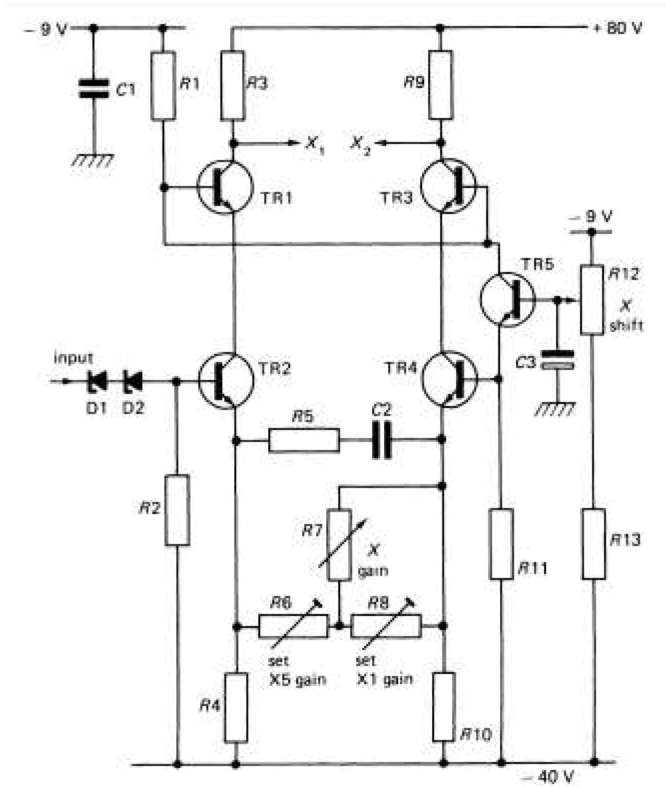
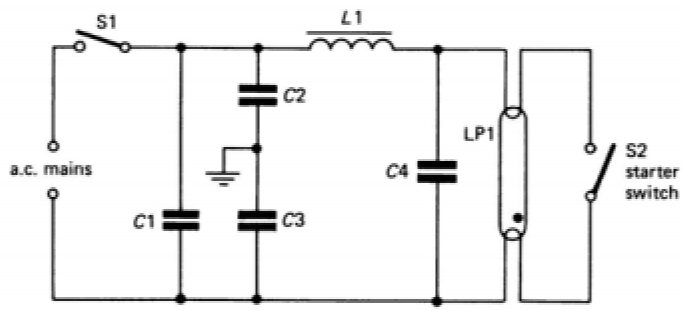


Figure above shows the X-deflection amplifier of an oscilloscope used for serv1cmg and fault-finding. The signal path here is somewhat more complicated as the single sawtooth input wave form must generate two push-pull output signals to drive the two X-deflection plates. The circuit has a degree of symmetry and comprises two transistors in each half of a 'long-tailed pair'. The two emitter electrodes ofTR2 and TR4 are coupled via R6 (preset) and R7 (the front panel 'X-gain' control). The two circuits R3, TRI, TR2, R4 and R9, TR3, TR4, RIO are identical and therefore they are drawn side by the side between the + 80 V and - 40 V lines. In this drawing the convention of positive supply line at the top and negative supply line at the bottom is followed with regard to the main + 80 V and - 40 V lines. The relative positions of the chassis and -9 V lines have however been altered to simplify the layout.

Circuit of fluorescent lamps



This is for a low-pressure fluorescent lamp. Whereas a filament lamp circuit would include only an on-off switch and a lamp, a fluorescent tube requires a power factor correction capacitor Cl , a ballast choke Ll, R.F. interference suppression capacitors C2, C3 and C4, and a starter switch S2. The layout is arranged with the a.c. mains input on the left to agree with the normal convention.

4.2.5.4 Learning Activities

1. Identified electrical symbols and abbreviations and their meaning interpreted according to BS 3939
2. Developed electrical diagrams and drawings as per established standards
3. Produced electrical drawings are in accordance with BS 3939
4. Interpreted electrical drawings and diagrams as per established standards

5.2.5.5 Self-Assessment

1. Name types of Electrical drawing
2. Draw the symbols for a complete semiconductor's devices

1.2.5.6 Tools, Equipment, Supplies and Materials

- Drawing room
- Drawing instruments e.g. T-squares, set squares, drawing sets
- Drawing tables
- Pencils, papers, eraser
- Masking tapes

4.2.5.7 References

K.Venkata Reddy Engineering Drawing 2nd Edition

S.K Bhattacharya Electrical Engineering Drawing 2nd Edition

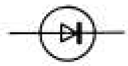
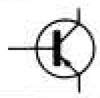
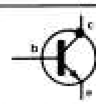
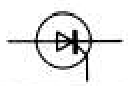
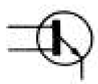
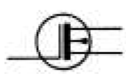
Kenneth Morling Geometric and Engineering Drawing 3rd Edition

4.2.5.8 Response for self-assessment

1. Mechanical drawing

Symbolic drawing

Graphic and charts

Component	Symbol	Ref.
p-n diode		D_1
zener diode		D_2
p-n-p transistor		TR_3
n-p-n transistor, can connected to collector		TR_4
cathode-controlled thyristor		CSR_5
unijunction transistor with *p*-type base		TR_6
junction-gate FET with *n*-type channel		TR_7
depletion-type *n*-channel insulated-gate FET		TR_8
enhancement-type *n*-channel insulated-gate FET		TR_9

2

Symbols for complete semiconductors devices

CORE UNTS

CHAPTER 5: PERFORMING ELECTRICAL INSTALLATION

Unit of learning code ENG/CU/EI/CR/01/4

Related Unit of Competency in Occupational Standard: Perform Electrical Installation

5.1 Introduction

This unit describes the competencies required to enable trainee be able to exhibit competency in the application of health, safety and environmental standards, preparation of working drawings, Assembly of tools, equipment, materials and drawing instruments, and performing electrical installation

5.2 Summary of Learning Outcomes

1. Apply health, safety and environmental standards
2. Prepare working drawings
3. Assemble tools, equipment, materials and drawing instruments
4. Perform electrical installation

5.2.1 Learning Outcome 1: Apply and Adhere to Safety Procedures

5.2.1.1 Introduction

To apply and adhere to safety successfully, one requires the ability to understand causes of accidents and sources of danger, apply good housekeeping and apply first aid where necessary.

5.2.1.2 Performance Standard.

5.2.1.3 Information Sheet

Non-statutory regulations

Statutory laws and regulations are written in a legal framework, some don't actually tell us how to comply with the laws at an everyday level. Non-statutory regulations and codes of practice interpret the statutory regulations telling us how we can comply with the law. They have been written for every specific section of industry, commerce and situation, to enable everyone to comply with, or obey the written laws. When the Electricity at Work Regulations (EWR) tell us to 'ensure that all systems are constructed so as to prevent danger' they do not tell us how to actually do this in a specific situation. However, the IEE Regulations tell us precisely how to carry out our electro technical work safely in order to meet the statutory requirements of the EWR. In Part 1 of the IEE Regulations, at 114, it states 'the Regulations are non-statutory. They may, however, be used in a court of law in evidence to claim compliance with a statutory requirement'. If your electro technical work meets the requirements of the IEE Regulations, you will also meet the requirements of EWR.

The IEE Wiring Regulations requirements for electrical installations

The Institution of Electrical Engineers Requirements for Electrical Installations (the IEE Regulations) are non-statutory regulations. They relate principally to the design, selection, erection, inspection and testing of electrical installations, whether permanent or temporary, in and about buildings generally and to agricultural and horticultural premises, construction sites and caravans and their sites.

PPE

PPE is defined as all equipment designed to be worn, or held, to protect against a risk to health and safety. This includes most types of protective clothing, and equipment such as eye, foot and head protection, safety harnesses, life jackets and high visibility clothing. Under the Health and Safety at Work Act, employers must provide free of charge any PPE and employees must make full and proper use of it.

Safety and work habits

Safety is the behavior undertaken to prevent injury to people and damage to machines and equipment. Many people are injured or killed in electrical accidents due to ignorance or carelessness. There are various safety/protective wear that needs to be used in a work environment

Figure 1 Protective wear

1. Safety helmet-Protects head from falling objects
2. Goggles-protects eyes from flying objects and excessive light
3. Ear muffles-Protects ears from excessive sound.
4. Dust coat/Overall- Protects personal clothing from dirt
5. Hand gloves- Protects hands from injury.
6. Safety boots- Protects feet from falling objects.

Safe working habits

1. **Handling of tools and equipment**

   All tools and equipment should be handled with care. They should be handled individually. They should NEVER be stacked as a pile.

2. **Handling of heavy loads**

   Always ask for assistance. Carry heavy loads with the back upright.

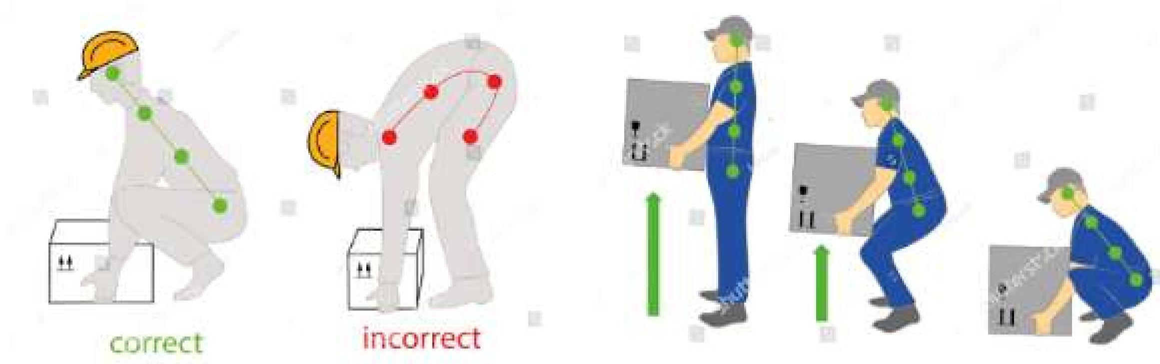


Figure 2 Handling of heavy loads

If the load is too heavy use a crane or other mechanical assistance.

3. **Movement of sharp items**

   Sharp items should be moved pointing downwards and away from the body. The movement should be slowly.

   Never run when carrying sharp items.

   ALWAYS warn other people when carrying sharp and/or long objects.

4. **Working environment**

   The working area should be well ventilated and well lit. The floor should be free from oil spillage or any slippery substance. Always wipe any liquid that is on the floor.

Care and maintenance of tools

Tools which are not properly taken care of can cause injuries, therefore:

1. Tools should be stored in their racks or kits.
2. After use the tools should be cleaned.
3. Wipe them to be free from dust and oil or grease.
4. Use cotton waste for cleaning.

5. Cutting tools should be sharpened from time to time.
6. Tools that require oiling should be oiled as planned.

Safety rules and regulations

1. Do not run in the workshop, always walk.
2. Work from marked work places.
3. Do not work on live circuits.
4. Always ensure the circuit is checked for correct functioning before connecting it to power.
5. Do not entertain horse play in the working area.
6. Clean the work area after the job is done.
7. All slippery floors should be cleaned/wiped.
8. Conceal all bare conductors.
9. When working with a ladder ensure it is properly supported.
10. Clear all pathways of any obstructions.

<u>**Dangers of electricity**</u>

1. Electric Shock

Electric shock is the passage of electricity in the human body. This can be due to getting in contact with live wires. When a person gets into contact with a live wire and gets an electric shock, the following steps should be followed to save the victim:

i. Use a dry insulator to remove the victim from electrical contact.
ii. Take the victim away from the place where the shock occurred.
iii. If the victim has stopped breathing lay he/she flat on the ground then apply first aid by KISS OF LIFE method of artificial respiration as follows.
iv. Call for medical help

Figure 3 Kiss of life position

Steps of Kiss of life

1. Place a support below the neck and loosen the clothing.
2. Clear all air passages.
3. Pinch the nose and breathe into victim's mouth until the chest rises.
4. Release the nose and let the air rush out.
5. Continue with this process until the victim breathes normally.
6. Take the victim to hospital for further medical checkup.

2. Electrical fire

Electrical fires can be caused by short circuits or loose connections. These fires cannot be put off by water because water is a good conductor of electricity. The fire extinguisher used in case of electrical fires include: carbon dioxide, dry sand, fire blanket, foam and dry powder. In the event of the fire, raise alarm, switch OFF the circuit and use the correct fire extinguisher to put it off. In case the fire is out of control use a designated exit route and escape. Always know the position of fire extinguishers in the workshop. Read the instruction on how they are operated and use them on the appropriate fires. Always know the position of emergency switches and use them in case of any danger in the workshop.

Classes of Fire

1. **Class A**: Fires that involve solid flammables and dusts, such as wood, plastics, paper and cardboard, fabric and textiles, and dusts such as grain dust and flour.
2. **Class B**: Fires that involve flammable liquids, such as gasoline, petroleum oil, paint, or diesel.
3. **Class C**: Fires that involve flammable gases, such as propane, butane, or methane.
4. **Class D:** Fires that involve combustible metals, such as magnesium, lithium, sodium, potassium, titanium, or Aluminium.
5. **Class F**: Fires that involve cooking oils and fats, such as vegetable oil, sunflower oil, olive oil, maize oil, lard, or butter (typically those used for deep-fat fryers).
6. **Class E**: These are electrical fires that involve live equipment and electrical sources

Types of fire extinguishers

1. **Water Extinguishers**

Water extinguishers are only suitable for **class A** fires, which means they can fight fires that involve wood, cardboard, paper, plastics, fabric and textiles, and other solid materials. Do not use water extinguishers on burning fat and oil fires and electrical appliances.

2. **Dry water mist**

These types of fire extinguishers will be solid red and will have the words ‘water mist’ printed within a white rectangle. Dry water mist extinguishers are unique in that they can extinguish almost **all types** of fires

3. **Foam Extinguishers**

Foam extinguishers are identifiable by the word ‘foam’ printed within a cream rectangle on their bodies. They are primarily water based but contain a foaming agent, which has rapid flame knock-down and a blanketing effect. It smothers the flames and seals vapour so that re-ignition cannot occur. They are suitable for fighting **class A and B** fires**. Warning:** these should not be used on any other fire classes, especially electrical fires.

4. **Carbon Dioxide (CO_2) Extinguishers**

These types of extinguishers can be identified by the text ‘carbon dioxide’ or ‘CO_2‘printed in white on a black rectangle. They also have a distinct type of hose. Carbon dioxide extinguishers are used for fighting **class B and electrical fires** – they suffocate the fire by displacing oxygen in the air. They must never be used on hot cooking oil and fat (class F) fires.

5. **Wet Chemical Extinguishers**

These types of fire extinguishers are identifiable by the words 'wet chemical' printed across a yellow rectangle. It also has an extended hose that you can hold and point at a given direction, which is useful when fighting fires on a kitchen top. Wet chemical extinguishers are used for fighting **class F** fires

First aid kit

First aid is the first treatment given to an accident victim before regular medical treatment is obtained. It is important for one to familiarize oneself with basic first aid skills. The ***first aid kit*** is a collection of supplies and equipment. The basic contents of the first aid kit includes; a pair of scissors, pain killers, surgical spirits, eye drops, cotton wool, adhesive plasters, roller bandages, petroleum jelly and sterilized dressings for use in giving first aid. All workshops should have a first aid kit. It can be used to address cuts, burns and even breakage of bones.

Figure 4 First aid box

Holger-Nielsen method

Steps

1. Lay the casualty in a prone position on a flat surface.
2. Place the casualty's hands one over the other under his forehead
3. The hand must be turned slightly on one side.
4. Nose and mouth must be unobstructed.
5. Place one knee with its inner side in line with the casualty's cheek, a few inches from the top of his head.
6. Place the other foot with the heel in line with the casualty's elbow.
7. Place your hands on the casualty's back on the lower part of the shoulders back, fingers pointing at casualty's feet.
8. Keeping the arms straight, rock forward gently until arms are vertical. The movement takes seconds counting "one, two". This pressure causes **expiration**
9. Then rock back counting, "three" for one second, and slide your hand past the casualty's shoulder until you can grab his upper arms near the elbows.
10. Rise and pull the arms until tension is felt for two seconds counting "four, five".
11. Do not raise chest from ground. This movement causes **inspiration**.
12. Your hands should remain straight, count "six" for one second

Safety signs

Safety signs must be displayed in appropriate places where they are easily seen. Examples of safety signs which MUST be clearly displayed and strictly observed are

5.2.1.4 Learning activities

Field/Visit to Kenya Red Cross Office

Visit Objective/Aim	Indicators	Special Instruction
To establish first aid methods	- Methods used for resuscitation - First aid kits contents	-Observe keenly methods of resuscitation -Observe keenly contents of first aid kit -Take notes

Practical assignment

Visit Objective/Aim	Indicators	Special Instruction
To establish firefighting techniques	**-** Fire extinguishers types - Types of fire	Participate in safety drills

5.2.1.5 Self-Assessment

1. What are the dangers of electricity?
2. Explain the steps to be followed when rescuing a non-conscious victim of an electric shock
3. Name ANY FOUR types of fire extinguishers.
4. Explain why it is important to wear the following protective clothing in a work environment:
   i. Helmet
   ii. Gloves
   iii. Goggles
   iv. Safety boots
   v. Dust coat

5.2.1.6 Tools, Equipment, Supplies and Materials

The following resources are provided

i. An electrical installation company
ii. A functional Safety department.
iii. Computers
iv. Stationery
v. Lecture room
vi. Workshop
vii. Projector

viii. Drawing equipment
ix. Workshop
x. Protective clothing

5.2.1.7 References

Donnely. (1980). *Electrical Installation theory and practice.*

Hyde. (1994). *Electrical Installation Principles and practice.*

ngari, c. k. (2019). *electrical installations for artisan level 2.* kenya literature bureau.

John Bird, (2007). *Electrical and Electronic Principles and Technology*,

https://www.osha.gov/sites/default/files/2019-03/electrical_safety_manual.pdf

https://safetyculture.com/topics/electrical-hazards/

5.2.2 Learning Outcome 2: Prepare Working Drawings

5.2.2.1 Introduction

To prepare working drawings successfully, one requires the ability to read and interpret drawings correctly to determine job requirements.

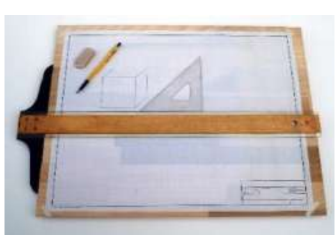
5.2.2.2 Performance Standard.

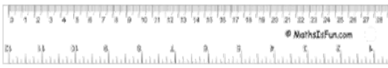
5.2.2.3 Information Sheet

Drawing Equipment and Materials

1. **Equipment**

S/N	Types drawing equipment	Application	Recommended care
1.	T-squares 	1. T-squares are used to draw straight horizontal lines. 2. The head of the square, the cross member, is placed along the left edge or the top of the drafting table, while the square's blade is laid across the table's top, over the drawing paper. 3. The drafter slides the square up, down or across on the table top, as required by a design, always keeping the flat side of the square flush with the table top's edge. This action keeps the square's blade parallel to the table top's edges.	1. Clean regularly 2. Tighten screws at joint to avoid non-parallel lines 3. Keep free from wet areas or any other liquids

2.	Set squares 	1. There are 30/60, 45/90, & adjustable set squares for drawing perpendicular and angled lines 2. The adjustable set square enables you to set the angle on the set square to anywhere between 0 ° and 90 °. 3. If you have an adjustable set square you can manage without the other two.	4. Clean regularly 5. Tighten screws at joints to avoid wrong angles (for adjustable set squares) 6. Keep free from wet areas or any other liquids
3.	Drawing sets/ compass 	Compasses are drawing instruments that are primarily used to perform the following tasks in geometry: i. To draw a circle around a point. ii. To transfer distances precisely.	1. Clean regularly 2. Tighten screws at joints to avoid inaccuracies 3. Keep free from wet areas or any other liquids to avoid corrosion
4.	Drawing boards 	1. They are used to draw parallel lines easily and precisely 2. The rulers/ Tee squares are used to precisely determine straight lines and angles and are individually adjustable. 3. Technical drawing boards are available in A4, A3, A2, A1 and A0 size which are designed for the corresponding paper formats.	1. Clean regularly 2. Keep free from wet areas or any other liquids to avoid corrosion

5.	Ruler 	It's used to measure dimensions and draw straight lines	Clean regularly
6.	Rulers and scale rules 	1. A scale rule is a scaled, three-edged ruler which has six different scales marked to its sides. A typical combination for building details is 1:20, 1:50, 1:100, 1:25, 1:75 and 1:125. 2. Today scale rulers are made of plastic, formerly they were made of hardwood.	Clean regularly

2. **Materials**

S/N	Drawing materials	Uses and care	Recommended care
1.	Pencils 	**A pencil** is an implement for writing or drawing, Most pencil cores are made of graphite powder mixed with a clay binder. Graphite pencils (traditionally known as 'lead pencils') produce grey or black marks that are easily erased. **B** grade means the core has more graphite, and will make a bolder,	1. Sharpen regularly. 2. Keep away from moist.

		darker line, and also be a little smudgier than a light pencil. **H** grade means the core has more clay, and will make a lighter, finer line, and will be less smudgy than a dark pencil. You will need a selection of pencils. A hard leaded pencil (3H) can be used for light lines, a softer pencil (H) for the outlines and an even softer pencil (HB) for printing. (More than one pencil of each grade will save you from frequent re-sharpening.)	
2.	Erasers 	They are used to erase pencil marks and lines. They assist in error correction and maintaining neat work**.** Choose a good quality rubber, one that does not smudge. 1. Clean regularly 2. Keep free from wet areas	Keep clean
3.	Sharpeners 	1. Sharpening of lead of pencils 2. Keep free from wet areas	1. Avoid breakage 2. Keep clean

<table>
<tr>
<td>4.</td>
<td>Drawing Paper

<table>
<tr><th>Design ation</th><th>Size (mm)</th><th>Area cm²</th></tr>
<tr><td>A0</td><td>841 × 1189</td><td>1 m²</td></tr>
<tr><td>A1</td><td>594 × 841</td><td>5000</td></tr>
<tr><td>A2</td><td>420 × 594</td><td>2500</td></tr>
<tr><td>A3</td><td>297 × 420</td><td>1250</td></tr>
<tr><td>A4</td><td>210 × 297</td><td>625</td></tr>
</table>
</td>
<td>Drawing paper sizes

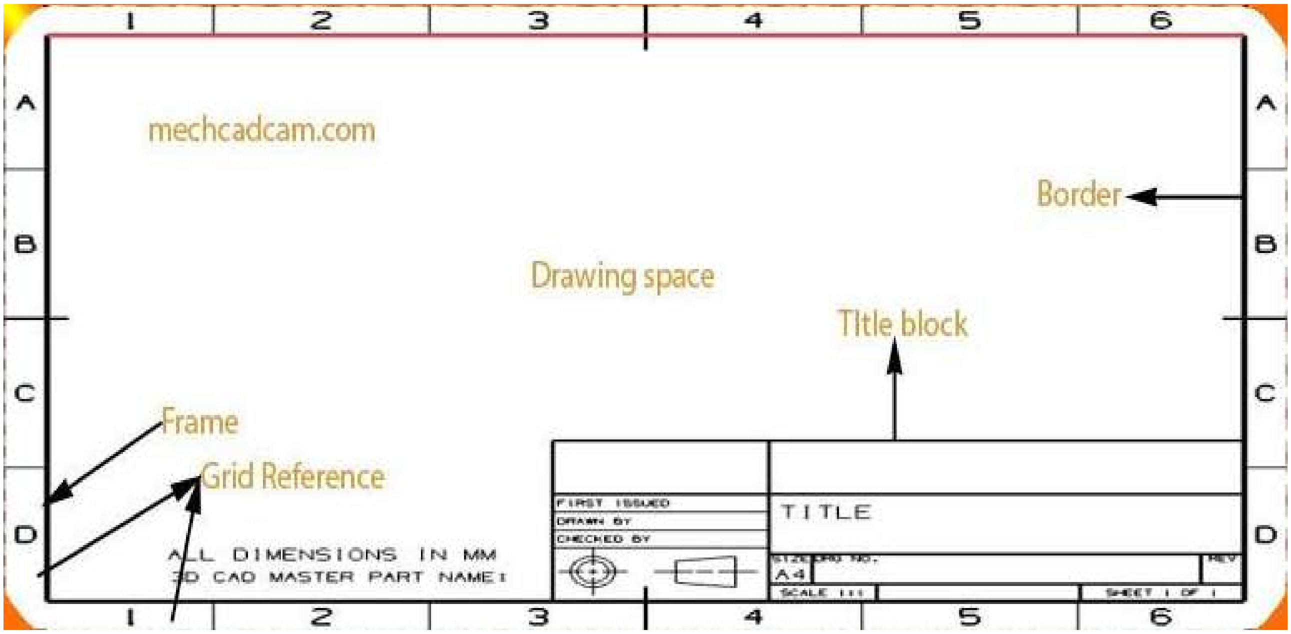
The British Standard BS8888 recommends that for normal practical purposes the area of the largest sheet is one square meter and the sides are in the ratio of 1:√2. The dimensions of the sheet are 841 mm × 1189 mm.</td>
<td>1. Keep free from wet areas
2. Package paper in enclosed covers to protect them from direct sunlight
3. Keep clean</td>
</tr>
<tr>
<td>5.</td>
<td>
Masking tape</td>
<td>The best tape to use to hold paper on the drawing board is masking tape but metal drawing board clips are easier to use.</td>
<td>Keep away from moist</td>
</tr>
</table>

Title block

The title block of a drawing, usually located on the bottom or lower right-hand corner, contains all the information necessary to identify the drawing and to verify its validity. A title block is divided into several areas as illustrated below.

The title block should lie within the drawing space such that, the location of it, containing the identification of the drawing, is at the bottom right hand corner. This must be followed, both for sheets positioned horizontally or vertically

The direction of viewing of the title block should correspond in general with that of the drawing. The title block can have a maximum length of 170 mm although this may vary from type of drawing to another



<u>**Types of electrical drawings**</u>

1. **Architectural drawings**

   These are drawings showing the building layout during its construction, the drawings consists of

   i. Floor plan
   ii. End and Front elevations
   iii. Structural

   The floor plans greatly assists the electrician to design the wiring systems. The legend and additional information in the plans will also aid the electrician in knowing other useful information like the floor finish, height and type of the ceiling e.t.c

2. **Layout diagram**

   This is a diagram of a system showing the actual placement components including dimensions from one component to the other.

3. **Circuit diagram**

   This is a simplified conventional graphical representation of an electrical circuit. In a circuit diagram, the arrangement of the components interconnections on the diagram does not correspond to their physical locations in the finished device

4. **Line diagram**

This is a one-line diagram or single-line diagram is a simplified notation for representing an electrical system. The one-line diagram is similar to a block diagram except that electrical elements such as switches, circuit breakers, transformers, and capacitors are shown by standardized schematic symbols.

5. **Pictorial diagram**

   This is a diagram that represents the elements of a system using abstract, graphic drawings or realistic pictures.

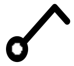
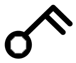
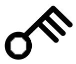
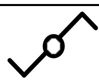
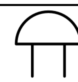
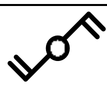
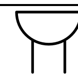
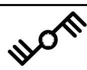
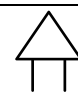
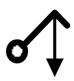
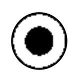
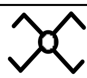
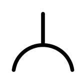
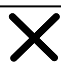
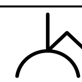
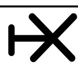
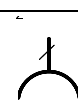
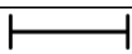
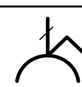
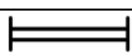
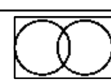
6. **Schematic diagram**

   This is a diagram that uses lines to represent the wires and symbols to represent components. It is used to show how the circuit functions.

7. **Wiring diagram (or pictorial)**

   This is a simplified conventional pictorial representation of an electrical circuit. It shows the components of the circuit as simplified shapes, and how to make the connections between the devices. A wiring diagram usually gives more information about the relative position and arrangement of devices and terminals on the devices.

Electrical Symbols

S/N	Symbol	Description	S/N	Symbol	Description
1.		One way, 1 gang switch	**13.**		Consumer control unit
2.		One way, 2 gang switch	**14.**		Distribution board
3.		One way, 3 gang switch	**15.**		Indicator board
4.		Two way, 1 gang switch	**16.**		Electric bell
5.		Two way, 2 gang switch	**17.**		Buzzer
6.		Two way, 3 gang switch	**18.**		Siren
7.		Cord operated switch	**19.**		Bell push
8.		Intermediate switch	**20.**		Unswitched single socket outlet
9.		Lighting switch	**21.**		Switched single socket outlet
10.		Wall mounted switch	**22.**		Unswitched Twin socket outlet
11.		Single Fluorescent fitting	**23.**		Switched Twin socket outlet
12.		Twin Fluorescent fitting	**24.**		Bell transformer

8. **Architectural Floor plan**

The electrician uses the plan to come up with the following drawings:

i. Lighting scheme and its switching arrangement
ii. Power points and circuiting including call and alarms circuits
iii. Conduit runs, trunking systems and number of cables
iv. Single line diagram showing the system protection devices and load balance

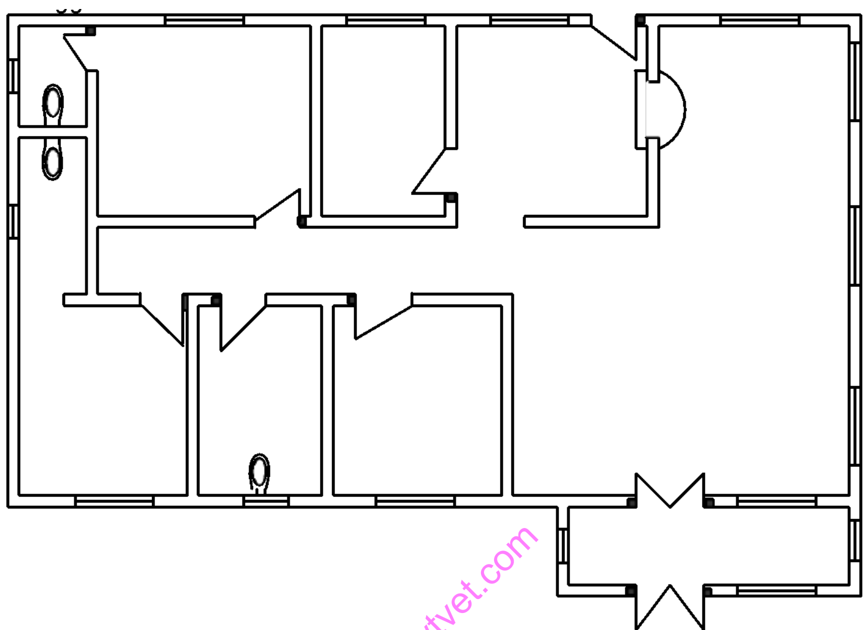


Figure 5 Floor plan of a residential building

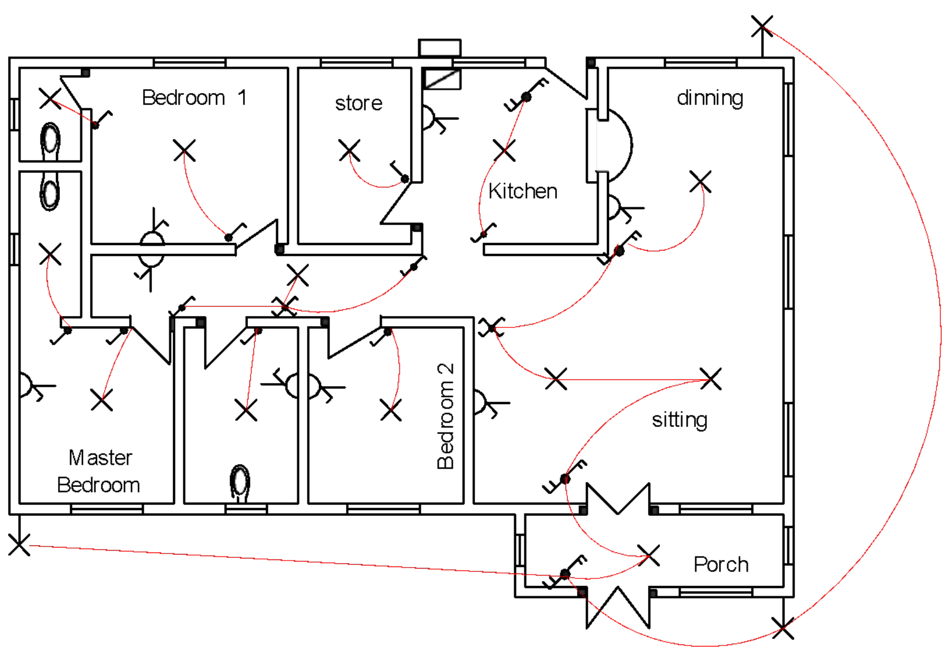


Figure 6 Lighting and power circuit of the plan

Layout diagram

This shows the exact position of components including measurements from one component to the other. The drawing uses BS 3939 symbols.

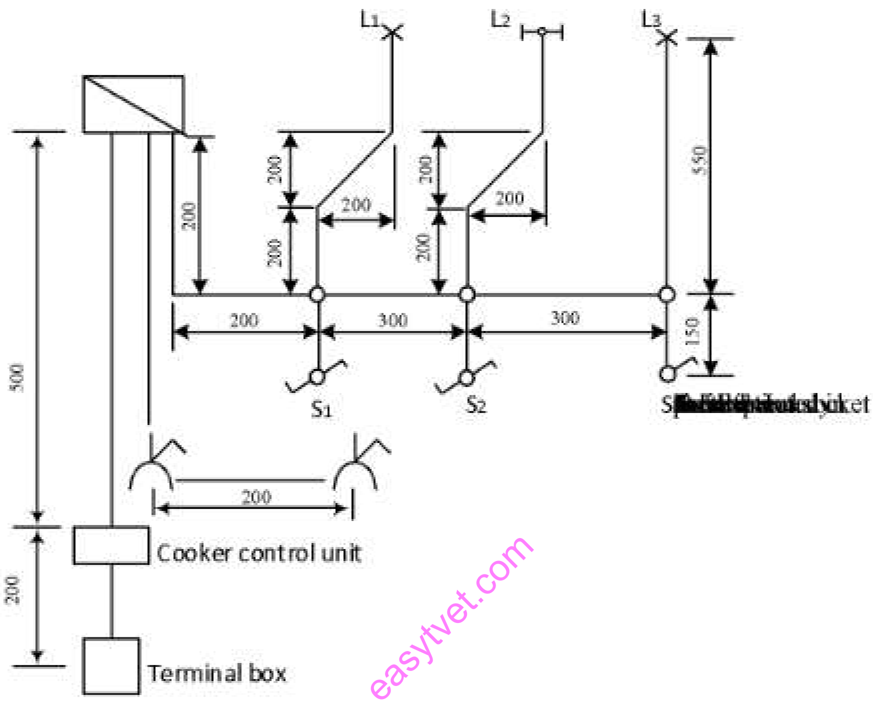


Figure 7. An electrical installation layout diagram.

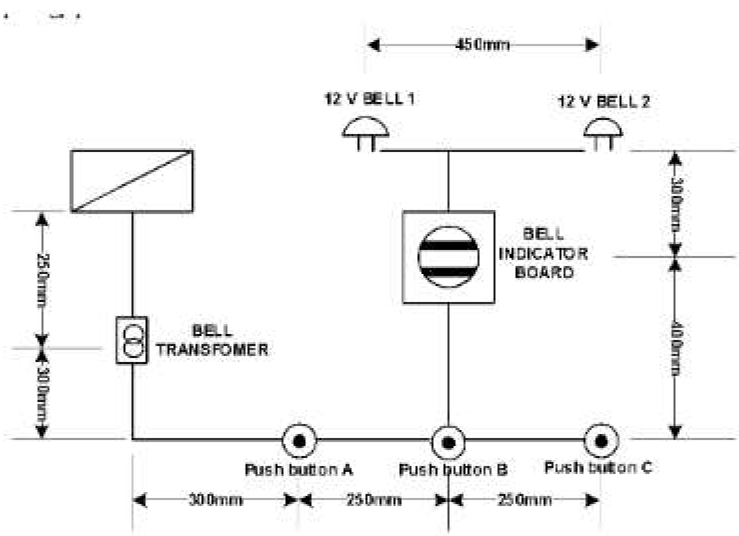


Figure 8 Call and alarm circuit layout diagram

Wiring diagram

This shows the exact cable runs for the electrical installation work to be carried out. It is an interpretation of the layout diagram. Figure 9 is a wiring diagram of layout diagram of figure 7.

Note the interpretation of the various symbols.

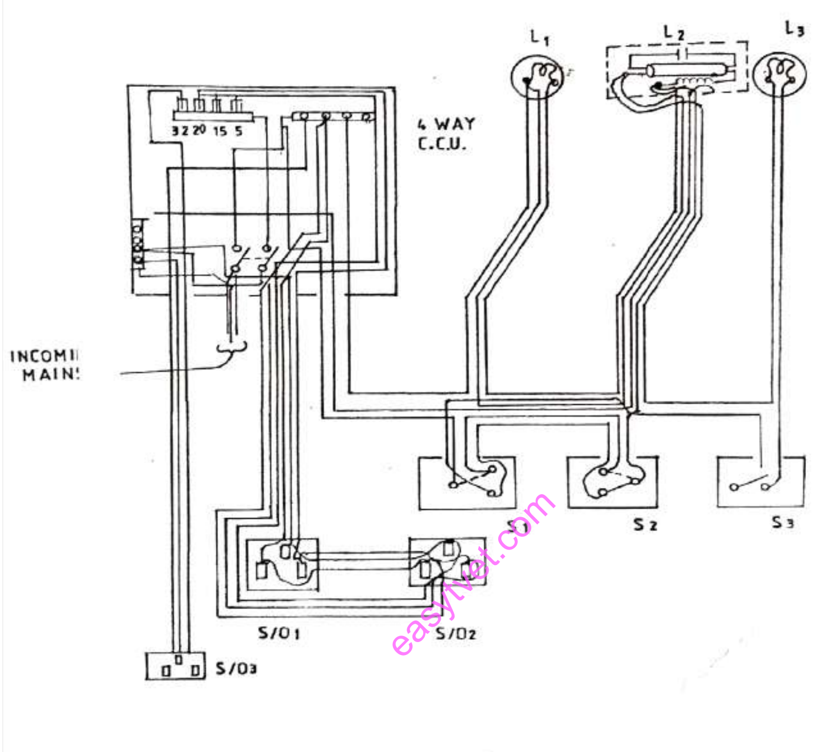


Figure 9 Wiring diagram of figure 7

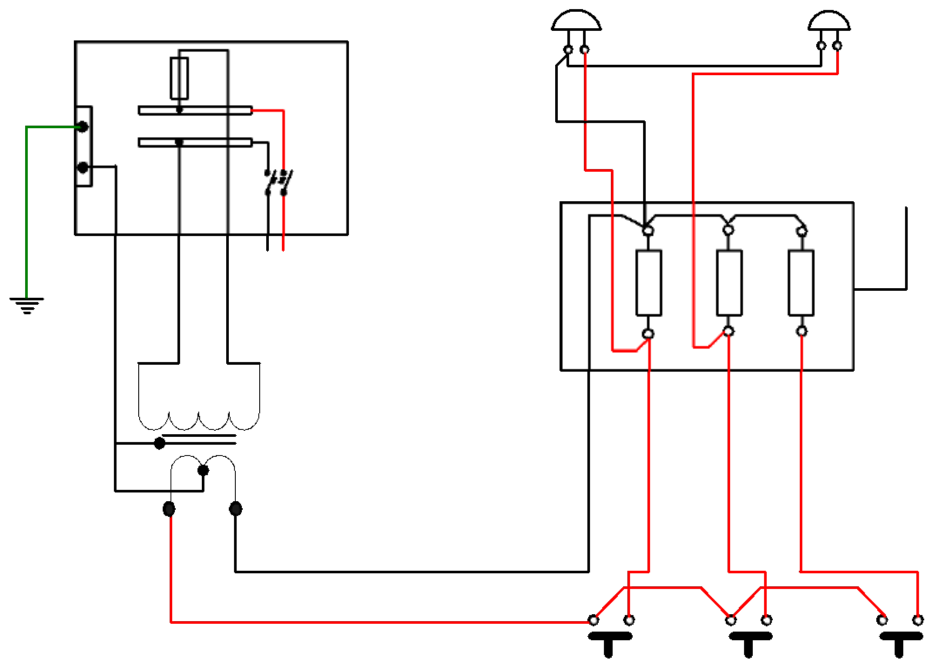


Figure 10 Wiring diagram for figure 8

5.2.2.4 Learning activities

Field/Visit to an electrical installation company

Visit Objective/Aim	Indicators	Special Instruction
To establish correct preparation of working drawings	- Drawing instruments types - Types of electrical drawings	-Observe keenly types of instruments - Observe keenly types of drawings used. -take notes

Practical assignment

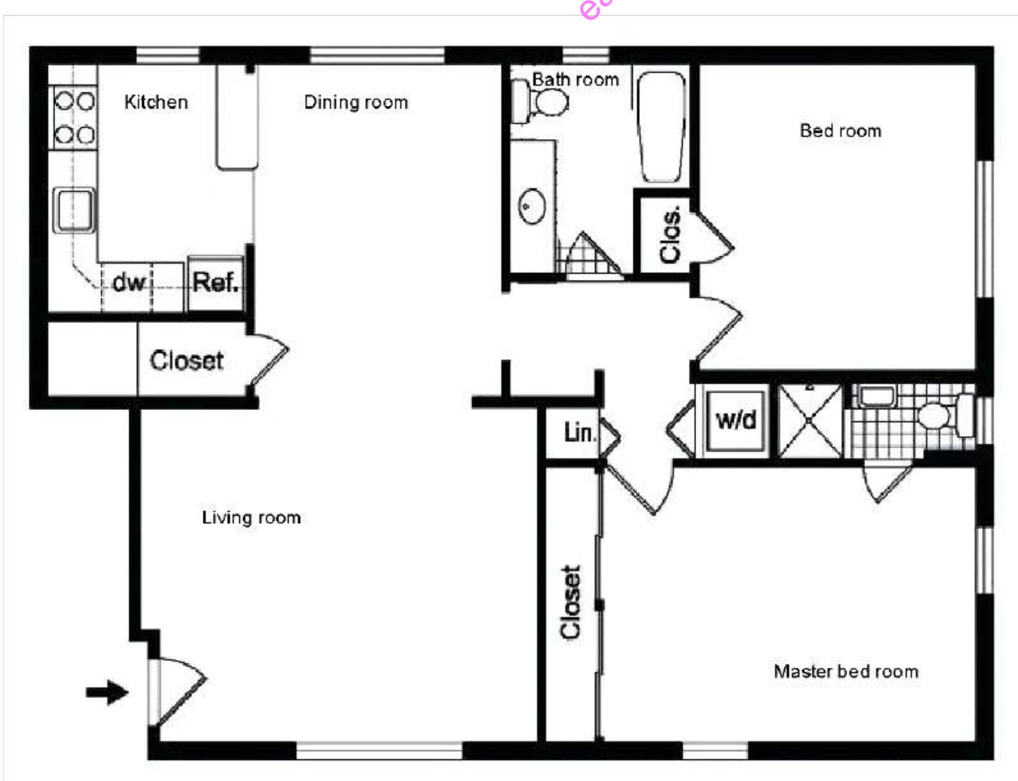
Visit Objective/Aim	Indicators	Special Instruction

To establish correct preparation of working drawings	- Drawing instruments types - Types of electrical drawings	To participate in working drawings preparation

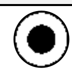
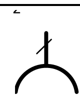
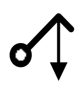
5.2.2.5 Self-Assessment

1. What is the difference between a layout and wiring diagram?
2. Name any two grading of drawing pencils
3. Sketch a combination pliers using free hand
4. Which of the following is not used in preparation of electrical working drawings?
   A. Pliers
   B. Pencil
   C. Ruler
   D. T-square

5. Given the floor plan of a residential building, design the lighting scheme and its switching arrangement.



5. Fill in the following table below

S/N	Symbol	Description
1.		
2.		Siren
3.		
4.		Two way, 2 gang switch
5.		Buzzer
6.		
7.		Intermediate switch
8.		
9.		Consumer control unit
10.		Twin Fluorescent fitting

5.2.2.6 Tools, Equipment, Supplies and Materials

The following resources are provided

i. An electrical installation company

ii. A functional Safety department.

iii. Computers

iv. Stationery
v. Lecture room
vi. Workshop
vii. Projector
viii. Drawing equipment
ix. Drawing room

5.2.2.7 References

Donnely. (1980). *Electrical Installation theory and practice.*

Hyde. (1994). *Electrical Installation Principles and practice.*

ngari, c. k. (2019). *electrical installations for artisan level 2.* kenya literature bureau.

John Bird, (2007). *Electrical and Electronic Principles and Technology*,

https://www.osha.gov/sites/default/files/2019-03/electrical_safety_manual.pdf

https://safetyculture.com/topics/electrical-hazards/

5.2.3 Learning outcome 3: Prepare Tools, Equipment & Materials

5.2.3.1 Introduction

To prepare tools, equipment and materials successfully, one requires to have knowledge in electrical installation tools, equipment and materials, calibration of instruments, care and maintenance of instruments.

5.2.3.2 Performance Standard

5.2.3.3 Information Sheet

Electrical installation tools, equipment and their use

Hammers

These are tools used in driving or pounding out nails they are made of hard steel, wood, plastic or rubber.

Bending spring

This is a tool used for bending PVC conduits

Stock and die

This is a tool used for making threads on metallic conduits

Side cutter

This is a tool used for medium and big cables.

Combination Pliers

These are made of metal with insulated handles. They are used for cutting, twisting, bending, holding and gripping wires and cables

Screw driver

It slot has a cross/flat tip and is used to drive screws with cross/straight heads.

Long nose pliers

This is used for cutting and holding wires. It made to reach tight space and or small opening where other pliers cannot reach. It is also used in making terminal loops of copper wires.

Wire stripper

A tool used for removing insulation from insulated cables.

Hacksaw

This is a tool used to cut metal conduit and armoured cable

Measuring tools

To   measure wire length and other items, the electrician finds considerable use for measuring tools such as the extension or zigzag rule, push-pull rule and a steel tape

Soldering equipment

In  doing electric wiring, splices and taps (connections made to wire) should be soldered, unless you use solderless connectors.

Drilling equipment

 Drilling equipment is needed to make holes in building structure passages of conduit sand wires

Ladders

The term ladder is generally taken to include step ladders and trestles. The use of ladders for working above ground level is only acceptable for access and work of short duration. It is advisable to inspect the ladder before climbing it. It should be straight and firm. All rungs and tie rods should be in position and there should be no cracks in the stiles. The ladder should not be painted since the paint may be hiding defects. Extension ladders should be erected in the closed position and extended one section at a time. Each section should overlap by at least the number of rungs indicated below:

1. Ladders of up to 4.8 m length – 2 rungs overlap
2. Ladders of up to 6.0 m length – 3 rungs overlap

3. Ladder over 6.0 m length – 4 rungs overlap

Draw wire/Fish tape

This is a tool used for drawing cables in conduits

Electrical instrument checking and calibration

A digital Multimeter is used to measure voltage, current and resistance and can be used to measure electrical continuity in a circuit. There are two types of Multimeter: digital and analogue. Multimeter should be calibrated or adjusted to a known zero-value prior to use for accurate readings.

Calibration of Multimeter

Electrical calibration refers to the process of verifying the performance of, or adjusting, any instrument that measures or tests electrical parameters to maintain their accuracy. Electrical calibration involves the use of precise devices that evaluate the performance of key properties for other devices called units under test (UUTs).

Equipment that are not calibrated can result in the wrong decision being made which has the potential for further damage to what the instrument was to be used for.

The fragile electronics within Multimeter are protected by a hard casing, which means they can usually be stored in a toolbox. Multimeter do not require any deep cleaning - just wipe them down with a damp (not wet) cloth, every now and then. Ensure your devices are fully functioning before each use. Change batteries and fuses when necessary and consider removing the batteries if the meter will not be used for an extended period of time.Many people do a field comparison check of two meters, and call them "calibrated" if they give the same reading. This isn't calibration. It's simply a field check. It can show you if there's a problem, but it can't show you which meter is right. If both meters are out of calibration by the same amount and in the same direction, it won't show you anything. Calibration typically requires a standard that has at least 10 times the accuracy of the instrument under test. Calibration, in its purest sense, is the comparison of an instrument to a known standard.

Two instruments, A and B, measure 100 V within 1 %. At 480 V, both are within tolerance. At 100 V input, A reads 99.1 V and B reads 100.9 V. But if you use B as your standard, A will appear to be out of tolerance. However, if B is accurate to 0.1 %, then the most B will read at 100 V is 100.1 V. Now if you compare A to B, A is in tolerance. You can also see that A is at the low end of the tolerance range. Modifying A to bring that reading up will presumably keep A from giving a false reading as it experiences normal drift between calibrations.

Why Multimeter is calibrated

A digital Multimeter is one of the most commonly used pieces of test and measurement instrumentation. Quality processes depend on its continual proper operation. However, time, environment, and physical use (or abuses) change a digital multimeter's characteristics. That's why it's important to periodically calibrate or verify the performance of a digital multimeter.

A multimeter should be calibrated or adjusted to a known zero-value prior to use for accurate readings.

How to calibrate a digital multimeter

1. Set the multimeter to the highest resistance range by turning the dial to the highest "ohm" setting.
2. Touch the test probes of your digital multimeter together.
3. Press the calibration knob until the display reads "0" on the digital multimeter if you don't see "0 ohms" initially**.**

Calibration may be required for the following reasons:

a) a new instrument
b) after an instrument has been repaired or modified
c) when a specified time period has elapsed
d) when a specified usage (operating hours) has elapsed
e) before and/or after a critical measurement
f) after an event, for example:

i. after an instrument has been exposed to a shock, vibration, or physical damage, which might potentially have compromised the integrity of its calibration

ii. sudden changes in weather

g) whenever observations appear questionable or instrument indications do not match the output of surrogate instruments

h) As specified by a requirement, e.g., customer specification, instrument manufacturer recommendation.

How to take care of your tools

Good tools can be quite an investment but only if you take good care of them, they'll return the favour. Keeping your tools properly stored, cleaned, and maintained will save you time and money and make your DIY endeavours that much more rewarding.

In keeping the tools and equipment, you need to work with the space you have. Maybe you hang them on pegboards, maybe you store them in boxes, bags, or chests, or maybe you keep them in drawers or on shelves in your shop. Whatever works for you is best.

Toolboxes also make for great tool storage, offering the primary advantage of portability. While some people opt to store all their tools in toolboxes, for most, the toolbox is a way of carrying around your most-used tools while leaving the bulk safely stored on pegboards, shelves, or drawers.

Basic maintenance of electric tools

To ensure that your **electric tools** work properly, you must take proper care of them. A good regimen of maintenance for your tools is one thing that you can do to make sure that the tool you need is working when you need it.

a) **Clean out the dust:** To make sure that your electric tools are ready for use, keep them clean and free of dust. The housing intake on your electric tools and the exhaust are especially important areas to keep clean. Take some time to clean out the dust every once in a while on your tools while they are sitting in storage.

b) **Check the cords:** Look for wear and tear on the power cords on your electric tools. There can be damage to the insulation and you should keep an eye out for loose wires. This will ensure that your electric tool can get the power that it needs to function without an accident. Wipe the cords down to keep them from becoming damaged from oil and grease. The prongs on the cords should be examined as well. Make sure that the casing is intact and the prongs are not loose.

c) **Oil some electric tools**: The electric tools in your toolbox that have a cutting surface should be lightly oiled to prevent rust. Examine the cutting surface for rust to make sure that your tools are kept in good condition.

d) **Storing your tools:** Keep your electric tools stored in their original cases and containers. This will keep them free of dust and dirt while they are not being used.

PROPER STORAGE OF TOOLS AND EQUIPMENT

The proper care and storage of tools and equipment are not only the concern of the management but of the workers who use the equipment.

Importance of proper storage of tools and equipment

1. It is an important factor for safety and health as well as good business.
2. Improves appearance of general-shop and construction areas.
3. Reduces overall tool cost through maintenance.
4. This also ensures that tools are in good repair at hand.
5. Teaches workers principles of (tool) accountability.

Pointers to follow in storing tools and equipment:

1. Have a designated place for each kind of tools.
2. Label the storage cabinet or place correctly for immediate finding.
3. Store them near the point of use.
4. Wash and dry properly before storing.
5. Store knives properly when not in use with sharp edge down.
6. Put frequently used items in conveniently accessible locations.
7. Gather and secure electrical cords to prevent entanglement or snagging.
8. Cutting boards should be stored vertically to avoid moisture collection.
9. Metal equipment can be stacked on one another after drying such as storage dishes and bowls.

10. Make sure the areas where you are storing the equipment are clean, dry and not overcrowded.

Tool Box for Storing Tools

For keeping tools safe, secure, and organized one can use portable and stationary toolboxes, rolling toolboxes, truck-mounted tool chests, and workbench/toolbox hybrids.

1. Rolling Toolboxes

Rolling toolboxes are larger for storing more tools, but they aren't portable outside of your work area. These are usually tall, upright storage containers with wheels on the bottom. They'll have large drawers for large tools, and smaller drawers on top for smaller tools.

2. Portable Toolboxes

Portable toolboxes are what most people think of when they think of tool storage. These boxes are rectangular, open with a metal clasp or lock, and have a handle for carrying from one job to another job. Most are made of heavy-duty plastic, metal, or canvas and have various compartments tucked inside for storing the most common tools. They're ideal for storing and transporting small, hand-held tools like pliers, hammers, pliers, and screwdrivers.

3. Truck-Mounted Toolboxes

For large tools which are needed to be taken to job sites or projects, a truck-mounted toolbox is the right storage. These are usually made of steel or some other type of indestructible metal, and are mounted and bolted to the bed of a truck. The lid will lock so the tools remain secure. This type of toolbox is best for storing and transporting large tools ladders

4. Stationary Toolboxes

Stationary toolboxes can hold a lot of tools, help keep them dry and secure, and organize your work area. These will usually have wheels, but they're only meant for initial placement of the tool chest.

5. Toolbox/Workbench Hybrids

This type features a rolling toolbox that has a big work surface attached. It comes in all kinds of widths and materials and makes a perfect portable workstation for lots of jobs.

5.2.3.3 Learning activities

Field/Visit to an electrical Installation company

Visit Objective/Aim	Indicators	Special Instruction
To establish tools used in Electrical installation works	- Types of tools - Tools storage	-Take notes -Observe keenly types of tools -Observe keenly types of tools

Practical Assignment

Visit Objective/Aim	Indicators	Special Instruction
To experience usage and storage of Electrical tools	- Tools used - Proper use of tools	Participate in an exercise of tools, equipment and material preparation

5.2.3.4 Self-Assessment

1. Name any four tools used in electrical installation work
2. Describe calibration of Multimeter
3. Why is calibration of multimeter important?
4. As an Electrical Installation Technician, what test do you perform to find an open circuit?
   A. Resistance test
   B. Continuity test
   C. Voltage check
   D. Ohm test

5. One of the following is the most accurate instrument used for testing insulation resistance, which one is it?
    A. Growler
    B. Megohmmeter
    C. Ohmmeter
    D. Tachometer
6. List any four tools used in break down maintenance

5.2.3.5 Tools, Equipment, Supplies and Materials

5.2.3.6 References

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5.2.4 Learning outcome 4: Perform Electrical Installation

5.2.4.1 Introduction

To apply and adhere to safety successfully, one requires the ability to understand causes of accidents and sources of danger, apply good housekeeping and apply first aid where necessary.

5.2.4.2 Performance Standard

5.2.4.3 Information Sheet

Meaning of terms

Circuit- an electric circuit is an arrangement of electrical conductors and associated devices for the purpose of carrying electricity.

Live conductor- It is that conductor which carry current towards the appliance from the source.

Live- means that under working condition a difference in voltage exists between the conductor and earth.

Neutral conductor- The conductor which carries current from the appliances to the source.

Earth- This is the conductive mass of the earth whose electric potential at any point is electrically taken to be zero.

Earth conductor- The conductor that has the same potential with the earth.

Phase conductor-A conductor of an AC system for the transmission of electrical energy other than a neutral.

Potential- The level of electric pressure.

Dead- At or about earth potential zero and disconnected from any live system.

Fuse- A device for opening a circuit by means of a fuse element designed to melt when excess current flows.

Insulation- suitable non-conducting material enclosing or surrounding or supporting a conductor.

Switch- A mechanical device for making and breaking non-automatically a circuit carrying current.

Consumer intake point-This is the point where the electricity power supplier terminates the service line to the consumer's premises. It is commonly known as a meter box or power house.

Conductor

A conductor is a material which offers a low resistance to a flow of electric current.

Conductors for everyday use must

a) Have low electrical resistance
b) Be mechanically strong and flexible
c) Be relatively cheap.

Silver is a better conductor than copper but it is too expensive for practical purposes. Other examples of conductors are aluminium, brass, and iron.

Types of Conductors

The most common electrical conductors used are copper and aluminium. Copper conductors are formed from a block of copper which is cold-drawn through a set of dies until the desired cross-sectional area is obtained. Aluminium wire is also drawn from a solid block

Characteristics of Aluminium and Copper as Conductors

Aluminium	**Copper**
Smaller weight for similar resistance and current-carrying capacity	Can easily be drawn into wires
Easier to machine	Has better electrical and thermal conductivity
Greater current density because of larger surface	Has greater mechanical strength
High resistivity (2.845μΩ-cm)	Is corrosion resistant
Light in weight	Has high scrap value
	Easy to joint
	Lower resistivity (1.78 μΩ-cm)

The determining factor in the use of one type of metal for conductors is usually that of cost. Aluminium cables are used where weight is a factor like for overhead transmission.

Stranding of Conductors.

Stranding of conductors is done to make the completed cable more flexible. A set number of strands are used in cables: 1, 3, 7, 19, 37, 61, 91, and 127. Each layer of strands is spiraled on to the cable in opposite direction to the previous layer. This system increases the flexibility of the completed cable and also minimizes the danger of **'bird caging'**, or the opening-up of the strands under a bending or twisting force.

Size of Stranded Conductors

The size of a stranded conductor is determined by the number of strands and the diameter of the individual strands. For example, a 7/0.85 mm cable consists of seven strands of wire, each strand having a diameter of 0.85 mm.

The cross-sectional area will be = $7\times\frac{\pi D^2}{4} = 3.142\times7\times\frac{0.85^2}{4}$ = 4.0 mm^2

Figure 11 Stranded conductor

Cable

A cable is defined in the I.E.E. Regulations as: "A length of insulated single conductor (solid or stranded), or of two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall covering for mechanical protection." A cable consists of two basic parts:

(a) The conductor (b) The insulator.

Construction of Cables

A cable derives its name from the type of insulation used.

Polyvinyl Chloride (P.V.C.) Cable.

This is also known as 'thermo-plastic' cable since the insulation is made from a synthetic resin which softens when heated. The process of manufacture is as follows:

Multi-core Cable.

This is cable which is made up of two or more insulated conductors. Multi-core cable is sheathed in a protective covering— for example, tough rubber for tough rubber-sheathed cables (t.r.s.) and p.v.c. for plastic cables.

Tough-Rubber-Sheathed (t.r.s.) Cable.

This is made of specially toughened rubber which is resistant to acids and alkalies.

Polychloroprene (p.c.p. or neoprene) Cable.

Uses an insulation somewhat similar to that of t.r.s. but capable of withstanding most weather conditions and particularly direct sunlight.

Heat-resisting, Oil-resisting and Flame-retardant (h.o.f.r.) Cables.

These cables are used in conditions damaging to P.V.C. cables such as high temperature and oil. The resistant qualities are developed by a vulcansing (or curing) process which forms an elastomer capable of withstanding tough conditions and still retaining its flexibility.

COMPARISON OF T.R.S. AND P.V.C. CABLE

t.r.s. Cable	*p.v.c. Cable*
Affected by oil and water	Largely unaffected by oil, water, and corrosive chemicals
More flexible	Hardens at low temperatures and softens at high
	temperatures
Must be protected against direct sunlight	Does not support combustion

The maximum operating temperature for both rubber PVC insulated cables is 45°C.

Flexible cable

The I.E.E. Regulations define a flexible cable as: "A cable consisting of one or more cores, each containing a group of wires, the diameters of the wires and the construction of the cable being such as to afford flexibility."

Flexible cord

A flexible cord is defined as: "A flexible cable in which the cross-sectional area of each conductor does not exceed 4 mm^2".

Twisted Twin Flex Cable

This is made up of a multi-strand tinned-copper conductor with silicon rubber insulation. *Application:* lighting flex.

Figure 12 Twisted twin flex.

Circular Flex. The rubber-insulated cores are formed into a circular section with cotton worming and contained in a cotton braiding.

Applications: connections to household appliances (iron boxes, kettles, etc.)

Circular Flex, Rubber Sheathed

This flex is also packed with jute or cotton to form a circular cross-section but an outer sheath of rubber replaces the cotton braiding.

Applications: vacuum cleaner and portable drill leads (3-core).

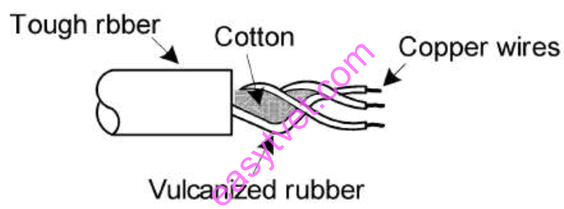


Figure 13 Circular flex, rubber sheathed.

Workshop (or Industrial) Flex

This flex is similar in construction to the above, but has the addition of a compounded braiding. *Application:* connections to industrial lighting.

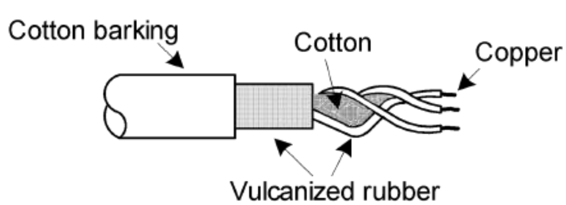


Figure 14 Workshop (or industrial) flex.

Permissible Voltage Drop in Cable.

Voltage drop is an essential feature in the calculation of cable size. Low voltage at the consumer's equipment leads to the inefficient operation of lighting, power equipment, and heating appliances.

The maximum voltage drop allowed between the consumer's terminals and any point in the installation is 2-5 per cent of the voltage supplied by the Electricity Supply Authority, including motor circuits.

Voltage Drop and the I.E.E. **Tables.**

The I.E.E. tables state the voltage drop across a section of cable when maximum current is flowing through it. If the current is halved, the voltage drop will also be halved. For example a 4 mm^2 twin-core cable has a current rating of 24A and a-voltage drop 10 mV per ampere per meter. If the current is halved (to 12 A) the voltage drop will be halved to 5 mV per ampere per meter.

Cable Sizes: Use of I.E.E. Tables

The **I**.E.E. Regulations contain comprehensive information regarding the current-carrying capacity of cables under certain conditions.

These tables supply:

(a) Cross-sectional area, number, and diameter of conductors;

(b) Type of insulation;

(c) Length of run for 1V drop;

(d) Current rating (a.c. and d.c.), for either single or bunched.

The following terms are used in the I.E.E. tables:

(a) Ambient temperature

(b) Rating factor.

Ambient Temperature. This is the temperature of the air surrounding the conductor. The current rating of a cable is decreased as the temperature of the surrounding air increases, and this changed current-carrying capacity can be calculated by using the relevant rating factor.

Rating Factor.

This is a number, without units, which is multiplied with the current to find the new current-carrying capacity as the operating conditions of the cable change. For example, a twin-core 10 mm^2 (7/1.35 mm) PVC cable will carry a maximum current of 40 A at an ambient temperature of 25 °C, but if the ambient temperature is increased to 65 °C the maximum current allowed will now be:

$40A \times 0.44$ (rating factor) = 17.6A

The rating factor is also dependent on the type of excess current protection. If cables are bunched together, their current-carrying capacity will decrease; a rating factor is therefore supplied for the bunching, or grouping, of cables.

Current Density and Cable Size.

The current density of a conductor is the amount of current which the conductor can safely carry without undue heating per unit cross-sectional area. For example, if a copper conductor has a current density of 300 A/cm^2 a copper conductor of cross-sectional 0.5 cm^2 will be capable of carrying one half of 300 A, that is, 150 A.

To calculate the current-carrying capacity of a cable (given cross-sectional area (cm^2) and current density (A/cm^2):

Current-carrying capacity = current density x cross-sectional area

Example.

Calculate the current-carrying capacity of a 0.1 cm^2 conductor if the current density of the conductor is 400 A/cm^2.

Current-carrying capacity = $400A/cm^2 \times 0.1cm^2 = 40$ A

Terminating and Jointing P.V.C. Cables

Stripping P.V.C. Cables.

A single-core PVC. cable should be stripped by holding the cutting knife at an angle to the cable and cutting away from the hand holding the cable. Multi-core cable is stripped by running the cutting knife along the center of the cable and then nicking the end of the cable to give two finger grips. This allows the sheathing to be pulled down the cable with the thumb and forefinger of each hand. The sheath is then folded on top of the cable and cut by drawing the knife between the sheathing and the cable.

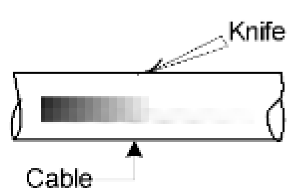


Figure 15 Stripping cable.

There are two basic methods of joining electrical conductors: (a) mechanical joints; and (b) soldered joints.

Mechanical Jointing.

This is done by using connector blocks. These consist of one-way or multi-way brass terminal blocks enshrouded with porcelain or plastic insulation. The connector must be capable of containing all the strands of the conductor.

Another method, usually used with larger cables, is **mechanical crimping**. This is done by placing a sleeve over the conductors to be jointed and crimping (squeezing) the connection with a manual or hydraulically operated crimping jack.

Soldered Joints.

Materials required: pliers, sharp knife, soldering bit, flux, blowlamp (or butane gas cylinder), solder, PVC. tape and black insulating tape.

Soldering Bit. Every joint which is made by twisting strands together must be soldered. Where a lot of single-core jointing is being carried out, it is often convenient to use a heavy bit which has a slot filed in it to take cables. The soldering bit should be heated until a green flame appears and must always be kept clean. Always' tin' the bit with flux and solder before using. *Flux.* The purpose of the flux is to remove the oxide film from the surface of the conductor and prevent it from re-forming.

Blowlamp. This should be operated as follows:

1. The lamp should not be more than two-thirds full.
2. Leave the valve open when starting.
3. Start lamp with small rag dipped in methylated spirits.
4. When the lamp is hot, the valve should be closed and the pump operated.
5. The pump forces the paraffin through the heated vaporizing tube and out of the nozzle where it is ignited under pressure.
6. The blowlamp should be played against an asbestos sheet until the flame is fully established.

Solder. Two basic types of solder are used in electrical work: fine solder (tinman's solder), which is **60** parts tin and **40** parts lead, and plumber's metal, which is **30** parts tin and **70** parts lead. Fine solder melts more easily, as tin has a lower melting point than lead, and so it is commonly used for electrical joints. Plumber's metal is used for 'plumbing' joints in armoured cables, as it remains in a plastic state, allowing it to be shaped, longer than fine solder.

Methods of Soldering.

There are three methods used for soldering conductors:

(a) Soldering bit,

(b) 'Stick' method

(c) (Metal) pot and ladle method.

Soldering Bit. The conductors to be jointed are first smeared with a resinous flux. The tinned bit is then applied under the joint until the heat penetrates it. The stick of solder is then applied to the joint until the solder flows freely through it.

'Stick' Method. In this method, the joint is first heated with a blowlamp, flux being applied. The solder is then applied by pressing the stick of solder against the heated joint until it penetrates the joint. Care should be taken to protect the insulation against the blowlamp flame.

Pot and Ladle Method. This method is commonly used by jointers when jointing heavy conductors. A solder pot is heated until the solder is running freely. The solder should not be overheated as this will burn the tin and a dross will form on the surface of the solder. When the solder has reached working temperature it is taken from the pot with a ladle. The solder is then poured over the prepared joint and is caught by another ladle placed under the joint. This action is repeated until the solder penetrates the joint.

Soldering Aluminium.

The following special points should be noted when soldering aluminium:

i. All surfaces must be scrupulously clean.

ii. When making a joint between stranded conductors ' step' the strands to increase the surface area.

iii. The surface must be heated *before* the flux is applied as the flux will only take when the temperature is high enough.

iv. Apply aluminum solder until the complete surface is bright.

v. Joints in aluminum should be protected from contact with the atmosphere. This can be done by painting, taping, or compounding.

Soldering a Socket (or Lug). The method used is as follows

1. Strip insulation back about 5 cm.
2. Tin the socket.
3. Smear both the socket and the bared conductor with flux.
4. Fit the socket to the conductor. The socket should be a hammer fit.

*If the socket is too large, the conductor can be enlarged with a tinned- wire binding or. Better still, by pressing a strand of cable into the centers of the conductor***.**

5 Play the blowlamp in the top of the socket until the heat has penetrated the conductor, and then apply a stick of solder to the lip of the socket. The completed connection should have a rim of solder showing round the lip the socket; this can be done by applying plumber's metal as the joint is cooling

6 When the termination is cooled, cut back damaged insulation and apply pvc or cambric tape

7 Tape is used to replace insulation which has been removed prior to jointing

Do not attempt to cool a soldered joint by pouring water over it. This can lead to an effect joint known as a dry joint. Never smooth the joint with a file but use a dry cloth before it sets.

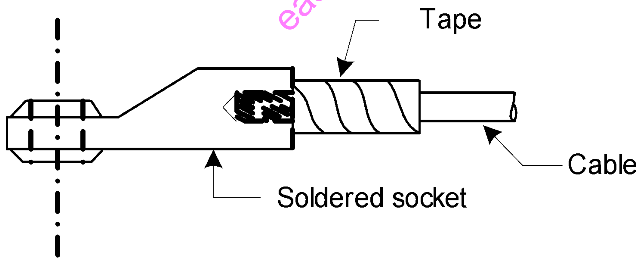


Figure 16 Section through soldered socket

Through joint

This joint is made by using mechanical connectors, compressor ferrules or grip-type (weak back) soldered sleeves.

The completed joint is wrapped with PVC tap. The joint can further be protected by the use of a cold pouring of resin compound to fill the protection box.

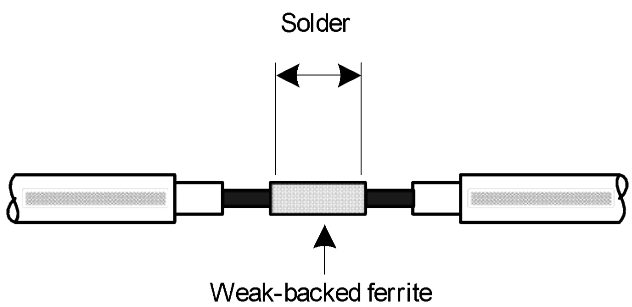


Figure 17 Straight-through joint using weak-backed ferrule

Straight-through joint using weak-backed ferrule

A weak-backed ferrule is a tubular piece of tinned-copper opened along the top and weakened at the bottom thus allowing it to be closed or opened easily.

Procedure of making the joint

1. Strip insulation back from both conductors.
2. Clean and tin ferrule
3. Place ferrule on cable. Butt cables together before tightening the ferrule
4. Wind small pieces of cloth at each end of the ferrule to contain the molten metal
5. Solder the connection
6. Remove damaged insulation and apply tape.

Tee (breeches) Joint

This joint is used to tee-off a service from an armoured cable. The weak-backed ferrule is often used. Mechanical connectors or compression ferrule can also be used

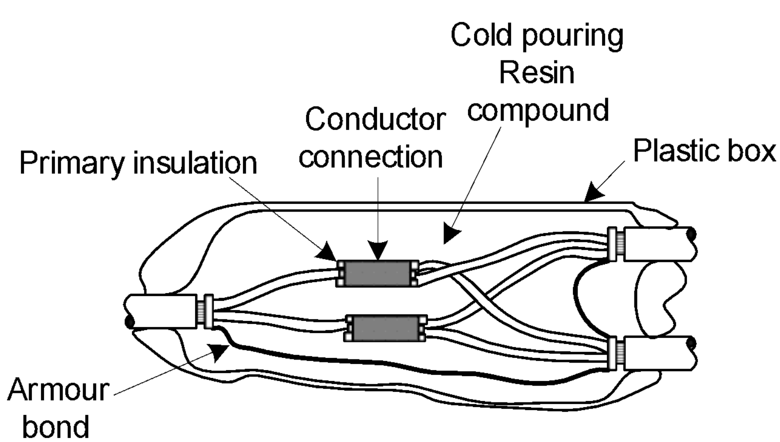


Figure 18 Tee (breeches) joint

Armoured cable

This cable is used where there is a likelihood of the insulation or conductor being subjected to mechanical damage. This can occur when the cable is run underground.

There are two main types of armoured cables:

a) Paper insulated lead covered steel wire or steel tape armoured cables, abbreviated as P.I.L.C.S.W.A. and P.I.L.C.S.T.A cables respectively
b) P.V.C.armoured cable

P.I.L.C.S.W.A.

The cable has the following parts

(a) An inner core of jute used to keep the cable circular.
(b) Copper or aluminium conductors insulated with mineral oil-impregnated paper.
(c) A lead sheath which contains the insulation and is also used as an earth continuity conductor
(d) Jute bedding tape impregnated with bitumen that protects the lead from armoring
(e) Galvanized steel wire (one layer) or steel tape (two layers).
(f) Bitumen impregnated jute serving

Termination of P.I.L.C.S.W.A. cable

1. Place binder 1m from end of cable
2. Remove serving to this point
3. Bend steel wire armoring back until it is clear to lead sheath
4. Remove about 13cm of lead sheath and clean the remainder
5. Place brass gland on cable, leaving approximately 10cm of lead sheath showing. Wedge gland with wood to keep it central on cable
6. Use plumber's metal to plumb the joint
7. Clean galvanized wire paraffin rag and shape the wire over the plumb
8. Clamp wires on the gland and bolt the gland on sealing chamber
9. Cut back paper insulation on conductors and make through-joint to V.R.I conductors, using weak-back ferrule
10. Assemble sealing chamber and pour in hot bitumen to seal oil-impregnated paper against moisture

P.V.C. Armoured Cable

This is made up of p.v.c insulated cores packed with p.v.c. to give a circular cross section. An outer p.v.c. sheath covers the galvanized steel wire.

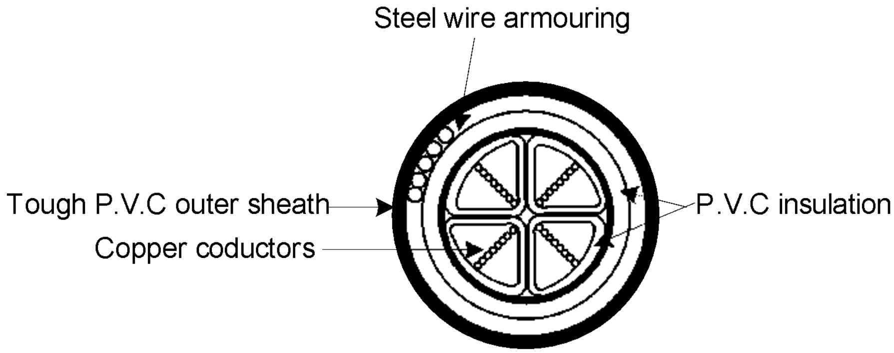


Figure 19 P.V.C Armoured cable

Termination of P.V.C. armoured cable

The following must be taken into consideration when terminating

(a) P.V.C. must be protected from heat

(b) P.V.C. tapes must be used for insulating the conductors

(c) Care must be taken when clamping and cleaning the galvanized wire so that it is not broken as it is the sole earth continuity conductor

(d) The temperature of the hot pouring compound should not melt the p.v.c. insulation of conductors. Dip a piece of scrap p.v.c. into the compound before pouring to test the temperature.

Mineral Insulated Metal Sheathed (M.I.M.S.) Cable

This cable consists of three parts. These are:

Copper or aluminium conductors

Each core consists of a single copper conductor. Common core numbers are 1,2,3,4 and 7

Insulation

The insulation between the cores is magnesium oxide. It can withstand high temperatures but is absorbent to moisture

Outer sheath

Is a seamless copper or aluminium tube

ADVANTAGES AND DISADVANTAGES OF M.I.M.S. CABLE

Advantages	Disadvantages
Heat resistant. Can withstand temperatures up to 250^{0}C	Expensive
The sheath provides an excellent earth continuity conductor	Termination takes time
Is mechanically strong must be protected against shape edges	Has greater voltage drop per metre at the same current rating
High current density	
Does not deteriorate with age	

WIRING SYSTEM

As defined in level one, a wiring system is a system of cables, accessories and protective devices that make a complete electrical system is premises (domestic, commercial or industrial).

Conduit installations

A conduit is a tube, channel or pipe in which insulated conductors are contained. The conduit, in effect, replaces the PVC outer sheath of a cable, providing mechanical protection for the insulated conductors. A conduit installation can be rewired easily or altered at any time, and this flexibility, coupled with mechanical protection, makes conduit installations popular for commercial and industrial applications. There are three types of conduit used in electrical installation work: steel, PVC and flexible.

Steel Conduit Wiring System

Steel conduits are made to a specification defined by BS 4568 and are either heavy gauge welded or solid drawn. Heavy gauge is made from a sheet of steel welded along the seam to form a tube and is used for most electrical installation work. Solid drawn conduit is a seamless tube which is much more expensive and only used for special gas-tight, explosion-proof or flameproof installations. Conduit is supplied in 3.75 m lengths. Steel conduit system offers the highest mechanical protection of all the wiring systems. They are available in the diameters of 16mm, 20mm, 25mm, and 32mm. The most commonly used is 20mm. Steel conduits come in varieties. These include; welded, solid drawn, black enamel and galvanized. Welded conduit has a welded seam along its entire length. This seam is almost invisible as the whole conduit is usually painted. It is the cheapest type of steel conduit. Solid drawn conduit is seamless and is used in situations where the installation is required to be gas tight and flame proof, for instance at petrol stations. Black enamel is a paint that is applied in most conduits. Galvanised steel conduits are used where dampness or steam is present. Conduit boxes make a major part of the system. They are made of steel with knock-outs for conduit entry. The boxes accommodate switches, socket outlets and other accessories. Metal conduits are threaded with stocks and dies and bent using special bending machines. The metal conduit is also utilized as the CPC and, therefore, all connections must be screwed up tightly and all burrs removed so that cables will not be damaged as they are drawn into the conduit. Metal conduits containing a.c. circuits must contain phase and neutral conductors in the same conduit to prevent eddy currents fl owing, which would result in the metal conduit becoming hot (Regulations 521.5.2, 522.8.1 and 522.8.11).

Tools

Apart from the electrician's ordinary tools such as rule, hacksaw, hammer, screwdrivers and pliers, it is necessary to have stocks and dies, file or reamer, bending machine and a pipe vice. For 16mm and 20mm conduit, the small stocks are available, but for 25mm and 32mm the medium stocks should be used. Stocks and dies for threading conduits should be clean, sharp and well lubricated, and should be rotated with a firm and steady movement. To get the best results stocks and dies should be of the self-clearing pattern to prevent soft swarf from clogging the chasers. Worn out dies and guides should always be replaced when showing signs of wear, otherwise the workmanship will suffer as a result of bad threads. Ratchet operated stocks and dies are available which are useful for the larger thread sizes and there are also powered conduit threading machines which offer certain advantages on a conduit installation where considerable amount of large conduit is being installed.

Conduit Bending

Regulations require that the minimum radius of a bend should be 2.5 times the outside diameter of the conduit. A pipe bender machine or a wooden block is used for bending. Before installation, all ends of conduits threaded conduits have to be fully installed before cables are drawn into them. Running couplers are used to join two conduits together

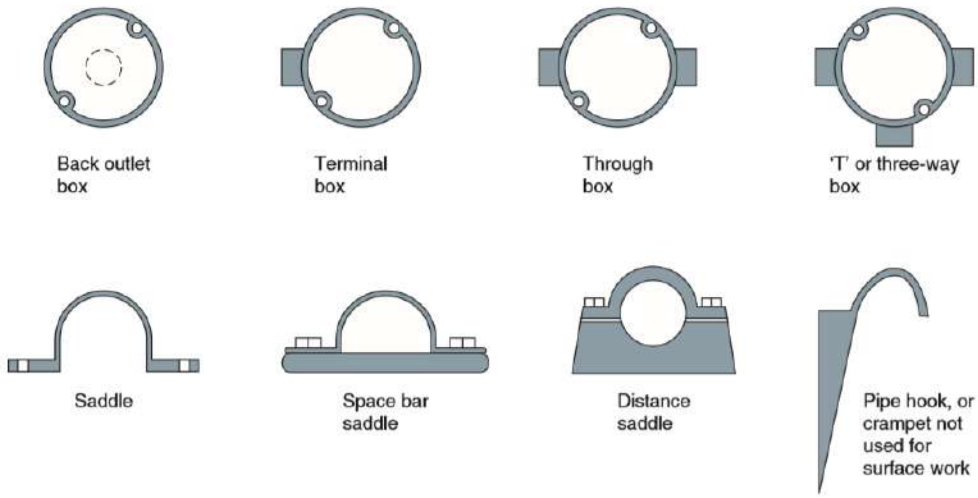
Conduit cutting

Conduit should be cut with a hacksaw. The ends of all conduits must be carefully reamed inside the bore with a file, or reamer to be certain that no sharp edges are left which might cause damage to the conductors when they are being drawn in. The reaming should be carried out after the threading has been completed.

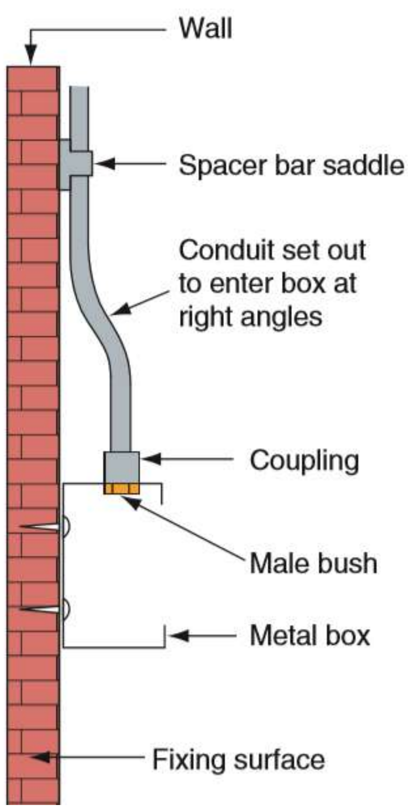
Checking Conduits for obstructions

When the length of conduit has been removed from the pipe vice, it is advisable to look through the bore to ensure that there are no obstructions. Some foreign objects such as stones may have entered the conduit during storage. If such obstructions are not detected before installation of the conduit considerable difficulty may be experienced when the conductors are being drawn in.

Fixing Conduits on Masonry or Wooden Surfaces



The method employed for fixing a conduit depends upon what the conduit has to be fixed on to. Some of the methods include



1) Distance Saddles

Distance saddles are most commonly used and are fixed by means of screwing into the wall or other surfaces. They are designed to space conduits approximately 10mm from the wall or ceiling. Distance saddles are generally made of malleable cast iron.

2) Spacer Bar Saddles

These are ordinary saddles mounted on a spacing plate. The spacing plate is approximately of the same thickness as the switches, sockets and other conduit fittings and therefore, serves to keep the conduit straight where it leaves these fittings. The purpose of the spacer bar saddle is to prevent the conduit from making contact with the plaster and cement walls and ceilings which could result in corrosion of the conduit.

3) Ordinary Saddles

These saddles are not extensively used. Fixing is by means of two screws. They provide a secure fixing and should be spaced not more than 1.3m apart.

4) Multiple Saddles

These are used where two or more conduits follow the same route. The proper method is for the conduits to be spaced so that when they enter conduit fittings there is no need to set the conduit. An alternative means of running two or more conduits together is to stagger the saddle positions, allowing the conduits to be placed closer together.

PVC Conduit

PVC conduit used on typical electrical installations is heavy gauge standard impact tube manufactured to BS 4607. The conduit size and range of fittings are the same as those available for metal conduit. PVC conduit is most often joined by placing the end of the conduit into the appropriate fitting and fixing with a PVC solvent adhesive. PVC conduit can be bent by hand using a bending spring of the same diameter as the inside of the conduit. The spring is pushed into the conduit to the point of the intended bend and the conduit then bent over the knee. The spring ensures that the conduit keeps its circular shape. In cold weather, a little warmth applied to the point of the intended bend often helps to achieve a more successful bend.

The advantages of a PVC conduit system are that it may be installed much more quickly than steel conduit and is non-corrosive, but it does not have the mechanical strength of steel conduit. Since PVC conduit is an insulator it cannot be used as the CPC and a separate earth conductor must be run to every outlet. It is not suitable for installations subjected to temperatures below 25°C or above 60°C. Where luminaires are suspended from PVC conduit boxes, precautions must be taken to ensure that the lamp does not raise the box temperature or that the mass of the luminaire supported by each box does not exceed the maximum recommended by the manufacturer (IEE Regulations 522.1 and 522.2). PVC conduit also expands much more than metal conduit and so long runs require an expansion coupling to allow for conduit movement and help to prevent distortion during temperature changes. All conduit installations must be erected first before any wiring is installed (IEE Regulation 522.8.2). The radius of all bends in conduit must not cause the cables to suffer damage, and therefore the minimum radius of bends given in Table 4E of the On

Site Guide applies (IEE Regulation 522.8.3). All conduits should terminate in a box or fitting and meet the boxes or fittings at right angles. Any unused conduit-box entries should be blanked off and all boxes covered with a box lid, fitting or accessory to provide complete enclosure of the conduit system. Conduit runs should be separate from other services, unless intentionally bonded, to prevent arcing occurring from a faulty circuit within the conduit, which might cause the pipe of another service to become punctured. Cables should be fed into the conduit in a manner which prevents any cable crossing over and becoming twisted inside the conduit. The cable insulation must not be damaged on the metal edges of the draw-in box. Cables can be pulled in on a draw wire if the run is a long one. The draw wire itself may be drawn in on a fish tape, which is a thin spring steel or plastic tape. A limit must be placed on the number of bends between boxes in a conduit run and the number of cables which may be drawn into a conduit to prevent the cables being strained during wiring.

Flexible Conduit

Flexible conduit manufactured to BS 731-1: 1993 is made of interlinked metal spirals often covered with a PVC sleeving. The tubing must not be relied upon to provide a continuous earth path and, consequently, a separate CPC must be run either inside or outside the flexible tube (Regulation 543.2.1). Flexible conduit is used for the final connection to motors so that the vibrations of the motor are not transmitted throughout the electrical installation and to allow for modifications to be made to the final motor position and drive belt adjustments.

Conduit runs to outlets in walls

Sockets near skirting level should preferably be fed from the floor above rather than the floor below.

When the conduit is run to a switch and other positions in walls it is usually run in a chase in the wall. These chases must be deep enough to allow at least 10mm of cement and plaster covering. Steel conduits buried in plaster should be given a coat of protective paint, or should be galvanised if the extra cost is justified. Make sure that the plaster is finished neatly round the outside edges of flush switch and socket boxes; otherwise the cover plates may not conceal any deficiencies in the plaster finish. When installing flush boxes before plastering, it is advisable to stuff the boxes with paper to prevent their being filled with plaster.

Space factor

Regulations require that for groups of mixed diameter cables, a space factor of 40% should not be exceeded. This means that only 40% of the conduit diameter should be used.

Other relevant regulations

1. There should not be more than two, 90^0 bends in one conduit run.
2. All conductors of alternating current circuit should be contained in the same conduit. This is to prevent out of balance magnetic fields from setting up eddy currents.
3. The steel conduit can be used as an earth continuity conductor. Therefore no separate earth conductor is required.

Installation of steel wire armoured cable

These cables are used extensively for main cables and distribution circuits and also for circuit wiring in industrial installations. The cables consist of multi-core pvc sheath and steel wire armouring (SWA) and pvc sheathed overall.

Important Consideration

- Thermo-plastic insulation will sustain serious damage if subjected to temperatures over 70^0 C for a prolonged period, therefore proper protection against sustained overloads is required.
- The insulation will harden, and become brittle in temperatures, below 1^0 C, therefore the cables should not be installed or handled when temperatures are approaching freezing, otherwise the insulation may tend to split

Termination of Armoured Cable.

An armoured cable also known as steel wire armoured (SWA) cable is designed to carry power for underground systems. The steel wires are used to provide mechanical protection and serve as earth conductors.

The cable gland used for terminating an armoured cable is as shown in figure 20 below.

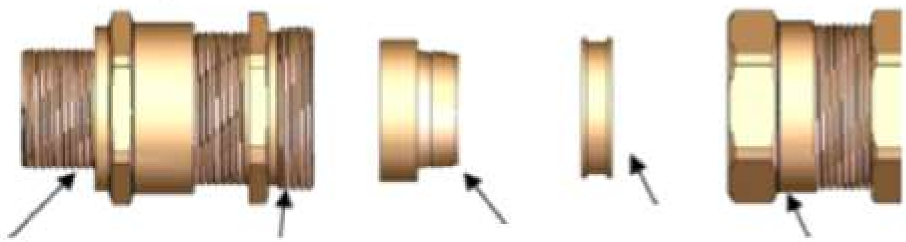


Figure 20 Exploded view of armoured cable gland

Procedure of Termination of Armoured Cable

1. Fit the shroud over the outer sheath and remove the cable outer sheath and the armour to suit the equipment. Remove a further 18mm of outer sheath to expose the armour. Remove any tapes or wrappings to expose cable inner sheath. Separate the gland into the assemblies "A and B". Ensure the outer seal is relaxed and pass the sub assembly "B" over the cable outer sheath and armour followed by the clamping ring "R". For large cable sizes the clamping ring may only pass over the armour.
2. Fix the detachable armour cone(C) in the recess of sub-assembly "A". Pass the cable through sub-assembly "A" and evenly space the armour around the cone.
3. Hold the main item with a spanner as you tighten sub-assembly "B" onto sub-assembly "A". Make sure that the two components have metal-to-metal contact. Disconnect sub-assembly "B" from sub-assembly "A".
4. Ensure that the inner seal is relaxed and secure sub-assembly "A" into the equipment as indicated.
5. Pass the cable through sub-assembly "A" and tighten the main item by hand until you get heavy resistance. Turn further a full turn with a spanner
6. Hold the main item with a spanner then retighten sub-assembly "B" onto sub-assembly "A".
7. Tighten the outer seal nut until either :

The outer seal nut makes a metal to metal contact with the gland body or

The outer seal nut cannot be further tightened because it is fully engaged.

Cable tray installations

Cable tray is a sheet-steel channel with multiple holes. The most common finish is hot-dipped galvanized but PVC-coated tray is also available. It is used extensively on large industrial and commercial installations for sup-porting MI and SWA cables which are laid on the cable tray and secured with cable ties through the tray holes. Cable tray should be adequately supported during installation by brackets which are appropriate for the particular installation. The tray should be bolted to the brackets with round-headed bolts and nuts, with the round head inside the tray so that cables drawn along the tray are not damaged. The tray is supplied in standard widths from 50 to 900 mm, and a wide range of bends, tees and reducers is available. The tray can also be bent using a cable tray bending machine to create bends such as that shown in figure 21. The installed tray should be securely bolted with round-headed bolts where lengths or accessories are attached, so that there is a continuous earth path which may be bonded to an electrical earth. The whole tray should provide a firm support for the cables and therefore the tray fixings must be capable of supporting the weight of both the tray and cables.

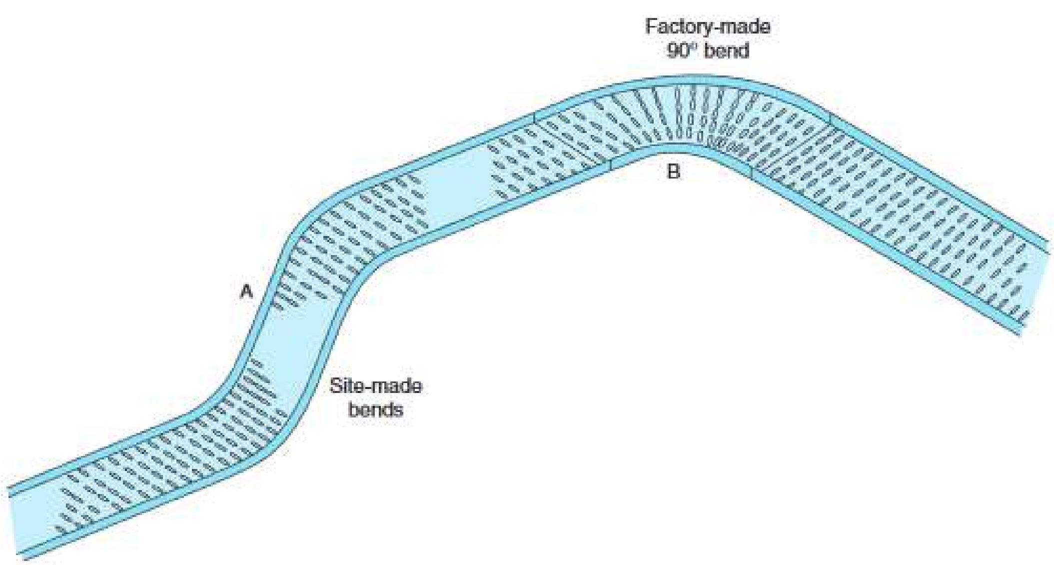


Figure 21 Cable tray with bends.

Types of Cable Trays

Several types of tray are used in different applications. A solid-bottom tray provides the maximum protection to cables, but requires cutting the tray or using fittings to enter or exit cables. A deep, solid enclosure for cables is called a cable channel or cable trough. A ventilated tray has openings in the bottom of the tray, allowing some air circulation around the cables, water drainage, and allowing some dust to fall through the tray. Small cables may exit the tray through the ventilation openings, which may be either slots or holes punched in the bottom. A ladder tray has the cables supported by a traverse bar, similarly to the rungs of a ladder, at regular intervals on the order of 4 to 12 inches (100 to 300 mm).

Ladder and ventilated trays may have solid covers to protect cables from falling objects, dust, and water. Tray covers for use outdoors or in dusty locations may have a peaked shape to shed debris including dust, ice or snow. Lighter cable trays are more appropriate in situations where a great number of small cables are used, such as for telephone or computer network cables. These trays may be made of wire mesh, called "cable basket", or be designed in the form of a single central spine (rail) with ribs to support the cable on either side. Channel Tray provides an economical support for cable drops and branch cable runs from the backbone cable tray system. Channel cable tray is used for installations with limited numbers of tray cable when conduit is undesirable. Large power cables laid in the tray may require support blocks to maintain spacing between conductors, to prevent overheating of the wires. Smaller cables may be laid unsecured in horizontal trays, or secured with cable ties to the bottom of vertically mounted trays. To maintain support of cables at changes of elevation or direction of a tray, a large number of specialized cable tray fittings are made compatible with each style and manufacturer. Horizontal elbows change direction of a tray in the same plane as the bottom of the tray and are made in 30, 45 and 90 degree forms; inside and outside elbows are for changes perpendicular to the tray bottom. These can be in various shapes including tees and crosses. Some manufacturers and types provide adjustable elbows, useful for field-fitting a tray around obstacles or around irregular shapes. Various clamping, supporting and splicing accessories are used with the cable tray to provide a complete functional tray system. For example, different sizes of cable tray used within one run can be connected with reducers

Metallic cable trays

The trays provide a safe open solution for routing cables and wires. Cable trays can be mounted onto a wall or suspended from a ceiling to provide a track that allows cables and wires to be routed around a building in an easily maintainable manner. Often made of galvanized or stainless steel cable trays not only provide a perfect cable management solution but also look aesthetically pleasing in any environment. Cable trays are available in three types, from light duty through to heavy duty; each system is supported by a fully integrated range of time saving fixings and fittings Suitable for installations in retail, industrial and offshore environments.

Trunking installations

A trunking is an enclosure provided for the protection of cables which is normally square or rectangular in cross-section, having one removable side. Trunking may be thought of as a more accessible conduit system and for industrial and commercial installations it is replacing the larger conduit sizes. A trunking system can have great flexibility when used in con-junction with conduit; the trunking forms the background or framework for the installation, with conduits running from the trunking to the point controlling the current-using apparatus. When an alteration or extension is required it is easy to drill a hole in the side of the trunking and run a conduit to the new point. The new wiring can then be drawn through the new conduit and the existing trunking to the supply point Trunking is supplied in 3 m lengths and various cross-sections measured in millimeters from 50 50 up to 300 150. Most trunking is available in either steel or plastic.

Metallic Trunking

Metallic trunking is formed from mild steel sheet, coated with grey or silver enamel paint for internal use or a hot-dipped galvanized coating where damp conditions might be encountered and made to a specification defined by BS EN 500 85. A wide range of accessories is available, such as 45° bends, 90° bends, Tee and four-way junctions, for speedy on-site assembly. Alternatively, bends may be fabricated in lengths of trunking, as shown in Figure 22. This may be necessary or more convenient if a bend or set is non-standard, but it does take more time to fabricate bends than merely to bolt on standard accessories.

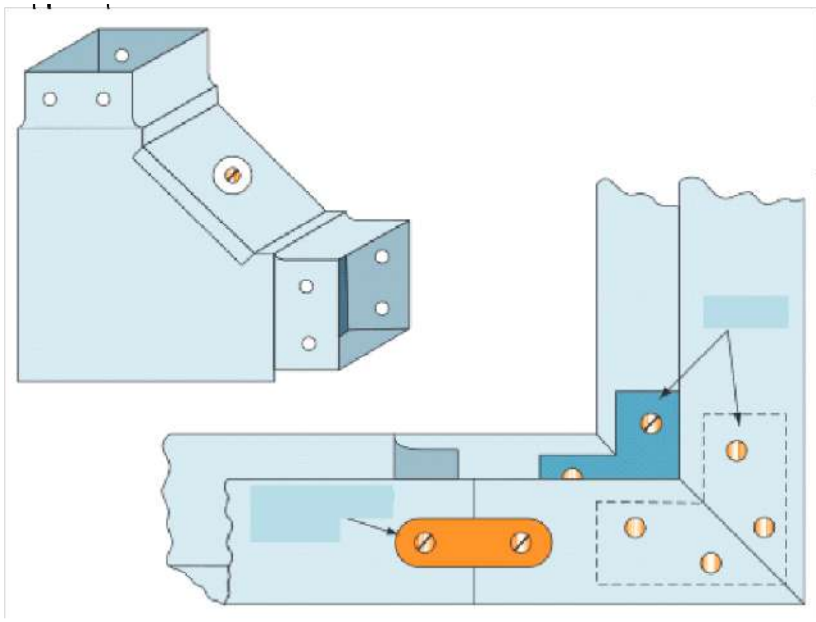


Figure 22 Trunking bends

When fabricating bends the trunking should be supported with wooden blocks for sawing and fi ling, in order to prevent the sheet-steel vibrating or becoming deformed. Fish plates must be made and riveted or bolted to the trunking to form a solid and secure bend. When manufactured bends are used, the continuity of the earth path must be ensured across the joint by making all fixing screw connections very tight, or fitting a separate copper strap between the trunking and the standard bend. If an earth continuity test on the trunking is found to be unsatisfactory, an insulated CPC must be installed inside the trunking. The size of the protective conductor will be determined by the largest cable contained in the trunking as per the IEE Regulations. If the circuit conductors are less than 16 mm^2, then a 16 mm^2 CPC will be required.

Non-Metallic Trunking

Trunking and trunking accessories are also available in high-impact PVC. The accessories are usually secured to the lengths of trunking with a PVC solvent adhesive. PVC trunking, like PVC conduit, is easy to install and is non-corrosive. A separate CPC will need to be installed and non-metallic trunking may require more frequent fixings because it is less rigid than metallic trunking. All trunking fixings should use round-headed screws to prevent

damage to cables since the thin sheet construction makes it impossible to countersink screw heads.

Mini-Trunking

Mini-trunking is very small PVC trunking, ideal for surface wiring in domestic and commercial installations such as offices. The trunking has a cross-section of $16 \times 16\ mm$, $25 \times 16\ mm$, $38 \times 16\ mm$ **or** $38 \times 25\ mm$ **and is ideal for switch drops or for housing auxiliary circuits such as telephone or audio equipment wiring. The modern square look in switches and socket outlets is complemented by the mini-trunking which is very easy to install (see Figure 23).**

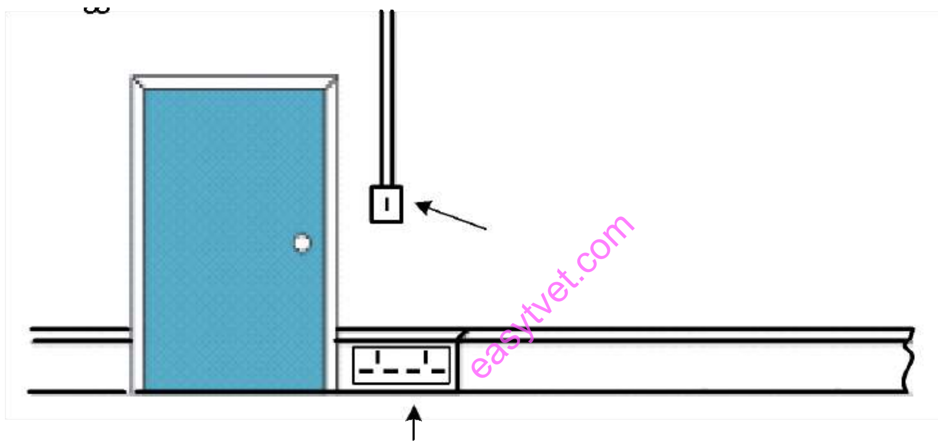


Figure 23 Typical installation of skirting trunking and mini-trunking.

Skirting Trunking

Skirting trunking is a trunking manufactured from PVC or steel and in the shape of a skirting board is frequently used in commercial buildings such as hospitals, laboratories and offices. The trunking is fitted around the walls of a room at either the skirting board level or at the working surface level and contains the wiring for socket outlets and telephone points which are mounted on the lid, as shown in Figure 23. Where any trunking passes through walls, partitions, ceilings or floors, short lengths of lid should be fitted so that the remainder of the lid may be removed later without difficulty. Any damage to the structure of the buildings must be made good with mortar, plaster or concrete in order to prevent the spread of fire. Fire barriers must be fitted inside the trunking every

5 m, or at every floor level or room dividing wall, if this is a shorter distance. Where trunking is installed vertically, the installed conductors must be supported so that the maximum unsupported length of non-sheathed cable does not exceed 5 m. PVC insulated cables are usually drawn into an erected conduit installation or laid into an erected trunking installation. Where a cable enclosure greater than 32 mm is required because of the number or size of the conductors, it is generally more economical and convenient to use trunking.

Final Circuits

Definition

A final sub-circuit is an outgoing circuit connected to a distribution board and intended to supply electrical energy to current-using apparatus, either directly or through socket outlets or fused spur-boxes.

Examples of final sub-circuits includes; lighting, socket-outlets, cooker and water heater. A final sub-circuit originates from the consumer control unit (CCU) or distribution board (DB). Each final sub-circuit is protected by an appropriate fuse or circuit breaker mounted in the consumer control unit.

IEE Regulations

i) Where an installation comprises more than one final sub-circuit, each shall be connected to a separate way in a distribution board.
ii) The wiring of each final sub-circuit shall be electrically separate from that of every other final sub-circuit.to facilitate disconnection of each final sub-circuit for testing.
iii) Every final sub circuit shall have means of protection against excess current
iv) The neutral conductor shall never be connected in the same order as that in which the live conductors are connected to the fuses or circuit breakers.
v) The neutral conductor shall never be connected to fuses, switches or circuit breakers.

Requirements for the consumer intake point

The IEE regulations requires that, every consumer's installation shall be adequately controlled by a switchgear readily accessible to the consumer which shall incorporate-

i) Means of isolating all the conductors of the installation of the premises from the supply.

ii) Means of excess current protection.

iii) Means of earth leakage protection.

Sequence of control

The sequence of the equipment forming the switchgear required shall be such that the means of isolation follows the consumer's terminals without the intervention of any other apparatus as shown in figure 24

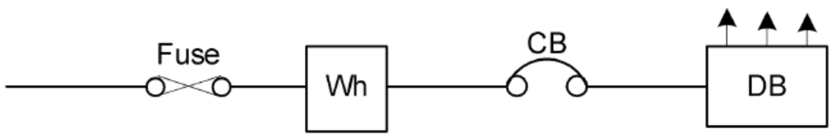


Figure 24 Sequence of control

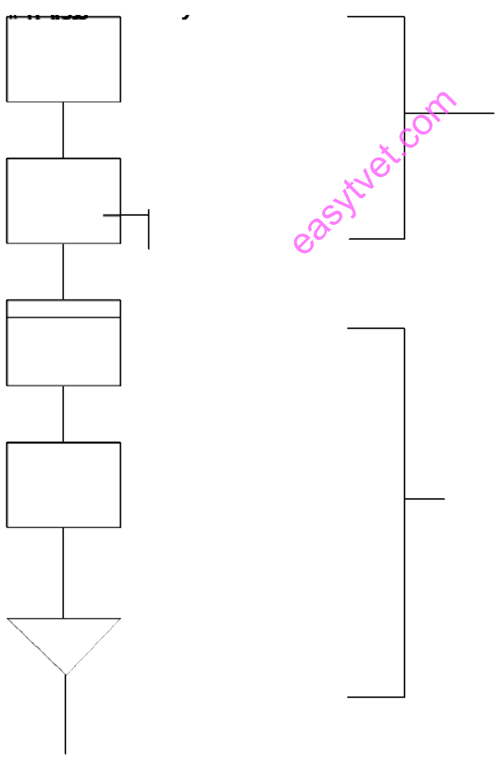


Figure 25 Single line diagram for the equipment at the consumer intake point

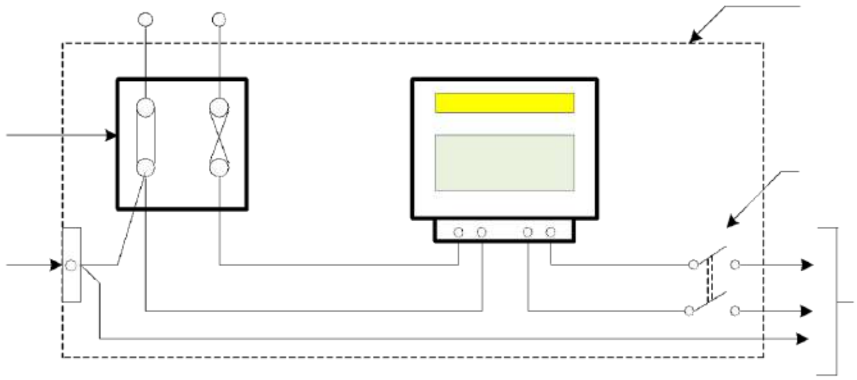


Figure 26 Circuit diagram for the equipment at the consumer intake point

Meter boxes can be mounted on the wooden /masonry surfaces or chased walls. When mounting a meter box, make sure that it is at the correct height which is reachable by a person standing on the ground. This is to make it easily accessible for energy meter reading, any repairs and replacements.

I.E.E regulations

i) Every consumer's installation shall have a means of isolation
ii) Every consumer's installation shall have a means of excess current protection.
iii) Every consumer's installation shall have a means of earth leakage protection.
iv) Where a consumer's installation comprises installation in two or more detached buildings, separate means of isolation shall be provided.
v) Every means of excess current protection shall be suitable for the maximum short-circuit current attainable.

Need For Switching

i. Used to put a circuit in use or out of use.
ii. Emergency switching.
iii. Isolating a circuit from the supply for maintenance.

Types of switches

1. Single pole switch
2. Double pole switch
3. Triple pole switch.

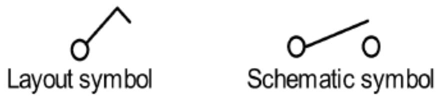
I.E.E regulation on switches

i) All single pole switches should always be connected in the live (phase) conductor only.

ii) Fuses shall also be inserted in the live only.

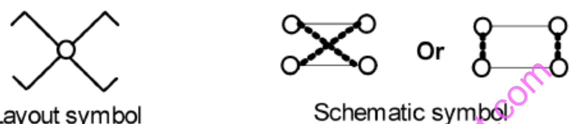
Types of single pole switches

1. One-way switch - This has one path only for current.



2. Two-way switch - This has two alternative paths for current (change over switch).

3. Intermediate switch – This has two double alternative current paths.



<u>Switching of lighting points</u>

One-way switching.

In the one-way switching, the lamp or set of lamps is switched from one particular point. An example is the switching at the entry of a room with one entry only.

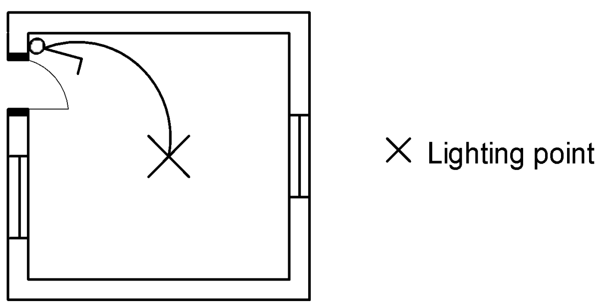


Figure 27 Layout of one room with one-way switching arrangement.

The ON and OFF control of the lighting point is only at one position.

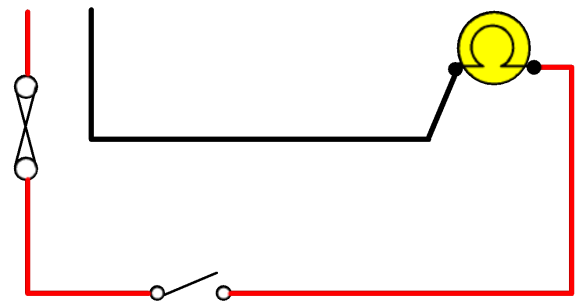


Figure 28 Schematic diagram showing one-way switch controlling one lamp.

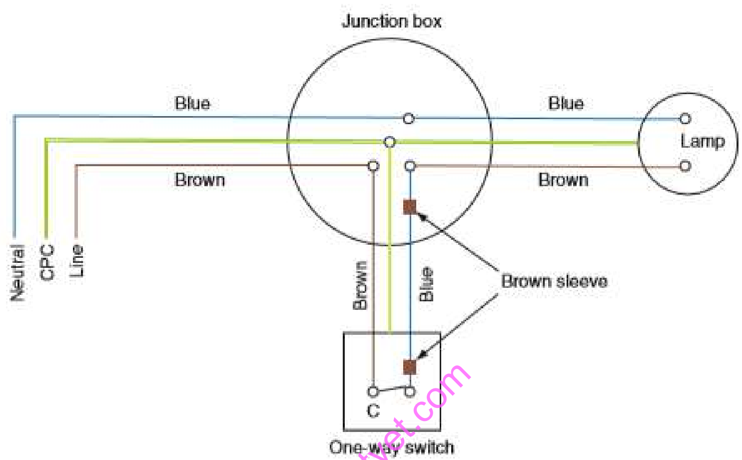


Figure 29 One way switching using a joint box

Two – Way Switching

Where it becomes necessary to have the lamp or set of lamps switched from two separate positions. An example is a long corridor or in a room with two entries.

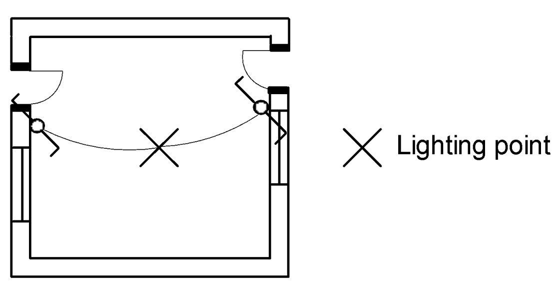


Figure 30 Layout of two-way switching arrangement.

The ON and OFF control of the lighting point is from two positions.

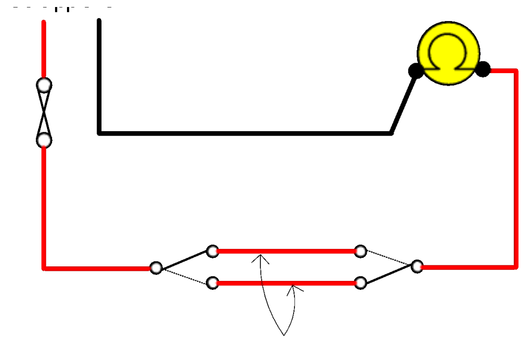


Figure 31 Schematic diagram showing two-way switch controlling lighting point.

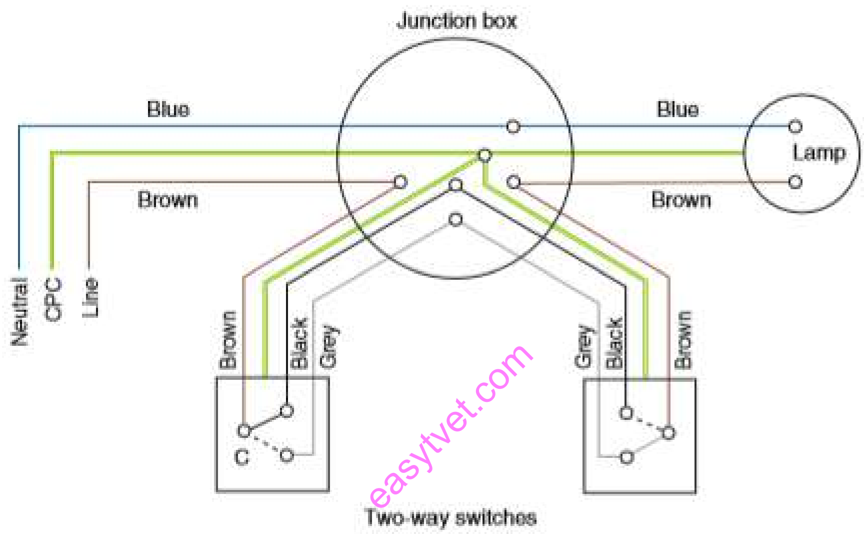


Figure 32 Two way switching using a joint box

Intermediate switching

This is used in conjunction with the *Two-way* switching where the switching of the lamps is from more than two points. All the other points of switching between the two two-way switches will be fitted with intermediate switches. An example of lamp controlled from THREE positions is shown in figure 33.

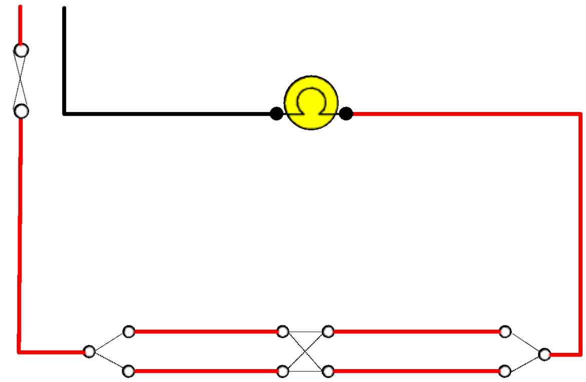


Figure 33. Intermediate switching

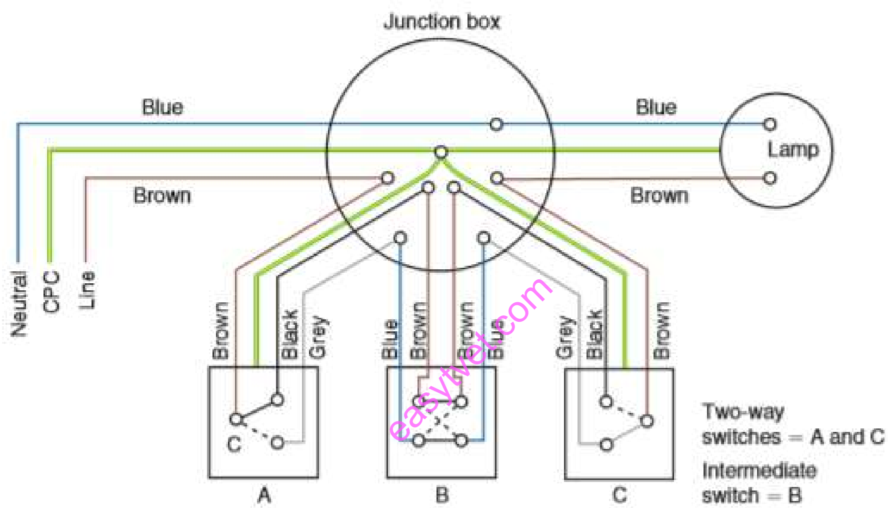


Figure 34 Intermediate switching using a joint box

Note

A lamp or set of lamps may be controlled from any number of positions provided we have 2 two-way switches and the rest of the switches been intermediate

Types of circuit connections

1. Series connection
2. Parallel connection

Series Connection

The current using equipment are connected in series or one after the other. One end of the equipment is connected to the other end *(End to End)* in series connection, the current flowing is the same and the voltage a cross each equipment will depend on the rating and its resistance

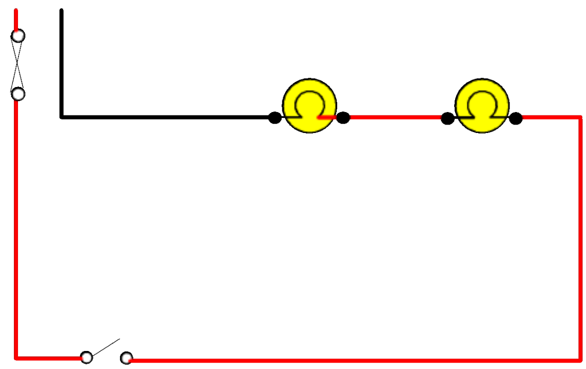


Figure 35 Series connection

The supply voltage is dropped individually across each lamp and depending on the ratings the voltage across each equipment will vary but the current flowing through all the equipment is the same. That is, if two lamps of equal resistance are connected in series to a $240\ V$ supply, the voltage which will appear across each lamp will be $120\ V$ and the current will be the same in all lamps

N.B

The lamps in above example may not produce light or be dim because the light produced is equal to

$$Power = V^{2/R}$$

And, V is below rated voltage

For a series connection to work, all lamps have to be good working condition in order to provide continuity of the circuit.

Disadvantages of series

1. If one lamp blows, all lamps go off.
2. Lamps will be dim (will not produce enough light) or may fail to light
3. Not reliable- Therefore for practical purposes series circuits are not used

Parallel connection

This is the most common arrangement for lighting circuits. All lamps are connected across the supply and each lamp receives the supply voltage a cross it. Each lamp can be controlled separately. If one lamp blows out, all the other will continue working.

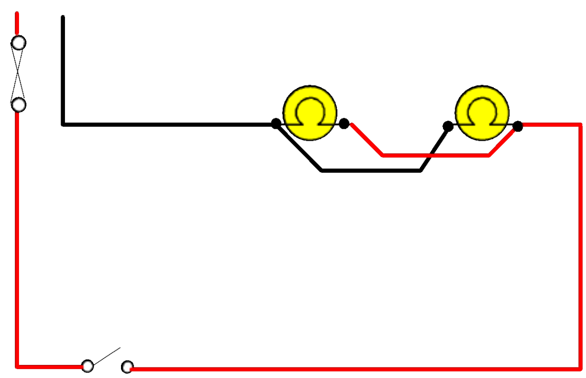


Figure 36 Parallel connection

Note:

If separately controlled, all switches are to be connected in the live conductor and that no wire goes directly to the lamp bypassing the switch.

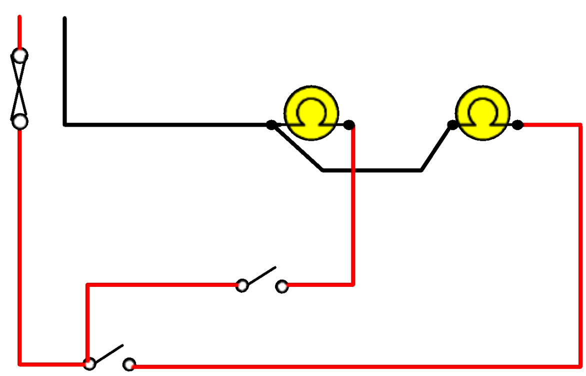


Figure 37. Separately controlled lamps

Advantages of parallel

i) All lamps receives rated voltage

ii) All lamps are bright
iii) If one lamp fails , other will not be affected
iv) Lamps can be controlled individually (separately)

Looping-In System

Looping-in of wires helps in saving materials and provides a clean piece of work. Looping – in can be done at:

i) Switches
ii) Lamp Holders
iii) Junction Boxes
iv) Ceiling Roses

If more than one lamp are to be switched from the same switch, it becomes cheaper to loop-in at the lamp holder for the second lamp. Figure 38 shows the theoretical diagram of a final sub-circuit of seven lamps, two controlled separately by 1-way switches, three controlled as a group by a 1-way switch, and two controlled by a 1-way switch. If the circuit were to be wired exactly as in the diagram, a large number of joints would be necessary. Figure 39 shows the same circuit as wired by the looping-in system. No joints are required except dry twisted joints in the terminals of the two-plate ceiling roses and of the single-pole one-way switches.

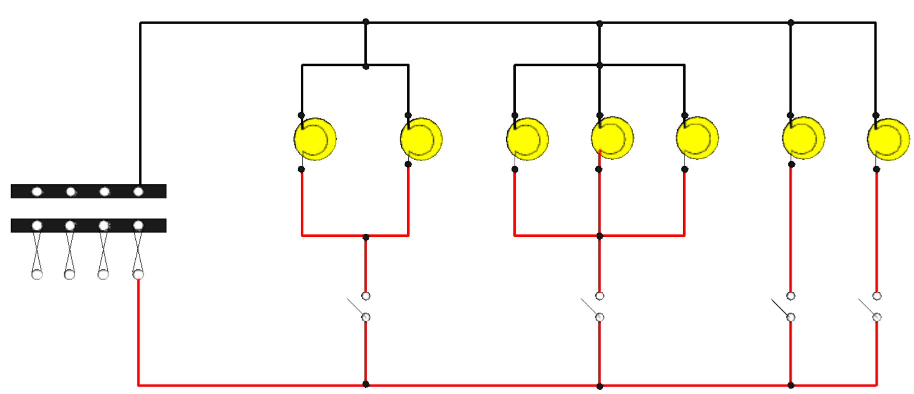


Figure 38 Control of lamps

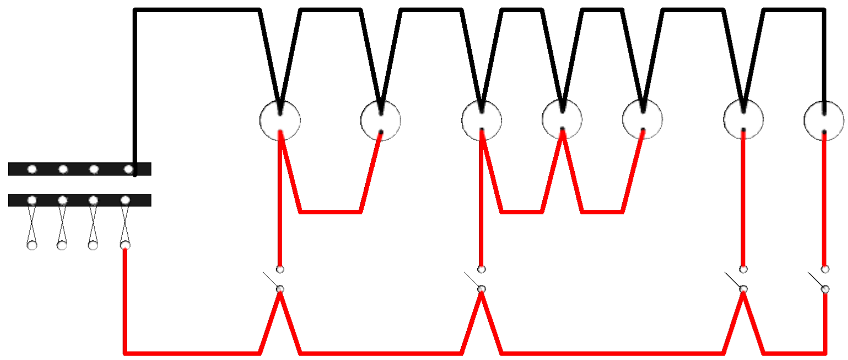


Figure 39 Looping in system

Looping in from a switch.

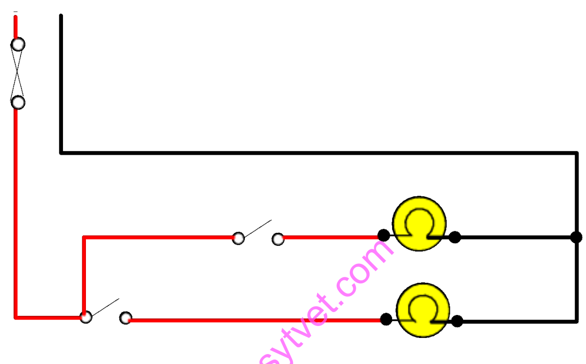


Figure 40 looping in from switch

In this system the Live to switch S_2 is normally looped from S_1.

Looping-in from a three plate ceiling rose

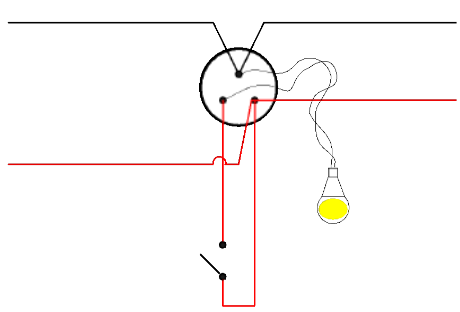


Figure 41. Looping in from ceiling rose

A ceiling rose must not be connected in such a manner that one that one terminal remains alive when the associated switch is OFF, unless that terminal cannot be touched when the ceiling rose is partially dismantled to allow flexible cord replacement.

Looping-in at Junction Boxes

In this method, all the circuit wires are brought to a common Box and distributed to the switches, ceiling roses, lamp holder's e.t.c.

This method of lopping in is only used where there are few lamps and more so where there is service wiring using twin core cables.

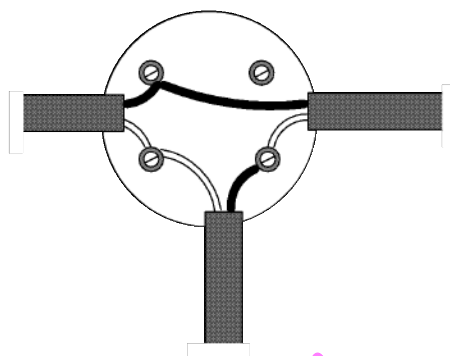


Figure 42 Looping in at joint box

Colour identification of cables

Single phase

Live -	Red
Neutral-	Black
Earth -	Green or green /yellow

Three Phase

L_1	-	Red	-	phase
L_2	-	yellow	-	phase
L_3	-	blue	-	phase
Neutral-		black		

Size of cables and rating of protective devices

Cables are manufactured in different sizes and compositions and each is designed to carry a maximum amount of current. The current a cable can carry are given in the I.E.E Regulation tables of current ratings. For lighting circuits the cable commonly used is the $1mm^{2 \text{ or } 1.5\ mm2}$ which is rated 18A depending on the type of cable. The most common cable used is single core and Twin flat and Twin with earth. Most lighting circuits will be rated at either 5A or 10A because most switches are rated 5A or 10A.

The I.E.E Regulations gives the protective ratings of different types of lamps as shown below.

Type of Holder	**Maximum Rating of fuse or Circuit Breaker.**
Small Bayonet type	5A
Small Edison –type screw	5A
Bayonet type	15A
Bi- pin type	15A

I.E.E Regulations on switches

1. Every switch or Circuit Breaker the purpose of which is not obvious shall be labeled to indicate the apparatus it controls.
2. All single pole switches shall be always connected to the live conductor.
3. Every switch or other electric control shall be placed so as to be out of reach of a person in contact with bath, shower unit etc.
4. In a two wire installation connected to a supply having neither pole connected with the earth, switch or circuit breaker shall be of double pole linked type and the fuses shall be installed in both poles.
5. In a two wire installation connected to a supply having one pole earthed, switches shall be connected in the live conductor only.

Power Circuits

Final power sub-circuits

A final power sub-circuit is a circuit that allows electrical appliances to access electrical power.
All final sub-circuits must be electrically separate that is there must be no “bunching” of neutral conductors. All neutral conductors must be connected at the distribution board in the same order as the line conductors.

Socket Outlet

A socket outlet is a device provided with female contacts which is intended to be fitted with the fixed wiring and intended to receive a plug. A device with protected current carrying contacts intended to be mounted in a fixed position and permanently connected to a fixed wiring of a an installation to enable the connection to it of a flexible cord or flexible cable by means of a plug, or is an accessory with 3 terminals marked *L*- live, *N*- Neutral and *E* – Earth fitted with the fixed wiring ready to receive a plug.

Plug

This is a device intended for connection to a fixed cord or flexible cable which can be engaged manually with a socket outlet and which has current carrying contact pins which may be exposed when not engaged. Socket outlet will be wired such that the terminal marked *L* will receive the live wire, the terminal marked *N* will receive the Neutral and the one marked *E* will receive the earth wire. Socket outlets must be installed in a place to wait for a plug but not the vice-versa

Note;

Sometimes the earth terminal is marked with the Earth symbol

There are two ways in which socket outlets may be wired

1. Radial circuit
2. Ring circuit

Radial Circuit

A radial circuit is a circuit in which the live, neutral and earth conductor start from the distribution board to sockets connected in series and terminate at the last socket.

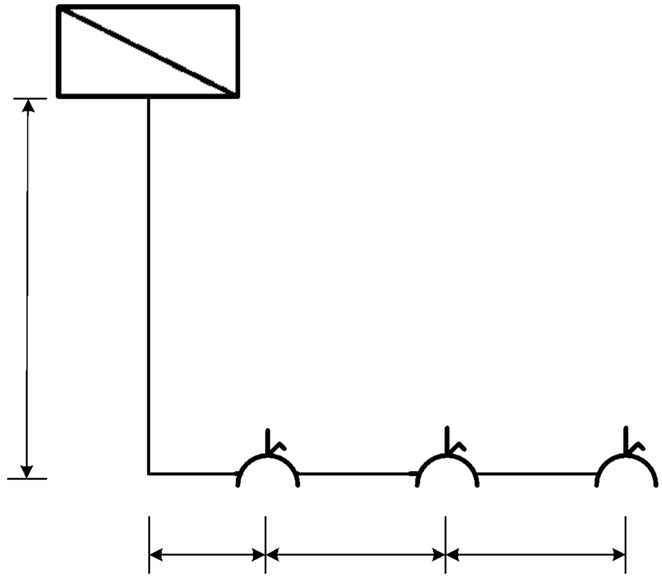


Figure 43. Layout diagram of a radial circuit

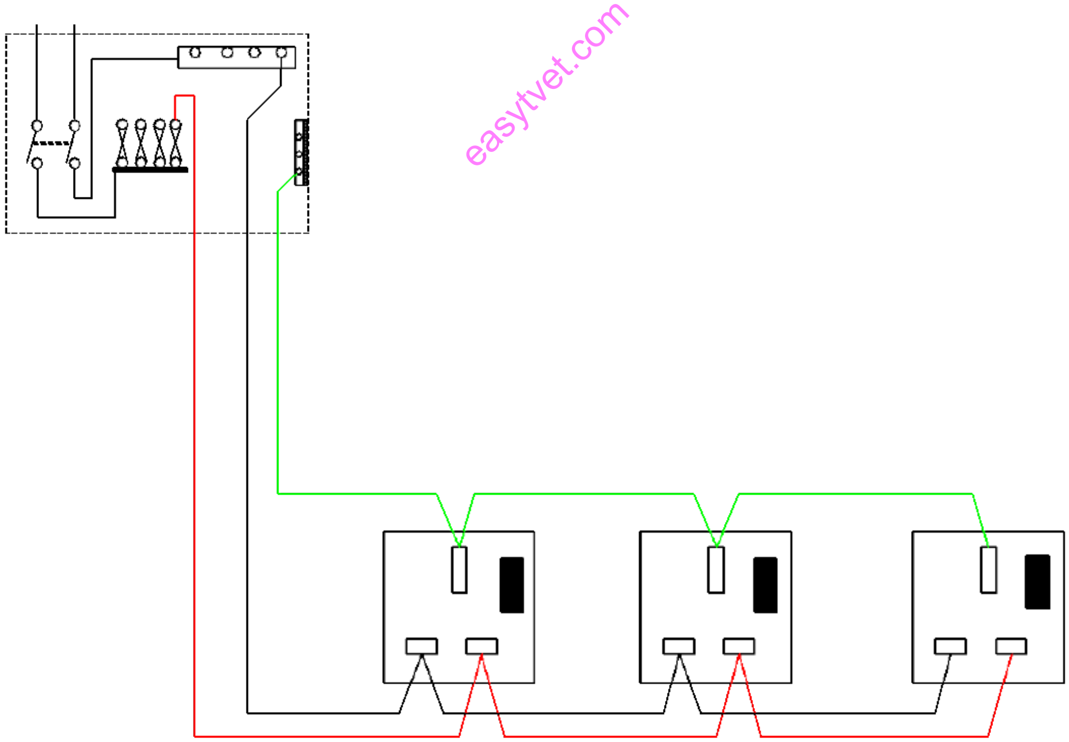


Figure 44 Wiring diagram for the radial circuit

Ring Circuits

A ring circuit is defined in the I.E.E. Regulations as " a final sub-circuit in which the current-carrying and the earth-continuity conductors are connected in the form of a loop, both ends of which are connected to a single way in a distribution board or its equivalent.

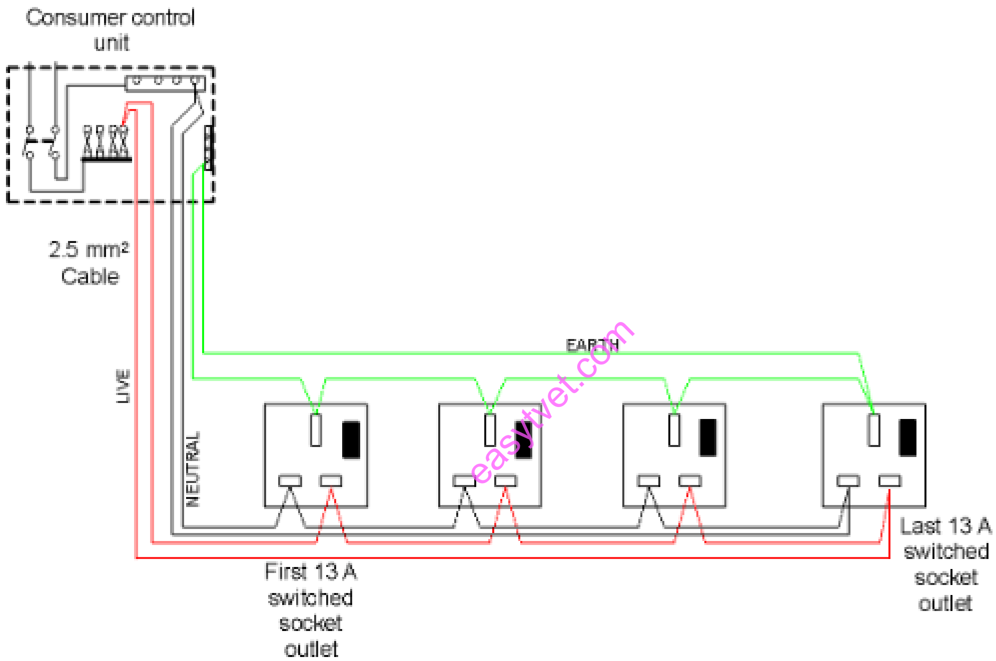


Figure 45. Wiring diagram for a ring circuit.

Spur

A spur is a socket that branches off a ring circuit. The number of spurs fed from a ring circuit must not exceed the number of sockets in the ring. The cables connecting the spur must be of the same size as that of the ring circuit. The minimum cable size for ring and radial circuit is $2.5mm^2$.

Advantages of a ring circuit over a Radial circuit

1. There is total safety in ring circuit than in Radial for the circuit is in form of a ring
2. An open circuit point in the Ring circuit will not affect any other socket in the system

This is because there are two paths of current and is one path is open the current will flow through the other

3. Smaller sizes of cables may be used in Ring than in a Radial. This is because the Ring has two parallel current paths
4. More loads may be fed or connected to a Ring circuit than a Radial circuit of the same capacity

Disadvantages of Ring over Radial

1. More cables lengths requires in a Ring than in Radial therefore becomes more expensive
2. It consumes more time to install a Ring circuit than Radial because more cables has to be installed.

I.E.E Regulations on Ring and Radial circuit

1. A Ring circuit it may serve an unlimited number of points but shall not serve an area of more than $100m^2$
2. For a Ring final sub-circuit the total number of spurs shall not exceed the total number of socket outlets and stationary appliances connected directly in the ring circuit.
3. Where two or more ring final sub circuit are installed, the socket outlet to be served shall reasonably be distributed among the separate ring circuit
4. For a Radial or Ring final sub circuit the Rating of the fuse or circuit breaker at the circuit breaker shall not exceed 30A
5. Each circuit conductor of a ring final sub circuit shall be run in the form of a Ring commencing and returning to the same way in the circuit breaker.
6. Except where Ring is run throughout in metallic conduct, Ducts or Trunking, Earth continuity conductor shall run in form of a ring originating and returning to same point in the circuit breaker.
7. For a Radial circuit the current rating of the circuit conductors shall not be less than Rating of the fuse or circuit breaker protecting the final sub- circuit

Electric Bell

There are various types of electric bells including the single stroke bell, the trembles, the buzzer and a continuously ringing bell, but all depend on the attraction exerted by the electromagnet or a soft iron armature.

i) Single stroke bell

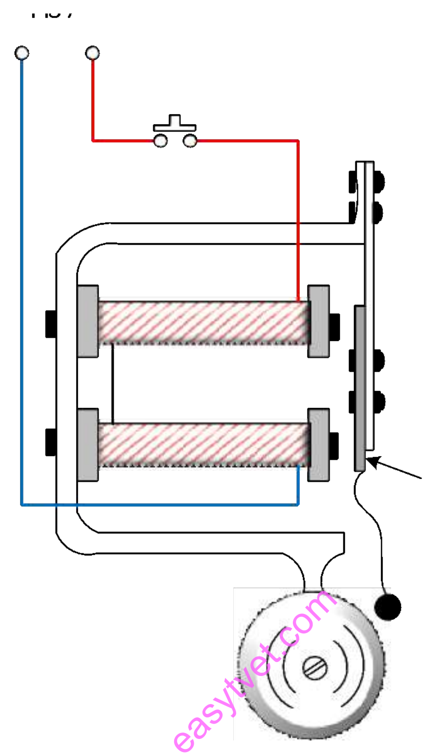


Figure 46 Single stroke bell

Construction

The bell is made up of two coils wound up with insulated copper wire on an insulated bobbin. The bobbins are slipped on to a U-shaped soft iron core and the magnetic circuit is completed by a soft-iron strip riveted to a spring-loaded armature. The striker is attached to the armature.

Operation.

1. the push-button is pressed
2. Current passes through the coil.
3. The coil is magnetized.
4. The soft-iron strip on the armature is attracted towards the coil.
5. The armature carries a striker which hits the gong.

6. The gong produces audible sound.
7. When the circuit is broken the coil becomes demagnetized and the spring pulls the armature back into its original position.
8. The striker will only operate when the push is operated hence a single stroke.

ii) **Trembler bell**

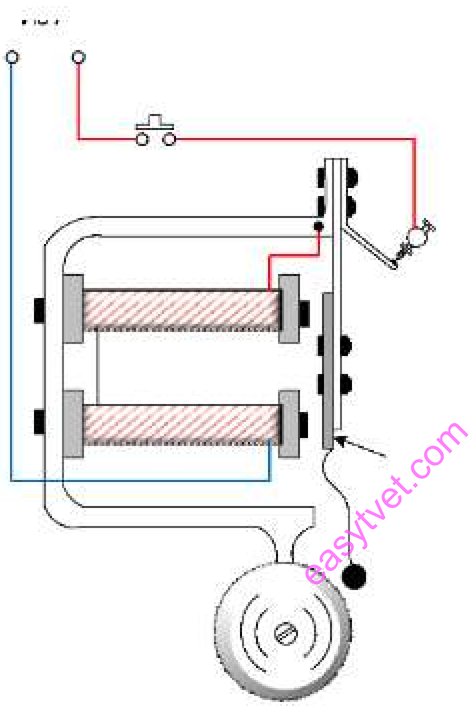


Figure 47 Trembler bell

Construction.

This type of bell is similar in construction to the single-stroke bell except that there is an adjustable pair of contacts between the armature and the push button contact.

Operation.

1. The push-button is pressed
2. Current passes through the coil.
3. The coil is magnetized.
4. The soft-iron strip on the armature is attracted towards the coil.

5. The armature carries a striker which hits the gong.
6. The gong produces audible sound.
7. When the circuit is broken the coil becomes demagnetized and the spring pulls the armature back into its original position.
8. The cycle is then repeated, giving a continual make-and-break action.

Continuous ringing bell

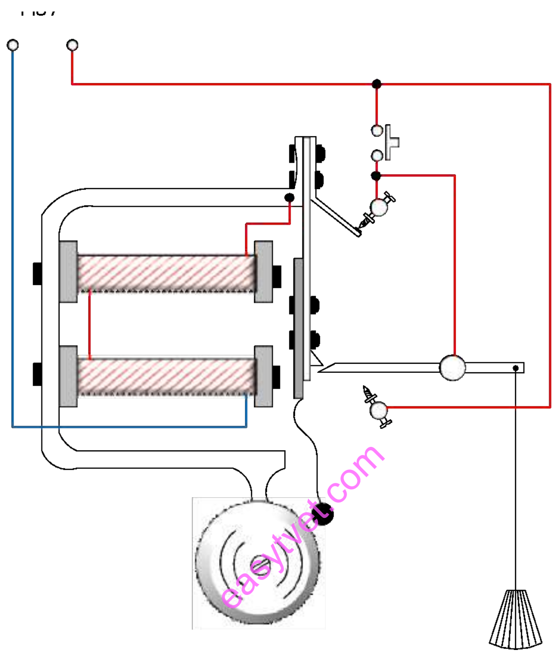


Figure 48 Continuous ringing bell

Construction

The continuous ringing bell differs in construction from the trembler bell in that a small lever is placed below the contact screw. This level drops automatically on the first stroke of the bell, and as it drop it shorts out the bell-push, thus causing the bell to ring continuously until the lever is reset by the cord. Confusion can arise in the drawing of this circuit if the operation of the lever is not understood.

Operation.

1. When the bell –push is operated the coils become an electromagnet and the armature is drawn towards them.
2. The lever drops on the first stroke and shorts the push.

3. The bell now operates as a trembler bell.
4. To stop the bell, pull the cord, thus resetting the lever.

iii) **The Buzzer**

The buzzer is a trembler bell without a striker and gong. The principle of operation is similar to that of the trembler bell, however, the sound it produces is like the buzz of a bee.

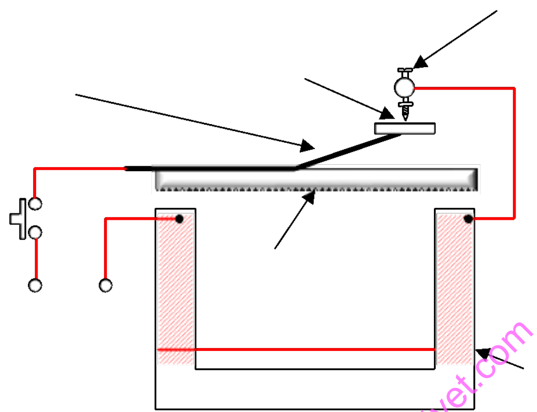


Figure 49 Buzzer

Bell Indicators

These are devices used to indicate the location where the bell is being rang by showing in the indicator board. These indicators coils are connected in series with the bell Indicator boards are situated at places where the intended person can access it. For example, it can be situated in the nurses' office to show when a patient is in need. During bell circuit installation comprising more than one bell push buttons operating the same bell, it is necessary to include an indicator board which will show from which push button the bell has been rung. There are three types of bell indicators.

1) Pendulum
2) Electrical replacement.
3) Mechanical replacement.

1. Pendulum type

In the pendulum type there are movements similar to that of the single stroke bell where a soft iron armature carrying a flag is pivoted at its end in front of an electromagnet. The coils of which are in series with the push concerned .When the push button is pressed, the electromagnet attracts the armature. When press the button is released, the electromagnet is demagnetized releasing the armature .The armature starts to swing in a pendulum motion before resting.

Disadvantages

i. When the person called happens to be away from the indicator board when the bell rings, the pendulum may stop swinging by he/she comes back.
ii. There may be confusion if more than one push buttons are pressed almost at the same time.

2. **Electrical replacement type**

In this arrangement, the element consists of two electromagnets, one of which is in series with the bell circuit. The second coil is connected in the replacement circuit. The armature is pivoted at its center about which it will rock. The flag arm is attached to the armature. When the current flows through the alarm circuit, one end of the armature is attracted, causing the flag to overbalance and fall to one side. To restore the flag, the current is passed through the replacement coil, which restores the flag to its original position.

3. **Mechanical replacement type**

Has an armature which is attracted by the electromagnet to show the flag in its appropriate space in the screen or window of the indicator board. The flag remains in this position even though the bell push button is released until it is reset by a lever that is pushed or turned around by hand.

Relays

This is an electrical device such that current flowing through it in one circuit can switch ON and OFF current in a second circuit.

Construction

Basic parts and functions of electromechanical relays include:

1. **Frame:** Heavy-duty frame that contains and supports the parts of the relay.
2. **Coil:** Wire is wound around a metal core. The coil of wire causes an electromagnetic field.

3. **Armature:** this is the relays moving part. The armature opens and closes the contacts.
4. **Contacts:** The conducting part of the switch that makes (closes) or breaks (opens) a circuit.
5. An attached **spring** returns the armature to its original position.

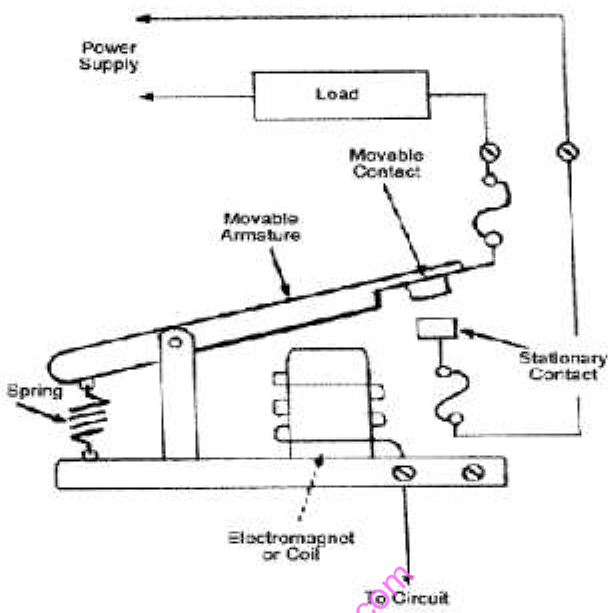


Figure 50 Electromechanical relay

Bell circuits

There are layout diagrams and wiring diagrams which use BS 3939 symbols.

An example of a layout diagram is shown in figure 51.

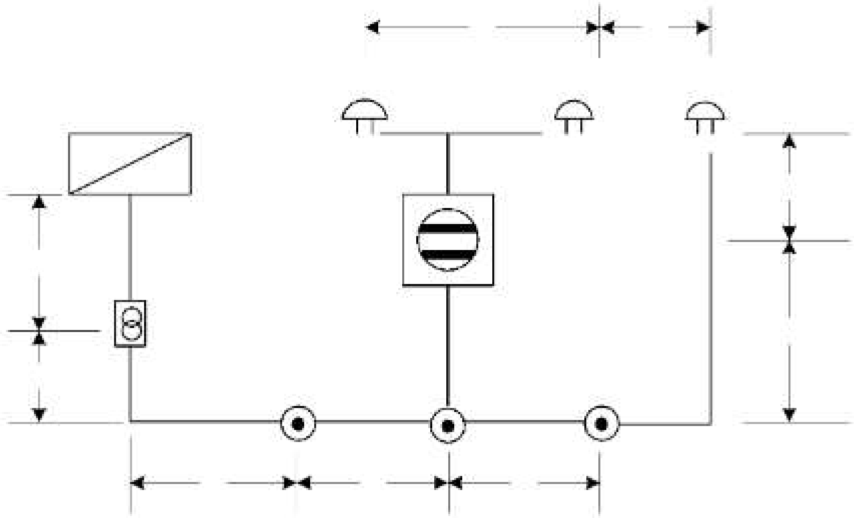


Figure 51layout diagram for alarm circuit

Description

Figure 51 shows a bell circuit layout diagram, push buttons A and B controls bells 1 and 2 simultaneously. The bells are connected in parallel, and push button C controls bell 3. Bells A and B are connected through an indicator board.

Figure 52 shows the wiring diagram of the layout diagram in figure 51

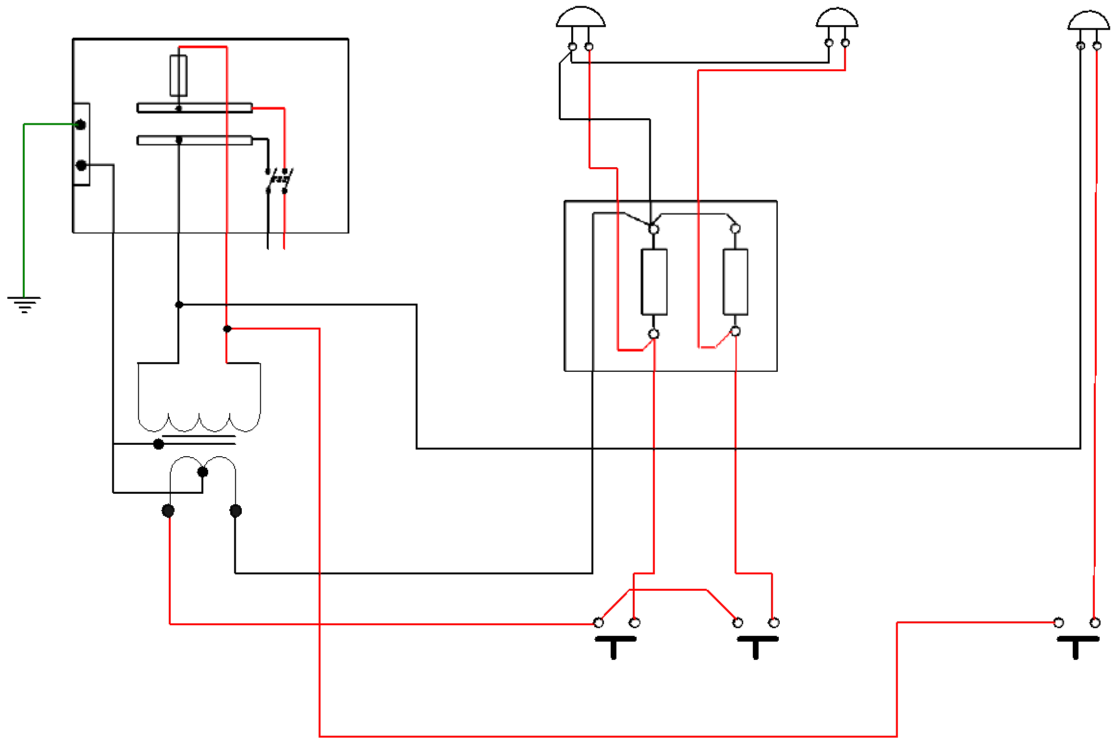


Figure 52 Bell circuit wiring diagram

ELECTRIC WATER HEATERS

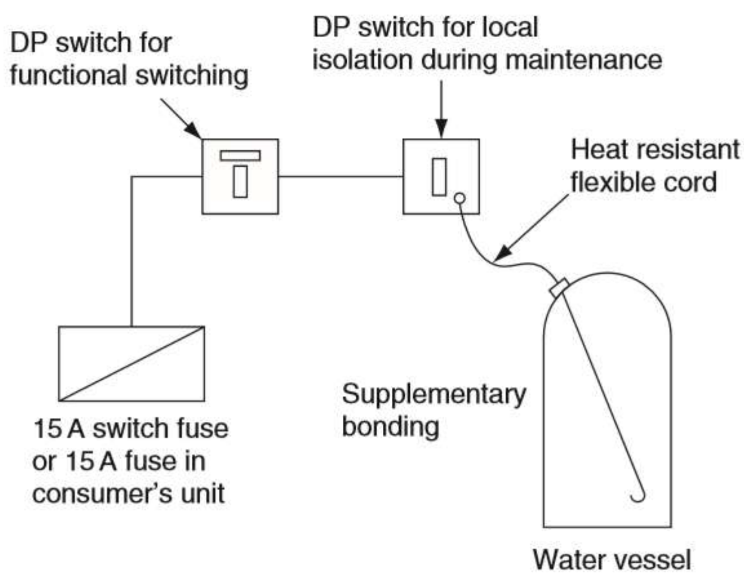


Figure 53. Water heater layout diagram.

There are two basic types of electric water heaters;

(a) The free outlet or non- pressure-type (N.P.T) and

(b) The pressure type.

Free Outlet Water Heater

Both types of water heater operate on the principle that water, when heated, becomes less dense (lighter) and rises. An immersion heater element is fitted at the bottom of the tank or vertically (through the center) so that all the water in the tank will be heated. The immersion heater will only heat the water above it. But in the free outlet type cold water is fed into the tank through an inlet valve. When this valve is opened, the incoming cold water pushes the less dense hot water in to the outlet pipe.

Construction

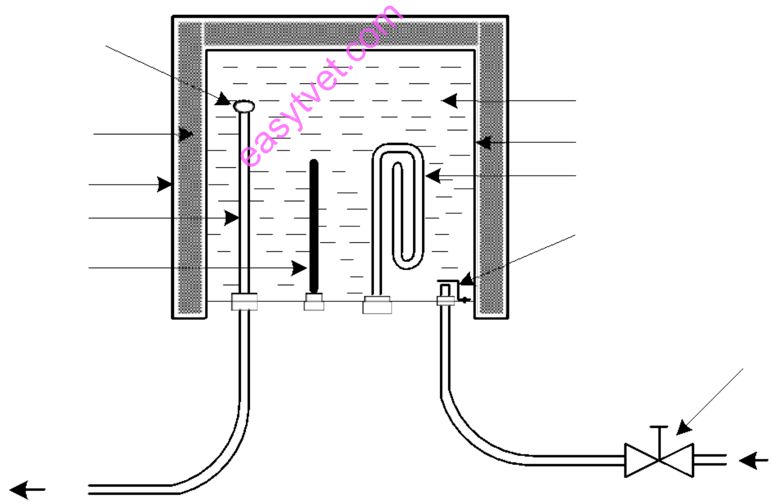


Figure 54 Free outlet water heater

Figure 54 shows the construction details of free outlet water heater. This type of water heater consists of a tinned-copper tank insulated against heat loss by a granulated cork or grass fiber lagging. The inlet valve is fitted with a baffle plate to keep the incoming cold water at the tank. The outlet pipe has an anti-drip syphon which is fitted to prevent the outlet from dripping when the inlet valve is closed. The heating element is composed of a nichrome wire spiral encased in a plated copper tube and insulated with a refractory (heat- resistant) material. The thermostat is used to control the temperature of the water in the tank.

Operation of the Thermostat

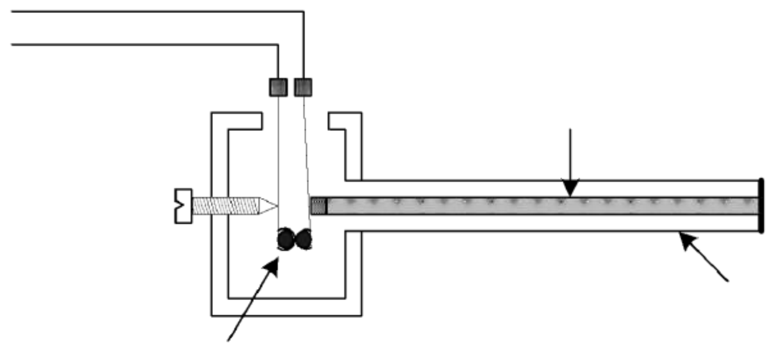


Figure 55 Water heater thermostat

The thermostat must be connected in the phase conductor.

The sequence of operation thermostat is as follows

- The heat from the water heats a brass tube, causing it to expand.
- An invar (non-expanding) rod is fixed at the end of the tube
- The movement of the brass tube draws the invar rod away from the contacts, breaking the heater circuit
- The point at which the contacts open is determined by the pressure on the contacts; an adjustable screw allows variations in the operating temperatures (generally 43^0C to 82^0C).

Pressure Type Water Heater

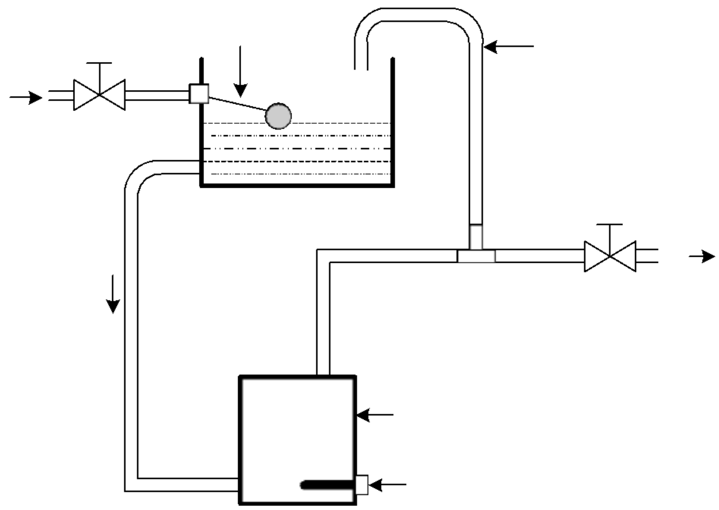


Figure 56 Pressure type water heater

In this type, the hot water tank is fed from a cold water cistern placed above it. The water supplying the cistern is controlled by a ball-valve. When hot water is drawn off the hot water tank (or cylinder) the cistern replenishes it and the ball-valve comes into operation to refill the cistern. In this way a constant pressure (or head) of water is kept on the hot water system.

Difference between pressure and free outlet types.

The free outlet type is controlled by one valve on the inlet side, and the pressure type is designed to supply one or more outlets on the hot water side.

Tank-less water heaters (Instantaneous)

These are water heaters that instantly heat water as it flows through the device, and do not retain any water internally except what is in the heat exchanger coil.

Copper heat exchangers are preferred in these units due to their high thermal conductivity and ease of fabrication.

Advantages

1. Plenty continuous flow of hot water
2. Plenty energy savings

Disadvantage

1. High initial cost

Operation

The heater is normally in the OFF position, but is equipped with flow sensors which will be activated when water flows through them. A feedback loop is used to bring water to the desired temperature. The water circulates through the copper heat exchanger and is heated by gas or electricity. Since there is no storage tank of hot water, the heater provides continuous supply of hot water.

Electric shower heads

In this type, an electric heating element is placed in shower heads to instantly heat water as it flows through. These self-heating shower heads are specialized point-of-use Tank-less water heaters and are widely used in some countries including Kenya.

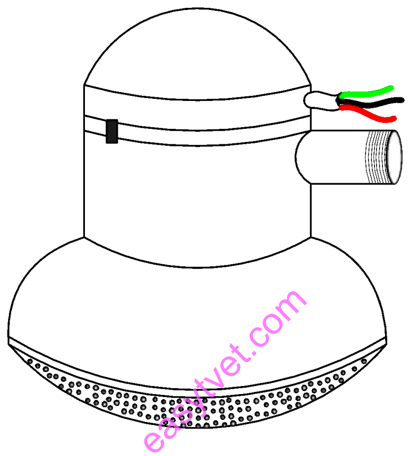


Figure. 57 Electric shower head

Electrical Machines

Electrical machines play an important role in industry as well as in our day to day life. They are used in power plants to generate electrical power and in industry to provide mechanical work, such as in steel mills, textile mills and paper mills

Alternating Current Motors

Motors that are designed to operate on alternating current are called alternating current motors. They convert electrical energy into mechanical energy. Alternating current motors are the most widely used type of motors because, all the generated electrical energy is in the form of alternating current. In addition, ac motors are simple in design, rugged in construction and require little maintenance.

All ac motors basically consist of a stationary part called the stator, a rotating part called the rotor and two end shields that house the bearings the rotor. The design of the rotor and the manner in which current is made to flow through it determines the classification of the motor and its performance characteristics. The stator contains windings which when connected to an alternating current source, creates a rotating magnetic field. At the same time a magnetic field is created in the rotor by electromagnetic induction which is similar to transformer action. The attraction between the stator and rotor fields causes the rotor field to follow the rotating stator field.Ac motors are particularly suitable for constant speed applications. However, variable speed motors are also manufactured. Alternating current motors operate on the either single-phase or three-phase supply.

Basic parts of ac motors

All ac motors have similar parts, with the exception of modifications or additions of special parts to a particular type of motor. AC motors essentially consist of:

(a) Frame: The frame is made of steel and it is the part into which the stator is pressed.

(b) Stator: The stator is made of a cylindrical core consisting of tightly held together steel laminations, with longitudinal slots around the inner circumference which firmly hold the stator coil windings.

Stator: During the manufacture of some stators, the windings are first wound into the stator slots and properly connected. The wound stator is then dipped into insulating vanish, baked and finally pressed into the frame. Figure 58 shows a completely wound stator and frame of an induction motor before assembly. In other words, the stator is first pressed into the frame and thereafter, individual wires of the coil are wound into the slots, as shown in figure 59. The completely wound stator is then dipped into insulating vanish and baked. Stator windings are made of copper wires

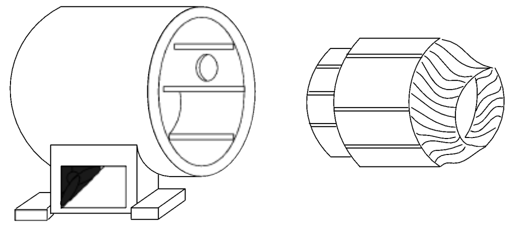


Figure 58. Completely wound stator before the core is pressed into the frame

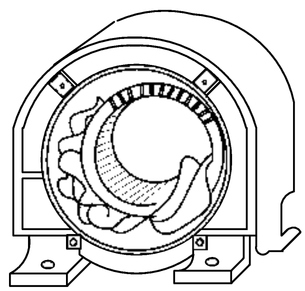
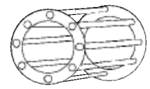


Figure 59. Partially wound stator after the core is pressed into the frame.

Rotor: There are two common types of rotors: the wound rotor and the squirrel-cage rotor. The wound rotor consists of a cylindrical core of steel laminations with longitudinal slots around the circumference. The slots hold coils of insulated copper wires which form the rotor windings. The ends of the windings are connected to slip rings in the three-phase motors and to commutator machines in single-phase repulsion and universal motors.

The squirrel-cage rotor consists of laminated cylindrical steel core with slots around its surface, but instead of holding coils of insulated copper wire, it is embedded with uninsulated large bars of copper or Aluminium conductors. The bars are short –circuited by brazing or welding them to end rings, made of identical material. If the structure formed by the bars and rings were to be viewed outside the core, it resembles a squirrel cage, and hence the name squirrel-cage rotor as illustrated in figure 60. In some rotors, however, the bars and rings are made of one piece of cast Aluminium. The rotor is always mounted on a high-grade steel shaft.



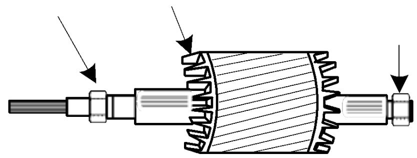


Figure 60 Squirrel-cage rotor

The rotor also carries cooling fans at both ends. These are important because a rise in temperature inside the motor lowers the motor output and in case of excessive temperatures, the insulation of the conductors would burn causing short circuits and fires.

End shields: The two end shields are made of cast steel and bolted to the frame. The end shields house the bearings. The purpose of the bearings is to support the weight of the rotor and to keep the rotor centered within the stator so that as it rotates, friction is minimized and also ensure that it does not strike or rub the stator core.

Single-phase motors

Single-phase ac motors are designed to operate from a single-phase ac supply. They are usually fractional kilowatt motors and are termed small motors. However, some single-phase motors are of 15kw and above and are manufactured for special applications. Single-phase motors are commonly found in house hold appliances such as refrigerators, food mixers, fans, vacuum cleaners and washing machines. They are also found in agricultural, commercial and industrial applications. Single-phase motors are small in size, robust in construction cheap easy to maintain and particularly useful where only the single-phase ac supply is available. Single-phase motors are divided into three classes:

i. Synchronous motors
ii. Induction motors
iii. Universal motors

The synchronous motor has a constant speed and is not self-starting. There are four types of single –phase induction motors, all named according to the method of starting them. The four in order of their increasing starting torque are: shaded pole, resistance start, capacitor start and repulsion motor. The universal motor also known as series motor, operates on either direct current or single-phase alternating current.

Single-phase synchronous motors.

The single-phase synchronous motor is usually used in timing devices such as wall clocks. It is very small in size and produces a small torque. It has a two-pole stator and the rotor is simply a slotted steel disk or a pile of disks bolted together but insulated from each other.

Operation

The stator contains two poles with their windings connected in series but in such a manner that the poles are of different polarities as shown in figure 55 (a). When single phase current is applied to the stator during the first alteration, the current increases from zero to maximum then falls to zero as shown in figure 61 (b). During the same period the pole pieces are magnetized and say, A becomes a north pole and B a south pole. The magnetic field so produced, varies in strength in similar pattern as the current. During the next alteration, the current changes direction and the polarity of the poles reverses; A becomes a South Pole and B a north pole. The magnetic field is said to be oscillating.

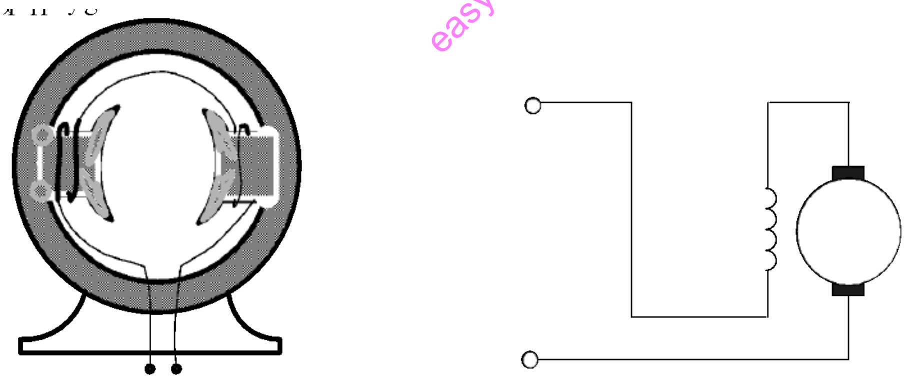


Figure 61 (a) Stator showing the two poles (b) Single- phase series motor

The change in magnetic field induces a voltage and therefore current in the rotor. This process is similar to induction in secondary winding of a transformer. The induced currents in the transformer create a magnetic field which always opposes the field causing it (Lenz's law). This means that a N-stator pole will produce a N-pole field and a S-pole stator pole, a S-pole field. The polarity of the rotor field changes at the frequency of the alternating current in the stator field. Since these changes are simultaneous, the rotor field pulsates and does not produce a torque. The rotor does not therefore rotate.

If the rotor is caused to rotate by applying an external force, it cuts the magnetic field of the stator. This induces current in the rotor which creates a rotor magnetic field. The pulsating stator magnetic field interacts with the rotor field. Since the induced field is always of the same polarity as the one creating it, and like poles repel, the rotor poles are repelled causing the rotor to rotate. The induced voltage causes induced currents which in turn create a magnetic field in the rotor. This voltage is produced in the following two ways;

(a) The alternating magnetic field of the stator cuts the rotor conductors and induces the rotor voltage. Since the action is similar to induction of secondary voltage in transformers, this kind of induced voltage is called transformer emf.
(b) As the rotor rotates, its conductors cut, or are cut by the rotating magnetic field and this induces voltage in the rotor. Voltage induced this way is called speed emf.

It is the combined effect of these alternating emf's which produces the torque that causes the rotor to turn. This applies to all induction motors. The rotor will rotate in either clockwise or anticlockwise direction depending on the direction of the external force applied. Once the rotor has started to rotate, it accelerates until it reaches the synchronous speed. The speed of the rotating field is called the synchronous speed and it depends on the frequency of the supply voltage. The synchronous speed inn r.p.m is calculated by multiplying the frequency of the ac input by 60 (number of seconds per minute) and dividing the product by the number of pairs of poles in the motor

$$Speed = 60\times\frac{frequency}{number\ of\ pairs\ of\ poles}\ rpm$$

Suppose a motor has 8 poles and is connected to 240v, 50Hz line. Its synchronous speed will be;

$$Speed = (60x50)/4 = 750\ rpm.$$

The actual speed of the rotor is less than the synchronous speed. If the rotor was to rotate at the same speed as the rotating speed, it would not cut the field, no current would be induced and hence no magnetic field would be created in it, and consequently no torque would be produced. For the rotor to sustain motion, there must be some difference the synchronous speed and the actual speed. The difference in speed is called SLIP. Slip is expressed as a percentage of synchronous speed. In single-phase synchronous motors, it is less than 4% and for practical purposes, the motor is considered to rotate at synchronous speed.

Resistance- start induction run motor (split-phase)

The resistance start, induction run motor is also referred to as split-phase motor. The main parts of the motor are frame, stator, squirrel-cage rotor, two end shields and a centrifugal switch mounted on the rotor shaft. Figure 62 shows parts of a disassembled resistance-start induction run motor.

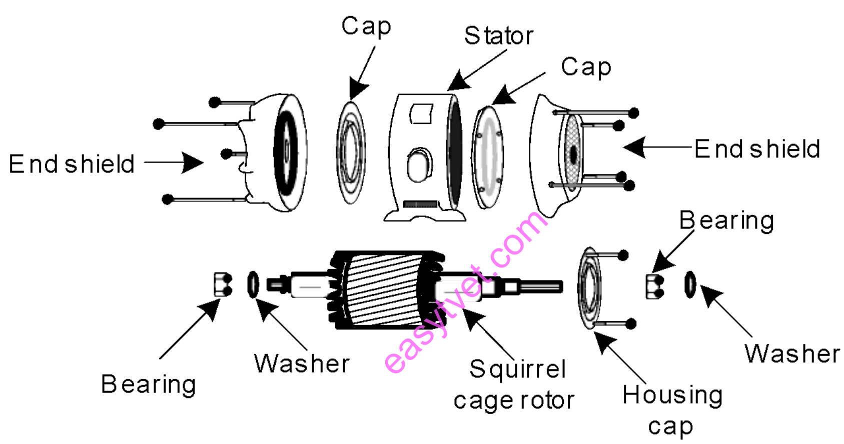
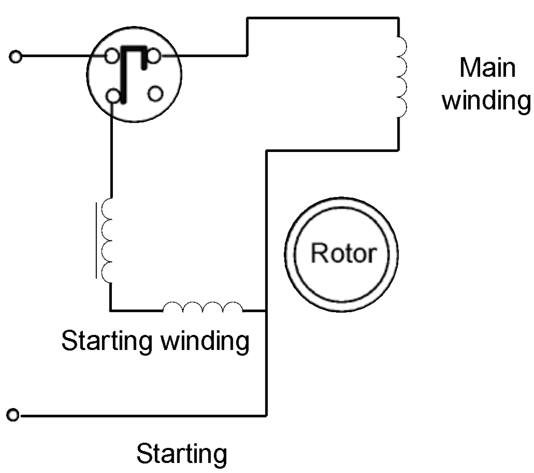


Figure 62 Parts of a disassembled resistance-start induction-run motor.



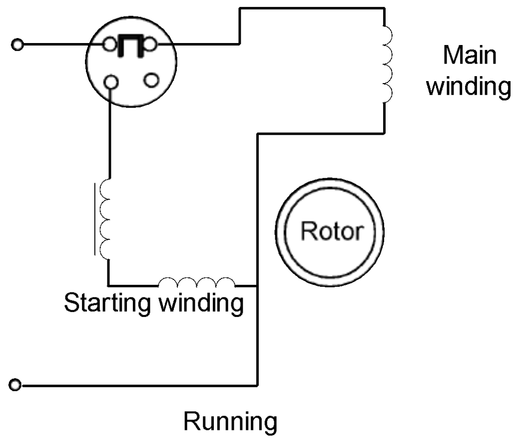


Figure 63. Split-phase motor.

Capacitor Start Motors.

There are two types of capacitor start motors, namely the capacitor start-induction run and capacitor start-capacitor run. The main difference between the two is that in the former, the starting winding and the capacitor are disconnected from the circuit when the motor attains 75% of the rated speed, while in the latter, the starting winding is permanently connected in the circuit.

Capacitor start-induction run motor

In this type of motor, a capacitor is connected in series with the starting winding as shown in figure 64. An electrolytic capacitor is commonly used.

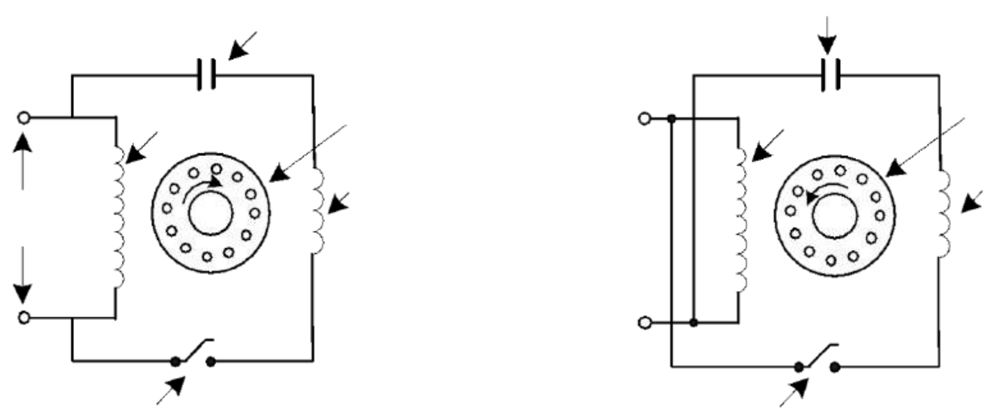


Figure 64. Connection of a capacitor-start induction-start run motor direction.

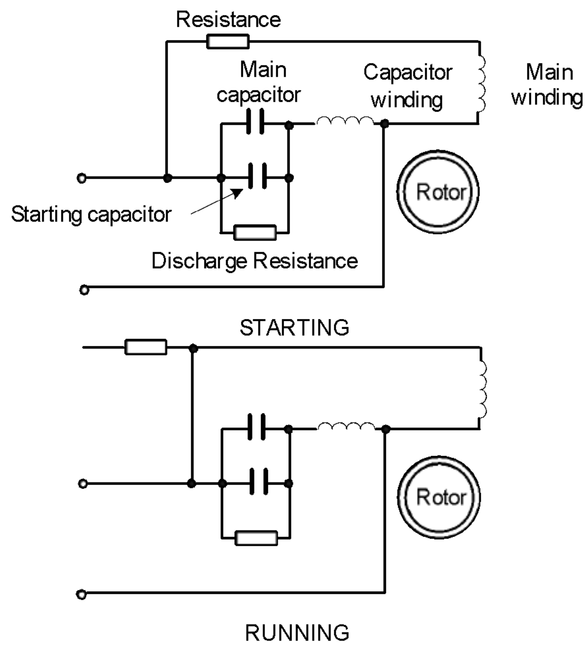


Figure 65. Single-phase capacitor start induction run.

Electrolytic capacitors have short duty service, and are easily damaged by frequent surge currents.

Therefore, the capacitor start-induction run motor is suitable for situations which require relatively few starts in a short period of time. Many manufacturers recommend that the motors be started less than 20 times in an hour.

Operation

The running winding of this motor is embedded in iron and therefore highly inductive. A capacitor of suitable size connected in the starting winding, causes a considerable phase difference between the currents in the two windings. The phase difference between these two currents gives the motor a high starting torque. It runs efficiently with fairly good power factor and its starting torque can be as high as three times its full load torque. It is essentially a constant speed machine and is used for light industrial work, office and domestic applications where better starting torque is required.

Capacitor start - Capacitor run motor

(i) Single-Capacitor Motor

This motor is known as capacitor start-capacitor run because the starting winding is left in the circuit during running. Figure 66 shows this type of motor with the centrifugal switch omitted meaning the motor continues running as a two phase machine. The running of this motor is smoother with good power factor but the capacitor and running winding be continuously rated. This motor is used where a high starting torque is not essential so that a lower value capacitor would be used for running continuously. It is mostly used in ventilating fans, small pumps, circulating pumps in central heating systems etc.

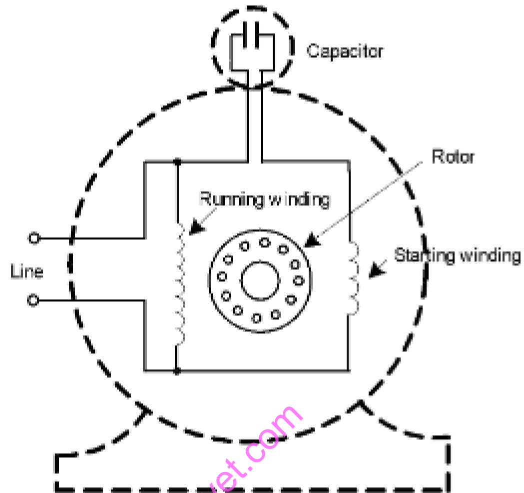


Figure 66. Connections in a single value capacitor-start, capacitor run motors

(ii) Two Value Capacitor Motor

This motor has two capacitors connected in parallel, and both connected in series with the starting winding as illustrated in figure 67. Usually an oil capacitor is connected permanently while an electrolytic capacitor is connected through a centrifugal switch. The motor starts with both capacitors in parallel and the switch opens the electrolytic capacitor when the motor has reached 75% of the rated speed. The motor then runs with the oil capacitor alone in series with the starting winding. This motor is a smooth running machine with high frequency, good power, and high starting torque with quiet running. It is used for light industries and office machines.

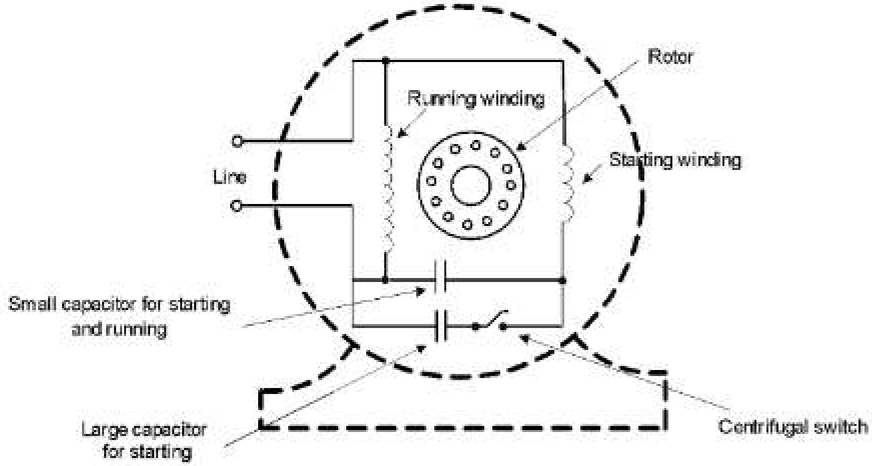


Figure 67. Internal connection of a two-value capacitor motor

Repulsion motors

Repulsion motors derive their names from the fact that they produce the torque required for rotation from the repulsion of two like poles. These motors have relatively high starting torque and draw less starting current than the other types of single phase motors.

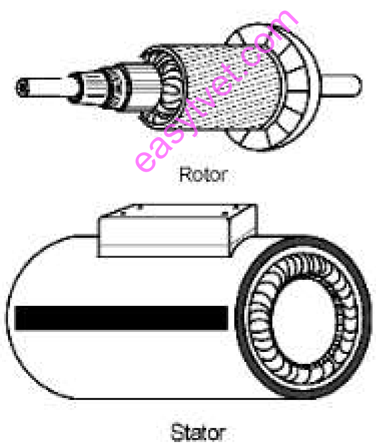


Figure 68. The main parts of a repulsion motor

Figure 68 illustrates the essential parts of a repulsion motor. These parts are;

(a) The stator, which has only one field winding similar to the running winding of single-phase motors. It usually contains four, six or eight poles.

(b) The rotor, which is the wound type. It has insulated copper windings and its terminations are connected to a commutator. Brushes ride on the commutator and short circuit the windings. Note that the rotor is not electrically connected to the ac source.

(c) The two end shields that house the bearings which support the rotor and the shaft

(d) The frame, whose purpose is to securely hold the stator core to which end-shields are bolted.

The construction of repulsion motors differs from split phase motors in that they have a wound rotor and the stator has only one type of field winding

Types of repulsion motors

There are three types of repulsion motors; these are the repulsion start- repulsion run motor, repulsion-start induction run and the repulsion induction motor. They are all reversible and have excellent starting torque.

(a) *Repulsion Start-Repulsion run motor.* This is the basic repulsion motor. Its speed can be varied by changing the value of the supply voltage. If all the mechanical load is removed, the motor will accelerate to a dangerous high speed called runaway speed. It is therefore used on permanent loads such as elevators.

(b) *Repulsion Start-Induction run motor.* This motor has a centrifugal device in the rotor. When the motor has attained approximately 75% of its rated speed, the centrifugal device passes a short-circuiting ring into the commutator, which short-circuits the commutator segments and current no longer flows through the brushes. The motor then runs as an induction motor. The motor has excellent starting torque and is reversible. The motor is used in commercial refrigerators, compressors and pumps.

(c) *Repulsion-Induction motor.* This type of repulsion motor has a squirrel cage winding on the rotor under the regular wound winding, as shown in figure 69. The added winding is inductive and serves to limit the no-load speed when the motor speeds above the synchronous speed. The motor has fairly constant speed from no-load speed because of the squirrel-cage winding. The motor does not have a centrifugal switch and therefore needs little maintenance and repairs. It starts as a repulsion motor and runs as an induction motor.

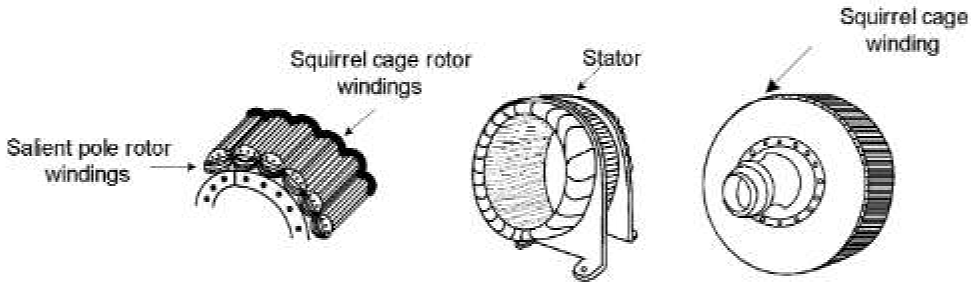


Figure 69 Details of the rotor of a repulsion-induction motor

Shaded pole motor

The shaded pole motor is a fractional kilowatt motor. It belongs to the group of split-phase motors. The motor does not have the regular starting winding, centrifugal switch or starter mechanism. The motor has a squirrel cage rotor. However, a short circuit ring is mounted around about a third of the pole area of each stator pole. The area covered by the ring is called the shaded pole and the ring is called the sheading coil. All the poles are shaded on the same side, and the shading coil is made of low resistance copper. Figure 70 shows a typical shaded pole motor.

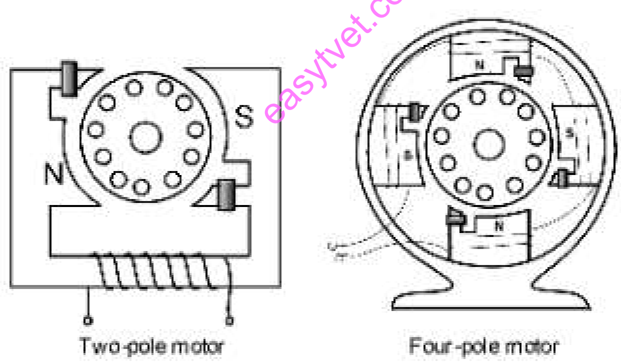


Figure 70 Shaded pole motor

Operation

The shading coil causes the building up and the collapse of magnetic field around the shaded pole to lag by opposing the change of current through it. This creates a shifting magnetic field along the surface of the pole.

UNIVERSAL MOTOR

Universal motor, also known as the series motor, is designed to operate on either single-phase alternating current or direct current. Figure 71 illustrates the main parts of the motor.

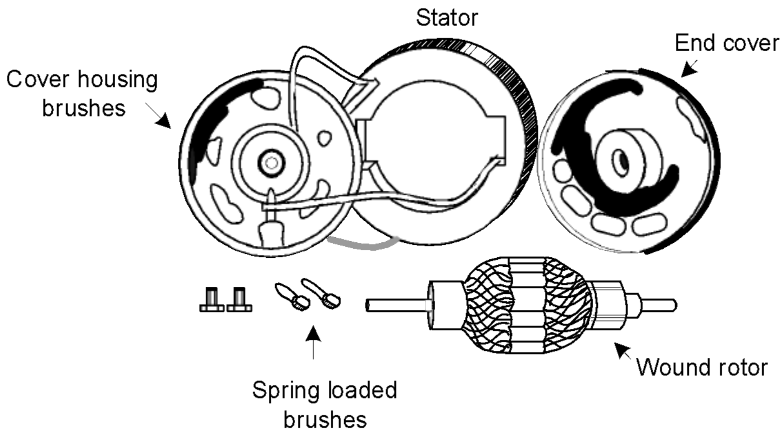


Figure 71 the main parts of a universal motor

The frame is made of cast Aluminium, cast iron or rolled steel. Two end shields, made of steel, serve the same purpose as in other motors. The stator is made of steel laminations securely held together and bolted to the frame. The rotor consists of a cylindrical core of steel laminations with longitudinal slots into which insulated copper windings are wound. The windings are wound in such a way that they create two opposite poles in the stator. The rotor windings are connected to commutator segments. Two carbon brushes ride on the commutator, and are connected to the field winding.

Operation

Stator and rotor windings are connected in series as shown in figure 72.

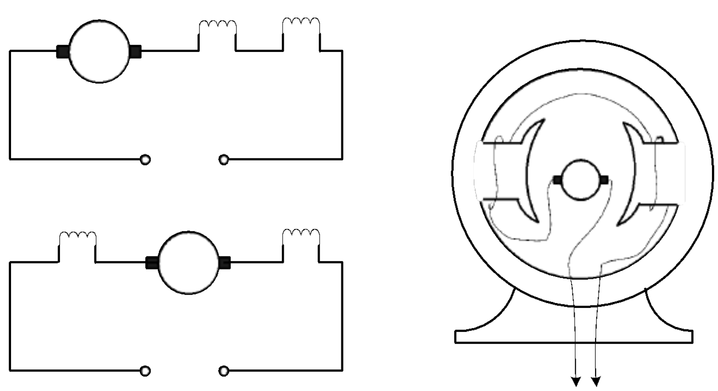


Figure 72 Series connected of field and rotor windings of a universal motor

When the motor is connected to single phase ac supply, the same amount of current flows through both the field and rotor windings because they are in series. By the method of connections, the magnetic field set up in the rotor will have the same polarity as the poles close to it. The two like poles will repel and produce torque, and the rotor therefore rotates, this is similar to torque production in a repulsion motor.

Universal motors are variable speed motors. The speed depends on the voltage applied and the load. The motor has very high starting torque. They are widely used in portable commercial such as saws, drills, grinders and sanders, domestic appliances such as food mixers, sewing machines and vacuum cleaners. They usually cause radio and TV interference because of sparking at the brushes. To obtain variable speeds, control rheostats, impedance coils tapped windings or centrifugal devices are used. The motors may achieve excessive high speeds and therefore they are normally started and operated with the load connected. The direction of rotation is changed by reversing either the field or armature connections

5.2.4.4 Learning activities

Field/Visit to an electrical Installation company

Visit Objective/Aim	Indicators	Special Instruction
To establish types of final circuits used during installation works	- Wiring systems used - Types of final circuits	-Take notes -Observe keenly types of final circuits - Observe keenly types of final circuits

Practical Assignment

Visit Objective/Aim	Indicators	Special Instruction
To experience and learn real electrical installation works	- Tools used - Procedures followed	Participate in real electrical installation work

5.2.4.5 Self-Assessment

1. What is a final power circuit?
2. Describe Consumer intake point
3. What are the requirements of a consumer intake point?
4. With the aid of a diagram, describe ring power circuit.

5. Which of the following is not part of a domestic consumer control unit?
   A. Neutral block
   B. Battery
   C. Double pole switch
   D. Earthing block/ terminal
6. When carrying out electrical installation work in a storey building, the following are safety measures to be observed except?
   A. Wearing of fitting suit with a proper neck tie
   B. Putting on helmets
   C. Wearing of safety boots
   D. Using properly insulated tools
7. A domestic consumer is usually supplied with a single-phase supply, what is the approximate value of supply voltage in this case?
   A. 415v
   B. 400v
   C. 240v
   D. 110v

5.2.4.5 Tools, Equipment, Supplies and Materials

5.2.4.6 References

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ngari, c. k. (2019). *electrical installations for artisan level 2.* kenya literature bureau.

John Bird, (2007). *Electrical and Electronic Principles and Technology*,

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https://safetyculture.com/topics/electrical-hazards/

5.2.4.7 Answers to Self-Assessment

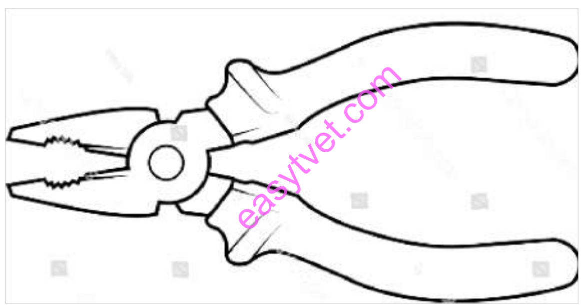
Apply and Adhere to Safety

1. *Dangers of electricity*
   - *Electric shock*
   - *Electrical burns*
   - *Fire*
2. *When a person gets into contact with a live wire and gets an electric shock, the following steps should be followed to save the victim:*
   i. *Use a dry insulator to remove the victim from electrical contact.*
   ii. *Take the victim away from the place where the shock occurred.*
   iii. *If the victim has stopped breathing lay he/she flat on the ground then apply first aid by KISS OF LIFE method of artificial respiration as follows.*
   iv. *Call for medical help*
3. *FOUR types of fire extinguishers.*
   i. *Dry water mist*
   ii. *Foam Extinguishers*
   iii. *Carbon Dioxide (CO_2) Extinguishers*
   iv. *Wet Chemical Extinguishers*
4. *Importance of wearing the following protective clothing in a work environment:*

i. Helmet – *To prevent head injury*
ii. Gloves – *To prevent hands from injuries/electric shock*
iii. Goggles – *to prevent eyes from injury*
iv. Safety boots – *To prevent foot injuries from sharp objects*
v. Dust coat – *To prevent soiling of inner clothing and injuries from rotating machines*

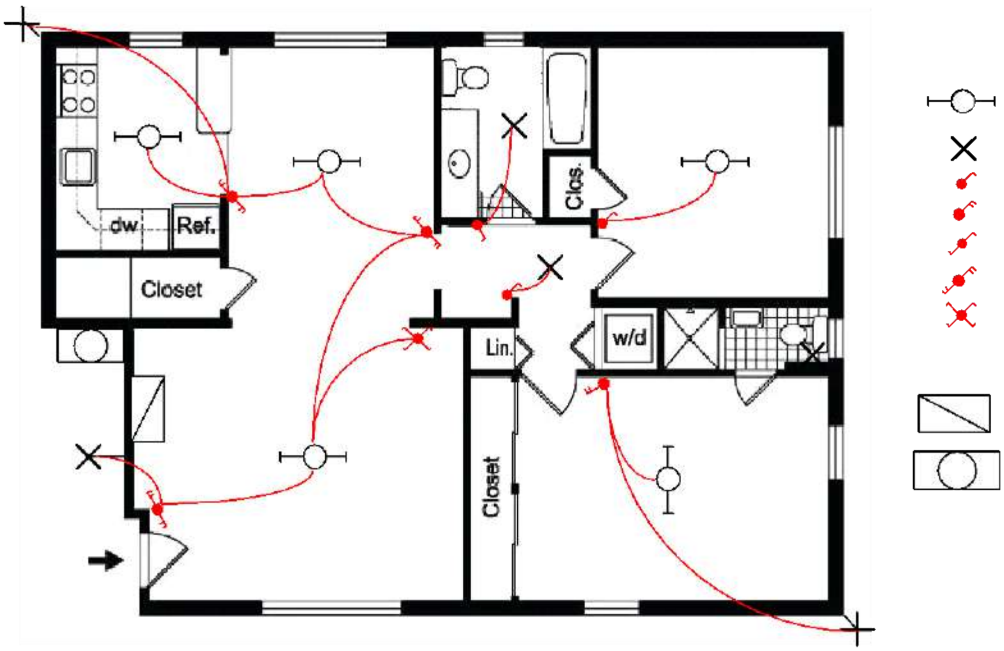
Prepare working Drawings

1. *A layout diagram shows the components position while a wiring diagram shows the actual wiring of the same components.*
2. *HB, 2H, 3H, H, B*
3. Sketch of combination pliers

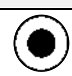
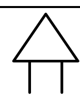
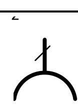
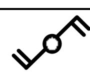
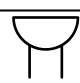
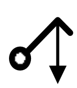
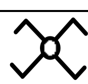


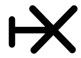
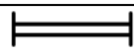
4. A

5. Lighting scheme and its switching arrangement.



6.

S/N	Symbol	Description
11.		Push button
12.		Siren
13.		Unswitched Twin socket outlet
14.		Two-way, 2 gang switch
15.		Buzzer
16.		Cord operated switch
17.		

		Intermediate switch
18.		Wall mounted switch
19.		Consumer control unit
20.		Twin Fluorescent fitting

Prepare Tools, Equipment & Materials

1. Tools used in electrical installation work (any four)
    i. *Combination pliers*
    ii. *Long nose pliers*
    iii. *Hacksaw*
    iv. *File*
    v. *Stock and die*
    vi. *Fish/draw wire*
    vii. *Screw driver*
    viii. *Measuring tape*
    ix. *Ladder*
    x. *Drilling machine*
    xi. *Bench vice*
    xii. *Reamer*

2. *How to calibrate a digital multimeter*
    (a) *Set the multimeter to the highest resistance range by turning the dial to the highest "ohm" setting.*
    (b) *Touch the test probes of your digital multimeter together.*
    (c) *Press the calibration knob until the display reads "0" on the digital multimeter if you don't see "0 ohms" initially.*
3. *Importance of calibrating multimeter.*

    A digital Multimeter is one of the most commonly used pieces of test and measurement instrumentation. Quality processes depend on its continual proper operation. However, time, *environment, and physical use (or abuses) change a digital multimeter's characteristics. That's why it's important to periodically calibrate or verify the performance of a digital multimeter. A multimeter should be calibrated or adjusted to a known zero-value prior to use for accurate readings.*

4. B
5. B
6. *Tools used in break down maintenance*
   i. *Ladder*
   ii. *Hammer*
   iii. *Pliers*
   iv. *Screw drivers e.t.c*

Perform electrical Installation

1. Final power circuit

   A final power sub-circuit is a circuit that allows electrical appliances to access electrical power.

   All final sub-circuits must be electrically separate that is there must be no "bunching" of neutral conductors.

2. Consumer intake point

   This is the point where the electricity power supplier terminates the service line to the consumer's premises. It is commonly known as a meter box or power house.

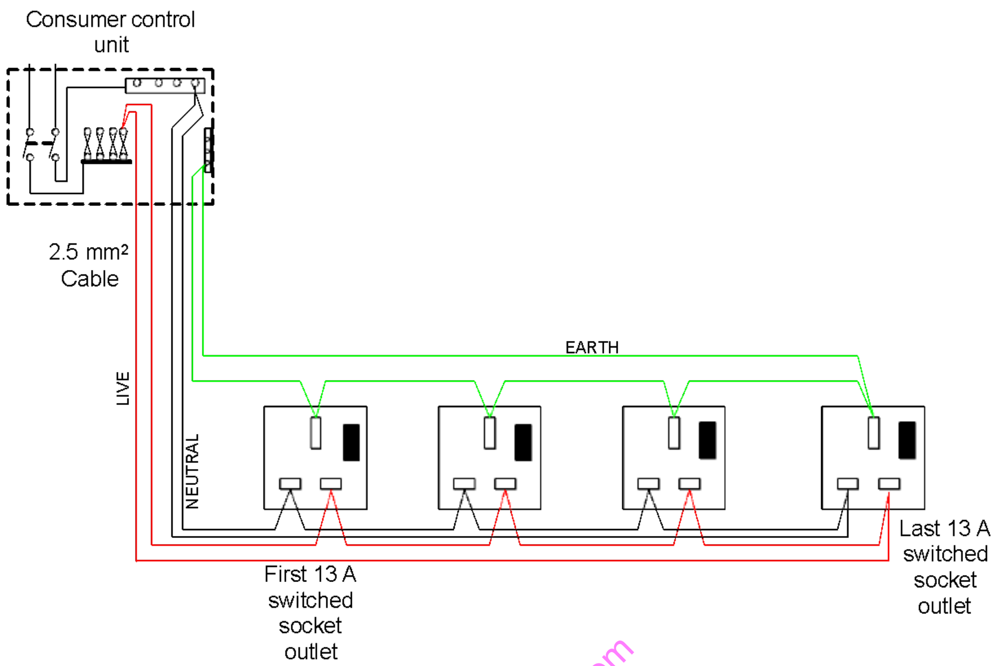
3. Requirements of a consumer intake point?

   The IEE regulations requires that, every consumer's installation shall be adequately controlled by a switchgear readily accessible to the consumer which shall incorporate-

   i) *Means of isolating all the conductors of the installation of the premises from the supply.*
   ii) *Means of excess current protection.*
   iii) *Means of earth leakage protection.*

4. Ring power circuit.

A ring circuit is defined in the I.E.E. Regulations as " a final sub-circuit in which the current-carrying and the earth-continuity conductors are connected in the form of a loop, both ends of which are connected to a single way in a distribution board or its equivalent.



Advantages of a ring circuit over a Radial circuit

i. *There is total safety in ring circuit than in Radial for the circuit is in form of a ring*

ii. *An open circuit point in the Ring circuit will not affect any other socket in the system This is because there are two paths of current and is one path is open the current will flow through the other*

iii. *Smaller sizes of cables may be used in Ring than in a Radial. This is because the Ring has two parallel current paths*

iv. *More loads may be fed or connected to a Ring circuit than a Radial circuit of the same capacity*

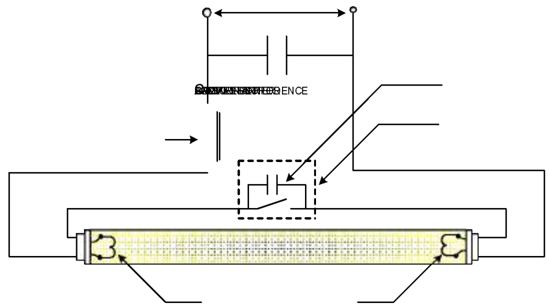
Disadvantages of Ring over Radial

i. *More cables lengths requires in a Ring than in Radial therefore becomes more expensive*

ii. *It consumes more time to install a Ring circuit than Radial because more cables has to be installed.*

5. Glow type method of starting a fluorescent lamp

i. The glow type



- *The starter contains of a small bulb filled helium gas and containing two contacts, one contact is mounted on a bi-metallic strip. The two contacts are normally open such that when the mains supply is switched ON, full mains voltage is applied to the starter contacts.*
- *This causes a glow discharge which warms the bimetallic strip which eventually bends closing the starter contacts.*
- *Once the starter contacts closes, full heating current flows through the lamp electrodes.* *After sometime the bimetallic strip cools to open the circuit thus striking the lamp. A tiny capacitor is connected across the starter switch to suppress radio interference*

7. B
8. A
9. C

CHAPTER 6: TESTING OF ELECTRICAL INSTALLATION

Unit of learning code: ENG/CU/EI/CR/03/4/A

Related Unit of Competency in Occupational Standard; Perform Testing of Electrical Installation

6.1 Introduction to the unit of learning

This unit covers the competencies required to carry out inspection and testing of an electrical installation. It covers testing activities starting from verifying the installed fittings and accessories, identifying the type of tests, carrying out the tests and issuing test certificates.

6.2 Summary of Learning Outcomes

1. Conduct physical inspection
2. Identify the test to be carried out and test equipment
3. Perform the test
4. Issue installation test and wiring certificates

6.2.1 Learning Outcome 1: Conduct Physical Inspection

Introduction to the learning outcome

This learning outcome specifies the content of competencies required to carry out Visual inspection, checking of physical condition, Firmness, Fitting points of the installation as per the established procedures and standards, and identified as per as-built drawings.

6.2.1.1 Performance Standard

Visual inspection is carried out.

Fitting points and equipment are identified as per as-built drawings.

Physical condition of the installation is checked as per established standards.

Firmness of the installation is checked as per the established standards.

6.2.1.2 Information Sheet

Definitions

Inspection. Examination of an electrical installation using all available means to ascertain correct selection and proper installation of electrical equipment.

Inspection and Testing

Periodic inspection and testing of internal wiring installations is necessary. Internal wiring should be checked every year for safe operations.

While carrying out inspection and testing of internal wiring installations, following points should be checked:

Incoming Service Line termination

Check and ensure the following:

1. Service line coming in to the premises is properly terminated and brought in

2. Check for fuse wire rating on each of the phases so as to ensure it is of correct rating

3. Check for wire sizes to be of correct size to carry the required current

4. Check for Earthing to be properly maintained at the service line side

Main Switch Board

A main switch board exists at the point of termination of service line. Supply is provided through this board in to the premises.

a) Ensure that the main switch board is closer to the point of supply in the premises
b) Check for fuses / circuit breakers used of adequate sizes for all phases
c) Check for correct ON/OFF working of Main Switch. A main switch plays a very important role as it helps to switch off the complete supply of the premises in case of emergency / repairs. It should always be in good working condition.
d) Check for any mechanical faults in switching operations that might cause it to remain continuously in ON state. This may be problematic in emergency cases when the electrician wants to switch the supply off
e) Ensure that the Switch board assembly is well covered to protect against rain / weather conditions
f) Inspect to see that you are clearly able to trace the neutral and earthing wires in different color
g) Inspect the electricity meter connections are properly fastened

Internal Wiring Circuits

Internal Wiring Circuits are to be checked for following points:

i. Ensure that each circuit branching out of Main Switch board has a connected load of not more than 800 watts or 10 points
ii. Test for Insulation resistance of conductor and earth to be as per IEC specifications
iii. Electrical resistance from connection with Earth electrode should not be more than one ohm
iv. Ensure metallic covering of iron clad switches, distribution boards are properly earthed
v. Test that that leakage current is less than 1/5,000 of maximum supply current.

General Content Inspection Checklist

1. Connection of conductors: Are terminations electrically and mechanically sound? Is insulation and sheathing removed only to a minimum to allow satisfactory termination?

2. Identification of conductors: Are conductors correctly identified in accordance with the Regulations?
3. Routing of cables: Are cables installed such that account is taken of external influences such as mechanical damage, corrosion, heat, etc.?
4. Conductor selection: Are conductors selected for current carrying capacity and voltage drop in accordance with the design?
5. Connection of single pole devices: Are single pole protective and switching devices connected in the line conductor only?
6. Accessories and equipment: Are all accessories and items of equipment correctly connected?
7. Thermal effects: Are fire barriers present where required and protection against thermal effects provided?
8. Protection against shock: What methods have been used to attain both basic protection and fault protection?
9. Mutual detrimental influence: Are wiring systems installed such that they can have no harmful effect on non-electrical systems, or those systems of different currents or voltages are segregated where necessary?
10. Isolation and switching: Are there appropriate devices for isolation and switching correctly located and installed?
11. Under voltage: Where under voltage may give rise for concern, are there protective devices present?
12. Labeling: Are all protective devices, switches (where necessary) and terminals correctly labeled?
13. External influences: Have all items of equipment and protective measures been selected in accordance with the appropriate external influences?
14. Access: Are all means of access to switchgear and equipment adequate?
15. Notices and signs: Are danger notices and warning signs present?
16. Diagrams: Are diagrams, instructions and similar information relating to the installation available?
17. Erection methods: Have all wiring systems, accessories and Equipment been selected and installed in accordance with the requirements of the Regulations, and are fixings for equipment adequate for the environment?

So, now that we have inspected all relevant items, and provided that there are no defects that may lead to a dangerous situation when testing, we can start the actual testing procedure.

Before testing begins, it is important that a full inspection of the complete installation is carried out.

Reasons for carrying out Electrical installation inspection

1. To ensure the safety of persons and livestock.

2. To ensure protection of property from fire and heat.

3. To ensure that the installation is not damaged so as to impair safety.

4. To ensure that the installation is not defective and complies with the current regulations.

5. Are in compliance with the safety requirements of the relevant equipment standards?

6. Have been correctly selected and erected according to the relevant rules and regulations and to the manufacturer's instructions, in order that performance is not adversely affected

7. Are suitable for the prevailing environmental conditions

Electrical installation inspection is accomplished by checking:

- The method of protection against electric shock
- The protection against thermal effects
- The precautions against propagation of fire
- The selection of the conductors for current-carrying capacity and voltage drop
- The choice and settings of the protective devices, the presence and correct location of suitable isolating and switching devices

- The selection of equipment and protective measures appropriate to external influences the correct identification of the circuits, overcurrent protective devices, switches, terminals, et cetera
- The presence of diagrams, warning notices, or similar information
- The adequacy of the conductor connections
- The presence and adequacy of protective conductors, including equipotential bonding
- The accessibility of the equipment for convenience of operation, identification, and maintenance
- In practice, Electrical installation inspection means checking the following items:
- Firmness of the accessories
- Correct color coding of cables.
- Maintenance points in place
- Good workmanship
- Separate circuits
- Adequate number of circuits
- Adequate number of socket-outlets
- All circuits suitably identified
- A suitable main switch provided
- Main breakers to interrupt all live conductors
- Main earthing terminal provided
- Correct fuses or circuit breakers installed
- All connections secure/loose connections

- Condition of accessories and fitting i.e. whether damaged or not
- The installation earthed in accordance with national standards
- Primary equipotential bonding connects services and other extraneous conductive parts to the primary earth facility
- Supplementary bonding has been provided in all bath and shower rooms
- The following items must be checked concerning protection against direct contact:
- Insulation of live parts
- Enclosures have a suitable degree of protection appropriate to external influences
- Enclosures have unused entries blanked off where necessary

Importance of Electrical installation Inspection

There are many reasons behind the necessity of getting an electrical inspection done. Some of the most common ones are:

- **Protection against possible surges**: This is a common phenomenon in different regions, especially when there is a storm. Electrical surges can not only ruin your appliances, but can also create short circuits in your house. When the inspection is being done, the inspector will check for different points in the wiring that can cause this type of mishap.

- **Fire**: Many a times it has been seen that an electrical short circuit has been the reason behind a fire breakout in a house. These short circuits are caused by different loose wires in the meter or in the cabling itself. During the inspection, the inspector can easily recognize these faults and ask you to rectify them.

- **Shocks**: Imagine touching an electronic appliance and immediately experiencing a surging electric current in your body. Although the impact may not be that disastrous; however, this could lead to other mishaps easily. Apart from this, the body current in an electronic appliance can easily hamper its performance or can render it completely non-workable. An electrical inspector can catch these faults in the wiring in time to rectify them.

6.2.1.4 Learning activities

Learning activity 1

Given an electrical installation premises, Check the Physical condition of the installation as per established standards. Use the following Observation Checklist to check the conditions.

Table 1.1: Observation checklist Learning activity 1

Observation Checklist				
Items to be evaluated	**Available/Done**	**Correct**	**Incorrect**	**Comment**
Connection of Conductors				
Identification of Conductors				
Routing of Cables				
Conductor Selection				
Connection of single pole devices				
Accessories and equipment selection				
Thermal effects considered				
Protection against shock				
Isolation and switching:				
Labeling				
External influences				
Accessibility				

Notices and signs				

Learning activity 2

You are assigned to identify the following electrical protective devices in an electrical installation for an inspection. Perform visual inspection on the devices.

Record your observations against the following checklist in table 1.2

Table 1.2: Observation Checklist activity 2

Observation checklist			
Items	Area of observation	Yes	No
Circuit breaker	Presence breakages		
	Presence of contacts		
	Presence of fasteners		
Double pole switch	Presence of breakages		
	Presence of contacts		
Triple pole switch with neutral	Presence of breakages		
	Presence of contacts		
	Presence of fasteners		
Isolator switch	Presence of breakages		
	Presence of contacts		
	Presence of fasteners		

6.2.1.5 Self-assessment: Learning Outcome 1

1. When a certificate is issued for Initial Verification purposes, for the certificate to be valid it MUST be accompanied by?

   A. inspection tick-sheet

   B. schedules of inspections and test results

   C. test results sheet

   D. Part 'P' certificate

2. Indicate three main areas, about which you would require information, in order correctly to carry out an initial verification of a new installation.
3. State three human senses that could be used during an inspection of an installation.
4. Apart from wear and tear state three areas of investigation that you would consider when carrying out a periodic inspection and test of an installation.
5. An Electrical Installation Certificate should be accompanied by signed documentation regarding three stages of an installation. What are these stages?

6.2.1.6 Tools, Equipment, Supplies and Materials

Tools

Phase Tester

Screw drivers

Equipment

- Test instruments
  - Continuity tester (ohmmeter)
  - Insulation resistance tester
  - Earth loop impedance tester
  - Test lamp

Materials and supplies

- BS 7671
- Guidance Note 3
- The On-site Guide.
- Stationery
- Wiring certificates

Reference materials

- BS 7671
- Guidance Note 3
- The On-site Guide.
- Manufacturers' manuals
- Relevant catalogues
- IEE regulations
- Standards
- County by-laws
- Occupational Safety and Health Act (OSHA)
- National Environmental Management Authority (NEMA) regulations
- National Construction Authority (NCA) regulations

- IEE tables

6.2.1.7 Reference

IEE Wiring Regulations: Inspection, Testing and Certification Sixth Edition Brian Scaddan, IEng, MIET

https://electrical-engineering-portal.com/inspection-electrical-installations-home-1

https://www.dfliq.net/blog/electrical-inspection-a-detailed-overview

6.2.2 Learning Outcome 2: Identify the test to be carried out and test equipment

6.2.2.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to identify installation to be tested, test points, test parameters and their expected values as per the established standards, appropriate test equipment as per the tests to carry out. In addition, it also specifies the content of competence required on checking the specifications and functionality of test equipment, preparation and safe storage for easy access in accordance with established procedure.

6.2.2.3 Performance Standard

i. The ***installation*** to be tested is identified per established standards
ii. Test points are identified as per established standards
iii. Test parameters and their expected values are identified as per established standards
iv. Appropriate ***Test equipment*** are identified as per the tests to carried out
v. Test equipment are checked for appropriate specifications and functionality
vi. Test equipment are prepared and stored for safe and easy access in accordance with established procedure

6.2.2.4 Information Sheet

Testing

Implementation of measures in an electrical installation by which its effectiveness is proved.

Reasons of electrical installation testing

1. To ensure that people and goods are kept safe and are protected in the event of a fault.
2. Facilitates preventive maintenance of installations, preventing serious faults which might prove expensive (production shutdown, etc.).
3. To guarantee people's safety with regard to these installations and the electrical
4. Equipment connected to them, standards have naturally been developed and updated to take changes into account.

Purpose of Electrical Installation Testing

All new completed electrical installation should be tested before connection to the supply. The purpose of the electrical installation condition report and testing is to provide, as far as is reasonably practicable:

i. To ensure that the installation is technically sound and free from any possible short circuits, etc.
ii. To know the cause of failure of a particular circuit or circuits or equipment and to locate the exact position of break down.
iii. To ensure that it is free from faults and is as per electricity rules.
iv. These tests will receive the attention of the owner before any possible undue damage occurs. i.e. to confirm that the installation is not damaged or deteriorated.
v. For the safety of persons and livestock.
vi. Protection against damage by fire and heat.

Types of tests

The IEE Regulations indicate a preferred sequence of tests and state that if, due to a defect, compliance cannot be achieved, the defect should be rectified and the test sequence started from the beginning. The tests for 'Site applied insulation', 'Protection by separation', and 'Insulation of non-conducting floors and walls' all require specialist high voltage equipment and in consequence will not be discussed here.

The sequence of tests for an initial inspection and test is as follows:

1. Continuity of protective conductor's tests.
2. Continuity of ring final circuit conductor's tests.
3. Insulation resistance tests.
4. Protection by barriers or enclosures.
5. Polarity tests.
6. Earth electrode resistance.
7. Earth fault loop impedance.
8. Additional protection (RCDs).

9. Prospective fault current (PFC) between live conductors and to earth.
10. Functional testing.
11. Voltage drop
12. Phase sequence.

One other test not included in Part 7 of the IEE Regulations but which nevertheless has to be carried out is external earth fault loop impedance (Ze).

Continuity of protective conductors

These include the cpcs (circuit protective conductor) of radial circuits, main and supplementary Protective bonding conductors. Two methods are available: either can be used for cpcs, but bonding can only be tested by the second.

Method 1

At the distribution board, join together the line conductor and its associated cpc. Using a low resistance ohmmeter, test between line and cpc at all the outlets in the circuit. The reading at the farthest point will be (R1+R2) for that circuit. Record this value; after correction for temperature it may be compared with the designer's value (more about this later).

Method 2

Connect one test instrument lead to the main earthing terminal and a long test lead to the earth connection at all the outlets in the circuit.

Record the value after deducting the lead resistance. An idea of the length of conductor is valuable, as the resistance can be calculated and compared with the test reading.

Table 1.3 gives resistance values already calculated for a range of lengths and sizes.

It should be noted that these tests are applicable only to 'all insulated' systems, as installations using metallic conduit and trunking, MICC and SWA cables will produce spurious values due to the probable parallel paths in existence. This is an example of where testing needs to be carried out during the erection process and before final connections and bonding are in place.

Table 1.2: Resistance (Ω) of Copper Conductors at 20°C

CSA(mm^2)	Lenth (m)									
	5	10	15	20	25	30	35	40	45	50
1.0	0.09	0.18	0.27	0.36	0.45	0.54	0.63	0.72	0.82	0.90
1.5	0.06	0.12	0.18	0.24	0.30	0.36	0.42	0.48	0.55	0.61
2.5	0.04	0.07	0.11	0.15	0.19	0.22	0.26	0.30	0.33	0.37
4.0	0.023	0.05	0.07	0.09	0.12	0.14	0.16	0.18	0.21	0.23
6.0	0.02	0.03	0.05	0.06	0.08	0.09	0.11	0.13	0.14	0.16
10.0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
16.0	0.006	0.01	0.02	0.023	0.03	0.034	0.04	0.05	0.051	0.06
25.0	0.004	0.007	0.01	0.015	0.02	0.022	0.026	0.03	0.033	0.04
35.0	0.003	0.005	0.008	0.01	0.013	0.016	0.019	0.02	0.024	0.03

If conduit, trunking or SWA is used as the cpc, then the verifier has the option of first inspecting the cpcs (circuit protective conductors) along its length for soundness then conducting the long-lead resistance test.

Continuity of ring final circuit conductors

The requirement of this test is that each conductor of the ring is continuous. It is, however, not sufficient to simply connect an ohmmeter, a bell, etc., to the ends of each conductor and obtain a reading or a sound. So, what is wrong with this procedure? A problem arises if an interconnection exists between sockets on the ring, and there is a break in the ring beyond that interconnection. From Figure 1.2 it will be seen that a simple resistance or bell test will indicate continuity via the interconnection.

However, owing to the break, sockets 4–11 are supplied by the spur from socket 12, not a healthy situation. So how can one test to identify interconnections? There are three methods of conducting such a test.

Two are based on the principle that resistance changes with a change in length or CSA; the other, predominantly used, relies on the fact that the resistance measured across any diameter of a circular loop of conductor is the same. Let us now consider the first two.

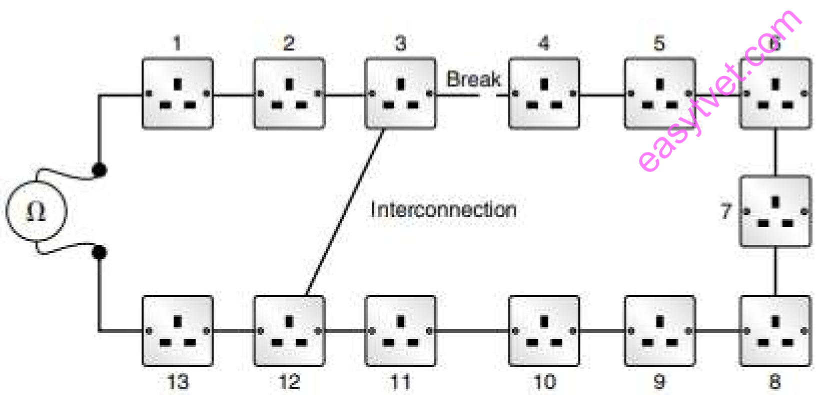


Figure 1.1: Ring circuit with interconnection

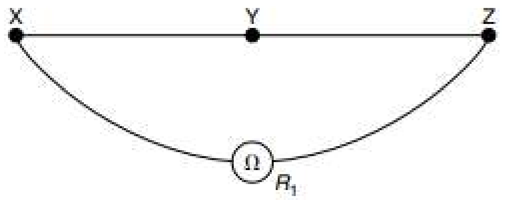


Figure 1.2: End to end conductor resistance.

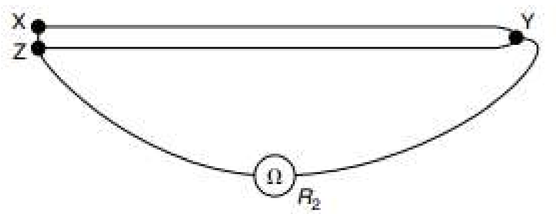


Figure 1.3: Doubled over end to end conductor resistance.

Method 1

If we were to take a length of conductor XYZ and measure the resistance between its ends (Figure 1.3), then double it over at Y, join X and Z, and measure the resistance between XZ and Y (Figure 1.4), we would find that the value was approximately a quarter of the original. This is because the length of the conductor is halved and hence so is the resistance, and the CSA is doubled and so the resistance is halved again.

In order to apply this principle to a ring final circuit, it is necessary to know the position of the socket nearest the mid-point of the ring.

The test procedure is then as follows for each of the conductors of the ring:

1. Measure the resistance of the ring conductor under test between its ends before completing the ring in the fuse board. Record this value, say R1.

2. Complete the ring.

3. Using long test leads, measure between the completed ends and the corresponding terminal at the socket nearest the mid-point of the ring. Record this value, say R2. (The completed ends correspond to point XZ in Figure 2. and the mid-point to Y.)

4. Measure the resistance of the test leads, say R3, and subtract this value from R2, i.e. R2−R3=R4 say.

5. A comparison between R1 and R4 should reveal, if the ring is healthy, that R4 is approximately a quarter of R1.

Method 2

The second method tests two ring circuit conductors at once, and is based on the following. Take two conductors XYZ and ABC and measure their resistances (Figure 1.5). Then double them both over, join the ends XZ and AC and the mid-points YB, and measure the resistance between XZ and AC (Figure 2.6)

This value should be a quarter of that for XYZ plus a quarter of that for ABC. If both conductors are of the same length and CSA, the resultant value would be half that for either of the original resistances. Applied to a ring final circuit, the test procedure is as follows:

1. Measure the resistance of both line and neutral conductors before completion of the ring. They should both be the same value, say R1.

2. Complete the ring for both conductors, and bridge together line and neutral at the mid-point socket (this corresponds to point YB in Figure 1.6).

Now measure between the completed line and neutral ends in the fuse board (points XZ and AC in Figure 1.6).

Record this value, say R2.

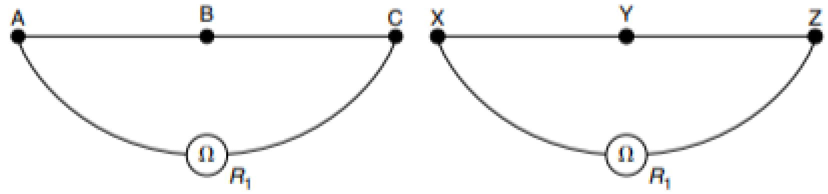


Figure 1.4: End to end conductor resistance.

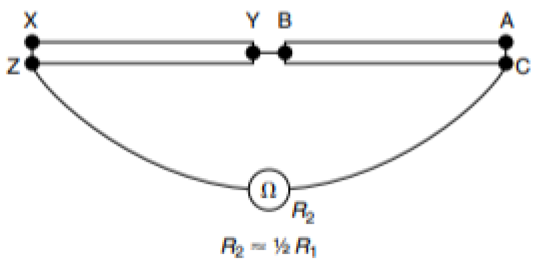


Figure 1.5: Doubled over conductors in parallel

3. R2 should be, for a healthy ring, approximately half of R1 for either line or neutral conductor.

When testing the continuity of a cpc which is a different size from either line or neutral, the resulting value R2 should be a quarter of R1 for line or neutral plus a quarter of R1 for the cpc.

Method 3 (generally used)

The third method is based on the measurement of resistance at any point across the diameter of a circular loop of conductor (Figure 1.7). As long as the measurement is made across the diameter of the ring, all values will be the same. The loop of conductor is formed by crossing over and joining the ends of the ring circuit conductors at the fuse board. The test is conducted as follows: 1. Identify both 'legs' of the ring.

2. Join one line and one neutral conductor of opposite legs of the ring.

3. Obtain a resistance reading between the other line and neutral (Figure 1.8). (A record of this value is important.)

4. Join these last two conductors (Figure 1.9).

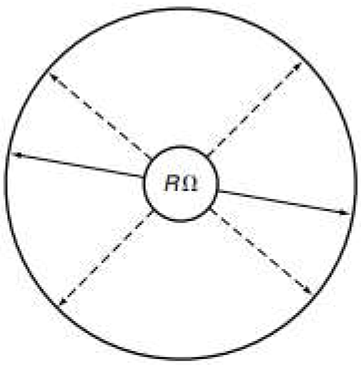


Figure 1.6: Resistance across diameter of circle of conductor.

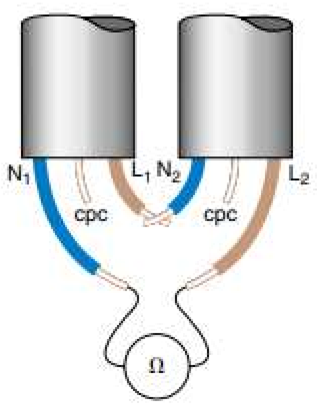


Figure 1.7: End to end double loop resistance.

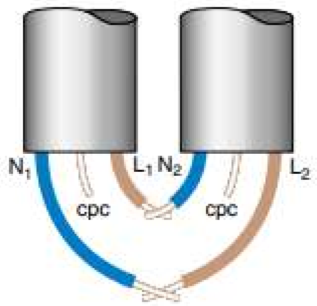


Figure1. 8: Both ends cross connected.

5. Measure the resistance value between L and N at each socket on the ring. All values should be the same, approximately a quarter of the reading in (3) above.

The test is now repeated but the neutral conductors are replaced by the cpcs. If the cable is twin with cpc, the cpc size will be smaller than the line conductor, and although the readings at each socket will be substantially the same, there will be a slight increase in values towards the Centre of the ring, decreasing back towards the start. The highest reading represents R1+R2 for the ring.

The basic principle of this method is that the resistance measured between any two points, equidistant around a closed loop of conductor, will be the same.

Such a loop is formed by the line and neutral conductors of a ring final circuit (Figure 2.0). Let the resistance of conductors be as shown. R measured between L and N on socket A will be:

$$\frac{0.2+0.5+0.3+0.4+0.1+0.3}{2} = \frac{2}{2} = 1\Omega$$

R measured between L and N at B will be :

$$\frac{0.3+0.2+0.5+0.2+0.3+0.4+0.1}{2} = \frac{2}{2} = 1\Omega$$

Hence all sockets on the ring will give a reading of 1Ω between L and N.

If there were a break in the ring in, say, the neutral conductor, all measurements would have been 2, incorrectly indicating to the tester that the ring was continuous. Hence the relevance of step 3 in the test procedure, which at least indicates that there is a continuous L–N loop, even if an interconnection exists.

Figure 2.1 shows a healthy ring with interconnection. Here is an example that shows the slight difference between measurements on the line/cpc test. Consider a 30m ring final circuit wired in 2.5mm2 with a 1.5mm2 cpc. Figure 2.2 illustrates this arrangement when cross-connected for test purposes.

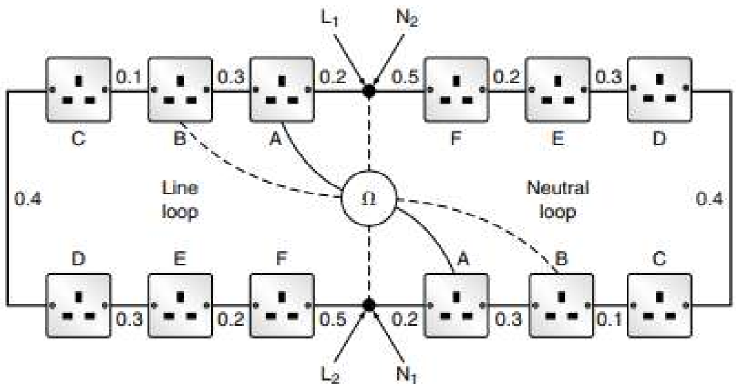


Figure 9: Equidistant loop measurements.

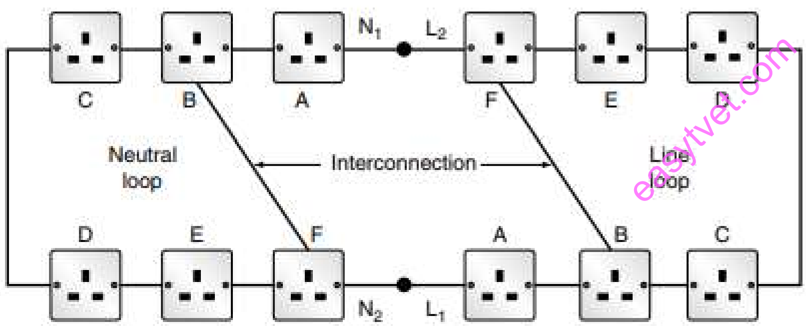


Figure 10: Healthy ring circuits with an interconnection.

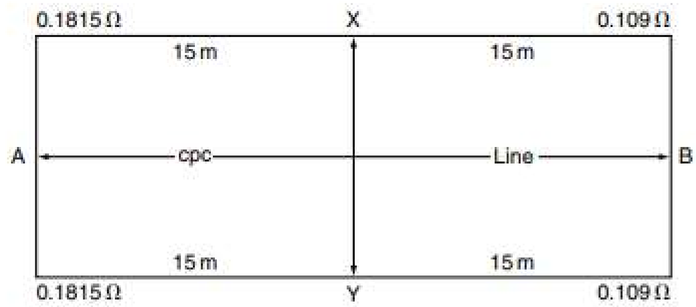


Figure 11: Ring with 2.5mm2 line and 1.5mm2 cpc.

From the resistance tables, 1.5mm2 conductor is seen to have a resistance of 12.1mΩ/m, and 2.5mm2, 7.27mΩ/m. This gives the resistance from X to A as 15×12.1/1000=0.1815Ω and from X to B as 15×7.27/1000=0.109.

The same values apply from Y to A and Y to B. So measuring across X and Y we have 2×0.1815=0.363, in parallel with 2×0.109= [(0.363×0.218)/(0.363+0.218)]Ω (product over sum)=0.137Ω. Measuring across A and B (the mid-point) gives 0.1815+0.109=0.29Ω, in parallel with the same value, i.e. 0.29Ω, which gives 0.29/2=0.145Ω. While there is a difference of 0.008Ω the amount is too small to suggest any faults on the ring. Note: If the line–neutral and line–cpc tests prove satisfactory this is also an indication that the polarity at each socket outlet is correct.

Protection by barriers or enclosures

If an enclosure/barrier is used to house or obscure live parts, and is not a factory-built assembly, it must be ascertained whether or not it complies with the requirements of the IP codes IP2X or IPXXB, or IP4X or IPXXD. For IP2X or IPXXB, the test is made using the British Standard Finger, which is connected in series with a lamp and a supply of not less than 40V and not more than 50V. The test finger is pushed into or behind the enclosure/barrier and the lamp should not light (Figure 2.3).

The test for IP4X or IPXXD is made with a 1.0mm diameter wire with its end cut at right angles to its length. The wire should not enter the enclosure to conform to IP4X. It may enter for 100 mm without touching live parts to conform to IPXXD.

Insulation resistance

An insulation resistance tester, which is a high resistance ohmmeter, is used for this test.

Clearly with voltages of these levels, there are certain precautions to be taken prior to the test being carried out.

Persons should be warned, and sensitive electronic equipment disconnected or unplugged.

A common example of this is the dimmer switch. Also, as many accessories have indicator lamps, and items of equipment such as fluorescent fittings have capacitors fitted, these should be disconnected as they will give rise to false readings. The test procedure is as follows: Poles to earth (Figure 2.4)

1. Isolate supply.
2. Ensure that all protective devices are in place and all switches are closed.
3. Link all poles of the supply together (where appropriate).
4. Test between the linked poles and earth.

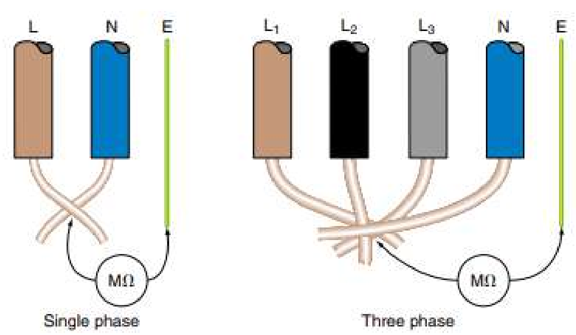


Figure2.4:Test between live conductors and earth

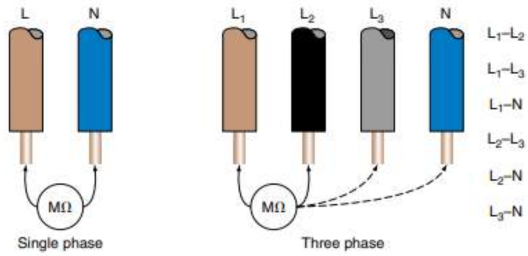


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Figure 12: Test between live conductors.

Between poles (Figure 2.5)

1. As previous test.

2. As previous test.

3. Remove all lamps, equipment, etc.

4. Test between poles.

Test results on disconnected equipment should conform to the relevant British Standard for that equipment. In the absence of a British Standard, the minimum value is 0.5MΩ. For small installations, the tests are performed on the whole system, whereas for larger complex types, the installation may be sub-divided into sections and tests performed on each section.

The reason for this is that as conductor insulation and the circuits they supply are all in parallel, a test on the whole of a large installation would produce pessimistically low readings even though no faults exist. Although for standard 400V/230V installations the minimum value of insulation resistance is 1MΩ, a reading of less than 2MΩ should give rise to some concern. Circuits should be tested individually to locate the source/s of such a low reading.

Polarity

It is required that all fuses and single-pole devices such as single-pole circuit breakers and switches are connected in the line conductor only. It is further required that the center contact of Edison screw lamp holders be connected to the line conductor (BS EN 60298 E14 and E27 ES types are exempt as the screwed part is insulated) and that socket outlets and similar accessories are correctly connected.

Ring final circuits

If method 3 for testing ring circuit conductor continuity was performed, then any cross-polarity would have shown itself and been rectified. Hence no further test is necessary. However, if method 1 or 2 were used, and the mid-point socket was correct, reversals elsewhere in the ring would not be detected and therefore two tests are needed:

1. Link completed line and cpc loops together at the fuse board and test between L and E at each socket. A no reading result will indicate a reversed polarity (Figure 2.6).

2. Repeat as in 1, but with L and N linked. RADIAL CIRCUITS For radial circuits, the test method 1 for continuity of protective conductors will have already proved correct polarity.

It just remains to check the integrity of the neutral conductor for socket outlet circuits, and that switch wires and neutrals are not mixed at lighting points.

This is done by linking L and N at the fuse board and testing between L and N at each outlet and between N and switch wire at each lighting point.

Also, for lighting circuits, to test for switches in line conductors, etc., link L and E at the fuse board and test as shown in Figure 2.7.

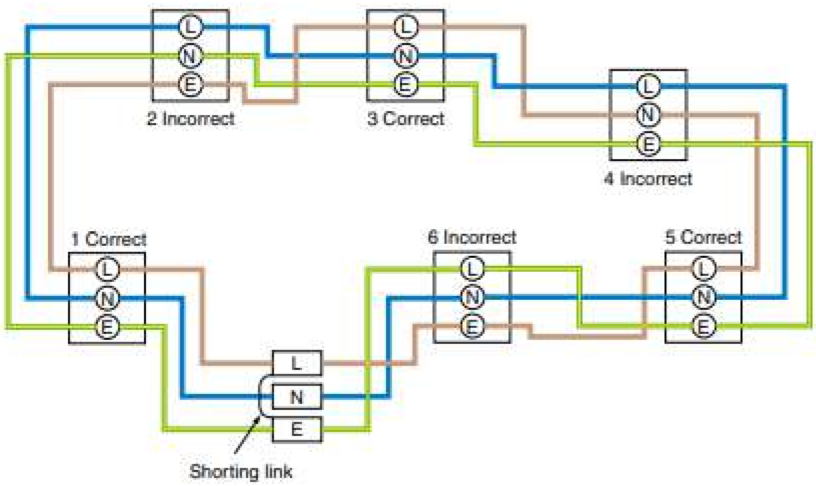

Figure 13: Polarity test if done separately to method 3 ring tests.

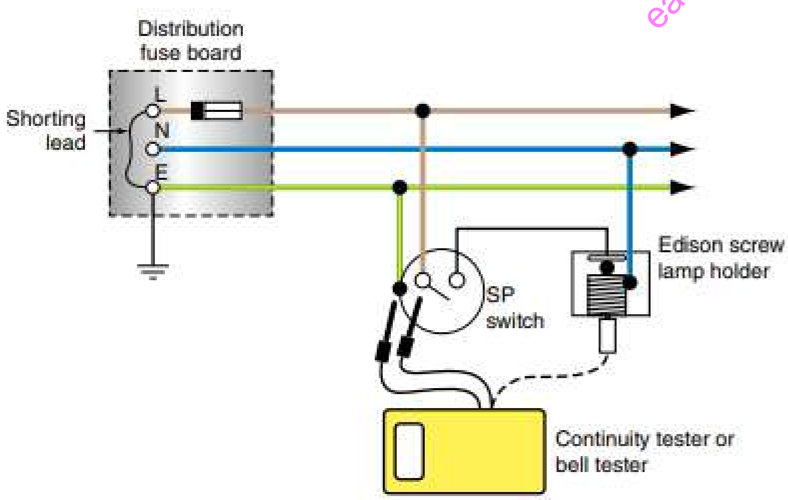

Figure 14: Polarity on ES lamp holder.

Earth electrode resistance

If we were to place an electrode in the earth and measure the resistance between the electrode and points at increasingly larger distances from it, we would notice that the resistance increased with distance until a point was reached (usually around 2.5m) beyond which no increase in resistance was noticed (Figure 2.8).

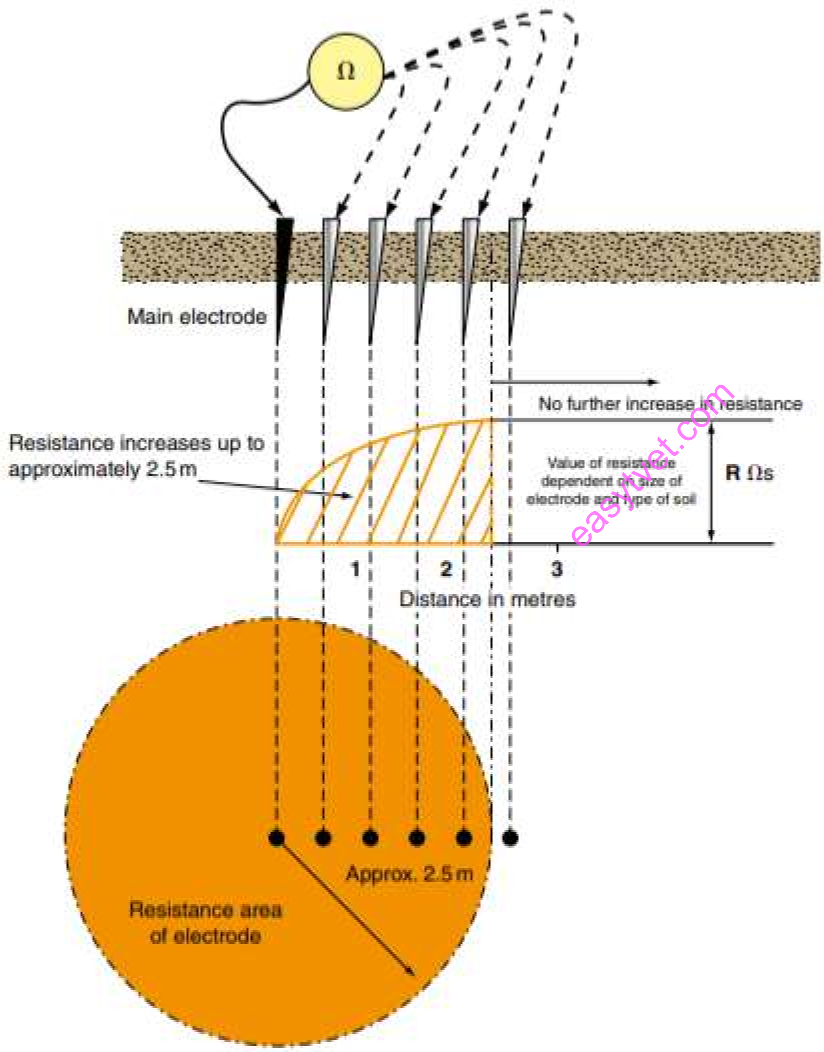

Figure 15: Electrode resistance areas

It is a requirement of the Regulations that for a TT system, exposed conductive parts must be connected via protective conductors to an earth electrode, and that the protection is by either an RCD or an overcurrent device, the RCD being preferred. Conditional on this is the requirement that the product of the sum of the resistances of the earth electrode and protective conductors, and the operating current of the protective device, shall not exceed 50V, i.e. $Ra \times Ia \leq 50V$. (Ra is the sum of the resistances of the earth electrode and the protective conductors connecting it to the exposed conductive part.) Clearly then, there is a need to measure the resistance of the earth electrode. This may be done in either of two ways.

Method 1

Based on the principle of the potential divider (Figure 2.9,), an earth resistance tester is used together with test and auxiliary electrodes spaced as shown in Figure 3.0. This spacing ensures that resistance areas do not overlap.

The method of test is as follows:

1. Place the current electrode (C2) away from the electrode under test, approximately 10 times its length, i.e. 30m for a 3m rod.

2. Place the potential electrode mid-way.

3. Connect test instrument as shown.

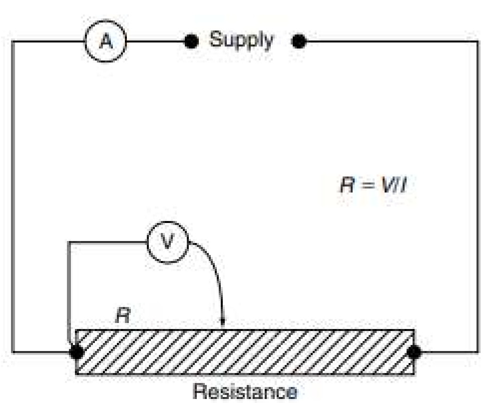

Figure 16: Potential divider.

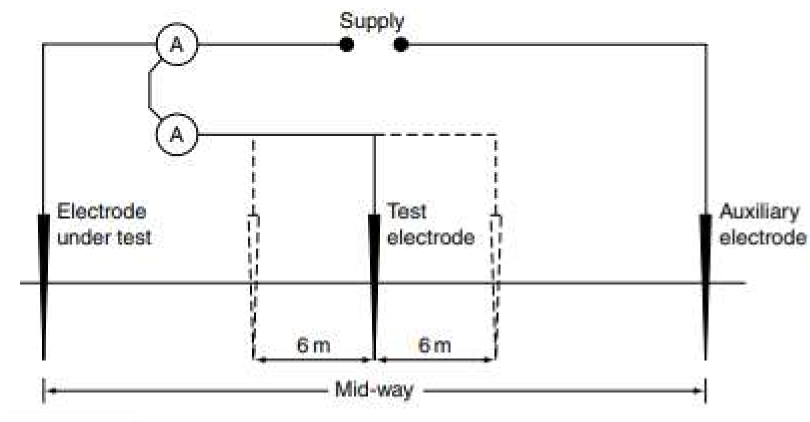

Figure 17: Positions of test electrodes.

4. Record resistance value.

5. Move the potential electrode approximately 6m either side of the mid-position, and record these two readings.

6. Take an average of these three readings (this is the earth electrode resistance). Three readings obtained from an earth electrode resistance test were 181Ω, 185Ω and 179Ω. What is the value of the electrode resistance?

$$Average\ value = \frac{181+185+179}{3} = 181.67\Omega$$

For TT systems the result of this test will indicate compliance if the product of the electrode resistance and the operating current of the overcurrent device does not exceed 50V.

Method 2

On TT systems protected by an RCD, a loop impedance tester is used and effectively measures Ze, which is taken as the earth electrode resistance.

External loop impedance Ze

This is carried out by connecting an earth fault loop impedance tester between the supply line conductor and the earthing conductor at the intake position with the earthing conductors disconnected.

This ensures that parallel resistance paths will not affect the reading. Wherever possible the installation should be isolated from the supply during the test. If this is not possible then all circuits should be isolated. When the test is completed reconnect the earthing conductor.

Earth fault loop impedance Zs

This has to be measured in order to ensure that protective devices will operate in the specified time under fault conditions. As the value of (R1+R2) Ω for a particular circuit will have already been established, Zs may be found by simply adding the R1+R2 value to Ze.

Alternatively, it may be measured directly at the extremity of a particular circuit. Whichever method is used, the value obtained will need to be corrected to compensate for ambient and conductor operating temperatures before a comparison is made with the tabulated values of Zs in the Regulations.

Note: All main protective and supplementary bonding must be in place during this test.

Additional protection

Residual current devices

Only the basic type of RCD will be considered here. Clearly, such devices must operate to their specification; an RCD tester will establish this. As with loop impedance testing, care must be taken when conducting this test as an intentional earth fault is created in the installation.

In consequence, a loop impedance test must be conducted first to confirm that an earth path exists or the RCD test could prove dangerous. It is important to know why an RCD has been installed as this has direct effect on the tests performed. The tests are as follows:

1. With the tester set to the RCD rating, half the rated current is passed through the device. It should not trip.

2. With full rated current passed through the device, it should trip within 200ms (300ms for RCBOs).

3. For RCDs having a residual current rating of 30mA or less, a test current of 5×IΔn should be applied and the device should operate in 40ms or less.

4. All RCDs have a test button which should be operated to ensure the integrity of the tripping mechanism. It does not check any part of the earthing arrangements or the device's sensitivity. As part of the visual inspection, it should be verified that a notice, indicating that the device should be tested via the test button quarterly, is on or adjacent to the RCD.

There seems to be a popular misconception regarding the ratings and uses of RCDs in that they are the panacea for all electrical ills and the only useful rating is 30mA!

Firstly, RCDs are not fail-safe devices; they are electromechanical in operation and can malfunction. Secondly, general purpose RCDs are manufactured in ratings from 5mA to 1000mA (30mA, 100mA, 300mA and 500mA being the most popular) and have many uses. The following list indicates residual current ratings and uses as mentioned in BS 7671.

Requirements for RCD protection

30mA

- All socket outlets rated at not more than 20A and for un-supervised general use.
- Mobile equipment rated at not more than 32A for use outdoors.
- All circuits in a bath/shower room.
- Preferred for all circuits in a TT system.
- All cables installed less than 50mm from the surface of a wall or partition (in the safe zones) if the installation is un-supervised, and also at any depth if the construction of the wall or partition includes metallic parts.
- In zones 0, 1 and 2 of swimming pool locations.
- All circuits in a location containing saunas, etc.
- Socket outlet final circuits not exceeding 32A in agricultural locations.

- Circuits supplying Class II equipment in restrictive conductive locations.
- Each socket outlet in caravan parks and marinas and final circuit for houseboats.
- All socket outlet circuits rated not more than 32A for show stands, etc.
- All socket outlet circuits rated not more than 32A for construction sites (where reduced low voltage, etc. is not used).
- All socket outlets supplying equipment outside mobile or transportable units.
- All circuits in caravans.
- All circuits in circuses, etc.
- A circuit supplying Class II heating equipment for floor and ceiling heating systems.

500mA

- Any circuit supplying one or more socket outlets of rating exceeding
- 32A, on a construction site.

300mA

- At the origin of a temporary supply to circuses, etc.
- Where there is a risk of fire due to storage of combustible materials.
- All circuits (except socket outlets) in agricultural locations.

100mA

- Socket outlets of rating exceeding 32A in agricultural locations.

Where loop impedance values cannot be met, RCDs of an appropriate

rating can be installed. Their rating can be determined from

$I\Delta n = 50 / Zs$ where $I\Delta n$ is the rated operating current of the device, 50 is the touch voltage and Zs is the measured loop impedance.

Prospective fault current

A PFC tester, usually incorporated with a loop impedance tester, is used for this. When testing at the intake position, probes and/or clips will be needed and hence great care needs to be taken when connecting to live terminals, etc. Measurements are taken between L and N, and L and E and the highest value recorded. For three phase supplies, the line to line.

PFC is determined from multiplying the L to N reading by $\sqrt{3}$ (1.732) or more simply by 2.

Phase sequence

For multi-phase circuits, e.g. supplies to three-phase motors, etc., it is important to check that the phase sequence is correct to ensure correct direction of rotation. A phase sequence instrument is used which is basically a small three-phase motor.

Functional testing

Tests on assemblies

These are carried out on a switchgear, interlock, control gear, etc., to ensure that they are mounted and installed according to the Requirements of the 17th Edition.

Voltage drop

There may be occasions when verification of voltage drop is required.

This would be achieved by calculation or by reference to charts or tables.

Periodic inspection and testing

After an installation has had an initial verification and been put into service, there is a requirement for regular periodic verification to take place. In some cases where, for example, a Local Authority is involved, the interval between tests is mandatory. In other cases, the interval is only a recommendation. For example, the recommended time between tests on domestic installations is 10 years, whereas places of public entertainment have a mandatory interval of one year.

Clearly, periodic tests may prove difficult, as premises are usually occupied and in full service, and hence careful planning and consultation are needed in order to minimize any disruption. A thorough visual inspection should be undertaken first, as this will indicate to the experienced inspector the depth to which he or she needs to go with the instrument tests, and an even more rigorous investigation may be required if drawings/design data are not available.

The visual inspection will need to take into account such items as safety, wear and tear, corrosion, signs of overloading, mechanical damage, etc.

In many instances, a sample of items inspected may be taken, for example a minimum of 10% of switching devices may be taken. If, however, the sample indicates considerable deterioration then all items must be inspected.

The test sequence where relevant and where possible should be the same as that for an initial verification. This is not essential: As with visual inspection, sample tests may be made, usually 10%, with the proviso that this is increased in the event of faults being found.

In the light of previous comments regarding sampling, it is clear that periodic verification is subjective, varying from installation to installation. It is also more dangerous and difficult and hence requires the inspector to have considerable experience. Accurate and coherent records must be made and given to the person/s ordering the work. Such records/reports must indicate any departures from or non-compliances with the Regulations, any restrictions in the testing procedure, any dangerous situations, etc.; if the installation was erected according to an earlier edition of the Regulations, it should be tested as far as possible to the requirements of the 17th Edition, and a note made to this effect on the test report.

It should be noted that if an installation is effectively supervised in normal use, then Periodic Inspection and Testing can be replaced by regular maintenance by skilled persons. This would only apply to, say, factory installations where there are permanent maintenance staff.

6

Identification and specification of test equipment

Testing instruments

In order to fulfill the basic requirements for testing to BS 7671, the following instruments are needed:

1. A low-resistance ohmmeter (continuity tester).
2. An insulation resistance tester.
3. A loop impedance tester.
4. A residual current device (RCD) tester.
5. A prospective fault current (PFC) tester.
6. An approved test lamp or voltage indicator.
7. A proving unit.
8. An earth electrode resistance tester.

Many instrument manufacturers have developed dual or multifunction instruments; hence it is quite common to have continuity and insulation resistance in one unit, loop impedance and PFC in one unit, loop impedance, PFC and RCD tests in one unit, etc.

However, regardless of the various combinations, let us take a closer look at the individual test instrument requirements.

Low-resistance ohmmeters/continuity testers

Bells, buzzers, simple multimeters, etc., will all indicate whether or not a circuit is continuous, but will not show the difference between the resistance of, say, a 10 m length of 10 mm^2conductor and a 10 m length of 1 mm^2 conductor.

I use this example as an illustration, as it is based on a real experience of testing the continuity of a 10 mm^2main protective bonding conductor between gas and water services. The services, some 10 m apart, were at either ends of a domestic premise.

The 10 mm^2 conductor, connected to both services, disappeared under the floor and a measurement between both ends indicated a resistance higher than expected.

Further investigation revealed that just under the floor at each end, the 10 mm^2 conductor had been terminated in a connector block and the joint between the two, about 8 m, had been wired with a 1 mm^2 conductor. Only a milli-ohmmeter would have detected such a fault.

Insulation resistance testers

An insulation resistance test is the correct term for this form of testing, not a megger test as megger is a manufacturer's trade name, not the name of the test.

A low-resistance ohmmeter should have a no-load source voltage of between 4 and

24 V, and be capable of delivering an A.C or D.C short circuit voltage of not less than 200 mA. It should have a resolution (i.e. a detectable difference in resistance) of at least 0.01 m **Ω**.

An insulation resistance tester must be capable of delivering 1 mA when the required test voltage is applied across the minimum acceptable value of insulation resistance.

Hence, an instrument selected for use on a low-voltage (50 V ac–1000 V ac) system should be capable of delivering 1 mA at 500 V across a resistance of 1 M **Ω**.

Loop impedance tester

This instrument functions by creating, in effect, an earth fault for a brief moment, and is connected to the circuit via a plug or by 'flying leads 'connected separately to line, neutral and earth.

The instrument should only allow an earth fault to exist for a maximum of 40 ms, and a resolution of 0.01 Ω is adequate for circuits up to 50 A. Above this circuit rating, the ohmic values become too small to give such accuracy using a standard instrument, and more specialized equipment may be required.

RCD tester

Usually connected by the use of a plug, although ‘ flying leads ’are needed for non-socket outlet circuits, this instrument allows a range of out-of-balance currents to flow through the RCD to cause its operation within specified time limits.

The test instrument should not be operated for longer than 2 s, and it should have a 10 per cent accuracy across the full range of test currents.

The instrument should only allow an earth fault to exist for a maximum of 40 ms, and a resolution of 0.01 Ω is adequate for circuits up to 50 A. Above this circuit rating, the ohmic values become too small to give such accuracy using a standard instrument, and more specialized equipment may be required.

Earth electrode resistance tester

This is a 3 or 4 terminal, battery powered, resistance tester.

PFC tester

Normally one half of a dual loop impedance/PFC tester, this instrument measures the prospective line-neutral fault current at the point of measurement using the same leads as for loop impedance.

Approved test lamp or voltage indicator

A flexible cord with a lamp attached is not an approved device, nor for that matter is the ubiquitous ‘testascope ’or ‘neon screwdriver’, which encourages the passage of current, at low voltage, through the body!

A typical approved test lamp is as shown in Figure 3.1.

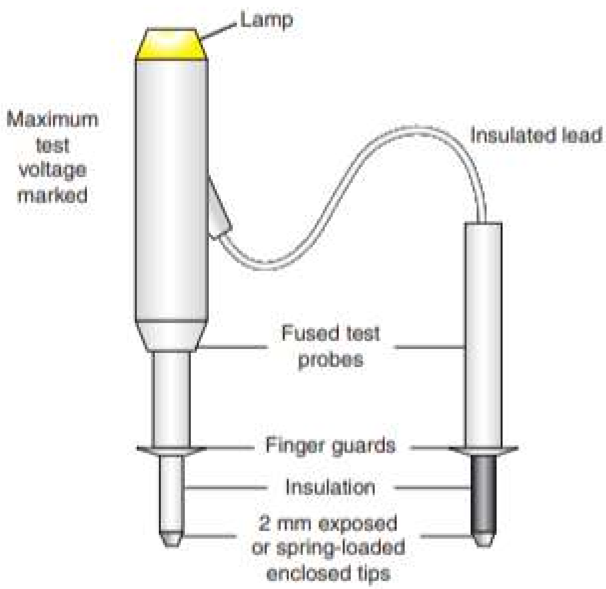

Figure 18: Approved test lamp

Note: Test lamps must be proved against a voltage similar to that to be tested. Hence, proving test lamps that incorporate an internal check, that is shorting out the probes to make a buzzer sound is not acceptable if the voltage to be tested is higher than that delivered by the test lamp.

Characteristics leads and probes associated with test equipment

The Health and Safety Executive, Guidance Note GS 38, recommend that the leads and probes associated with test lamps, voltage indicators, voltmeters, etc., have the following characteristics:

1. The leads should be adequately insulated and, ideally, fused.

2. The leads should be easily distinguished from each other by color.

3. The leads should be flexible and sufficiently long for their purpose.

4. The probes should incorporate finger barriers, to prevent accidental contact with live parts.

5. The probes should be insulated and have a maximum of 2 mm of exposed metal, but preferably have spring loaded enclosed tips.

Calibration of test equipment

Calibration for test equipment is done to ensure that your instruments always perform as expected.

Calibration of measuring test equipment or electrical test equipment such as data loggers, multimeters, oscilloscopes, power supplies or tachometers is required to ensure that your measuring instruments always perform according to expected specifications and standards.

Purpose of Calibration

To ensure readings from an instrument are consistent with other instruments and to determine the accuracy of the instrument i.e. that it can be trusted for its observed/displayed measured value.

Importance of calibration for industry

- To ensure that products are manufactured to specifications.
- To demonstrate that the industry operates a quality system and technically competent and are able to generate technically valid results.
- To increase quality & value of product.
- The calibrated measuring instruments (working standards) have the assurance of an unbroken chain of national/international measuring standards

A standard preventative maintenance service on all instruments

- Pre-service calibration checks are taken
- The equipment is checked internally for any damage, loose electrical connections or foreign material. The cover/s are refitted after all practical foreign material is removed.
- The instrument is then checked externally for damage, inoperative switches, frozen leveling feet or poorly adjusted tare bars. Any old and excess stickers are removed and the housing is cleaned as necessary Corner load, linearity and calibration errors are corrected to obtain optimum performance
- A service sticker is attached to the Instruments which includes the Service and Calibration Report numbers, date the instrument was serviced and when the next preventative maintenance service is recommended

http://nunesinstruments.com/calibration.htm https://www.intertek.com/testing-analysis/calibration/

Test equipment care, storage and maintenance

Care of test instruments The EAWR (1989) require that all electrical systems, this includes test instruments, be maintained to prevent danger.

This does not restrict such maintenance to just a yearly calibration, but requires equipment to be kept in good condition in order that it is safe to use at all times.

In consequence it is important to ensure the continual accuracy of instruments by comparing test readings against known values.

This is most conveniently achieved by the use of 'checkboxes 'which are readily available. Whilst test instruments and associated leads, probes and clips, etc., used in the electrical contracting industry are robust in design and manufacture, they still need treating with care and protecting from mechanical damage.

Keep test gear in a separate box or case away from tools and sharp objects and always check the general condition of a tester and leads before they are used.

6.2.2.5 Reference

IEE Wiring Regulations: Inspection, Testing and Certification Sixth Edition Brian Scaddan, IEng, MIET

https://electrical-engineering-portal.com/inspection-electrical-installations-home-1

https://www.dfliq.net/blog/electrical-inspection-a-detailed-overview/

http://nunesinstruments.com/calibration.htm

https://www.intertek.com/testing-analysis/calibration/

6.2.2.6 learning activities

Learning activity 1

In an electrical installation equipment store, identify measuring instruments that are used to test the presence of voltage in a circuit and perform the voltage test using each of the equipment you identified.

Learning activity 2

Identify the testing instrument found in an electrical installation workshop to test for ring continuity and perform the testing on an existing power circuit.

6.2.2.7 Self-assessment: Learning Outcome 2

1. Identify the type of instrument that would be used to measure leakage current in a circuit.

   A. voltmeter

   B. test lamp

   C. Voltage tester

   D. clamp meter

2. Before carrying out an Insulation Resistance test on a lighting circuit, its essential to...

   A. ensure all light switches are in the off position

   B. link the line and cpc in the CCU

   C. disconnect the earthing conductor

   D. remove all loads from the circuit

3. Continuity of protective conductors (R2) tests are carried out using

   A. a volt meter

   B. a low ohms meter

   C. an insulation resistance tester

   D. a continuity tester

4. State the overall effect on Insulation Resistance if twice as many circuits are added to an existing consumers unit (CCU).

   A. Insulation Resistance would remain the same

   B. Insulation Resistance would increase

   C. Insulation Resistance would decrease
   D. Insulation Resistance would be be 200M Ohms

5. Where is a live polarity check carried out to verify that the supply to an installation is correct?

A. at the end of any installed circuit

B. at the end of every circuit

C. at the mains intake position

D. at any socket outlet

6. During a test on an installation, the following readings were obtained: 20 MΩ; 8 kA; 22 ms. List the instruments which gave these readings.
7. List the first three tests that should be carried out during an initial verification on a new domestic installation.
8. The test for the continuity of a cpc in a radial circuit feeding one socket outlet uses a temporary link and a milliohmmeter, state:

a) where the temporary link is connected.

b) Where the milli-ohmmeter is connected.

c) What the meter reading represents.

9. List three precautions to be taken prior to commencing an insulation resistance test on an installation.
10. List three reasons for conducting a dead polarity test on an installation.
11. Figure 2 shows the layout of the electrical installation in a new detached garage. You are to carry out an initial verification of that installation.

(a) What documentation/information will you require in order to carry out the verification?

(b) Where should it be located?

(c) What particularly important details regarding this installation should have been included on such documentation?

(d) What consideration should be given to the existing installation from which this new installation is fed?

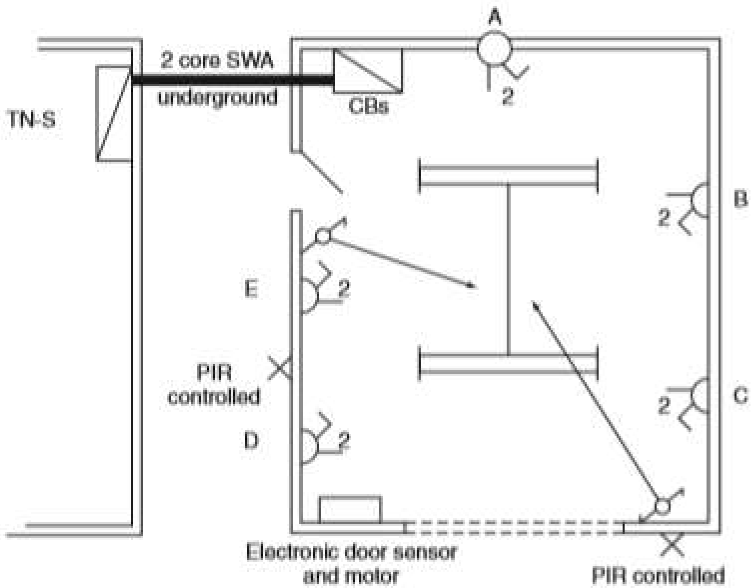

Figure 3.1: Shows the layout of the electrical installation in a new detached garage

(**Source:** IEE Wiring Regulations: Inspection, Testing and Certification Sixth Edition Brian Scaddan, IEng, MIET)

Tools, Equipment, Supplies and Materials

Tools

Phase Tester

Screw drivers

Equipment

- Test instruments
  - Continuity tester (ohmmeter)
  - Insulation resistance tester
  - Earth loop impedance tester
  - Test lamp

Materials and supplies materials

- BS 7671
- Guidance Note 3
- The On-site Guide.
- Stationery
- Wiring certificates

References

- Manufacturers' manuals
- Relevant catalogues
- IEE regulations
- Standards
- County by-laws
- Occupational Safety and Health Act (OSHA)
- National Environmental Management Authority (NEMA) regulations
- National Construction Authority (NCA) regulations
- IEE tables

7

6.2.3 Learning outcome 3: Perform Testing of Electrical Installation

6.2.3.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to carry out **Visual inspection** and tests as per test standards and procedures as guided by IEE Regulation, OSHA and EHS.

6.2.3.2 Performance Standard

1. Test sequence procedure is decided based on the test standards
2. Safety precautions are adhered to as per OSHA
3. Additional precaution is observed on the installation in hazardous environment as per EHS standard
4. **Tests** are carried out in line with the IEE regulations
5. Test results are recorded and compared with standards values
6. Test report is compiled and shared with relevant parties

6.2.3.3 Information Sheet

Purpose of Electrical Installation Testing

All new completed electrical installation should be tested before connection to the supply. The purpose of the electrical installation condition report and testing is to provide, as far as is reasonably practicable:

- To ensure that the installation is technically sound and free from any possible short circuits, etc.
- To know the cause of failure of a particular circuit or circuits or equipment and to locate the exact position of break down.
- To ensure that it is free from faults and is as per electricity rules.
- These tests will receive the attention of the owner before any possible undue damage occurs. i.e. to Confirm that the installation is not damaged or deteriorated.
- For the safety of persons and livestock.
- Protection against damage by fire and heat.

Reasons of electrical installation testing

- To ensure that people and goods are kept safe and are protected in the event of a fault.

- Facilitates preventive maintenance of installations, preventing serious faults which might prove expensive (production shutdown, etc.).
- To guarantee people's safety with regard to these installations and the electrical
- Equipment connected to them, standards have naturally been developed and updated to take changes into account.

The electrical testing is divided into 2 parts:

1. **Visual inspection** to guarantee that the installation complies with the safety requirements (presence of an earth electrode, protective devices, etc.) and does not show any visible evidence of damage.

2. **Measurements/Tests**

Types of Electrical Installation Tests

The tests should be made on a new electrical installation before it is switched on to the mains are as under:

1. Insulation resistance test between installation and earth.
2. Insulation resistance test between conductors.
3. Testing of polarity.
4. Testing of earth continuity paths.
5. Earth resistance test.
6. Continuity test
7. Earth loop impedance test

Insulation Resistance Test between Installation and Earth

This test is performed to know the standard of insulation of wires and cables used in the installation.

It also ensures that the insulation is sufficient enough to avoid any possible leakage of current to earth.

The leakage of the current to earth should not exceed 0.02% of the full load current.

Before performing insulation resistance test between installation and earth the conditions to be fulfilled for the position of the main switch, fuses, switches, and other points should be as under:-

- Main switch in OFF position, fuses beyond the main switch should be in position, all switches in ON position.
- All lamps and other equipment should be in their position.

For testing the whole installation, the test is conducted on the main switch. A testing set known as megger is used for the test. It is a special form of the ohmmeter**.**

To perform this test, the **phase and the neutral is short-circuited** temporarily at any suitable point as shown in Figure below;

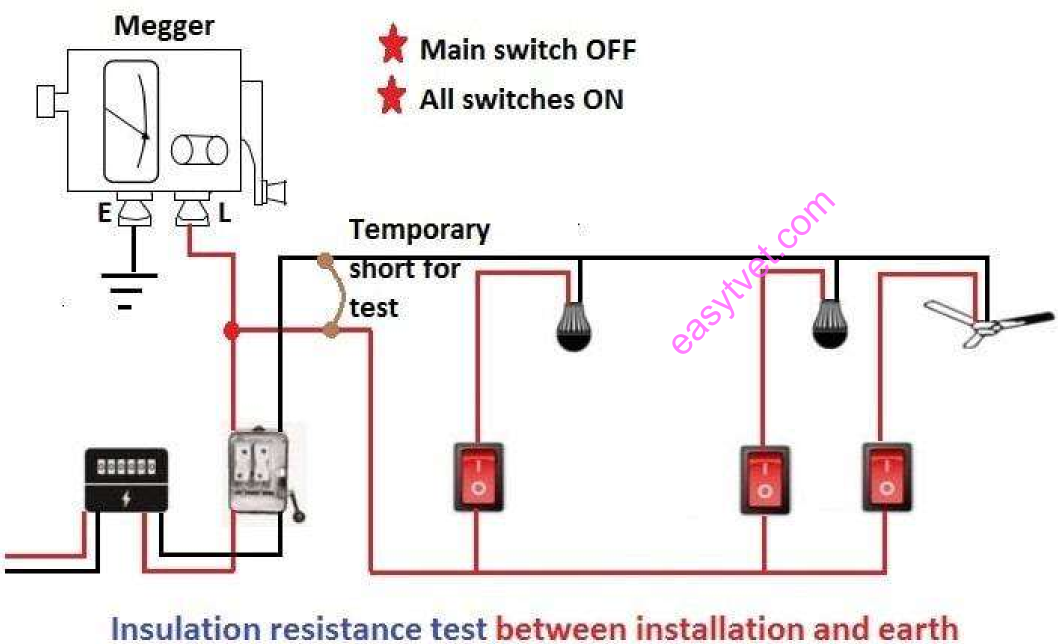

Figure 3.2: Insulation Resistance Test between Installation and Earth

- The 'L' (line terminal) of the megger is connected to the short circuit point in the main switch and the earth terminal marked (E) is connected to earth continuity conductor or some good earth point near-by.

The handle of the tester is turned at a high speed so that sufficient testing voltage is produced. The reading on the dial of the megger is noted.

The **insulation resistance thus measured should not be less than 0.5 MΩ** on a firm, sound and fixed wiring. If the insulation resistance is below this value, the wiring section giving that value should be rewired or checked thoroughly until the required value is obtained.

Insulation Resistance Test between Wiring Conductors

To ensure that the insulation of the cables or wires is not damaged and there is no leakage between them, this test is performed.

Before performing this test, the position of the main switch, fuses, switches, etc. should be as follows:

- ***Main switch in OFF position,***
- ***All switches in ON position,***
- ***All lamps and other appliances should be removed,***
- ***Fuses beyond the main switch should be in position***.

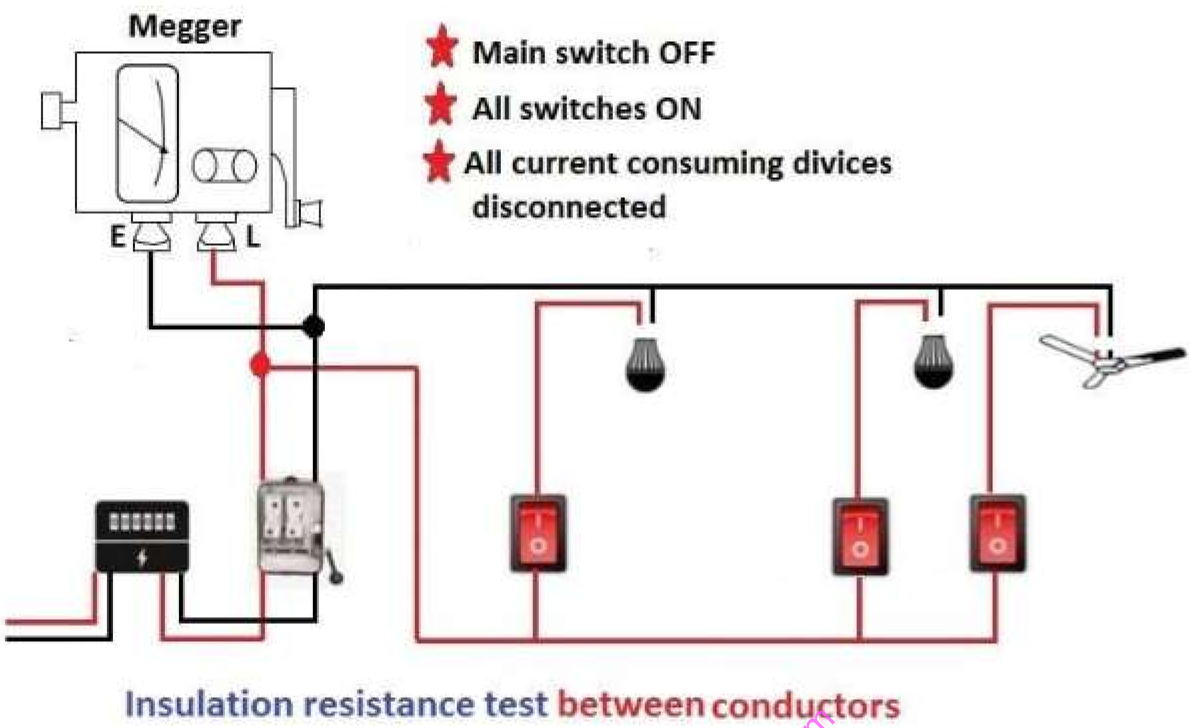

Figure 3.3: Insulation Resistance Test between Wiring Conductors

The line terminal of the megger is connected to phase terminal of the installation and the earth terminal of megger is connected to neutral wire.

The insulation resistance so measured should not be less than 1MΩ, for an installion and 0.5 MΩ for an appliance,

Refer from IEE Regulations

Polarity Test in House Wiring

In a low voltage installation, this test is performed to verify that all single pole switches have been connected to phase wire throughout the installation.

It is very necessary to place all switches on phase so that when a switch is made OFF, the connected appliance is quite dead.

If the switch is connected to the neutral wire then the connected appliance will get phase even if the switch is in OFF position and remain alive.

There is absolutely no difference in the functioning of the switch in either case, but from the safety point of view to avoid shock, etc. the phase should always be given through the switch and neutral direct to the point.

The simple method of conducting the polarity test is by using a test lamp.

Before performing this test the position of the main switch, fuses, switches, etc. should be as under main switch in ON position, all switches in OFF position, all lamps and other appliances should be removed.

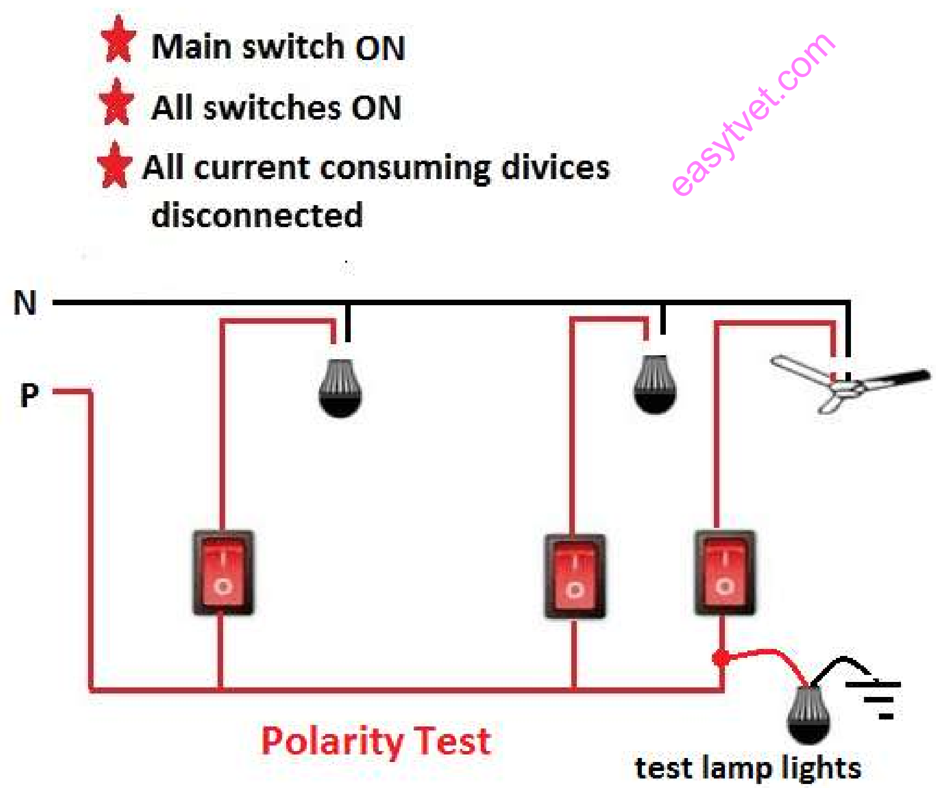

Figure 3.4: Polarity Test in House Wiring

One end of the test lamp is connected to earth wire and the other end to the incoming terminal of the switch.

If the lamp lights, it indicates that the switch is connected to phase wire, otherwise to neutral wire.

Earth Continuity Test of Electrical Installation

To perform this test with the help of megger, the main switch is opened, the main fuses are withdrawn, all the switches are made ON and all the lamps are put in position.

The 'L' (line terminal) of the megger is connected to the phase conductor in the main switch and 'E' (earth terminal) of the megger is connected to an earth point.

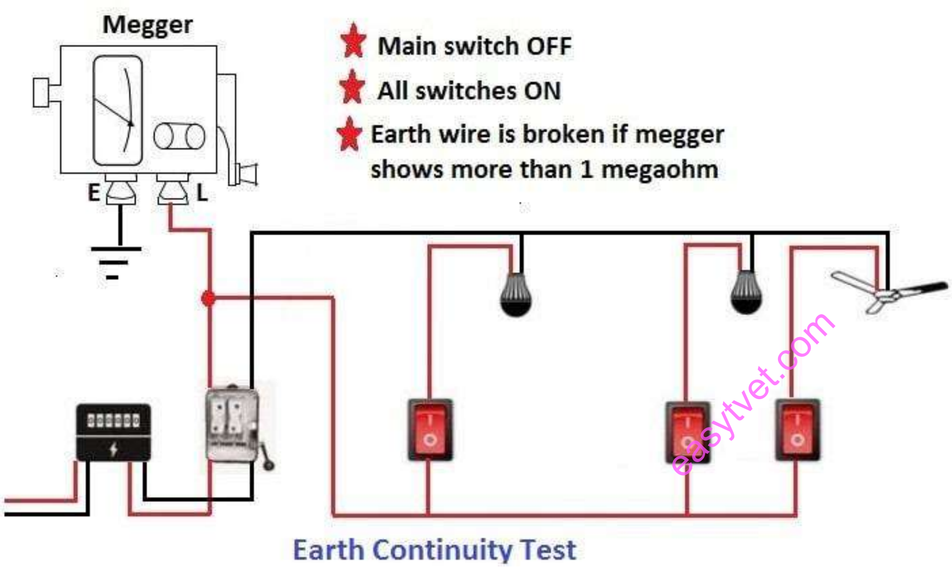

Figure 3.5: Earth Continuity Test of Electrical Installation

In this test, megger should indicate a resistance value between 0.5 and 1 mega ohm.

In this case, if earthing of all the metallic parts and the earth wire will be in good condition, a sufficient amount of current will flow through test circuit and megger will show a reading up to 1 MΩ.

If it will be in bad condition then it will offer high resistance to the current. As a result, a very low quantity of current will flow and megger will show a reading more than 1 MΩ.

Therefore, **if the megger shows a high reading (more than 1 MΩ), it means that the main switch or conduit is not**

properly earthed or the earth wire is broken somewhere requiring correction.

Earth Resistance Test

Resistance of earth is the resistance between infinite earth and earth electrode. This depends upon mainly three factors

1. The resistance of the electrode itself,
2. The contact resistance between electrode surface and soil,
3. The resistivity of soil between the electrode and infinite earth.

https://www.electrical4u.com/resistance-of-earth/#:~:text=%20Resistance%20of%20Earth%20%201%20The%20resistance,between%20the%20electrode%20and%20infinite%20earth.%20More%20

Test Methods for Measuring Earth Resistance

There are six basic test methods to measure earth resistance

1. Four Point Method (Wenner Method)
2. Three-terminal Method (Fall-of-potential Method / 68.1% Method))
3. Two-point Method (Dead Earth Method)
4. Clamp-on test method
5. Slope Method

(1) Four Point Method (Wenner Method):

- This method is the most commonly used for measuring soil resistivity,

Required Equipment:

- Earth Tester (4 Terminal)
- 4 No's of Electrodes (Spike)
- 4 No's of Insulated Wires
- Hammer
- Measuring Tap

Connections:

First, isolate the grounding electrode under measurement by disconnecting it from the rest of the system.

Earth tester set has four terminals, two current terminals marked C1 and C2 and two potential terminals marked P1 and P2.

P1 = Green lead, C1 = Black lead, P2 = Yellow lead, C2 = Red lead

In this method, **four small-sized electrodes** are driven into the soil at the **same depth and equal distance from one another** in a straight line.

The distance between earth electrodes should be at least **20 times greater** than the electrode depth in ground.

Example, if the depth of each earth electrode is 1 foot then the distance between electrodes is greater than 20 feet.

The earth electrode under measurement is connected to **C1** Terminal of Earth Tester.

Drive another potential Earth terminal **(P1)** at depth of 6 to 12 inches from some distance at **C1** Earth Electrode and connect to **P1** Terminal of Earth Tester by insulted wire.

Drive another potential Earth terminal **(P2)** at depth of 6 to 12 inches from some distance at **P1** Earth Electrode and connect to **P2** Terminal of Earth Tester by insulted wire.

Drive another Current Electrode **(C2)** at depth of 6 to 12 inches from some distance at **P2** Earth Electrode and connect to **C2** Terminal of Earth Tester by insulted wire.

Connect the ground tester as shown in the picture.

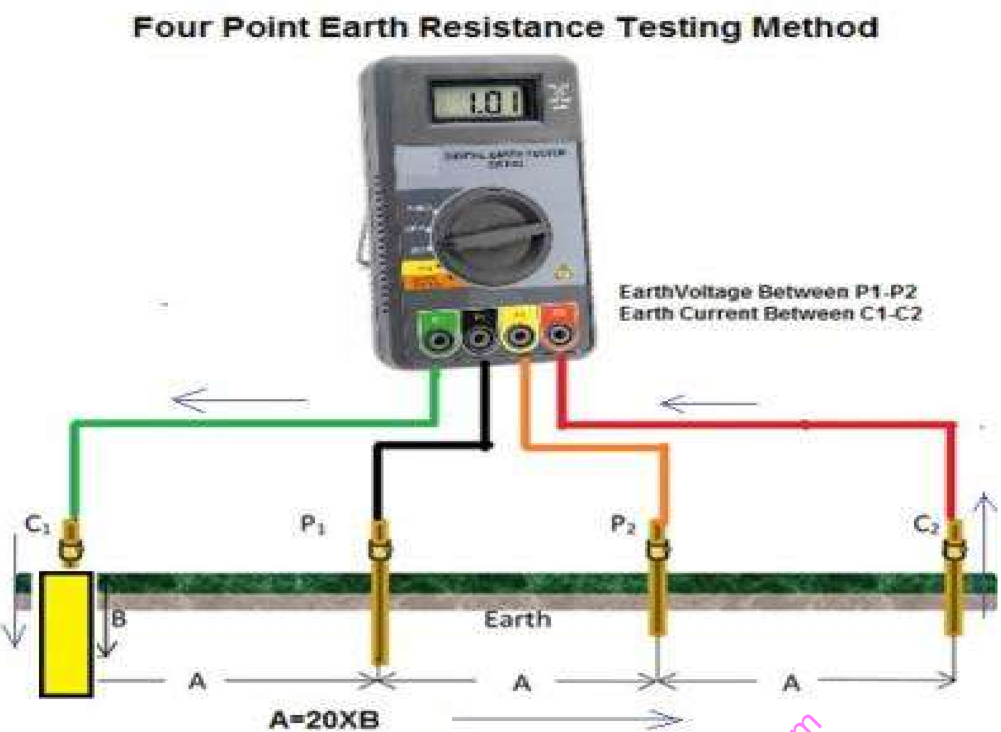

Figure 3.6: Four-point earth resistance testing method

Testing Procedure:

Press START and read out the resistance value. This is the actual value of the ground Resistance of the electrode under test.

Record the reading on the Field Sheet at the appropriate location. If the reading is not stable or displays an error indication, double check the connections. For some meters, the RANGE and TEST CURRENT settings may be changed until a combination that provides a stable reading without error indications is reached.

The Earthing Tester has basically Constant Current generator which injects current into the earth between the two current terminals C1 (E) and C2 (H).

The potential probes P1 & P2 detect the voltage ΔV (a function of the resistance) due to the current injected in the earth by the current terminals C1 & C2.

The test set measures both the current and the voltage and internally calculates and then displays the resistance. R=V/I

If this ground electrode is in parallel or series with other ground rods, the resistance value is the total value of all resistances.

Ground resistance measurements are often corrupted by the existence of ground currents and their harmonics. To prevent this, it is advisable to use Automatic Frequency Control (AFC) System. This automatically selects the testing frequency with the least amount of noise enabling you to get a clear reading.

Repeat above steps by increasing spacing between each electrode at equal distance and measure earth resistance value.

Average the all readings

An effective way of decreasing the electrode resistance to ground is by pouring water around it. The addition of moisture is insignificant for the reading; it will only achieve a better electrical connection and will not influence the overall results. Also, a longer probe or multiple probes (within a short distance) may help.

Application:

It is advisable for Medium or Large electrode System.

It is use for Multiple Depth Testing

Advantage:

This is most accurate Method.

It is Quick, easy method.

Extremely reliable conforms to IEEE 81;

Disadvantage:

There need to turn off the equipment power or disconnect the earth electrode.

One major drawback to this method is that it requires a large distance for measurement.

This distance can range up to 2,000 feet or more for ground systems covering a large area or of very low resistance.

Time consuming and labor intensive

2) Three Point (Fall-of-potential) Method.

The Fall-of-Potential method or Three-Terminal method is the most common way to measure earth electrode system resistance, but it requires special procedures when used to measure large electrode systems

There are three basic fall-of-potential test method.

Full fall-of-Potential: A number of tests are made at different spaces of Potential Probe "P" and the resistance curve is plotted.

Simplified Fall-of-Potential: Three measurements are made at defined distance of Potential Probe"P" and mathematical calculations are used to determine the resistance.

8% Rule: A single measurement is made with Potential Probe “P” at a distance 61.8% (62%) of the distance between the electrode under test and “C”.

Required Equipment:

- Earth Tester (4 Terminal or 3 Terminal)
- 4 No’s of Electrodes (Spike)
- 4 No’s of Insulated Wires
- Hammer
- Measuring Tap

Connections:

First, isolate the grounding electrode under measurement by disconnecting it from the rest of the system.

For Small System:

For 4 Terminal Earth Tester Short Current Terminal (C1) and Potential Terminal (P1) together with a short jumper on the earth tester and connect it to earthing electrode under test.

For 3 Terminal Earth Tester Connect current terminal (C1) to the earth electrode under measurement.

Drive another Current Electrode (C2) into the earth 100 to 200 feet at depth of 6 to 12 inches from the center of the electrode and connect to C2 Terminal of earth tester.

Drive another potential terminal (P2) at depth of 6 to 12 inches into the earth midway between the Current Electrode (C1) and Current Electrode (C2) and connect to Earth Tester on P2

For Large System

Place the current electrode (C2) 400 to 600 feet from the measuring Earth Current Electrode (C1)

Place the potential electrode (P1)8% of the distance from the Earth Current Electrode (C1)

Measure the resistance

Move the current electrode (C2) farther 50 to 100 Feet away from its present position.

Place the potential electrode (P2) 61.8% of the distance from the Earth Current Electrode (C1).

Spike length in the earth should not be more than 1/20th distance between two spikes.

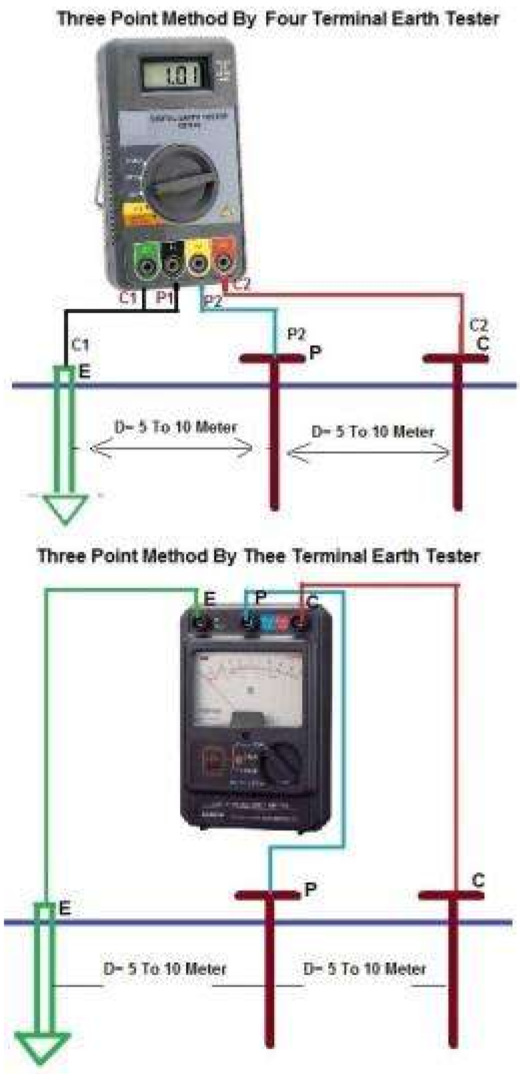

Figure 3.7: Three Point (Fall-of-potential) Method

Testing Procedure:

- Press START and read out the resistance value. This is the actual value of the ground electrode under test.
- Move the potential electrode 10 feet farther away from the electrode and make a second Measurement.
- Move the potential probe 10 feet closer to the electrode and make a third measurement.
- If the three measurements agree with each other within a few percent of their average, then the average of the three measurements may be used as the electrode resistance.
- If the three measurements disagree by more than a few percent from their average, then additional measurement procedures are required.

- The electrode center location seldom is known. In this case, at least three sets of measurements are made, each with the current probe a different distance from the electrode, preferably in different directions.
- When space is not available and it prevent measurements in different directions, suitable measurements can be made by moving the current probe in a line away from or closer to the electrode.
- For example, the measurement may be made with the current probe located 200, 300 and 400 feet along a line from the electrode.
- Each set of measurements involves placing the current probe and then moving the potential probe in 10 feet increments toward or away from the electrode.
- The starting point is not critical but should be 20 to 30 feet from the electrode connection point, in which case the potential probe is moved in 10 feet increments toward the current probe, or 20 to 30 feet from the current probe, in which case the potential probe is moved in 10 feet increments back toward the electrode.
- The spacing between successive potential probe locations is not particularly critical, and does not have to be 10 feet, as long as the measurements are taken at equal intervals along a line between the electrode connection and the current probe.
- Larger spacing means quicker measurements with fewer data points. Smaller spacing means more data points with slower measurements.
- Once all measurements have been made, the data is plotted with the distance from the electrode on the horizontal scale and the measured resistance on the vertical scale.

Importance of Position of Current Electrode (C2):

- Fall-of-Potential measurements are based on the distance of the current and potential probes from the center of the electrode under test.
- For highest degree of accuracy, it is necessary that the probe is placed outside the sphere of influence of the ground electrode under test and the auxiliary earth.
- If we Place Current Electrode (C2) too near to Earth Electrode (C1) then the sphere of influence, the effective areas of resistance will overlap and invalidate measurements taken.
- For the accurate results and to ensure that the ground stakes are outside the spheres of influence.
- Reposition the inner Potation Electrode (P1) 1meter in either direction and take a fresh measurement. If there is a significant change in the reading (30 %), we need to increase the distance between the ground rod under test, the inner

stake (probe) and the outer stake (auxiliary ground) until the measured values remain fairly constant when repositioning the inner stake (probe).

- **The best distance for the current probe is at least 10 to 20 times the largest dimension of the electrode.**
  - Because measurement results are often distorted by underground pieces of metal, underground aquifers, etc. so re measurements are done by changing axis of earth spike by 90 degrees, by changing the depth and distance several times, these results can be a suitable ground resistance system.

    The table is a guide for appropriately setting the probe (inner stake) and auxiliary ground (outer stake).

Table 3: Appropriately setting the probe (inner stake) and auxiliary ground (outer stake).

Distance of Probe Depth of the ground electrode	**Distance to the inner stake**	**Distance to the outer stake**
2 m	15 m	25 m
3 m	20 m	30 m
6 m	25 m	40 m
10 m	**30 m**	50 m

Application:

- It is advisable for High Electrical Load.
- It is suitable for small and medium electrodes system (1 or 2 rods/plates).
- It is useful for homogeneous Soil

Advantage:

- The three-point method is the most reliable test method;
- This test is the most suitable test for large grounding systems.
- Three-terminal is the quicker and simpler, with one less lead to string Spacing for Current Probe

Disadvantage:

- Individual ground electrodes must be disconnected from the system to be measured.
- It is extremely time consuming and labor intensive.
- There are situations where disconnection is not possible.
- Knowledge of location of center probe is necessary
- Time consuming and labor intensive Ineffective if the electrical center is unknown.
- If less measurements are being made then less accurate than full Fall of Potential

61.8% Rule:

- It is proven that the actual electrode resistance is measured when the potential probe is located 61.8% of the distance between the center of the electrode and the current probe. For example, if the current probe is located 400 feet from the electrode center, then the resistance can be measured with the potential probe located 61.8% x 400 = 247 feet from the electrode center.
- The 61.8% measurement point assumes the current and potential probes are located in a straight line and the soil is homogeneous (same type of soil surrounding the electrode area and to a depth equal to 10 times the largest electrode dimension).
- The 61.8% measurement point still provides suitable accuracy for most measurements.

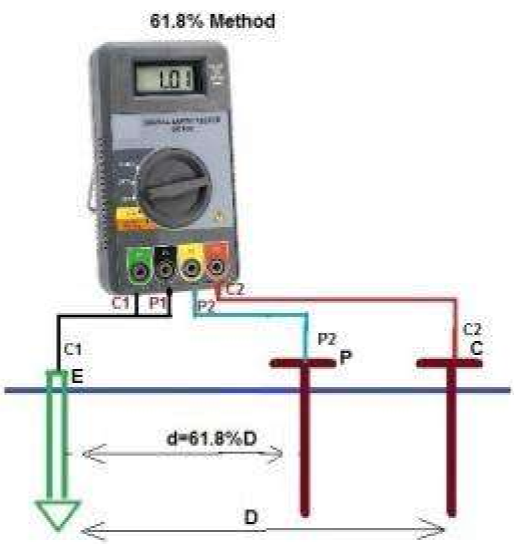

Figure 3.8: 61.8% method

- Suppose, the distance of Current Spike from Earth Electrode D = 60 ft, Then, distance of Potential Spike would be 62 % of D = 0.62D i.e. 0.62 x 60 ft = 37 ft.

Application:

- It is suitable for small and medium electrodes system.
- It is useful for homogeneous Soil

Advantage:

- Simplest to carry out.
- Required minimum calculation;
- Fewest number of test probe moves.

Disadvantage:

- Soil must be homogeneous.
- Less accurate
- Susceptible for non-homogeneous soil

Tests of protective devices

- Fuses / Circuit-breakers

  To check the specifications of the protective devices such as fuses or circuit breakers, a fault loop impedance measurement is carried out to calculate the corresponding short-circuit current. A visual inspection can then be used to check that the sizing is correct.

- Residual current devices (RCDs)

  RCDs, which detect earth leakage currents, can be tested using two methods:

- The basic test, also called a pulse test, which determines the trip time (in milliseconds)
- The step test, which determines the trip time and trip current, thus detecting any RCD ageing.

Fault finding

This is not an exact science as faults in electrical systems can be many, varied and difficult to locate. What we can state however, are the main symptoms of electrical faults, these are:

- Loss of Supply
- Fire
- Shock.

Table 1.4 indicates such symptoms, their possible common causes and the action to be taken. Column 2 illustrates, in general terms, the possible causes of faults. Table 1.5 summarizes these in more detail. Many faults are easily located, many are not, in all cases observe the following general procedure whenever possible:

1 Determine the nature/symptom of the problem.
2 Ask client/personnel for their recollections: how, when and where the problem occurred (this can save so much time).
3 Carry out relevant visual and instrument checks to locate the fault.
4 Rectify if possible.
5 Re-test.

6 Re-instate system.

Table 4: Indicates Symptoms, possible common causes and the action to be taken

Symptom	Possible common Cause	Diagnosis	Action
Complete loss of supply	1. Fault on suppliers(REC) main cable/equipment 2. Fault on service cable 3. Main fuse or CB operated 4. Main DB switch OFF 5. Main RCD operated	1. Check adjacent properties are also OFF 2. Check adjacent properties are ON 3. Check adjacent properties are ON 4. Visual check 5. Visual check	1. Contact REC 2. Contact REC 3. Contact REC 4. Switch back on 5. Re- set, if it trips, then switch off all CB's re-set and turn on each CB until one causes the main RCD to operate. This is likely faulty circuit
Loss of supply to a circuit	1. Circuit fuse or CB operated 2. Conduct broken or out of terminal	1. Visual check 2. Check fuse/CB are OK	1. Replace OR re-set as operation may be due to an overload. If protection still operates, do NOT reset until fault has been found, usually

			by carrying out insulation test 2. Locate faulty out visual check/ continuity
Fire/ burning	1. Overloaded cable 2. Damaged insulation 3. Water in fitting/accessories	1. 1,2 &3 visual check and smell	3. 1,2 &3 turn off supply, to circuit(s) investigate fuse and cable sizes, check for water ingress, damaged insulation, visually and using an insulation resistance tester
Electric shock	1. Exposed live part 2. Insulation breakdown 3. Earthing and bonding inadequate 4. Appliances incorrectly wired or damaged and with inappropriate fusing 5. Incorrect polarity in accessories	1. Use of an approved voltage indicator between exposed and/or extraneous conductive parts	1. Turn off supply to circuit(s) check visually for covers missing etc. 2. Carry out insulation resistance and polarity tests on circuit and

			cables, and establish that all Earthing and bonding is in place and all protective devices are suitable for disconnection times

Table 5: Summary of table 1.4 in more detail.

General cause	Detail
Insulation breakdown	**1.** Damage by installer **2.** Damage by other trades **3.** Damage by user (misuse, nails in walls, etc. **4.** 4. overloading
Fuse, circuit breaker or Residual Current Device operating instantly circuit is switched on	**1.** Short circuit caused by: a) Damaged insulation b) Crossed polarity at terminations c) Water penetration in joint box's seal, gland etc. **2.** Faulty appliances

Fuse or Circuit breaker operating regularly after a period of time.	**1.** Overload caused by too many loads on a circuit, or machinery stalling or with too much mechanical load **2.** Slight water penetration or general dampness
Fuse or Circuit breaker operates with no apparent fault	Transient over voltage caused by switching surges, motor starting etc

6.2.3.4 Learning activities

Learning Activity 1

Do the activity at home or during vacant time

1. Perform an insulation resistance test on an electrical installation in your institution

Learning Activity 2

By the guidance of your trainer, perform the following tests on an existing electrical installation circuit:

i. Polarity test
ii. Earth test
iii. Insulation resistance test
iv. Ring continuity test
v. Earth loop impedance test

6.2.3.5 Self-assessment learning outcome 3

1. Identify the unit of measure for an insulation resistance test

   A. ohms

   B. killo - ohms

   C. Mega - ohms

   D. Milli - ohms

2. On a continuity of ring circuit conductors test, state the purpose of taking test readings at socket outlets once the incoming and outgoing lines and cpcs have been cross-linked in the CCU.

   A. to record the (R1+R2) value

   B. to ensure the cpc is continuous

   C. to prove the circuit is a ring

   D. to ensure that the live is continuous

3. The following readings were obtained during the initial tests on a healthy ring final circuit:

   L1 - L2 -0.8 Ω; N1-N2- 0.8 Ω; cpc1-cpc2-0.8 Ω

   (a) What readings would you expect?

   (i) Between L and N Conductors at Each Socket Outlet?

   (ii) Between L and cpc At Each Socket Outlet?

   (iii) What the L to cpc reading represents?

4. What happens to:

   (a) Conductor resistance when conductor length increases?

   (b) Insulation resistance when cable length increases?

   (c) Conductor resistance when conductor area increases?

6.2.3.6 Tools, Equipment, Supplies and Materials

Tools

Phase Tester

Screw drivers

Equipment

- Test instruments
  - Continuity tester (ohmmeter)
  - Insulation resistance tester
  - Earth loop impedance tester
  - Test lamp

Materials and supplies materials

- BS 7671
- Guidance Note 3
- The On-site Guide.
- Stationery
- Wiring certificates

References

- Manufacturers' manuals
- Relevant catalogues
- IEE regulations
- Standards
- County by-laws
- Occupational Safety and Health Act (OSHA)
- National Environmental Management Authority (NEMA) regulations
- National Construction Authority (NCA) regulations
- IEE tables

Reference materials

- Standards
- County by-laws
- Occupational Safety and Health Act (OSHA)
- National Environmental Management Authority (NEMA) regulations
- National Construction Authority (NCA) regulations
- IEE tables

6.2.3.7 Reference

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6.2.4 Learning outcome 4: Issue installation test results and wiring completion Certificates

6.2.4.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required in issuing test and wiring certificate as per test standards and procedures as guided by IEE Regulation, OSHA and EHS.

6.2.4.2 Performance Standard

Test certificate is issued to the relevant parties

Wiring certificate is issued to the relevant parties

6.2.4.3 Information Sheet

Having completed all the inspection checks and carried out all the relevant tests, it remains to document all this information. This is done on;

- Electrical Installation Certificates (EICs),
- Periodic Inspection Reports (PIRs),
- schedules of inspections, schedules,
- test results,
- Minor Electrical Installation Works Certificates (MEIWCs) and any other documentation you wish to append to the foregoing.

Examples of such documentation are shown in BS 7671 and the
IEE Guidance Note 3 on inspection and testing.

This documentation is vitally important. It has to be correct and signed or authenticated by a competent person.

EICs and PIRs must be accompanied by a schedule of test results and a schedule of inspections for them to be valid.

It should be noted that three signatures are required on an EIC, one in respect of the design, one in respect of the construction and one in respect of the inspection and test.

(For larger installations there may be more than one designer, hence the certificate has space for two signatures, i.e. designer 1 and designer 2.) It could be, of course, that for a very small company, one person signs all three parts.

Whatever the case, the original must be given to the person ordering the work, and a duplicate retained by the contractor.

One important aspect of an EIC is the recommended interval between inspections.

This should be evaluated by the designer and will depend on the type of installation and its usage. In some cases, the time interval is mandatory, especially where environments are subject to use by the public.

The IEE Guidance Note 3 give recommended maximum frequencies between inspections.

A PIR is very similar in part to an EIC in respect of details of the installation, i.e. maximum demand, type of earthing system, Ze, etc.

The rest of the form deals with the extent and limitations of the inspection and test, recommendations, and a summary of the installation.

The record of the extent and limitations of the inspection is very important. It must be agreed with the client or other third party exactly what parts of the installation will be covered by the report and those that will not. The interval until the next test is determined by the inspector.

With regard to the schedule of test results, test values should be recorded unadjusted, any compensation for temperature, etc., being made after the testing is completed.

Any alterations or additions to an installation will be subject to the issue of an EIC, except where the addition is, say, a single point added to an existing circuit, and then the work is subject to the issue of an MEIWC.

Summary

1. The addition of points to existing circuits requires an MEIWC.
2. A new installation or an addition or alteration that comprises new circuits requires an EIC.
3. An existing installation requires a PIR.

Note

Points (2) and (3) must be accompanied by a schedule of test results and a schedule of inspections.

As the client/customer is to receive the originals of any certification, it is important that all relevant details are completed correctly

This ensures that future inspectors are aware of the installation details and test results which may indicate a slow progressive deterioration in some or all of the installation.

These certificates, etc., could also form part of a 'sellers pack' when a client wishes to sell a property.

The following is a general guide to completing the necessary documentation and should be read in conjunction with the examples given in BS 7671 and the IEE Guidance Note 3.

Types of electrical wiring certificates

1. Electrical Installation Completion Certificate
2. Minor Electrical Installation Works Certificate

Minor Electrical Installation Works Certificate

This certificate should be made out and signed or otherwise authenticated by a skilled person in respect of the design, construction, and inspection and testing of the minor Electrical Installation work.

A Minor Electrical Installation Works Certificate will indicate the responsibility for design, construction, inspection and testing of the work described on the certificate.

The Minor Electrical Installation Works Certificate is intended to be used for additions and alterations to an installation that do not extend to the provision of a new circuit.

Examples include the addition of socket-outlets or lighting points to an existing circuit, the relocation of a light switch etc.

This Certificate may also be used for the replacement of equipment such as accessories or luminaires, but not for the replacement of distribution boards or similar items.

Appropriate inspection and testing, however, should always be carried out irrespective of the extent of the work undertaken.

Issuance of the Minor Electrical Installation Works Certificate

This Certificate is normally issued to confirm that the electrical installation work to which it relates has been designed, constructed, inspected and tested in accordance with British Standard 7671 (the IET Wiring Regulations).

The person ordering the work receives and the contractor retains a duplicate.

An 'original' Certificate or a copy of it, you should be passed, to the owner.

A separate Certificate should be issued for each existing circuit on which minor works have been carried out.

This Certificate is not appropriate if the contractor requested, undertakes more extensive installation work, for which you should be issued an Electrical Installation Certificate.

The Certificate should be retained in a safe place and be shown to any person inspecting or undertaking further work on the electrical installation in the future.

If you later vacate the property, this Certificate will demonstrate to the new owner that the minor electrical installation work carried out complied with the requirements of British Standard 7671 at the time the Certificate was issued

Electrical installation completion certificate

This certificate should be made out and signed or otherwise authenticated by a skilled person or persons in respect of the design, construction, inspection and testing of the work.

Electrical Installation Certificates indicates the responsibility for design, construction, inspection and testing, whether in relation to new work or further work on an existing installation.

Issuance of electrical installation certificate

The Electrical Installation Certificate is to be used only for the initial certification of a new installation or for an addition or alteration to an existing installation where new circuits have been introduced, or the replacement of a consumer unit/distribution board.

It is not to be used for a Periodic Inspection, for which an Electrical Installation Condition Report form should be used.

For an addition or alteration which does not extend to the introduction of new circuits, a Minor Electrical Installation Works Certificate may be used.

The 'original' Certificate is to be issued to the person ordering the work (Regulation 644.4). A duplicate should be retained by the contractor.

1. This Certificate is only valid if accompanied by the Schedule of Inspections and the Schedule(s) of Test Results.
2. The signatures appended are those of the persons authorized by the companies executing the work of design, construction, inspection and testing respectively. A signatory authorized to certify more than one category of work should sign in each of the appropriate places.
3. The time interval recommended before the first periodic inspection must be inserted. The proposed date for the next inspection should take into consideration the frequency and quality of maintenance that the installation can reasonably be expected to receive during its intended life, and the period should be agreed between the designer, installer and other relevant parties.
4. The page numbers for each of the Schedule of Inspections and the Schedule(s) of Test Results should be indicated, together with the total number of sheets involved.
5. The maximum prospective value of fault current recorded should be the greater of either the prospective value of short-circuit current or the prospective value of earth fault current.

Electrical installation certificate

This safety Certificate is issued to confirm that the electrical installation work to which it relates has been designed, constructed, inspected and tested in accordance with British Standard 7671 (the IET Wiring Regulations).

The person ordering the work receives and the contractor retains a duplicate.

An 'original' Certificate or a copy of it, you should be passed, to the owner.

The “original” Certificate should be retained in a safe place and be shown to any person inspecting or undertaking further work on the electrical installation in the future.

If you later vacate the property, this Certificate will demonstrate to the new owner that the electrical installation complied with the requirements of British Standard 7671 at the time the Certificate was issued.

The Construction (Design and Management) Regulations require that, for a project covered by those Regulations, a copy of this Certificate, together with schedules, is included in the project health and safety documentation.

For safety reasons, the electrical installation needs to be inspected at appropriate intervals by a skilled person or persons, competent in such work. The maximum time interval recommended before the next inspection is stated under 'NEXT INSPECTION'.

This Certificate is intended to be issued only for a new electrical installation or for new work associated with an addition or alteration to an existing installation.

It should not be issued for the inspection and testing of an existing electrical installation. An 'Electrical Installation Condition Report' should be issued for such an inspection.

This Certificate is only valid if accompanied by the Schedule of Inspections and the Schedule(s) of Test Results.

6.2.4.4 Learning activities

Learning Activity 1

Imagine you are an electrical technician in an Electrical Contractor's Company. Design and plan the schedule of inspection for the ongoing projects of the company.

Learning Activity 2

Exercise

Objective: To be able to understand the checklist items when doing initial installation inspection and perform the inspection for a communication facility.

With the guidance given by the trainer, Perform initial installation inspection on the installation and complete the following form.

Materials: An **installation inspection checklist** template, and a pen

Template

INSTALLATION INSPECTION CHECKLIST

Client: ……………………………………………………Contractor: ……………………..……………

Physical Address: ………………………………………………………………………………………

Make: ………………… Model: …………………. No. of Ports: ………..………

Visited by certification committee: Date: …………………….. Time: …………………………

Serial No.	PARTICULARS OF THE INSTALLATION	YES	NO
	MANDATORY REQUIREMENTS		
	(A) The Main Terminal Equipment		
1.	The main terminal equipment has been Type approved		
2.	The main terminal equipment has been properly accommodated in a spacious easily accessible area with proper ventilation		
3.	The main equipment has been properly mounted or fixed		
4.	The main terminal equipment cabinet has been properly closed except during maintenance		
5.	The main terminal equipment earth wire has been properly connected with the correct colour code.		
6.	The main terminal equipment earth has not been commoned to commercial power earth		
	(B) Power provision and facilities		
1.	Power cable properly clipped, trunked or cleated		
2.	Power cable has not been jointed		
3.	Power fail facility has been provided		
4.	Power fail facility extensions have been installed and are functional		
5.	The equipment room has been provided with at least one 13 amps socket.		
6.	Power has not been supplied through a multi socket extension cable		
7.	Power socket has been reserved for the terminal equipment only		
8.	All power connections needing protection have been fitted with the correct fuses		
9.	Power fail back-up (Generator or Battery has been provided and is functional		
10.	Correct separation between the power and communications cables has been observed to avoid power infringement		
	(c) Internal Wiring		
1.	The main discase has been provided and well fixed on the wall		
2.	The main discase has been properly closed		
3.	The main discase has been properly earthed		
4.	Terminated pairs on discases have been well done and soldered where necessary		
3.	All Line Jack Units (LJUs) have been properly fixed on the wall		
4.	All LJUs have been properly closed		

5.	LJUs are accessible for maintenance purposes		
6.	Trunkings have been provided for all Telecommunications Cables		
7.	Telecommunications Cables and wires with no trunking have been properly fixed and stapled		
8.	Trunking has been provided between the main equipment and discase		
9.	There are no dry or open joints on the PVC internal cables		
10.	Dropwires have not been used for internal wiring		
	(d) Block Wiring		

Serial No.	**PARTICULARS OF THE INSTALLATION**	**YES**
1.	The local internal distribution point or the main distribution frame (MDF) is accommodated in a spacious easily accessible room.	
2.	The room has adequate natural or electrical lighting	
3.	The lead in cable ducts at the MDF have been well sealed to stop water and rodents from entering the room	
4.	The distribution cables are well formed and laced inside the MDF room	
5.	The terminations at the MDF have been properly done and soldered	
6.	The terminations at the discases have been properly done and soldered	
7.	Lockable access to risers is provided for every floor with adequate electrical lighting	
8.	Conduits leaving for various rooms, flats and offices are as per specifications and originate from the local MDF/DP room	
9.	The cables are well formed, laced and well-fixed along the cable risers	
10.	Labeling and sign writing has been done where necessary	
11.	Discases, block terminals or box connections are fitted at suitable accessible areas on every floor	
12.	All discases and sub-discases have been properly earthed	
13.	The main MDF earth has been well provided at the correct value of 0-2 ohms	
14.	The current wiring distribution diagrams are kept securely in DP/MDF room.	
(e) General Issues		
1.	Installation and Commissioning manuals for the installation have been provided	
2.	The installation work has been provided according to the submitted drawings and approved drawings	
3.	Access to the premises has been allowed	
4.	Access to the equipment and the wiring has been allowed	
5.	The client has moved from the premises where the equipment was initially installed	
6.	The equipment has been recovered or interchanged after an operational problem	
7.	The certification team was able to locate the premises	
8.	The maintenance contractor is prompt after calls in case of any problem	

9.	The equipment is giving the client proper and an interrupted service	
10.	The installation is neat, organized and well laid out.	
(f) Any other findings by the Certification Committee		
	RESULTS (ACCEPTED / REJECTED/CANCELLED/DEFFERED) **Certification Committee Team Members** Name: ……………………………….Signature: ……………………… Name: ……………………………… Signature: ……………………… Name ……………………………….Signature: ……………………… **Contractor's Representative** Name: …………………………………..Signature………………………………… **Client or Representative** Name: ……………………………………………Signature…………………………	

6.2.4.5 Self-Assessment learning outcome 4

1. An electrical installation certificate for a new installation will require THREE signatories, Identify one of these signatories.

   A. the clerk-of-works

   B. the customer

   C. building control

   D. the inspector/tester

2. An electrical installation completion certificate for a new installation will require THREE signatories, Identify one of these signatories.

   A. the constructor

B. the clerk-of-works

C. the owner

D. the local council

3. When a certificate is issued for Initial Verification purposes, for the certificate to be valid it MUST be accompanied by?

A. test results sheet

B. schedules of inspections and test results

C. inspection tick-sheet

D. Part 'P' certificate

4. An electrical installation certificate for a new installation will require THREE signatories, Identify one of these signatories.

A. the owner

B. the designer

C. the local authority

D. the site manager

6. When the installation of a new circuit to an existing installation has been completed, the inspector will issue?

A. a condition report

B. a schedule of the tests completed

C. a minor-works certificate

D. an initial verification certificate

7. Identify the non-statutory document that details the construction and safe use of electrical test instruments and equipment.

A. HSE guidance note GS38

B. Electricity at Work regulations

C. BS7671 On-site guide

D. Electrical Regulations book

5. _________ document deals with inspection, testing and certification

6. For an addition or alteration of Electrical Installation Works. Which Certificate may be used?

7. Who issues the certificate of a new electrical installation?

8. Which certificate is normally issued after an inspection and testing of a new installation?

6.2.4.6 Tools, Equipment, Supplies and Materials

- Continuity tester (ohmmeter)
- Insulation resistance tester
- Earth loop impedance tester
- Test lamp

Materials and supplies

- A template form for periodic inspection courtesy of IET
- A Template form of model Electrical Installation Certificate courtesy of IET
- A Template form of A Model Minor Electrical Installation Works Certificate Courtesy of IET
- BS7671

Get the template forms from:

1. https://electrical.theiet.org/media/2209/bs-76712018-model-forms-minor-electrical-installation-works-certificate.pdf

2. https://electrical.theiet.org/media/2387/bs-767122018-model-forms-electrical-installation-certificate.pdf

Reference materials

- Standards
- County by-laws
- Occupational Safety and Health Act (OSHA)
- National Environmental Management Authority (NEMA) regulations
- National Construction Authority (NCA) regulations
- IEE tables

6.2.4.7 Reference

IEE Wiring Regulations: Inspection, Testing and Certification Sixth Edition Brian Scaddan, IEng, MIET

https://electrical-engineering-portal.com/inspection-electrical-installations-home-1

https://www.dfliq.net/blog/electrical-inspection-a-detailed-overview/

6.2.5 Sample Response to Self-Assessment

6.2.5.1 Responses for Self-assessment: Learning Outcome 1

1. B
2. **Visual**

   Touch

   Smell

3. **To ensure safety of persons and livestock**

   To ensure protection from fire and heat

   To ensure that the installation is not damaged so as to impair safety

   To ensure that the installation is not defective and complies with current regulations

4. **Design**

   Construction

Inspection and testing

6.2.5.2 Responses for Self-assessment: Learning Outcome 2

1. D
2. D
3. B
4. C
5. C
6. **Insulation Resistance Tester**
   Prospective Short Circuit Current Tester
   RCD Tester

7. **Continuity Of Protective Conductors**

   Continuity Of Ring Final Circuit Conductors

   Insulation Resistance

8.

a) **Between L and E at the consumer unit**

b) **Between L and E at the socket outlet**

c) **This value is (R 1+ R 2) for the circuit.**

9. **check on existence of electronic equipment**

- **check there are no neon's, capacitors, etc., in circuit**
- **all switches closed and accessories equipment removed**
- **no danger to persons or livestock by conducting the test**

10. **all single pole devices in line conductor only**

    center contact of Edison screw lamp holders in line conductor

- **All accessories correctly connected.**

11.

(a) The results of the assessment of general characteristics sections 311, 312 and 313, and diagrams, charts and similar information regarding the installation (5 marks)

(b) In or adjacent to the distribution board (3 marks)

(c) Reference to the electronic door sensor and the PIR controlled external luminaires as these could be vulnerable to a typical test (3 marks)

(d) Maximum demand, rating of consumer unit, earthing and bonding arrangements, capacity of main protective device, etc. (4 marks)

6.2.5.3 Responses for Self-assessment: Learning Outcome 3

1. C
2. A
3. (a)

   (i) **0.4 Ω**

   (ii) **0.4 Ω**

   (iii) **(R 1+ R 2) for the ring**

4.

   (a) **Increase**s

   (b) **Increase**s

   (c) **Decrease**s

6.2.5.4 Responses for Self-assessment: Learning Outcome 4

1. D
2. A
3. B
4. B
5. D
6. A
7. **To ensure accessories, etc., to relevant standard**
   To ensure compliance with BS 7671
   To ensure no damage that may cause danger

4.

(a) The Electricity at Work Regulations

(b) **BS 7671**

Guidance Note 3

The On-site Guide.

8. ***BS7671***
9. **Minor Electrical Installation Works Certificate**
10. **Contractor**
11. **Electrical Installation Certificate**

CHAPTER 7: ELECTRICAL INSTALLATION BREAKDOWN MAINTENANCE

Unit of learning code ENG/CU/EI/CR/03/4/A
Related Unit of Competency in Occupational Standard: Perform Electrical System Breakdown Maintenance

7.1 Introduction

This unit describes the competencies required to enable trainee be able to exhibit competency in the application of health, safety and environmental standards, prepare of working drawings, assemble tools, equipment, materials and drawing instruments, and perform electrical installation

7.2 Summary of Learning Outcomes

1 Identify system failure
2 Troubleshoot cause of failure
3 Repair the installation
4 Test the repaired system

7.2.1 learning outcome 1: Identify System Failure

7.2.1.1 Introduction

To perform breakdown maintenance successfully, one requires the ability to obtain information about the failure from the user, refer to manuals for the system and do visual inspection to identify system failure to identify test points.

7.2.1.2 Information Sheet

Breakdown maintenance

This is a type of maintenance that involves repairing a broken down machine or system after its continued use until it completely breaks down. For example, this type of maintenance would occur if you wait until a machine stops working before fixing it. This is one of several common maintenance types.

Types of Maintenance

The different types of maintenance include:

1. **Corrective**, in which the maintenance department corrects defects that users find.
2. **Preventive**, in which a certain level of service is maintained to identify and to fix potential vulnerabilities. This is done while the machine is still working to prevent the likelihood of an unexpected breakdown. An example would be changing an HVAC filter every six months.
3. **Predictive**, in which physical variables that may indicate a problem with the equipment, such as vibration, temperature, and power consumption, are monitored. This is done to predict potential problems with the equipment. This strategy offers cost savings over time-based and routine maintenance. An example would include installing sensors in an HVAC system that would provide notification when it's time for a filter change.
4. **Zero hours maintenance**, in which equipment is analyzed, as well as scheduling intervals and replacing parts that are worn in advance of a breakdown
5. **Period maintenance**, also called time-based maintenance, consists of basic tasks that users complete, such as cleaning and lubrication.
6. **Breakdown maintenance** as described above, which is usually used for machines of low importance that may have backups in place.

Breakdown maintenance is triggered by either:

1. A planned event, such as run-to-failure maintenance.
2. An unplanned event, such as the need for reactive or corrective maintenance.
3. This type of maintenance is also used as a last-resort attempt to extend the life of equipment that has lost functional abilities. Breakdown maintenance tends to cost more than preventive maintenance.

Maintenance Models

All maintenance models described above include visual inspection and lubrication. For most types of equipment, these steps should be taken at least once a month to find potential problems early. Visual inspections are cost-effective, and applying lubricant will always cost less than fixing the problems associated with a lack of lubricant.

In addition to these common elements, components of each model are as follows:

1. **Corrective model:** Arising breakdown repair applied to the least critical equipment.
2. **Conditional model:** The corrective model plus tests to determine the next action steps, used with equipment that is unlikely to fail.
3. **Systematic model:** Includes tasks done regardless of the condition of the equipment, measurements and tests to determine potential issues, and repair of identified faults. This model is used for equipment that is moderately available and important. These tasks, however, do not need to be done on a fixed schedule.
4. **High-availability model:** Used for equipment for which failure would be catastrophic, including items with above 90 percent of availability and resultant high production costs and demand. Often, no time can be allotted to stop this machine for preventive, corrective, or systematic maintenance. For this reason, it requires predictive maintenance techniques along with an equipment shut down for a complete overhaul at least once a year. This type of model is commonly used for continuously rotating equipment, power production turbines, high-temperature furnaces, and reaction tanks or reactor deposits.

Additional Maintenance Considerations

Maintenance plans must account for both legal regulations about maintenance and specialized knowledge or resources required to perform the maintenance in question. Legal maintenance requirements typically apply to equipment that has the potential to harm people or the environment and outline specific tests, tasks, and inspections that must be included in the maintenance plan. Examples include:

1. Pressurized equipment and devices
2. High- and medium-voltage installations
3. Lifts
4. Fire prevention facilities and equipment
5. Chemical storage tanks.

Maintenance must be a competent electrician.

Breakdown Maintenance:

Breakdown maintenance is maintenance performed on a piece of equipment that has broken down, faulted, or otherwise cannot be operated. The goal of breakdown maintenance is to fix something that has malfunctioned. To the contrary, preventive maintenance is performed in order to keep something running.

Sometimes breakdown maintenance is performed because of an unplanned event. For example, if a critical piece of machinery breaks, the maintenance is performed because of the imminent need for that machine to operate again. However, breakdown maintenance can be planned for in advance, which is what we might call "good" breakdown maintenance.

Breakdown maintenance workflow

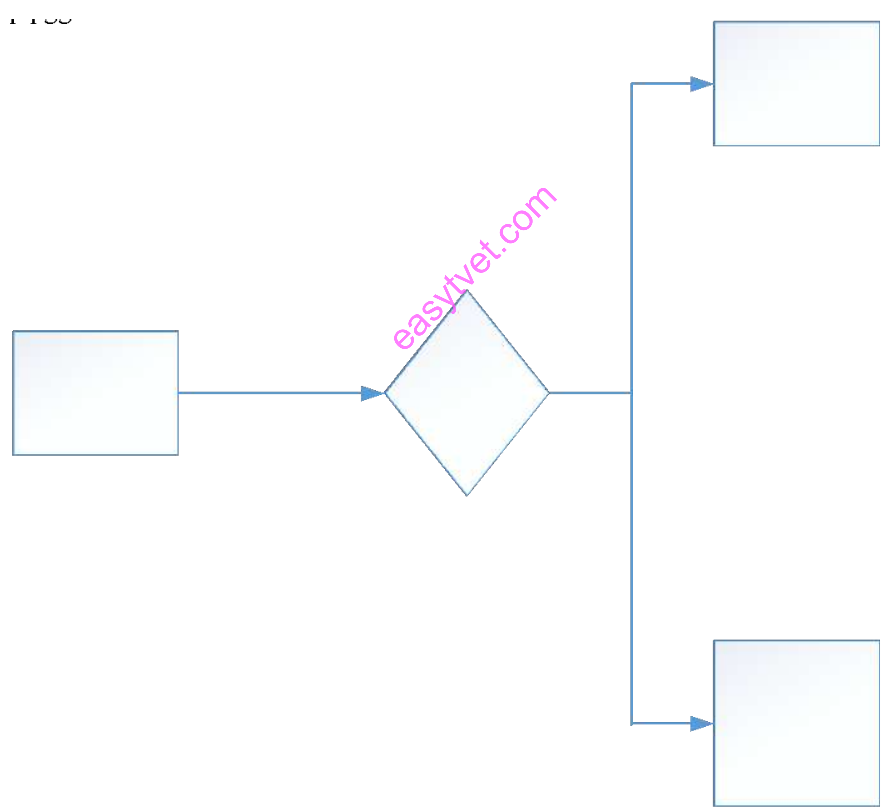


Figure 1 Breakdown maintenance flow chart

There are two types of breakdown maintenance:

1. planned and
2. Unplanned.

Planned breakdown maintenance

Planned breakdown maintenance means that the organization is prepared for a breakdown and even expects it to happen. The equipment runs until it breaks, which initiates a run to failure (RTF) trigger. While RTF triggers can be unplanned, breakdown maintenance plans use RTF as a way of lowering the cost of maintenance.

This kind of plan needs to be rigorously documented and controlled. Employees should be clear on exactly which parts will break down and which parts will be maintained normally via preventive maintenance. Without these checks, a breakdown maintenance plan can be exploited or run awry.

Unplanned breakdown maintenance

Unplanned breakdown maintenance, on the other hand, occurs when a piece of equipment fails or breaks unexpectedly—also called an unplanned downtime event. While some facilities may not utilize a planned breakdown maintenance plan, nearly every facility needs resources in place for unplanned breakdown maintenance. After all, every piece of equipment will break or fault at some point in its life.

Examples of breakdown maintenance

Breakdown maintenance is unique in its applications because it cannot be used with certain industries or products, especially ones that involve health and safety. This means that breakdown maintenance is most frequently used when parts are inexpensive or nonessential.

Here are some examples in which breakdown maintenance is applicable:

1. Equipment can't be repaired at all (inaccessible, designed to not be repaired)
2. Asset consists of inexpensive or easy-to-replace parts
3. Non-critical pieces of equipment (like hand tools)
4. Objects/equipment that are disposable or meant to be replaced at the end of their lifespan
5. Short-life assets (batteries, high flow pumps)

As you can see from these examples, breakdown maintenance becomes viable when there's no inherent safety risk to letting a part or piece of equipment break. As an example, consider a facility's light bulbs. If a light bulb is not linked to a safety feature, it doesn't make financial sense to replace it before it has burned out.

However, breakdown maintenance is absolutely not viable when people's lives can be endangered by a part or product breaking. For example, the aviation industry cannot rely on parts breaking down to fix them because doing so could threaten the personal wellbeing and safety of people on planes. This is also true for tire manufacturers who are responsible for road safety. When it comes to people's lives, preventive and predictive maintenance are the right choice.

Advantages and disadvantages of breakdown maintenance

Advantages

Failed equipment can lead to disastrous consequences, but a clearly-documented breakdown maintenance plan can actually have a few significant benefits for an organization.

1. Minimizes maintenance cost by cutting out unnecessary preventive maintenance
2. Lowers cost of replacing disposable items frequently (light bulbs, tools, fuses)
3. Downtime for repairs is consolidated
4. Low staffing needs
5. Simple and easy to understand when maintenance is required

Disadvantages

1. The downsides of breakdown maintenance are especially important to weigh given the nature of the maintenance plan. For example, breakdown maintenance should never be used with safety equipment because a single lapse can cost one or multiple employees their health or their lives.
2. Form of waste in a manufacturing environment
3. Safety issues can occur with unplanned failures
4. Can be costly depending on parts that fail
5. Requires careful planning and execution
6. Can be difficult to pinpoint source of issues

Machine checks

Various instruments are required to perform checks on machines and equipment, either when the supply is on and they are in operation, or when the supply is off and the machines are at standstill. Instruments required will include an insulation tester, continuity tester, doctor tester, feeler gauge, spring balance, and straight edges and string lines.

Instruments required for supply-off checks

Insulation tester

This is also referred to as a megger. This is an instrument which produces a d.c. output of 500 V which is sufficient test voltage for machines operating on supplies up to 650 V. Tests can be applied to check the insulation values between connections, terminal and windings connected to different poles, or between these and the exposed metalwork of the equipment. Circuit diagrams, or electrical knowledge of the plant is required to ensure that there are no connections which would lead to false values being obtained. The minimum insulation value should be around 1MΩ, although if the machine is damp, it may need drying out to obtain this figure

Continuity tester

This is a meter used to check the actual ohmic values of the windings of a machine, or resistance values of starting or speed control equipment. Again, detailed knowledge is required to ensure that there are no parallel paths when the equipment is fully connected which would lead to false low values being obtained, or is any alternative circuit is connected across (in parallel) with an open circuit winding.

Ductor tester

This is a device for the measure of very low resistance values which are not practical to read on the continuity tester that is, small fractions of an ohm, may be 0.01Ω or so. The tester circulates a heavy current and measures the millivolt (mV) drop across the resistance path. If a doctor is not available, this form of test can be carried out using a heavy current supply, such as a car battery and connecting an ammeter in series with a voltmeter across in parallel with the resistance path to be measured.

$$R = \frac{V}{I}\Omega$$

For example, if on such a test, the current in the circuit is 60A and the millivoltmeter reads 30 mV, the resistance would be 0.0005 Ω, a very difficult value to read directly on an ohmmeter. This instrument is used for the measurement of heavy current armature windings of d.c machines, the copper bars in the rotor of a squirrel-cage motor, or the joints and terminations on busbar and heavy-current cable installations.

Feeler gauges

These are sets of long, parallel blades ranging in thickness from 0.0254 mm, up to around 0.762mm. They are used for checking air gaps between the rotor and stator core of rotating machines, to give an indication of the amount of wear in the bearings. If the bearings are not worn, the readings will be the same all around the circumference. If they are worn, the gap at the top will be higher than that at the bottom. If the difference is large, new bearings will be required to prevent ‘fouling’ between the cores on rotation.

Note: On machines which are almost enclosed, inspection covers at 90^{o} are positioned on the ‘end covers’ of the motor frame to enable the air gap to be checked.

Spring balance

This is used to check the tension on contacts and on brush gear of machines and equipment. The brush is hooked to the balance, gently pulled away from the slip ring or commutator and the tension value read on the scale. It can then be compared with the manufacturer's instructions

Straight edge and string lines

These are used to check horizontal and lateral alignments.

<u>Instruments required for supply-on checks</u>

Voltmeter

This is a meter designed to measure voltages at the supply and at different points on the switchgear and the machines. These can be compared with the manufacturer's data or against the readings of similar machines

Approved test lamp

This is another method of testing for the presence of supply or voltage although is does not indicate the actual value.

Test lamps must be of the standard- approved type which contain the necessary safety current-limited device, such as resistors and fuses, so that in the event of a fault, there

is no risk of an explosion. They are shrouded with insulation to prevent electric shock while in use.

Ammeter

This meter is used to check the value of the current in the supply conductors and in the various circuits of switchgear and machines, to compare with manufacturer's data, nameplate details, etc. Ordinary ammeter do, of course, need to have the circuit disconnected and then be connected in series. This is where the clip-on type ammeter is of advantage.

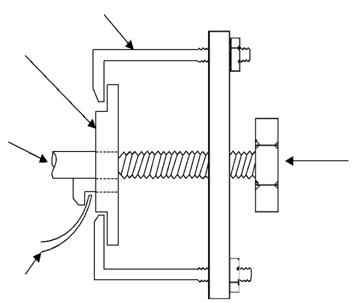
When checking current consumption of machines, in some cases the start current may be up to eight to ten times the full load value, so be sure of the ammeter range and allow the motor to run up to speed.

Multi-test instruments

Current, voltage, insulation and resistance continuity values can all be measured by one instrument which has all the necessary scales and ranges. These are selected as required by the use of a multi-position switch, or a set of outlet sockets. The instrument contains a battery to provide the current flow to measure resistance on the continuity range, plus a power-pack to step the voltage to 500V d.c. for the insulation tests. It is known as the *Electrician's Universal Meter.*

Dismantling of standard electrical machines

1. Clean excess dirt, oil, grease, etc from surfaces.
2. Depending on the weight and size of the machine, place it in a suitable position on floor stand or work bench
3. Any sign of rust on parts to be removed should be sprayed with release fluid
4. Withdraw the key from pinion coupling pulley etc. and then withdraw pinion, etc . See figure 1 for these operations.
5. Undo nuts from end cover bolts and mark the positions of covers relatives to stator frame.
6. Examine for type of bearings, it may need removal of oil rings on the sleeve type.
7. Remove end covers which will leave ball or roller type bearing on the shaft.
8. Remove rotor or armature from stator. On large machines this may heed lifting gear or two people, one at each of the shaft.
9. If the motor is fitted with a commutator or slip rings, try to leave these in position on the shaft.



Note ; when the withdrawal screw is fully tightened and there is no movement of coupling, etc. a sharp (shock) blow with hammer on the screw head will ‘shock it ‘and should produce movement.

Figure 2 Motor coupling pinion or pulley withdrawal tool.

These operations now leave the machine available for cleaning, inspection and maintenance. To assemble the machine reverse the above steps.

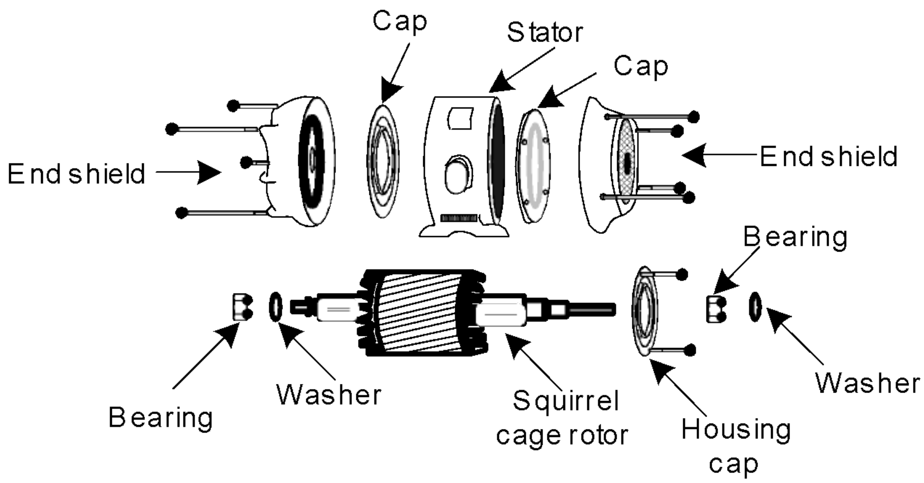


Figure 3 Parts of a disassembled motor.

Inspection of machinery and control gear

All electrical machinery and control gear should be inspected and tested at regular intervals. The frequency of the inspections will depend on the type of equipment and conditions under which it operates. A record of each inspection, together with test results should be kept for future reference.

The inspection of electrical machinery falls into two categories- mechanical and electrical.

Mechanical inspection

1. Visibly check the machine for mechanical damage
2. Check the machine for correct alignment to ensure that no undue stresses are imposed to the bearings
3. Check the air gap (where possible) with feeler gauges.
4. Check the mechanical operation of switchgear and control gear, paying particular attention to contact condition and pressure
5. If starters are fitted with dash-pots, check the grade and level of the oil
6. In the case of any oil-immersed equipment, check that the oil level is correct and the oil is clean

Electrical inspection

1. Check all connections on machinery and control gear, taking note of the condition of the wiring
2. Carry out protective conductor continuity and insulation resistance tests
3. Check fuses for correct rating and also check that any motor-overload current settings are correct
4. Run machinery, listening for knocks, strange noises, etc, and check that all equipment in the circuit is functioning correctly

<u>D.C machines – inspection and maintenance</u>

Owing to their more complex construction, d.c. machines require more frequent maintenance than the common types of a.c. motors. On d.c. machines, the important points to check are the running condition, yoke and field windings, brushes, brush holders, brush springs, armature assembly, bearings, shaft, connection, wiring and insulation.

Running condition

With machine running, check for excessive noise and sparking at the brushes.

Yoke and field windings

With machine isolated from the supply, check that the yoke and field windings are in good condition

Brushes and brush holders

Check that the brushes and brush holders are in good condition and the brushes move freely in their holders. Brushes worn to half their original length should be preplaced, and the new brushes properly bedded in with brush-bedding tape or fine sandpaper.

Brush springs

Check that the brush springs are in good condition that spring pressure is adequate and even on all brushes. A small spring balance may be used for this.

Armature assembly

Check that the coils are in good condition and held securely at the commutator end by their bands. Check the commutator for concentricity, irregularities and cleanliness. Dirt may be removed with a commutator brush, and fine sandpaper will remove slight roughness. Emery cloth must not be used for this purpose as it leaves a greasy film on the commutator. If the commutator is badly worn or eccentric it must be skimmed on a lathe or on a special skimming machine, after which the insulation between the segments may have to be cut back.

Bearings

Check bearings as for as possible for condition and correct lubrication.

Shaft

Check the shaft for concentricity and general condition

Connections and wiring

Check that all connections are tight and that wiring is in good condition with no signs of heat damage.

D.C machine faults

Symptoms	Tests
Starter of the d.c. motor will not hold in 'ON 'position although the motor starts correctly	1. Check that the overload trip is not stuck in the operated position and that remote 'stop' buttons; etc, are not operated 2. Test 'no-volt coil' for short or open circuit 3. In the case of series motors, or starter where the no-volt coil is not in series with a shunt winding, check the no-volts coil circuit for continuity
Excessive sparking at commutator	1. Check brush-gear for correction tension, brushes sticking in holders etc 2. Check polarity of interpoles, if fitted 3. Test the armature windings for short on open-circuits
D.C generator fails to excite	1. May be due to loss of residual magnetism; 'flash' using a suitable battery 2. Check that the rotation of the armature is in the correct direction and that field connections have not been reversed. 3. Check field and armature circuits for open or short -circuits

A.C motor faults

Symptoms	Tests
Motor completely dead	1. Check the voltage at the isolator and motor terminals
Contactor starter does not operate although supply at isolator is correct	1. Check that overload trips limit trips interlocks and remote stop buttons are not operated and that the starter controls are correctly set to the start position

	2. Test continuity of the contactor coil and its associated circuits
Fuses blow or overload trips operate when any attempts is made to start the motor	1. Check that the motor is free to rotate 2. Check that the starter is being operated correctly 3. Test insulation resistance
Single –phase motor hums but refuses to start	1. Check that the motor is free to rotate (particularly for small size motors) 2. Test continuity of main and starting windings and of the centrifugal switch or starting relay 3. Test that the supply is actually reaching the starting winding via the capacitor, if fitted.

7.2.1.3 Learning activities

Field/Visit to an established electrical workshop

Visit Objective/Aim	Indicators	Special Instruction
To establish sources failure	• Failed systems • Methods used to identify failures	• Take notes • Observe keenly methods used to identify failed system

Practical assignment

Visit Objective/Aim	Indicators	Special Instruction
To acquire skills in system failures identification	• Failed systems • Methods used to identify failures	Participate in the process

7.2.1.4 Self - Assessment

1. As an Electrical Installation Technician, what is one rule you should always follow when working on electric or electronic equipment?
   A. Power source
   B. Safety first

C. Location of equipment
D. Required tools

2. As an Electrical Installation Technician, what should you do to the power supply when working on an electrical system?
   A. Close and tag the circuit breakers and main switches
   B. Open and tag the circuit breakers
   C. Open and tag the circuit breakers and main switches
   D. Open and tag the main switches
3. What is failure of equipment?
4. What are the benefits of maintenance?
5. Which human senses that can be used during an inspection of an installation?
6. Apart from wear and tear, what are three other areas of investigation that you would consider when carrying out a periodic inspection and test of an installation?
7. Describe breakdown maintenance
8. What are the two categories of machinery inspection?

7.2.1.5 Tools, Equipment, Supplies and Materials

The following resources are provided

i. An electrical installation company
ii. A functional Safety department.
iii. Computers
iv. Stationery
v. Lecture room
vi. Workshop
vii. Projector
viii. Drawing equipment
ix. Workshop
x. Protective clothing

7.2.1.6 References

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7.2.2 learning outcome 2: Troubleshoot Cause of Failure

7.2.2.1 Introduction

To perform breakdown maintenance successfully, the technician requires the ability to conduct troubleshooting safely, record system failure results and compare parameters against standards values

7.2.2.2 Information Sheet

Trouble shooting electrical installations procedure

Types of fault

The types of faults which may occur in electrical circuit fall into four general groups

1. Open-circuit fault (loss of continuity)
2. Earth fault (flow resistance between live conductor and earthed metalwork)
3. Short circuit fault (low resistance between phase and neutral conductors)
4. High value series resistance fault (bad joint or loose connection in conducting path)

These types fault occur in lighting and power circuits, appliances, apparatus and electric motor. Before any fault can be found and rectified, it is necessary for the electrician to adopt a method or system based on a sound knowledge of circuitry and electrical theory, and on experience. The electrician detailed to repair a faulty circuit is in many ways like a doctor who makes his diagnosis on the basic of the symptoms reveled through a visual inspection or a test using the correct instruments. Haphazard tests carried out at random seldom lead to success in the quick location of faults. The investigation must always be based on an intelligent assessments of the faulty and the probable cause, judged from its effects. In many instances faults arise from installation or circuits which do not in some way or other comply with the requirements of the IEE. Regulations, or else are used in such a manner that the abuse results in a fault. Most faults are easily located by following up reports such as "there was a flash at the lamp; 'the wires got red hot '; the lamp goes dim when it is switched on' or bedroom light will come on only when the bathroom switch is ON'. By careful questioning these reports will enable the electrician to locate the fault quickly and restore the circuit to normal operation again. The following are some common installation defects and omissions which eventually lead to fault;

1. The provision of double-pole fusing on two wire systems with one pole permanently earthed. This frequently occurs with final circuit distribution boards when the main and/or sub main control equipment is single-pole and solid neutral.
2. Fuse protection not related to the current rating of cables to be protected, this is very often due to the equipment manufactures fitting the fuse-carriers with a fuse-element of maximum rating for the fuse-units in the equipment.to locate the fault
3. Connecting boxes for sheathed- wiring systems placed in inaccessible positions in roof voids and beneath floors. Indiscriminate bunching of too many cable using screw-on or inadequate connections
4. Insufficient protection provided for sheathed wiring, e.g. to switch positions and on joints in roof voids
5. Incorrect use of materials, not resistant against corrosion, in damp situations(e.g. enameled conduit and accessories and plain steel fixing screws)
6. Inadequate of complete omission of segregation between cables and/or connections, housed within a common enclosure, supplying systems for extra low voltage; or telecommunication and power and/or lighting operating at a voltage in excess of extra-low voltage.
7. Insufficient attention given in cleaning ends of conduit and/or providing, omission of bushings to prevent abrasion of cables at tapped entries, particularly at switch positions.
8. Insufficient precautions taken against the entry of water to duct and/or trucking systems, particularly where installed within the floor
9. Incorrect use of PVC insulated and/or a sheathed cables and flexible cords, instead of heat-resistant type, for connections to immersion heaters, thermal storage block heaters e.t.c.
10. Incorrect use of braided and twisted flexible cord for bathroom pendant fittings and similar situations subject to damp or condensation.
11. The incorrect use of accessories apparatus or appliances inappropriate for the operating conditions of the situation in which they are require to function. This often applies to agricultural and farm institutions.
12. Installation of cable of insufficient capacity to carry the starting current of motors, causing excessive volt drop.
13. Incorrect rating of fuse element to give protection to the cable supplying this motor.

There are many approaches in trouble shooting Electrical installations. Among them is the procedure outlined below:

Step 1: Observe

Through careful observation and a little bit of reasoning, most faults can be identified as to the actual component with very little testing. When observing malfunctioning equipment, look for visual signs of mechanical damage such as indications of impact, chafed wires or loose components. Don't forget to use your other senses when inspecting equipment e.g. smell, listening, check temperature, etc.

Step 2: Define problem area

Determine the problem area of the malfunctioning equipment. Often times when equipment malfunctions, certain parts of the equipment will work properly while others not. The key is to use your observations (from step 1) to rule out parts of the equipment or circuitry that are operating properly.

Step 3: Identify possible causes

Once the problem area(s) have been defined, it is necessary to identify all the possible causes of the malfunction. It is necessary to list (actually write down) every fault which could cause the problem no matter how remote the possibility of it occurring.

Step 4: Determine most probable cause

Once the list of possible causes has been made, it is then necessary to prioritize each item as to the probability of the cause of the problem.

Step 5: Test and repair

Make sure you follow all your companies' safety precautions, rules and procedures while troubleshooting as faulty equipment may be hazardous. Once you have determined the most probable cause, you must either prove it to be the problem or rule it out.

Fault finding

The location and nature of a fault in an electrical system can usually be quickly determined by systematic tests. The tests to be carried out depends upon the symptoms of the fault. As an example, if a motor shows no sign of life at all, it is advisable to check the supply first.

Most of the tests can be carried out using;

i. Voltage indicator, test lamp, or voltmeter for checking the supply
ii. Continuity tester.
iii. Insulation tester.

Faults in Electrical Appliances

Electrical appliances are electrical machines or equipment which perform household functions

Electric Iron

The electric iron has the following parts:

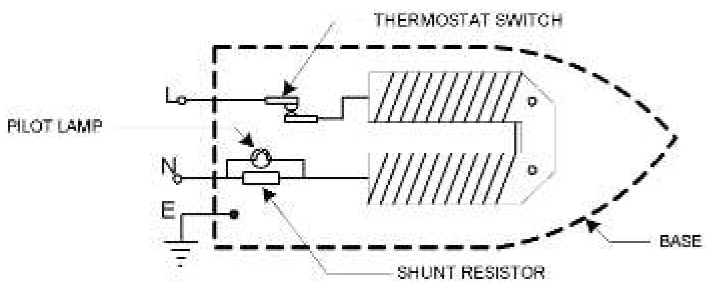

Figure 4 Parts of Iron box

Thermostatic switch

This controls the temperature of the iron by switching it ON and OFF as determined by the setting

Non-inductive coil

It consists of a wire wound in tape form on a mica former. It is insulated with mica and placed on the base plate. The winding is such that no magnetic field is created when the iron is ON. The coil heats up the base plate that is used for ironing

Pilot light

This is used to indicate when the iron is heating. It comes ON when the iron is heating

Common electrical problems in the house

S/N	Problem	Probable cause
1	Loose top plug	i. Defects in manufacture ii. Overheating inside
2	Broken light switch	i. Mechanical blow ii. Defects in manufacture

3	Simple short circuit	i. Breakdown in insulation ii. Poor workmanship
4	Cut or damaged extension cord	i. Mishandling ii. Manufacturers defects
5	Flickering or dimming lights	i. This could be a sign of a poor connection and can lead to eventual arcing ii. Loose/corroded connections making intermittent contact that could result in sparking, overheating, and fire.
6	Light bulbs burn out frequently	You may have a loose connection in the socket or circuit or worn out insulation causing overheating.
7	Dead socket outlets	i. Dead socket outlets can result from a tripped poor connection (and possible arcing) ii. A tripped breaker due to excessive heat buildup resulting in melted wires or outlets.

Common Faults in an Electric Iron

S/N	Fault	Probable causes
1	Iron does not heat up when connected to electrical power	i. Blown fuse ii. Broken conductor iii. Damaged thermostat iv. Broken coil v. Broken shunt resistor
2	Sole plate gives shock when touched	Loose earth connection
3	Pilot light is OFF but iron operates normally	Burnt bulb
4	Iron stuck ON (overheats), no temperature control.	Thermostat stuck ON

Electric Cooker

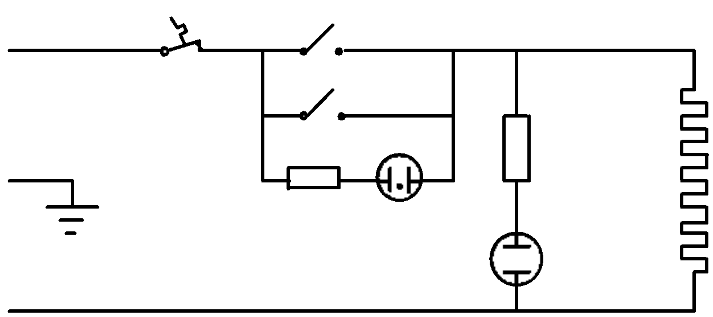

Figure 5. Circuit Diagram of an Electric Cooker

Electric oven

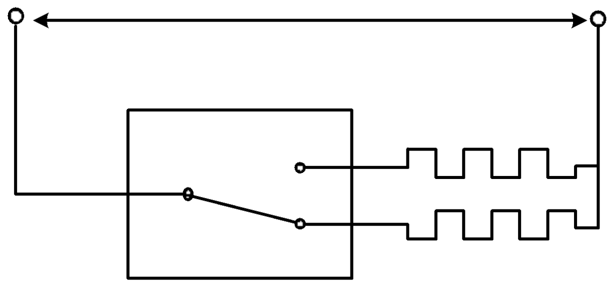

Figure 6. Circuit Diagram of Electric Oven

Common faults in an Electric Cooker and Electric oven

S/N	Fault	Probable causes
1	Coil does not heat up	1. Burnt/broken coil 2. Faulty thermostat 3. Broken cables
2	Temperature control not possible	Thermostat stuck or closed
3	Base plate gives shock	Live wire touching base plate and loose/ broken earth wire

Electric Kettle

An electric kettle has a coil and thermostat as the main components.

Common faults in an Electric Kettle

S/N	Fault	Probable causes
1	Coil does not heat up	1. Burnt/broken coil 2. Faulty thermostat 3. Broken cables
2	Temperature control not possible	Thermostat stuck or closed
3	Kettle gives shock	Live wire touching kettle and loose/ broken earth wire

Motor operated appliances

Many domestic appliances use electric motors for operation. They include:

1. Hand drill
2. Food mixers
3. Fruit blenders
4. Hair driers
5. Refrigerators
6. Air conditioners
7. Washing machines
8. Air fans
9. Vacuum cleaners

The most common motor used is the A.C. series motor (universal motor). This motor runs on both AC and DC.

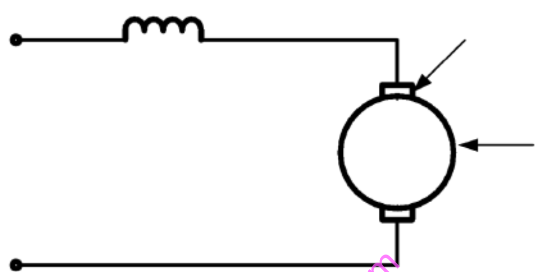

Figure 7. Circuit diagram of Universal motor

Common Faults in Electric Motors

S/N	Fault	Probable causes
1.	Excessive vibration	Uneven foundations defective rotor unbalance
2.	Frame heating	1. Excessive load, foreign matter in the air gap or cooling circuit, excessive ambient temperature. 2. Partial short circuit in windings
3.	Motor is dead	1. Broken wires 2. Blown fuse 3. Field open 4. Brushes disconnected
4.	Heating of bearings	1. Too much grease. 2. Too little grease 3. Incorrect assembly. 4. Bearing overloaded
5	Brushes heating	1. Excessive load 2. Brushes not bedding or sticking in holders 3. Incorrect grade of brushes
6.	No rotation	1. Supply failure (either single phase or complete loss of power) 2. Inefficient torque 3. Reversed phase

7.	Steady electrical hum	1. Running single phase excessive load 2. Reversed phase 3. Uneven airgap
8.	Mechanical noise	1. Foreign matter in airgap or damaged bearings. 2. Misaligned coupling
9.	Pulsating electrical hum	1. Defective rotor 2. Defective wound rotor. Loose connection, partial short circuit e.t.c

Phase Tester

Is used to identify or test a live conductor or the presence or voltage in a circuit

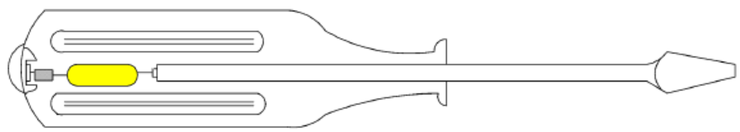

Figure 8. Phase Tester

Ohmmeter

The ohmmeter is used to determine continuity in a circuit. It establishes the whether a conductor is broken or continuous. The circuit must not have power when continuity is being determined by an ohmmeter.

Insulation Resistance Tester

Insulation resistance tester is used to measure the resistance between conductors and resistance is the insulation.

General Procedure for Repair

1. *Carry out visual inspection.*

   The appliance is physically inspected for any breakage or damage or burns. Correct the defect and test to see if the appliance is in good order.

2. *Carry out continuity test and insulation resistance test.*

   Use a circuit diagram to carry out continuity test. If a fault is detected move to step 3.

3. *Dismantle the appliance*

   As you dismantle mark the parts that go together for easier assembly. Clean the parts and trace where the fault is occurred by carrying out electrical measurements.

4. *Repair the appliance*

   Once the fault has been identified, replace or repair the faulty component.

5. *Assemble the appliance*

Assemble the appliance to its original form. Follow the reverse process of dismantling.

6. *Test the appliance*

Carry out the physical tests to ensure the joints are firm and that there are no loose conductors that can cause short circuit.

Carry out electrical tests to ensure to ensure continuity and good insulation resistance.

Connect the appliance to power to test its working.

7.2.1.5 Learning activities

Field/Visit to an established electrical workshop

Visit Objective/Aim	Indicators	Special Instruction
To establish techniques used in troubleshooting	• Failed systems • Readings	• Take notes • Observe keenly techniques used in troubleshooting

Practical assignment

Visit Objective/Aim	Indicators	Special Instruction
To acquire skills in electrical equipment troubleshooting	• Failed systems • Instruments	Participate in the process

7.2.2.4 Self - Assessment

1. What types of common faults interrupt power through a circuit?
   A. Intact wiring, loose terminals, faulty relays, and faulty switches
   B. Broken wiring, loose terminals, faulty relays, and faulty switches
   C. Broken wiring, tight terminals, faulty relays, and faulty switches
   D. Intact wiring, tight terminals, faulty relays, and faulty switches
2. A piece of equipment must be tested after being repaired, what is the purpose of testing it?
   A. Ensure technician skills are adequate
   B. Ensure future maintenance will not be required
   C. Ensure operators can properly operate equipment

D. Ensure system works properly

3. An electrical circuit needs to be tested for voltage, how would you connect a digital multimeter to that circuit?
   A. Connect in series
   B. Connect in parallel
   C. Connect in parallel-series
   D. Connect in phase
4. As an Electrical Installation Technician, what test do you perform to find an open circuit?
   A. Continuity test
   B. Resistance test
   C. Voltage check
   D. Ohm test
5. As an Electrical Installation Technician, what are the **two** important things to do when faced with equipment which is not functioning properly?
6. During troubleshooting of electrical equipment, what are some of the safety tips to be observed?
7. Explain the following terms used in fault diagnosis.
   i. Replacement time
   ii. Checkout time
8. Outline the general procedure for repair

7.2.2.5 Tools, Equipment, Supplies and Materials

The following resources are provided

i. An electrical installation company
ii. A functional Safety department.
iii. Computers
iv. Stationery
v. Lecture room
vi. Workshop
vii. Projector
viii. Drawing equipment
ix. Workshop

x. Protective clothing

7.2.2.6 References

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7.2.3 learning outcome 3: Prepare List of Tools, Equipment & Materials

7.2.3.1 Introduction

To perform breakdown maintenance successfully, one requires the ability to Identify maintenance tools, equipment and materials while observing safety, check tools, equipment and materials specifications and functionality in accordance with established standards and calibrate equipment as per manufacturer's specifications

7.2.3.2 Information Sheet

Meaning of terms

Repair

This is the restoration of a damaged or broken machine /system to a good working condition.

Replacement

This is the physical replacement of a damaged or broken machine/ system with a working one.

Electrical Installation Tools, Equipment and their use

Hammers

These are tools used in driving or pounding out nails they are made of hard steel, wood, plastic or rubber.

Bending spring

This is a tool used for bending PVC conduits

Stock and die

This is a tool used for making threads on metallic conduits

Side cutter

This is a tool used for medium and big cables.

Combination Pliers

These are made of metal with insulated handles. They are used for cutting, twisting, bending, holding and gripping wires and cables

Screw driver

It has a cross/flat tip and is used to drive screws with cross/straight slot heads.

Long nose pliers

This is used for cutting and holding wires. It made to reach tight space and or small opening where other pliers cannot reach. It is also used in making terminal loops of copper wires.

Wire stripper

A tool used for removing insulation from insulated cables.

Hacksaw

This is a tool used to cut metal conduit and armoured cable

Measuring tools

To measure wire length and other items, the electrician finds considerable use for measuring tools such as the extension or zigzag rule, push-pull rule and a steel tape

Soldering equipment

In doing electric wiring, splices and taps (connections made to wire) should be soldered, unless you use solderless connectors.

Drilling equipment

Drilling equipment is needed to make holes in building structure passages of conduit sand wires

Ladders

The term ladder is generally taken to include step ladders and trestles. The use of ladders for working above ground level is only acceptable for access and work of short duration. It is advisable to inspect the ladder before climbing it. It should be straight and firm. All rungs and tie rods should be in position and there should be no cracks in the stiles. The ladder should not be painted since the paint may be hiding defects. Extension ladders should be erected in the closed position and extended one section at a time. Each section should overlap by at least the number of rungs indicated below:

1. Ladder up to 4.8 m length – 2 rungs overlap
2. Ladder up to 6.0 m length – 3 rungs overlap
3. Ladder over 6.0 m length – 4 rungs overlap

Draw wire/Fish tape

This is a tool used for drawing cables in conduits

Electrical instrument checking and calibration

A digital Multimeter is used to measure voltage, current and resistance and can be used to measure electrical continuity in a circuit. There are two types of Multimeter: digital and analogue. Multimeter should be calibrated or adjusted to a known zero-value prior to use for accurate readings.

Calibration of Multimeter

Electrical calibration refers to the process of verifying the performance of, or adjusting, any instrument that measures or tests electrical parameters to maintain their accuracy. Electrical calibration involves the use of precise devices that evaluate the performance of key properties for other devices called units under test (UUTs).

Equipment that are not calibrated can result in the wrong decision being made which has the potential for further damage to what the instrument was to be used for.

The fragile electronics within Multimeter are protected by a hard casing, which means they can usually be stored in a toolbox.

Multimeter do not require any deep cleaning - just wipe them down with a damp (not wet) cloth, every now and then. Ensure your devices are fully functioning before each use. Change batteries and fuses when necessary and consider removing the batteries if the meter will not be used for an extended period of time.

Many people do a field comparison check of two meters, and call them "calibrated" if they give the same reading. This isn't calibration. It's simply a field check. It can show you if there's a problem, but it can't show you which meter is right. If both meters are out of calibration by the same amount and in the same direction, it won't show you anything. Calibration typically requires a standard that has at least 10 times the accuracy of the instrument under test.

Calibration, in its purest sense, is the comparison of an instrument to a known standard.

Two instruments, A and B, measure 100 V within 1 %. At 480 V, both are within tolerance. At 100 V input, A reads 99.1 V and B reads 100.9 V. But if you use B as your standard, A will appear to be out of tolerance. However, if B is accurate to 0.1 %, then the most B will read at 100

V is 100.1 V. Now if you compare A to B, A is in tolerance. You can also see that A is at the low end of the tolerance range. Modifying A to bring that reading up will presumably keep A from giving a false reading as it experiences normal drift between calibrations.

Why Multimeter is calibrated

A digital Multimeter is one of the most commonly used pieces of test and measurement instrumentation. Quality processes depend on its continual proper operation. However, time, environment, and physical use (or abuses) change a digital multimeter's characteristics. That's why it's important to periodically calibrate or verify the performance of a digital multimeter.

A multimeter should be calibrated or adjusted to a known zero-value prior to use for accurate readings.

How to calibrate a digital multimeter

1. Set the multimeter to the highest resistance range by turning the dial to the highest "ohm" setting.
2. Touch the test probes of your digital multimeter together.
3. Press the calibration knob until the display reads "0" on the digital multimeter if you don't see "0 ohms" initially.

Calibration may be required for the following reasons:

a) a new instrument
b) after an instrument has been repaired or modified
c) when a specified time period has elapsed
d) when a specified usage (operating hours) has elapsed
e) before and/or after a critical measurement
f) after an event, for example:
    i. after an instrument has been exposed to a shock, vibration, or physical damage, which might potentially have compromised the integrity of its calibration
    ii. sudden changes in weather

g) whenever observations appear questionable or instrument indications do not match the output of surrogate instruments

h) As specified by a requirement, e.g., customer specification, instrument manufacturer recommendation.

How to take care of your tools

Good tools can be quite an investment but only if you take good care of them, they'll return the favour. Keeping your tools properly stored, cleaned, and maintained will save you time and money and make your DIY endeavours that much more rewarding.

In keeping the tools and equipment, you need to work with the space you have. Maybe you hang them on pegboards, maybe you store them in boxes, bags, or chests, or maybe you keep them in drawers or on shelves in your shop. Whatever works for you is best.

Toolboxes also make for great tool storage, offering the primary advantage of portability. While some people opt to store all their tools in toolboxes, for most, the toolbox is a way of carrying around your most-used tools while leaving the bulk safely stored on pegboards, shelves, or drawers.

Basic maintenance of electric tools

To ensure that your **electric tools** work properly, you must take proper care of them. A good regimen of maintenance for your tools is one thing that you can do to make sure that the tool you need is working when you need it.

a) **Clean out the dust:** To make sure that your electric tools are ready for use, keep them clean and free of dust. The housing intake on your electric tools and the exhaust are especially important areas to keep clean. Take some time to clean out the dust every once in a while on your tools while they are sitting in storage.

b) **Check the cords:** Look for wear and tear on the power cords on your electric tools. There can be damage to the insulation and you should keep an eye out for loose wires. This will ensure that your electric tool can get the power that it needs to function without an accident. Wipe the cords down to keep them from becoming damaged from oil and grease. The prongs on the cords should be examined as well. Make sure that the casing is intact and the prongs are not loose.

c) **Oil some electric tools**: The electric tools in your toolbox that have a cutting surface should be lightly oiled to prevent rust. Examine the cutting surface for rust to make sure that your tools are kept in good condition.

d) **Storing your tools:** Keep your electric tools stored in their original cases and containers. This will keep them free of dust and dirt while they are not being used.

7.2.3.3 Learning activities

Field/Visit to an established electrical workshop

Visit Objective/Aim	Indicators	Special Instruction
To establish tools, equipment and materials preparation techniques	i. Tools ii. Equipment iii. Materials	i. Take notes ii. Keenly observe tools handling iii. Keenly observe tools storage

Practical assignment

Visit Objective/Aim	Indicators	Special Instruction
To acquire skills in tools, equipment and materials preparation techniques	i. Tools ii. Equipment iii. Materials	i. Participate in the process ii. Handle tools properly iii. Store tools properly

4. 7elf - Assessment

1. As an Electrical Installation Technician, what test do you perform to find an open circuit?
   A. Resistance test
   B. Continuity test
   C. Voltage check
   D. Ohm test
2. One of the following is the most accurate instrument used for testing insulation resistance, which one is it?
   A. Growler

B. Megohmmeter
C. Ohmmeter
D. Tachometer

3. List any four tools used in break down maintenance
4. Describe safe the usage of ladder during maintenance of an electrical system
5. Explain the basic maintenance procedure of electric tools
6. Explain why a multimeter is calibrated
7. Why is calibration required?

7.2.3.5 Tools, Equipment, Supplies and Materials

The following resources are provided

i. An electrical installation company
ii. A functional Safety department.
iii. Computers
iv. Stationery
v. Lecture room
vi. Workshop
vii. Projector
viii. Drawing equipment
ix. Workshop
x. Protective clothing

7.2.3.6 References

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7.2.4 leaning outcome 4: Repair the Installation

7.2.4.1 Introduction

To repair the system successfully, one requires the ability to observe safety precautions are as per OSHA, repair system in accordance with maintenance manual, use tools and equipment for repair and record repair activities according to the established procedure.

7.2.4.2 Information Sheet

Remedy of common faults in an installation

S/N	Problem	Probable cause	Action to be taken
1	Loose top plug	i. Defects in manufacture ii. Overheating inside	Turn off the breaker. Double check for voltage to the outlet
2	Broken light switch	i. Mechanical blow ii. Defects in manufacture	Turn off the circuit breaker then use a flathead screwdriver to remove the faceplate. Test the two wires connected to the screw for electricity.
3	Simple short circuit	i. Breakdown in insulation ii. Poor workmanship	Reset the breaker. Repeated occurrences with the same appliance indicate it's the appliance – not the electrical system.
4	Cut or damaged extension cord	i. Mishandling ii. Manufacturers defects	Unplug both ends. Cut off the old plug. Gently score and peel back the insulation jacket, twist them and crew them into the back of the plug. Then close the plug and secure the wires.
5	Flickering or dimming lights	i. This could be a sign of a poor connection and can lead to eventual arcing ii. Loose/corroded connections making intermittent contact that could result in sparking, overheating, and fire.	Put off the light and troubleshoot the problem

6	Light bulbs burn out frequently	You may have a loose connection in the socket or circuit or worn out insulation causing overheating.	Open the lamp holder and identify the problem then fix it
7	Dead socket outlets	i. Dead socket outlets can result from a tripped poor connection (and possible arcing) ii. A tripped breaker due to excessive heat buildup resulting in melted wires or outlets.	i. Replace the damaged socket outlet ii. Carry out rewiring if the cables are damaged

Remedy of Faults in an Electric iron

S/N	Fault	Probable causes	Remedy
1	Iron does not heat up when connected to electrical power	i. Blown fuse ii. Broken conductor iii. Damaged thermostat iv. Broken coil v. Broken shunt resistor	i. Replace fuse with the correct size ii. Repair or replace broken conductor iii. Damaged thermostat iv. Replace coil v. Replace broken shunt resistor
2	Sole plate gives shock when touched	Loose earth connection	Tighten earth connection
3	Pilot light is OFF but iron operates normally	Burnt bulb	Replace bulb
4	Iron stuck ON (overheats) - no temperature control.	Thermostat stuck ON	Replace or repair thermostat

Remedy of Faults in Electric cooker and electric oven

S/N	Fault	Probable causes	Remedy
1	Coil does not heat up	i. Burnt/broken coil ii. Faulty thermostat iii. Broken cables	Replace coil Replace thermostat Replace cables
2	Temperature control not possible	Thermostat stuck closed	Service/replace thermostat

3	Base plate gives shock	Live wire touching base plate and loose/ broken earth wire	Check wire and rectify the fault

Remedy of Faults in Electric kettle

S/N	Fault	Probable causes	Remedy
1	Coil does not heat up	i. Burnt/broken coil ii. Faulty thermostat iii. Broken cables	Replace coil Replace thermostat Replace cables
2	Temperature control not possible	Thermostat stuck closed	Service/replace thermostat
3	Kettle gives shock	Live wire touching kettle and loose/ broken earth wire	Check wire and rectify the fault

Remedy of Faults in Electric motors

S/N	Fault	Probable causes	Remedy
1.	Excessive vibration	Uneven foundations defective rotor unbalance	Check level and alignment of base and realign uncouple from driven machine, remove motor pulley or coupling. Run motor between each of these operations to determine whether the unbalance is in the driven machine, pulley or rotor. Rebalance
2.	Frame heating	Excessive load, foreign matter in the air gap or cooling circuit, excessive ambient temperature. Partial short circuit in windings	i. Check airgap, dismantle motor and clean. ii. Check windings with suitable meter. Repair if defective or return to manufacturer.
3.	Motor is dead	i. Broken wires ii. Blown fuse iii. Field open iv. Brushes disconnected	
		i. Too much grease. ii. Too little grease iii. Incorrect assembly. iv. Bearing overloaded	i. Remove surplus grease. ii. Wash bearings. iii. Assemble squarely on shaft

4.	Heating of bearings		iv. This may be due to misalignment of the drive, excessive end thrust imposed on motor or too much belt tension. Take appropriate steps to reduce the load on bearing.
5	Brushes heating	i. Excessive load ii. Brushes not bedding or sticking in holders iii. Incorrect grade of brushes	i. Reduce load ii. Carefully rebend or clean brushes and adjust pressure iii. Ensure brushes used are those specified by the motor manufacturer
6.	No rotation	i. Supply failure (either single phase or complete loss of power) ii. Inefficient torque iii. Reversed phase	i. Disconnect motor immediately with a single-phase fault serious overloading and burnout may rapidly occur. Ensure correct supply is restored to motor terminals. ii. Check starting torque required and compare with motor rating, taking into account type of starter in use. Change to larger motor or to different type of starter. iii. Check and correct connections in turn
7.	Steady electrical hum	i. Running single phase excessive load ii. Reversed phase iii. Uneven airgap	i. Check if all supply lines are live with balanced voltage. Compare line current with that given on motor name plate. Reduce load or change to larger motor. ii. Check and correct connections in turn iii. Check airgap with feelers. If because of worn bearings, fit new ones
8.	Mechanical noise	i. Foreign matter in airgap or damaged bearings. ii. Misaligned coupling	i. Check airgap, dismantle rotor and clean, check with a listening stick. If confirmed, try rotating outer face of bearing 180°. If still unsatisfactory fit new bearing. ii. Check coupling gap and realign
		i. Defective rotor ii. Defective wound rotor. Loose connection, partial short circuit e.t.c	i. Check speed at full load. If it is low and if there is a periodic swing of current when running, a defective rotor is indicated and the matter should be referred to the manufacturer.

9.	Pulsating electrical hum		ii. Checks should be made on a wound rotor machine for rotor resistance and open circuit voltage between slip-rings.

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Remedy of Faults in Fluorescent lamps

		Faulty lamp					Faulty starter					Faulty choke				Faulty p.f capacitor					Faulty wiring or circuit						
	If trouble is encountered, first look below for symptoms	Air leak or cracked tube	Broken electrode or lamp cap	Mercury deficient	Low emission	Life expired	Contacts stuck together	Air leak or open circuit fault	Short-circuited suppressor	Internal fault	Incorrect type	Open-circuited winding	Earth fault	Short-circuited turns	Wrong type or tapping	Open circuits	Earth fault	Short circuit	Wrong capacitance	Fault discharge resistor	Short–circuited lampholder	Component wrongly connected	Loose connection	Earth wiring	Crossed wiring in two-lamp units	Wrong supply voltage	No supply or fuse blown
A	lamp does not attempt to start; no glow from ends	x	0			x		x		x	x	x	x									X	X	X			0
B	Lamp flashes on and off				x	0				X	X				X						X	X			x	x	
C	Lamp ends glow steadily but lamp does not start						0		0	0	x											X		x			

D	Faint glow at one end of lamp		x																				x				
E	Lamp lights but is dim			X		x									x												
F	Lamp takes excessive time to start				x	X				X	x				x						x		x	x		x	
G	Premature end-blackening of lamp										x			x	x						X	X		X	X	x	
H	Choke overheats												X	X	X							X		X		x	
I	Supply fuse blown or lamp electrodes fused												X	X			X	X		X		X		x			
J	Low power factor															X			X							x	
K	Excessive radio interference					o				x												X	x				
When possible faults has been located, make these tests to find which component is faulty		LAMP Check lamp in good circuit and if proved faulty replace with a new lamp; see note below					STARTER Check operation of starter in good circuit and if found faulty, fit new replacement.					CHOKE Check insulation resistance, continuity and, if possible, impedance. Make sure tapping and rating are correct				CAPACITOR Check, is possible ,insulation resistance and capacitance, measure value of discharge resistor					CIRCUIT Check circuit against wiring diagram, examine all connections and terminal. Check fuses supply voltage and, if possible, insulation resistance of complete fitting.						

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7.2.4.3 Learning activities

Field/Visit to an established electrical workshop

Visit Objective/Aim	Indicators	Special Instruction
To establish techniques used in repair of electrical installation	i. Failed systems ii. Tools	• Take notes • Observe keenly techniques used in repair of electrical installation,

Practical assignment

Visit Objective/Aim	Indicators	Special Instruction
To acquire skills in electrical installation repair	i. Failed systems ii. Tools	Participate in the process

7.2.4.4 Self - Assessment

1. As an Electrical Installation Technician, what are the two basic rules you should follow when working with hand tools?
   A. Use the proper tool and ensure it is properly checked out from tool issue
   B. Ensure it is properly checked out from tool issue
   C. Use the proper tool and keep it in working order
   D. Ensure it is properly checked out from tool issue and is the proper tool
2. One of the following steps will make your troubleshooting easier, which one is it?
   A. Review system operation, analyze symptoms, detect and isolate trouble
   B. Review system operation, clean and inspect, detect and isolate trouble
   C. Review system operation, analyze symptom, and perform clean/inspect
   D. Analyze symptoms, clean and inspect, detect and isolate the problem

3. What types of common faults interrupt power through a circuit?
   A. Intact wiring, loose terminals, faulty relays, and faulty switches
   B. Broken wiring, loose terminals, faulty relays, and faulty switches
   C. Broken wiring, tight terminals, faulty relays, and faulty switches
   D. Intact wiring, tight terminals, faulty relays, and faulty switches
4. A piece of equipment must be tested after being repaired, what is the purpose of testing it?
   A. Ensure technician skills are adequate
   B. Ensure future maintenance will not be required
   C. Ensure operators can properly operate equipment
   D. Ensure system works properly

5. State possible remedy for the following faults in an electrical installation
   (a) Dead socket outlets
   (b) Flickering or dimming lights
   (c) Light bulbs burn out frequently

7.2.4.5 Tools, Equipment, Supplies and Materials

The following resources are provided

i. An electrical installation company
ii. A functional Safety department.
iii. Computers
iv. Stationery
v. Lecture room
vi. Workshop
vii. Projector
viii. Drawing equipment
ix. Workshop
x. Protective clothing

7.2.4.6 References

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https://electrical-engineering-portal.com/maintenance-management-of-electr

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7.2.5 Learning Outcome 5: Test the Repaired System

7.2.5.1 Introduction

To test repaired system successfully, one requires the ability to identify test points as per established standards, perform tests while observing safety rules and as per established procedure, record test results, compare parameters against standard values and prepare maintenance report according to approved format

7.2.5.2 Information Sheet

Visual inspection

The purpose of inspection is to ensure that all that was specified or intended in the design is in the right place and functioning. Visual inspection will involve;

1. Checking workmanship-that the installation is neat
2. Checking whether cable sizes with proper colour code are used
3. Checking whether proper models and rating of components are used.

Purpose of Testing a repaired Installation

The reason for testing an installation is to detect faults before dangerous situations arise.

Factors which the installation must be protected against are:-

i. Earth leakage and danger of electric shock
ii. Excess current
iii. Moisture and corrosion

The main tests to be carried out on a complete electrical installation are:-

1. Verification of polarity test
2. Effectiveness of earthing test
3. Ring circuit continuity test
4. Insulation resistance test
5. Earth fault loop impedance test

The tests should be carried out on:

a) New installations
b) Additions to existing installations
c) Existing installations periodically

Verification of Polarity Test

The purpose of this test is to check the phase conductor is taken through the fuse and switch to the appliance the reason for this test is to ensure that the neutral wire is earthed at the supply authority's substation.

The Neutral must never be broken by a fuse or switch.

Preparation for the test

1. Supply OFF
2. Lamps and appliances OUT
3. All switches OFF
4. Neutral links IN
5. Fuses OUT

Instrument used: Ohmmeter or Bell set

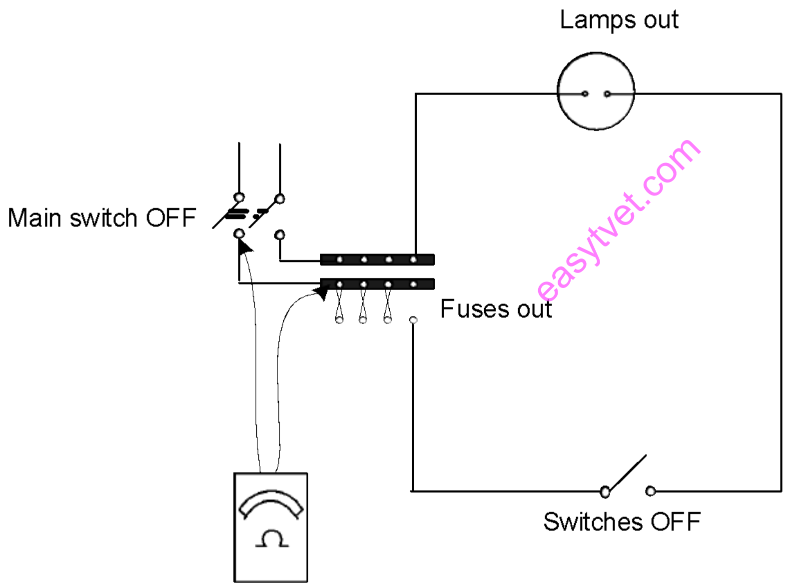


Figure 9 Verification of polarity test

Reading: Zero Ohms on Ohmmeter

NB – This test should not be carried out on a LIVE installation.

Effectiveness of earthing tests

The purpose of this test is:-

i. To measure the resistance of the earth continuity conductor.
ii. To check that the earth continuity heavy leakage currents.
iii. To ensure that the earth electrode is effectively connected to the general mass of earth.

Earth Continuity

Earth continuity is making sure that should there be an electrical fault, all exposed metalwork in a building is bonded together and connected to the earth block in the consumer unit, leaking the current to earth and automatically disconnecting the supply. An earth continuity test will verify that exposed metalwork in a building is bonded together and connected to the earthing block in the consumer unit.

The ohmmeter leads are connected between the points being tested, between simultaneously accessible conductive parts e.g. pipe works, sinks etc. This test will verify that the conductor is sound.

Earth fault loop test

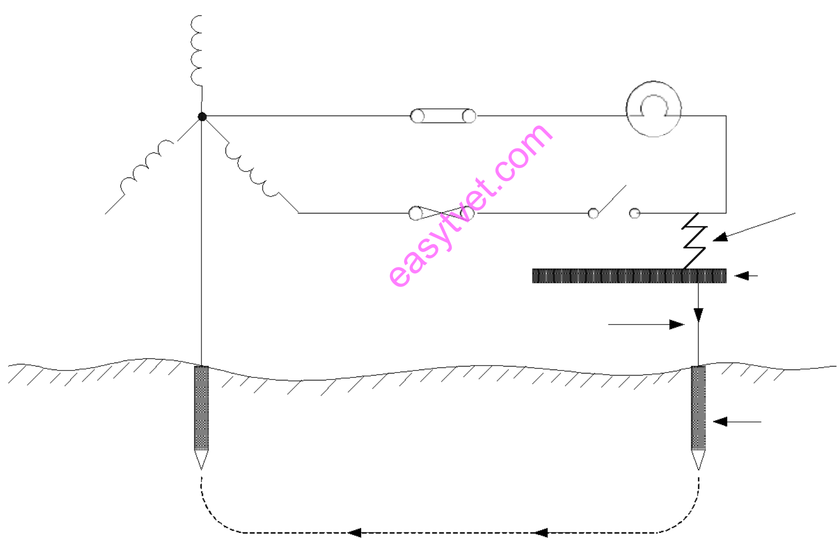


Figure 10 Earth fault loop test

The earth fault loop is the path which the leakage current will take back to the supply transformer when there is an earth leakage in an installation. The path is as shown below.

The test must be carried out on a new or largely modified installations where earth-leakage protection relies on the operation of fuses or excess current circuit – breakers.

1. The leakage current flows from the faulty conductor into the earth continuity conductor.
2. It then flows along the earth continuity conductor to the earthing lead.
3. The earthing lead carries the current to the earth electrode.

4. The leakage current now takes the shortest path back to the earthed neutral of the supply transformer.

The purpose of this test is to show that the earth fault loop is capable of carrying heavy leakage currents so that the protective gear (e.g. fuses) will operate when leakages occur between the line conductor and the earthed metalwork of the installation.

Apparatus: Line-earth loop tester (Megger).

Method

The Line-earth loop tester, operating on fall mains voltage, passes a short duration current of approximately 20A from the line conductor, through the consumer's earth continuity conductor and the earth return path to the neutral of the supply transformer. This instrument measures the value of the loop in Ohms.

Readings

The minimum permissible reading depends on the operating conditions but the two main factors are:-

Operating current of fuse or circuit breaker protecting circuit.

Supply voltage.

Example

If the circuit fuse operated at 50A and the supply voltage is 240V then the resistance of the earth fault loop must not be more than $\frac{240\,V}{60\,A} = 4\Omega$. If the resistance is higher than this value the fuse will not open under serious fault conditions.

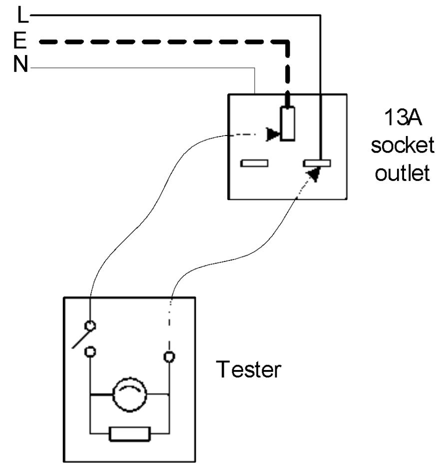


Figure 11 Circuit of megger line-earth loop tester

Factors determining resistance of earth fault loop are as follows.

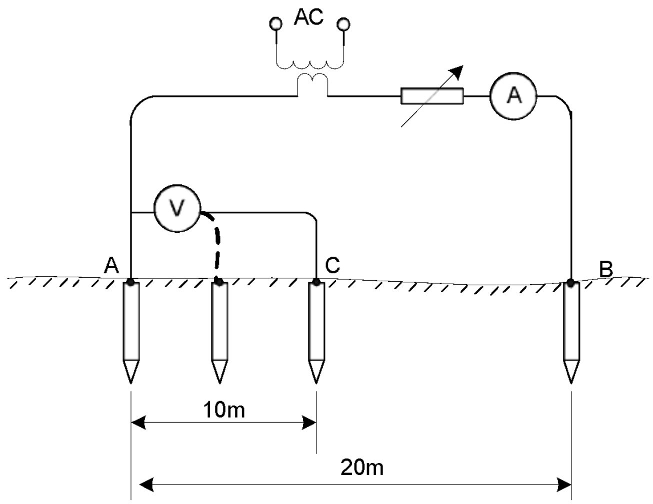
1. The continuity of the metallic circuit up to the earth electrode (the earth continuity conductor and the earthing lead).
2. The resistance of the body of earth surrounding the earth electrode.

Earthing Lead – The minimum size of copper earthing lead is $1mm^2$. The earthing lead connecting an earth–leakage circuit-breaker to an earth electrode need not exceed $2.5mm^2$. The earthing lead should be protected against mechanical damage and corrosion and the clamp used for connecting the earth lead to the earth electrode should be non-ferrous and should be accessible for inspection.

The resistance area is the name given to the resistance of the body of earth surrounding the earth electrode.

The resistance area is measured using

1. An alternating current (at a maximum pressure of 40V) is connected between the main earth electrode A and an auxiliary electrode B, placed about 30m from A. An ammeter is placed in series with the supply to measure the current through the circuit.
2. A second auxiliary electrode C is placed between A and B and the voltage (potential difference) is measured between A and C. the resistance of the resistance area is found by taking various readings from point A towards point B. Outside the resistance area the resistance is constant .



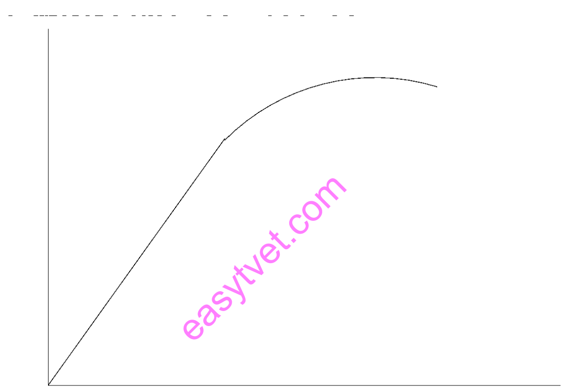


Figure 12 Resistance area measurement

$$R = \frac{Voltage\ between\ \ A\ and\ C}{Current}$$

Insulation Tests

The purpose of the insulation resistance test is to make sure that there is no possibility of leakage currents flowing between insulated conductors and also to make sure that there is no leakage of current between the conductors of the installation and 'the general mass of earth.

Earth Insulation Resistance Test

The purpose of the earth insulation resistance test is to detect whether there is existence of possible leakages to earth and locate the actual leakage.

Preparation for the test:

The following should be observed.

a) Supply OFF
b) Fuses IN; neutral links IN
c) All switches ON
d) All lamps IN
e) Connect all poles together

Test Instrument

The instrument used for insulation resistance testing is a hand-driven d.c. generator which should be capable of supplying a d.c. voltage more than twice the voltage normally supplied to the circuit. The voltage need not exceed 500V for low-voltage circuits (low-voltage range: 50V to 1000V). The test should be carried out at the nearest possible point to the supply authority's equipment.

Method

1. Connect one wire of insulation tester to earthed metalwork (case of main switch, trunking, and conduit).
2. Connect other wire to phase (or phases) and neutral in turn

Reading

The accepted reading will depend upon the size of the installation but should not be less than one megohm. An outlet, in this instance, includes points and switches but a switch combined with a socket outlet, appliance, or light fitting, is regarded as one outlet. These are the readings when an installation is complete.

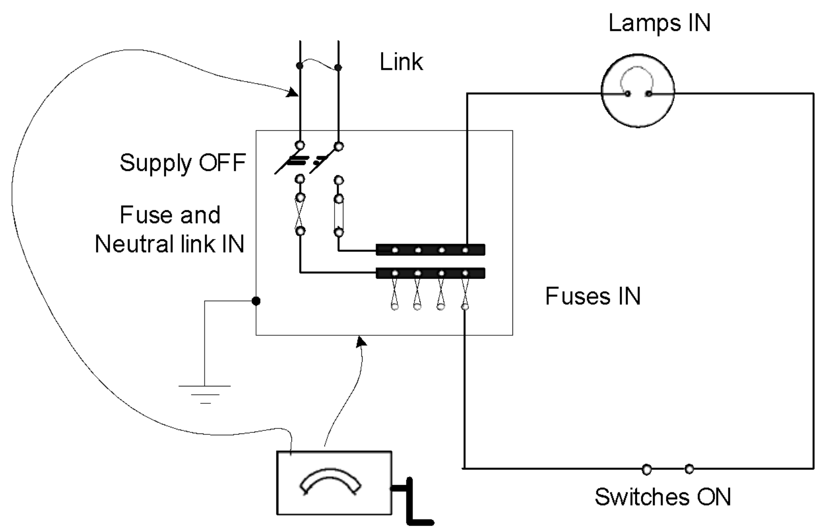


Figure 13 Insulation resistance test.

If the reading obtained is less than the minimum allowed, then the installation must be sub-divided to isolate the faulty circuit.

Between Poles Test

The purpose of the between poles test is to make sure that there are no short circuit or low-resistance connections between the 'live' conductors in the installation.

Preparations for Test

1. Supply OFF
2. Lamps OUT; appliances OFF
3. All switches ON; all fuses and neutral links IN

Test Instrument

Insulation resistance tester (e.g. megger). The test should be carried out at the nearest possible point to the supply Authority's equipment.

Method

Connect insulation resistance tester between phase and neutral

Readings

The minimum readings required are similar to those for the earth insulation resistance test on the same installation.

Test of Ring Circuit Continuity

On completion of a ring circuit installation a test, similar to that carried out to check the verification of polarity, must be carried out to ensure the continuity of all time, neutral and earth continuity conductors throughout the ring circuit. This test is carried at the point of connection in the distribution fuse board prior to the completion and connection of the ring circuit conductors.

Tests to be carried out are given below

1. Verification of polarity – Used to check that phase wire is switched and fused. Reading on ohmmeter or bell set-zero or continuity.
2. Earthing tests – To ensure that the metalwork of the installation is 'effectively connected to the general mass of earth'.
   (a). testing earth continuity conductor. Maximum reading, 0.5 Ω.
   (b). Testing earth fault loop impedance by current injection. Reading determined by setting of protective equipment.
   (c). testing effectiveness of earth electrode. Reading determined by setting of protective equipment.
3. Insulation tests (a) between poles (b). Earth insulation resistance (between all conductors and earth).
4. Ring circuit should be tested with ohmmeter or bell set for continuity of ring.

Commissioning

After completion of the installation, it is the duty of the contractor to now hand over the completed building to the owner. This is achieved by filling in details of the installation on completion certificate and handing it over to owner and a copy to the supply authority.

Completion Certificate.

Upon completion of new installation or a major extension on existing installation and inspection and testing has been carried out. The contractor the contractor should issue out a completion certificate. The certificate gives details of the installation including the name and address of the customer number of appliances, method of earthing and readings of the tests carried out. The certificate states that the installation has been carried out in accordance with the I.E.E regulations and also recommends periodic inspection and testing.

Inspection Certificate.

After an installation has been re-inspected and tested as recommended in the completion certificate on specified date an inspection certificate is completed and handed on to the consumer. The certificate contains more details than the completion certificate since it gives full range of tests of the installation

7.2.5.3 Learning activities

Field/Visit to an established electrical workshop

Visit Objective/Aim	Indicators	Special Instruction
To establish techniques used in testing an installation	• Instruments • Readings	• Take notes • Note instruments used • Note measurement values.

Practical assignment

Visit Objective/Aim	Indicators	Special Instruction
To acquire skills in testing an electrical installation	• Instruments • Readings	Participate in the process

7.2.5.4 Self -Assessment

1. The picture below shows one of the instruments used by electrical artisans in their daily activities, What is the name of the instrument?

A. Tester
B. Earth loop tester
C. Multimeter
D. Voltmeter

2. What is the test voltage used when performing an insulation resistance test on a 230V system?
   A. 50V
   B. 500V
   C. 24V
   D. 250V
3. Who is supposed to carry out periodic testing on an existing installation?
   A. Energy regulatory commission.
   B. Competent Person
   C. Kenya power
   D. Building inspector
4. What is the purpose of testing a repaired Installation?
5. What are the main tests to be carried out on a complete electrical installation
6. With the aid of a diagram describe verification of polarity test
7. Describe what is an inspection certificate

7.2.5.5 Tools, Equipment, Supplies and Materials

The following resources are provided

i. An electrical installation company
ii. A functional Safety department.
iii. Computers
iv. Stationery
v. Lecture room
vi. Workshop
vii. Projector
viii. Drawing equipment
ix. Workshop
x. Protective clothing

7.2.5.6 References

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https://www.onupkeep.com/learning/maintenance-types/breakdown-mainten

7.2.6 Answers to Self-Assessment

7.2.6.1 Identify System Failure

1. B
2. C

The termination of the ability of an equipment to perform its required function

3. What are the benefits of maintenance?

   i. *Maximize the useful life of equipment/facilities*
   ii. *Reduce accidents and fire risks (keeping Equipment safe)*
   iii. *Minimize the possibility of failure or breakdown because this will result in lost production.*
   iv. *Minimize operating costs by preventing major repair works from arising*
   v. *Maximize the production/operation capacity from the given equipment resources*
   vi. *Improve the morale of operatives*
   vii. *Reduce the chances of scrap in production*
   viii. *Enable product or service quality and customer satisfaction to be achieved through correctly adjusted, serviced and operated equipment.*
   ix. *Give cost records which are helpful when it comes to considering replacement.*

4. Which human senses that can be used during an inspection of an installation?

   i. *Visual*
   ii. *Touch*
   iii. *Smell*

5. Apart from wear and tear, what are three other areas of investigation that you would consider when carrying out a periodic inspection and test of an installation?

   i. *To ensure safety of persons and livestock*
   ii. *To ensure protection from fire and heat*
   iii. *To ensure that the installation is not damaged so as to impair safety*
   iv. *To ensure that the installation is not defective and complies with current regulations.*

7. Describe breakdown maintenance

The breakdown maintenance is a type of maintenance that involves using a machine until it completely breaks down and then repairing it to working order. The is a type of maintenance that involves using a machine until it completely breaks down and then repairing it to working order. For example, this type of maintenance would occur if you *wait until a machine stops working before fixing it. This is one of several common maintenance types.*

8. What are the two categories of machinery inspection?

i. *Mechanical inspection*

ii. *Electrical inspection*

7.2.6.2 Troubleshoot Cause of Failure

1. B
2. D
3. B
4. A
5. As an Electrical Installation Technician, what are the **two** important things to do when faced with equipment which is not functioning properly?
   - *Be sure you understand how the equipment is designed to operate. It makes it much easier to analyze faulty operation when you know how it should operate.*
   - *Note the condition of the equipment as found. You should look at the state of the relays which lamps are lit. Look for signs of mechanical damage, overheating, unusual sounds smells etc.*
   - *Test the operation of the equipment including all of its features. Make note of any feature that is not operating properly. Make sure you observe these operations very carefully.*

6. During troubleshooting of electrical equipment, what are some of the safety tips to be observed?
   - *Be informed, be aware of the Hazards, Make sure you know and understand all the rules and regulations that apply to the work you are doing.*
   - *Follow all safety rules and procedures, these are designed to protect you. Do not take short cuts.*
   - *Use the troubleshooting simulator in this program to practice your troubleshooting skills in a safe environment.*

- *Wear all required personal protective equipment. In the event of equipment failure or accident contact, your personal protective equipment may save your life.*

7. Explain the following terms used in fault diagnosis.

   Replacement time - *this involves removal of the faulty, followed by connection and wiring, as appropriate of a replacement.*

   Checkout time - *this involves verifying that the fault condition no longer exists and that the system is operational.*

8. Outline the general procedure for repair

   i. *Carry out visual inspection*.

   ii. Carry out continuity test and insulation resistance test.

   iii. Dismantle the appliance

   iv. Repair the appliance

   v. Assemble the appliance

   vi. *Test the appliance*

7.2.6.3 Prepare list of tools, Equipment & Materials

1.B

2.B

3. List any four tools used in break down maintenance

   i. Ladder

   ii. Hammer

   iii. Pliers

   iv. Screw drivers e.t.c

4. Describe safe the usage of ladder during maintenance of an electrical system

   The term ladder is generally taken to include step ladders and trestles. The use of ladders for working above ground level is only acceptable for access and work of short duration. It is advisable to inspect the ladder before climbing it. It should be straight and firm. All rungs and tie rods should be in position and there should be no cracks in the stiles. The ladder should not be painted since the paint may be hiding defects. Extension ladders should be erected in the closed position and extended one section at a time. Each section should overlap by at least the number of rungs indicated below:

   1. *Ladder up to 4.8 m length – 2 rungs overlap*
   2. *Ladder up to 6.0 m length – 3 rungs overlap*

3. *Ladder over 6.0 m length – 4 rungs overlap*

5. Explain the basic maintenance procedure of electric tools

To ensure that your electric tools work properly, you must take proper care of them. A good regimen of maintenance for your tools is one thing that you can do to make sure that the tool you need is working when you need it.

a) *Clean out the dust: To make sure that your electric tools are ready for use, keep them clean and free of dust. The housing intake on your electric tools and the exhaust are especially important areas to keep clean. Take some time to clean out the dust every once in a while on your tools while they are sitting in storage.*
b) *Check the cords: Look for wear and tear on the power cords on your electric tools. There can be damage to the insulation and you should keep an eye out for loose wires. This will ensure that your electric tool can get the power that it needs to function without an accident. Wipe the cords down to keep them from becoming damaged from oil and grease. The prongs on the cords should be examined as well. Make sure that the casing is intact and the prongs are not loose.*
c) *Oil some electric tools: The electric tools in your toolbox that have a cutting surface should be lightly oiled to prevent rust. Examine the cutting surface for rust to make sure that your tools are kept in good condition.*
d) *Storing your tools: Keep your electric tools stored in their original cases and containers. This will keep them free of dust and dirt while they are not being used.*

6. Why Multimeter is calibrated

A digital Multimeter is one of the most commonly used pieces of test and measurement instrumentation. Quality processes depend on its continual proper operation. However, time, environment, and physical use (or abuses) change a digital multimeter's characteristics. That's why it's important to periodically calibrate or verify the performance of a digital multimeter. A multimeter should be calibrated or adjusted to a known zero-value prior to use for accurate readings.

7. Why is calibration required?

Calibration may be required for the following reasons:

a) *a new instrument*

b) after an instrument has been repaired or modified

c) when a specified time period has elapsed

d) when a specified usage (operating hours) has elapsed

e) before and/or after a critical measurement

f) after an event, for example:

iii. after an instrument has been exposed to a shock, vibration, or physical damage, which might potentially have compromised the integrity of its calibration

iv. sudden changes in weather

g) whenever observations appear questionable or instrument indications do not match the output of surrogate instruments

h) As specified by a requirement, e.g., customer specification, instrument manufacturer recommendation.

7.2.6.4 Repair the Installation

1. A
2. A
3. B
4. D
5. State possible cause and remedy for the following faults in an electrical installation
   (a) Dead socket outlets
   (b) Flickering or dimming lights
   (c) Light bulbs burn out frequently

(a) *Dead socket outlets can result from a tripped poor connection (and possible arcing), a tripped breaker due to excessive heat buildup resulting in melted wires or outlets. Replace the damaged socket outlet, carry out rewiring if the cables are damaged*

(b) This could be a sign of a poor connection and can lead to eventual arcing

Loose/corroded connections making intermittent contact that could result in sparking, overheating, and fire. Put off the light and fix these problems *(c) You may have a loose connection in the socket or circuit or worn out insulation causing overheating. Open the lamp holder and identify the problem then fix it.*

7.2.6.5 Test the Repaired System

1. C
2. B
3. B

4. What is the purpose of testing a repaired Installation?

The reason for testing an installation is to detect faults before dangerous situations arise.

Factors which the installation must be protected against are:-

i. Earth leakage and danger of electric shock

ii. Excess current

iii. Moisture and corrosion

5. What are the main tests to be carried out on a complete electrical installation?

1. Verification of polarity test

2. Effectiveness of earthing test

3. Ring circuit continuity test

4. Insulation resistance test

5. Earth fault loop impedance test

6. With the aid of a diagram describe verification of polarity test

The purpose of this test is to check the phase conductor is taken through the fuse and switch to the appliance the reason for this test is to ensure that the neutral wire is earthed at the supply authority's substation.

The Neutral must never be broken by a fuse or switch.

Preparation for the test

1. Supply OFF

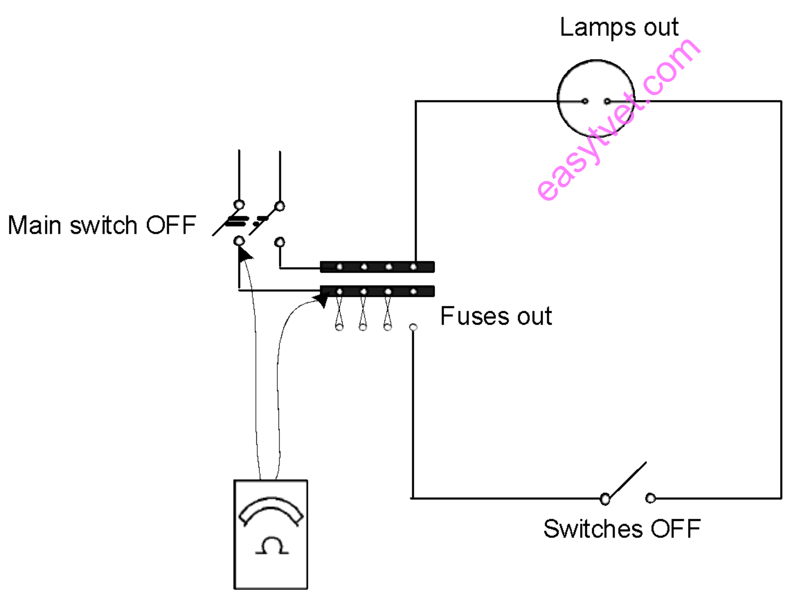
2. Lamps and appliances OUT

3. *All switches OFF*
4. *Neutral links IN*
5. *Fuses OUT*

Instrument used: Ohmmeter or Bell set

7. Describe what an inspection certificate is.

After an installation has been re-inspected and tested as recommended in the completion certificate on specified date an inspection certificate is completed and handed on to the consumer. The certificate contains more details than the completion certificate since it gives full range of tests of the installation



Reading: Zero Ohms on Ohmmeter

This test should not be carried out on a LIVE installation.