CHAPTER 8: ELECTRICAL INSTALLATION MAINTENANCE

Unit of learning code ENG/CU/PO/CR/01/6

Related Unit of Competency in Occupational Standard: Maintain electrical installation systems

8.1 Introduction to the unit of learning

This unit covers the competencies required to carry out maintenance in electrical installation systems. The maintenance includes scheduling, inspection of electrical system, preparation of list of tools, material and equipment, system maintenance and tests.

8.2 Summary of Learning Outcomes

1. Prepare maintenance schedule
2. Inspect electrical installation
3. Perform installation servicing
4. Conduct installation tests

8.2.1 Learning Outcome 1: Prepare maintenance schedule

8.2.1.1 Introduction to learning outcome

This learning outcome entails definition of maintenance, types of maintenance and procedures, Scheduling maintenance based on service manuals as well as Safety precautions to be observed.
Information sheet

12.2.1.2 Performance standards

12.2.1.2.1 Type of the system to be maintained is identified
12.2.1.2.2 The maintenance type and scope are defined
12.2.1.2.3 Relevant manual/service instruction is referred to
12.2.1.2.4 Maintenance schedule is developed in accordance with the service checklist
12.2.1.2.5 Relevant maintenance procedures are referred to where applicable

12.2.1.3 information sheet

Prepare maintenance schedule

Maintenance is the keeping of equipment, building and services of the plant in satisfactory repair and operating conditions.

Importance of Maintenance

- It helps the industry to maintain continuous supply of goods and services.
- Keeps equipment running (operating)
- Keeps the installation efficient

Control of Maintenance Work

In order that there should be some control over the work of maintenance, four rules should be rigidly enforced.

- All requests for maintenance work must be made preferably in writing) to one central control point (maintenance supervisor). No work should be carried out without the knowledge and approval of the maintenance supervisor. Lack strict adherence to this rule will allow a waste of skilled staff and inability to keany schedule of essential work.
- No maintenance work should be undertaken by productive staff unless the operator is seconded to the maintenance department.
- Maintenance stores must be as carefully controlled as any other of the company's stores, as the absence of a vital, part can lead to an expensive plant shut down.
- Records of work carried out, including a statement of materials required, should be kept as those assist in selling rational maintenance, replacement and depreciation policies

Maintenance Policies

Within the context of maintenance, failure is defined as an inability to produce work in the appropriate manner rather than inability to produce any work. Work carried out before failure is said to be overhaul, or planned maintenance work while that carried out after failure is emergency, breakdown or recovery work.

In order to come up with rational policies there is need to collect and analyze maintenance information and data of the installations to actual times taken and work Involved when carrying out maintenance tasks and also maintenance costs. From here a choice can then be made of one or a combination of several of the following five types of maintenance policies

- Time base ('overhaul every x months')
- Wok based ('overhaul when x volume of work is produced')
- Opportunity based ('maintain when available')
- Condition based ('repair when parameter is at level p')
- Emergency based ('continue to operate until plant fails, then maintain)

The new above policy decisions as an address to the following questions

- Should maintenance consist of service or repair or both?
- What should be the timing of service or preventive work in order to involve minimum effort and cost and yet minimize the probability of breakdown resources?
- How should the repair work be conducted?
- What should be the size of maintenance teams?
- How should information be gathered to enable the above question be answered?

Duties of Maintenance

The duties of maintenance can be classified into five

- Inspection
- Engineering
- Production
- Clerical

- Housekeeping

1. **Inspection**

Inspection is concerned with the routine scheduled checks of the plant, building and its equipment and their conditions and to check or needed repairs. On intensively used production equipment Inspection is much more frequent and detailed than function of housing, eg production machines, motors and belting may be inspected once every week, boilers, furnaces and compression equipment every month, overhead cranes may be Inspected every 4 to 6 months.

Facilities will normally be inspected at Intervals in order to determine whether services and\or preventive maintenance is required is likely to be required in the rear future. Such work may Involve visual inspection or the measurement certain of the physical characteristics of a facility. It may Involve the whole facility or simply these parts, which are known to be liable to failure.

A report should be made after such inspection showing the condition of plants, probable reasons for their development and suggested repairs and replacement. A succession of these reports often indicates their weaknesses, which may be developing or may call for change in the inspection interval.

2. **Engineering**

Engineering is concerned with developing changes and improvement in the plant building or the operating equipment. Recurring breakdowns in certain equipment may suggest a need for engineering by the maintenance department to determine what has caused the difficulty. After the study, maintenance would then develop some modification to prevent or at least reduce such future recurrences. In its engineering capacity, for example, maintenance might be deciding to study and develop ways of directing sufficient illumination towards a particular job through stronger fixture brazing arrangement.

3. **Production**

This puts into operation the ideas developed by the engineering phase. It is also concerned with the performing work suggested by inspection function as well as performing other tasks such as servicing and lubricating of equipment. The implementation aspects of maintenance are the part that will the classified under this heading.

4. **Clerical Work**

This is largely keeping records of cost, time progress on jobs etc. It is also responsible for maintaining records to the important features of the plant, equipment and other properties. These may include records of property maps, complete building drawing. Complete writing and power line drawings, maps of underground piping of water, steam, air and similar lines, complete layout drawings of whole machinery, showing types, location and date purchased, spares parts required etc., and records of all inspection, adjustment, repairs, and replacement by department, equipment and date.

5. **House keeping**

As the name suggest, it means taking care of the detail of the upkeep and cleaning of the buildings, equipment, tools and plant facilities.

These five functions are in essence the total duties of maintenance department.

Types of Maintenance

Fundamentally there are only two types of maintenance,

a. preventive maintenance carried out before failure
b. breakdown maintenance carried out after failure.

Preventive Maintenance

This is also called overhaul, schedule or planned maintenance.

It is generally defined orderly routine of inspecting, cleaning, testing, furnishing, adjusting, and lubricating machines. The main objective of this of program is to avoid or reduce the number of avoidable breakdowns. It is a cores mechanical tear and wear.

A good preventive maintenance program provides for plant shut down during periods of inactivity or least usage for purpose of major overhauls. This ensures continuity of operation and lessens the danger of breakdowns at peak loads.

When preparing routine inspection schedule, it must be recognized that too frequent inspection are a waste time and money and that insufficient inspection places equipment in virtual jeopardy. The frequency of inspection should depend on the equipment' contribution to profitable production, its duty cycle, age, overload etc.

In order to carry out a preventive maintenance schedule it is first necessary to produce an inventory of every item, its service, its role and method required for maintenance, the acceptable frequency of maintenance and attention needed. The selection would be based on the consequences in failure in regard to such factors as safety, productivity and the frequency based on analysis of the past records.

This program is a corrective measure carried out on an item before it fails prevent failure. In most cases, the whole factory would be closed due to overhauls. It embraces type 1 and 3 of maintenance policies.

Planning a preventive maintenance program

A) The most important phase of a preventive maintenance program is the recording and interpretation of data pertinent to each piece of equipment.

B) Maintenance personnel should be selected to the basis of qualification on the job.

C) A skilled maintenance force should be kept abreast of the latest techniques and developments in the field. Files of equipment, manufacturer's bulletins and instructions should be available to all maintenance personnel.

D) Only modern testing equipment, proper tools and latest methods should be used

(e) A carefully selected assortment of spare parts is essential to a good maintenance program and represents insurance against prolonged shutdowns. Overstocking and understocking should be avoided, since overstocking in excessive holding of funds as well as losses due to theft and obsolescence of equipment, while under stocking leads to production in jeopardy if a break down occurs.

F) Safe operation of machines and safety to personnel should the uppermost when planning any maintenance program.

Objectives of Preventive Maintenance

(a) To minimize the possibilities of anticipated production interruption by identifying any condition which might lead to it.

(b) To make plant equipment ad machines available and ready for use.

(C) To reduce the work content of maintenance Jobs that would be occasioned by breakdowns

(d) to ensure safety of employees.

Advantages (Benefits) of Preventive Maintenance(a) A good preventive maintenance ensures co and lessens the chances of breakdown at peak load.

(b) lt enables troubles to be detected in their early stages so that corrective action can be taken before expensive damage is done

(c) The relatively high cost of down time due to equipment failure is avoided particularly in processing plants, assembly.

(e) The total cost of down lime and emergency and clock repairs, which can be staggering are minimized (f) The probability of law suits that may arise from Injury to personnel and failure to meet commitments because of unavoidable break down are eliminated

(g) Leads to better spare parts control leading to minimum Inventory level and reduction in maintenance.

Running Maintenance

This is part of preventive maintenance, which is done more routinely. It involves walking around and inspecting machines through observation while in operation in order to ascertain loose parts like nuts, screws, parts which by their nature require oiling, greasing, etc. and being able to take the necessary action i.e. tightening or replacing loose nuts, rivets, clips, etc., oiling, greasing, adjusting offset parts, etc.

Total Preventive maintenance

This is where you have workers perform preventive maintenance activities. It's based on the machines they operate, rather than use separate personnel for the task. It is a system where employees are given greater responsibility for quality productivity and the general functioning of the system.

Predictive Maintenance

It is an attempt to determine when maintenance activities. It is based on historical records, analysis of technical data to predict when a piece of equipment of a plant is about to fall. The better the predictions of failures are, the more effective preventive maintenance will be. A good preventive maintenance effort relies on complete records for each piece of equipment Records must include information such as data of installation, operating hours, dates and types of insurance and dates and types of repairs

Break Down Maintenance

It is also called corrective, emergency or recovery work. itis typo 4 and 5 of maintenance policies.

This is a maintenance, which is carried out on an item, which has failed in its service. It is repair work, which is carried out through fault diagnosis, analysis and identification to establish its position it is done by repairing the faulty part so as to restore its operation. Some of the worn out or broken parts are removed and replaced.

Repair or breakdown maintenance is remedial; taking place alter an item has ceased to operate. The need to repair is not necessarily that result of inefficient or Insufficient inspection, service or preventive maintenance, since in some cases the cost of repairs will be less than the accumulated cost of preventive work.

Causes of Breakdown

(a) Failure to identity and replace worn out parts

(b) Lack of lubrication.

(C) Inefficient cooling system

(d) difference towards minor faults

(e) Use of standard or wrong fluids.

Disadvantages of Breakdown Maintenance

(a) It is expensive since It results in high cost of down time due to outage for during repair work the equipment is scheduled out of service.

(b) It results to disruption of production and losses thereof, excessive delays or reduction in output.

(c) Failure of machines may cause accident leading to losses and strained industrial relations.

Reasons why breakdowns should be avoided

(a) Avoid production disruptions

(b) Prevent addition to production costs

(c) Maintain high quality products,

(d) Avoid missed delivery dates

Adverse consequences when breakdown occurs

(a) Production capacity is reduced and orders are delayed

(b) There is on production but overheads contiue increasing the cost per unit.

(c) There are quality issues, product may be damage

(d) There are safety issues, employees or customers may be injured

Handling Breakdowns

The following are some are some major approaches used to deal with breakdown maintenances.

(a) Have standby or back up and that can be quickly pressed into service.

(b) Have inventories, of spare parts that can be installed as needed, thereby avoiding lead times involved in ordering parts and buffer inventories, so that other equipment will be less likely to be affected by short-term downtime of a particular piece of equipment.

(c) Have operators who are able to perform at least minor repairs on the equipment.

(d) Repair people who are well trained and readily available to diagnose and correct problem with equipment.

1. **Learning Outcome 2:** Inspect electrical installation

1.2.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to inspect electrical installation in the electrical installation maintenance. It includes recording of inspection findings, Identification and documentation of maintenance tools, materials and equipment specifications of identified tools, materials and equipment against safety standards Inspection procedure

1.2.1.1 Performance Standard

1. System is inspected according to the established procedure
2. Instances where the maintenance activities cannot be fully met or where there are defects outside the planned schedule are identified and recorded

1.2.1.3 Information Sheet

Definition of terms

Double installation-insulation comprising both basic (functional) insulation and supplementary (protective) insulation.

Earth fault loop impedance- the impedance (total opposition to flow of current) of the earth fault current loop (phase to earth loop) starting and ending at point of earth fault.

Earthing conductor- a protective conductor which connects a main earthing terminal of an installation to the earth electrode or to the other means of earthing.

Electrical installation-an assembly of associated electrical equipment such as machines, apparatus, writing materials etc. to fulfill a specific purpose within a consumer's premises.

Final circuit- a circuit connected directly to current-using equipment's or sockets-outlets or other outlets points.

Flexible cords-a flexible cable is in which the cross-sectional area of each conductor does not exceeds $4mm^2$.

Isolation-the cutting off circuit or circuits from the source of electrical energy.

Live(alive)-a conductor or object is said to be 'live' when a difference of potential exists between it and earth.

Live part-a conductor or conductive part intended to be energized in normal use, including a neutral conductor but not including a PEN conductor.

Ohmmeter-an indicating instrument for be providing a direct reading of resistance. It's used for measuring conductor resistance and insulation resistance and resistances.

Protective conductor- a conductor for some measure of protection against electric shock and intended for connecting together parts of the system that are exposed and extraneous which are conductive.

Residual current device-a mechanical switching device or Association of devices intended to cause the opening of contacts when device residuals currents attain a given value under specified conditions.

Socket-outlets-a device with protected current-carrying contacts intended to be mounted in affixed position and permanently connected to the fixed wiring of the installation, to enable the connection flexible cord or flexible cables by means of a plug.
Switch gear-apparatus for controlling the distribution of electrical energy or for controlling or protecting electrical circuits, machines and current using appliances.
a **A TN system**-is a system having one or more points of the supply sources directly earthed. There are three systems which fall in this category:

I. TN-C system- neutral and protective functions combined in a single conductor through the system.
II. TN-S system- neutral and protective conductors separated trough the system.
III. TN-S-C system-as in (1) above but only in part of the system.

b. **A TT system**-is a system having one point of the supply directly earthed and the exposed conductive parts of installation are connected to an earth electrode which are connected to an earth electrode which is electrically independent of the electrical installation being earthed.
Trunking (for cables) –a fabricated casing for cables normally of rectangular cross sectional of which one side is removable or hinged to allow cable (s) to be laid therein.

In order to make sure that this work is carried out satisfactorily the inspection and test procedure must be carefully planned and carried out and the results correctly documented.

We inspect material after the completion of work for three key reasons to ensure:

- compliance with BS 7671
- compliance with the project specification (commissioning)
- that it is safe to use.

Compliance with BS 7671

BS 7671 Part 6 states that every electrical installation shall, either during construction, on completion, or both, be inspected and tested to verify, so far as is reasonably practicable, that the requirements of the Regulations have been met. In carrying out such inspection and test procedures, precautions must be taken to ensure no danger is caused to any person or livestock and to avoid damage to property and installed equipment.

BS 7671 requires that the following information be provided to the person carrying out the inspection and test of an installation:

- the maximum demand of the installation expressed in amperes per phase
- the number and type of live conductors at the point of supply

- the type of earthing arrangements used by the installation, including details of equipotential bonding arrangements
- the type and composition of circuits, including points of utilization, number andsize of conductors and types of cable installed (this should also include details ofthe ‘reference installation method’ used)
- the location and description of protective devices (fuses, circuit breakers etc.)
- details of the method selected to prevent danger from shock in the event of an earth fault, e.g. earthed equipotential bonding and automatic disconnection of supply
- the presence of any sensitive electronic devices.

NB: It is important to remember that periodic inspection and testing must be carried outon installations to ensure that the installation has not deteriorated and still meets allrequirements. Tests will also need to be carried out in the event of minor alterationsor additions being made to existing installations.

Compliance with the project specification

Once the installation is complete, we need to test it against the original specification for the work. This is in order to check that the finished installation matches the requirements laid out by the customer and is fit for use in the environment where it will be used. The tasks involved in checking compliance with project specification are as follows.

- **Pre-commissioning** – this involves a full inspection of the installation and the carrying out of all tests required before the installation is energized (continuity,polarity and insulation resistance).
- **Commissioning** – includes all tests which require power to be available, e.g., the measurement of the earth-fault loop impedance and functional testing of residual current devices (RCDs).

As commissioning involves the initial energizing of an installation, this task has to be carried out in a controlled manner with the knowledge of everyone involved. This means that all other persons working on site at the time of the energizing must be informed that power will be applied to the installation, so that all precautions can be taken to prevent danger. The commissioning process is intended to confirm that the installation complies with the designer’s requirements. As such, commissioning includes the functional testing of all equipment, isolation, switching, protective devices and circuit arrangements

Safe to use

The final act of the commissioning process is to ensure the safe and correct operation of all circuits and equipment which have been installed, and that the customer's requirements have been met. This will also confirm that the installation works and, more importantly, will work under fault conditions; after all, it is under fault conditions that lives and property will be at risk. The testing of electrical installations can cause some degree of danger; it is the responsibility of the person carrying out the tests to ensure the safety of themselves and others. **Health and Safety Executive Guidance Note GS38 (Electrical test equipment for use by electricians**) details relevant safety procedures and should be observed in full.

- When using test instruments the following points will help to achieve a safe working environment. The person carrying out the tests must have a thorough understanding of the equipment being used and its rating.
- The person carrying out the tests must ensure that all safety procedures are being followed, e.g. erection of warning notices and barriers where appropriate.
- The person carrying out the tests should ensure that all instruments being used conform to the appropriate British Standard, i.e. BS EN 61010 or older instruments manufactured to BS 5458 (provided these are in good condition and have been recently calibrated).
- The person carrying out the tests should check that test leads including probes and clips are in good condition, are clean and have no cracked or broken insulation. Where appropriate the requirements of GS38 should be observed, including the use of fused test leads.

Purpose of a periodic inspection

Initial inspection and testing is necessary on all newly completed installations. In addition, because all the electrical installations deteriorate due to a number of factors (such as damage, wear and tear, corrosion, excessive electrical loading, ageing and environmental influences) periodic inspection and testing must be carried out at regular intervals. The purpose of a periodic inspection and test is to:

- Confirm the safety of persons and livestock against the effects of electric shock or burns
- Ensure protection against damage to property by fire or heat arising from an installation defect
- Confirm that the installation has not been damaged and has not deteriorated to the extent that it may impair safety
- Identify any defects in the installation or non-conformity with the current edition of the Regulations that may cause danger.

The intervals between tests is determined by the following.

- Legislation requires that all installations must be maintained in a safe condition and therefore must be periodically inspected and tested. Table 8.01 details the maximum period between inspections of various types of installation.
- Licensing authorities, public bodies, insurance companies and other authorities may require public inspection and testing of electrical installations.
- The installation must comply with BS 7671.
- It is also recommended that inspection and testing should occur when there is a change of use of the premises, any alterations or additions to the original installation, any significant change in the electrical loading of the installation, and where there is reason to believe that damage may have been caused to the installation.

Domestic or if change of occupancy	10 years
Highway power supplies	6 years
Churches	5 years
Commercial or if change of occupancy	5 years
Educational premises	5 years
Hotels	5 years
Hospitals	5 years
Laboratories	5 years
Offices	5 years
Public Houses	5 years
Shops	5 years
Village halls	5 years
Agricultural/Horticultural	3 years
Caravans	3 years
Cinemas	3 years
Emergency Lighting	3 years
Industrial	3 years
Leisure Complexes	3 years
Places of public entertainment	3 years
Theaters	3 years
Caravan parks	1 year
Fire alarms	1 year
Fish farms	1 year

Launderettes	1 year
Marinas	1 year
Petrol filling stations	1 year
Residential accommodation or if change of occupancy	1 year
Swimming pool	1 year
Construction sites	3 Months

Table 3 Frequency of Inspection

In the case of an installation that is under constant supervision while in normal use, such as a factory or other industrial premises, periodic inspection and testing may be replaced by a system of continuous monitoring and maintenance of the installation, provided that adequate records of such maintenance are kept.

When carrying out the design of an electrical installation, and particularly when specifying the type of equipment to be installed, the designer should take into account the likely quality of the maintenance programme and the periods between periodic inspection and testing to be specified on the Electrical Installation Certificate. Both Section 6 of the Health and Safety at Work Act and the Construction (Design and Management) Regulations require information on the requirements for routine checks and periodic inspections to be provided. The advice of the Health and Safety Executive in their Memorandum of Guidance on the Electricity at Work Regulations indicates that practical experience of an installation's use may indicate the need for an adjustment to the frequency of checks and inspections, i.e. more often or less frequent depending on the likely deterioration of the installation during its normal use. This would be a matter of judgement for the duty holder.

Routine Checks

Electrical installations should still be routinely checked in the intervening time between periodic inspection and testing. In domestic premises it is likely that the occupier will soon notice any damage or breakages to electrical equipment and will take steps to have repairs carried out. In commercial or industrial installations, a suitable reporting system should be available for users of the installation to report any potential danger from deteriorating or damaged equipment. In addition to this, a system of routine checks should be set up to take place between formal periodic inspections. The frequency of these checks will depend entirely on the nature of the premises and the usage of the installation. Routine checks are likely to include activities such as those listed in Table

Activity	Check

Defect reports	Check that all reported defects have been rectified and that the installation is safe.
Inspection	• Breakages • Wear or deterioration • Signs of overheating • Missing parts (screws & covers) • Switch gear still accessible • Enclosure door secure • Labels still adequate(readable) • Loose fittings
Operations	Check operations of • Switch gear (where reasonable) • Equipment (switching on and off) • RCD (using test buttons)

Table 4: Routine Checks

The recommended period between both routine checks and formal inspections are given in Table above taken from *IEE Guidance Note 3*. The requirements for such inspections are stated in BS 7671 Chapter 62 and specify that all inspections should provide careful scrutiny of the installation without dismantling or with only partial dismantling where absolutely necessary. It is considered that the unnecessary dismantling of equipment or disconnection of cables could produce a risk of introducing faults that were not there in the first place.

In summary, the inspection should ensure that:

- the installation is safe
- the installation has not been damaged
- the installation has not deteriorated so as to impair safety
- any items that no longer comply with the Regulations or may cause danger are identified.

In practical terms the inspector is carrying out a general inspection to ensure that the installation is safe. However, the inspector is required to record and make recommendations with respect to any items that no longer comply with the current edition of the Regulations.

Statutory and Non-Statutory Documentation

These include the following

- The Electricity Supply Regulations (1988).
- The Electricity at Work Regulations.
- BS 5266 Pt. 1 Code of Practice for emergency lighting systems (other than cinemas).Other Regulations and intervals cover testing of batteries and generators.
- BS 5839 Pt. 1 Code of Practice for the design, installation and servicing of fire alarm systems.
- Local authority conditions of license.
- SI 1995 No 1129 (clause 27) The Cinematography (Safety) Regulations.

Inspection Process

In new installations, inspection should be carried out progressively as the installation is installed and must be done before it is energized. As far as is reasonably practicable, an initial inspection should be carried out to verify that:

- all equipment and material is of the correct type and complies with applicable British Standards or acceptable equivalents
- all parts of the fixed installation are correctly selected and erected
- no part of the fixed installation is visibly damaged or otherwise defective
- the equipment and materials used are suitable for the installation relative to the environmental conditions.

The following items must be covered in an inspection.

1. **Connection of conductors:** Every connection between conductors and equipment or other conductors must provide durable electrical continuity and adequate mechanical strength. Requirements for the enclosure and accessibility of connections must be considered.
2. **Identification of each conductor:** BS 7671 provides a schedule of colour identification of each core of a cable and its conductors. It should be checked that each core of a cable is identified as necessary. Where it is desired to indicate a phased rotation or a different function for cores of the same colour, numbered sleeves are permitted.
3. **Routing of cables:** Cable routes shall be selected with regard to the cable's suitability for the environment, i.e. ambient temperature, heat, water, foreign bodies, corrosion, impact, vibration, flora, fauna, radiation, building use and structure. Cables should be routed out of harm's way and protected against mechanical damage where necessary. Permitted cable routes are clearly defined in the *IEE On-Site Guide*; alternatively, cables should be installed in earthed

metal conduit or trunking.

4. **Current-carrying capacity:** Where practicable, the cable size should be assessed against the protective device based upon information provided by the installation designer.
5. **Verification of polarity:** It must be checked that no single pole switch or protective device is installed in any neutral conductor. A check must also be made that all protective devices and switches are connected in the line conductor only (unless the switch is a double pole device) and that the Centre contact of Edison screw lamp holders are connected to the line conductor. No switches are permitted in the Circuit Protective Conductor.
6. **Accessories and equipment:** Correct connection is to be checked. BS 7671 is a schedule of types of plug and socket outlets available, the rating and the associated British Standards. Particular attention should be paid to the requirements for a cable coupler. Lamp holders should comply with BS 5042 and be of temperature rating T2.
7. **Selection and erection to minimize the spread of fire:** A fire barrier or protection against thermal effects should be provided if necessary to meet the requirements of BS 7671. The Regulations require that each ceiling arrangement be inspected to verify that it conforms with the manufacturer's erection instructions. This may be impossible without dismantling the system and it is essential, therefore, that inspection should be carried out at the appropriate stage of the work and that this is recorded at the time for incorporation in the inspection and test documents.
8. **Protection against direct contact:** Direct contact as defined in BS 7671 is the contact of persons or livestock with live parts. Live parts are conductors or conductive parts intended to be energized in normal use including a neutral conductor but by convention not a combined Protective Earthed Neutral (PEN) conductor. Protection is provided using the following methods.
    - **Insulation.** Is the insulation damaged or has too much been removed? Although protection by insulation is the usual method there are other methods of providing basic protection.
    - **Barriers.** Where live parts are protected by barriers or enclosures, these should be checked for adequacy and security. Have all covers, lids and plates been securely fitted?
    - **Obstacles.** Protection by obstacles provides protection only against an intentional contact. If this method is used, the area shall be accessible only to skilled persons or to instructed persons under supervision. Obstacles can include a fence around a transformer sub-station and barbed wire fencing on power pylons.
    - **Out of reach.** Placing out of reach protects against direct contact. Increased distance is necessary where bulky conducting objects are likely to be handled in the vicinity
    - **Fault protection:** Fault protection as defined by BS 7671 is the contact of persons or livestock with exposed conductive parts which have

become live under fault conditions. An exposed conductive part is a conductive part of equipment which can be touched but is not live although it can become live under fault conditions. Examples of exposed conductive parts could include metal trunking, metal conduit and the metal case of an electrical appliance, e.g. a classroom overhead projector.

9. Earthing provides protection against this type of fault. We also need to check that extraneous conductive parts have been correctly bonded with protective conductors. An extraneous conductive part is a conductive part that is liable to introduce a potential, generally earth potential, and not form part of an electrical installation; examples of extraneous conductive parts are metal sink tops and metal water pipes. The purpose of the bonding is to ensure that all extraneous conductive parts which are simultaneously accessible are at the same potential. Methods of fault protection are given in BS 7671 as:

   - earthed equipotential bonding and automatic disconnection of supply (most common)
   - use of class II equipment
   - non-conducting location
   - earth-free local equipotential bonding
   - electrical separation.

10. **Protective devices:** Have they been set correctly for the load? If rewirable fuses have been fitted, has the correct size of fuse wire been used? If a socket is to be provided for outdoor equipment, has a 30 mA rated RCD been fitted?
11. **Checks on documentation:** Diagrams, schedules, charts, instructions and any other information must be available if inspection and testing is to be carried out in a satisfactory manner.
12. **Checks on warning notices:** These should be fixed to equipment operating in excess of 250 volts where this voltage would not normally be expected.

Preparing for inspection

- ✓ Where a diagram, chart or tables are not available, a degree of exploratory work may be necessary so that inspection and testing can be carried out safely and effectively. Notes should be made of any known changes in environmental conditions, building structure and alterations, which may have affected the suitability of the wiring for its present load and method of installation.

- ✓ A careful check should be made of the type of equipment on site so that the necessary precautions can be taken, where conditions permit, to disconnect or shortout electronic and other equipment which may be damaged by subsequent testing. Special care must be taken where control and protective devices contain electronic components. It is essential to determine the degree of these disconnections before planning the detailed inspection and testing.
- ✓ For safety, it is necessary to carry out a visual inspection of the installation beforebeginning any tests or opening enclosures, removing covers etc. So far as is reasonably practicable; the visual inspection must verify that the safety of persons, livestock and property is not endangered. A thorough visual inspection should be made of all electrical equipment that is not concealed and should include the accessible internal condition of a sample of the equipment. External conditions should be noted and damage identified or, if the degree of protection has been impaired, the matter should be recorded on the schedule of the report. This inspection should be carried out without power supplies to the installation, wherever possible, in accordance with the Electricity at Work Regulations 1989.
- ✓ The inspection should include a check on the condition of all electrical equipment and materials, taking into account any available manufacturer's information with regard to the following:
  - Safety
  - Damage
  - Age
  - Wear and Tear
  - Excessive loading (overloading)
  - External influences
  - Corrosion
  - Suitability
- ✓ The assessment of condition should take account of known changes in conditions influencing and affecting electrical safety, e.g. extraneous conductive parts, plumbing, structural changes etc. It would not be practicable to inspect all parts ofan installation; thus a random sample should be inspected. This should include:
  - checking that joints and connections are properly secured and that

there is nosign of overheating

- checking switches for satisfactory electrical and mechanical conditions
- checking that protective devices are of the correct rating and type; check for accessibility and damage
- checking that conductors have suffered no mechanical damage and have no signs of overheating
- checking that the condition of enclosures remains satisfactory for the type ofprotection required

Periodic inspection and test

BS 7671 requires that the results of any periodic inspection and test should be recorded on a periodic inspection and test report of the type illustrated in Figure 8.02. The report should include the following:

- a description of the extent of the inspection and tests and what parts of theinstallation were covered.
- any limitations (e.g. portable appliances not covered)
- details of any damage, deterioration or dangerous conditions which were found
- any non-compliance with BS 7671
- schedule of test results.

If any items are found which may cause immediate danger, these should be rectified immediately. If this is not possible then they must be reported to a responsible person without delay.

When inspecting older installations, which may have been installed in accordance with a previous edition of the *IEE Wiring Regulations*, provided that all items which do not conform to the present edition of BS 7671 are reported, the installation may still be acceptable, provided that no risk of shock, fire or burns exists.

Details of the client..

Name……………………………………………………………………………
…………

Address:……………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
…………………………………………………………......

Purpose of the report……………………………..

Details of the installation

Occupier……………………………………………………………………………
……………….

Installation address (if different from)………………………………………………

………………………………………………………………………………………
…………………..

Description of premises: Domestic ☐ commercial ☐ Industrial ☐ Other ☐

Estimated age of the installation……....................................…… Years

Evidence of alterations or additions………………………………………… Yes/No

Date of last
inspection…………………………………………………………………………

Records
availability……………………………………………………………………….

Extent and the limitations of the inspection

Extent of the installation covered by the
report……………………………........................

………………………………………………………………………………………
……………………………………..

………………………………………………………………………………………
……………………………………..

Limitations……………………………………………………………………… …………………………………..   ……………………………………………………………………………………… ……………………………………   ……………………………………………………………………………………… ……………………………………..   This inspection has been carried out in accordance with BS 7671(IEE wiring regulations). Cables concealed within trunking and conduit cables concealed under floors buried underground installed in roof spaces or generally hidden within the fabric of the building have not been inspected.
Next inspection   (we recommend that this installation should be further inspected and tested after an interval of not more than………. months\years providing that any observations requiring urgent are attended without delay.
Declaration   Inspected and tested by   Name……………………………………Signature……………………………… ………   For and on behalf of ……………………………Position……………………………………………   Address………………………………………. ………………………………………………………   ……………………………………………………. ………………………………………………………………..   …………………………………………………….   Date……………………………………………………....

Table Periodic inspection and test Report

Statutory and Non-statutory regulations

BS 7671 states that, as far as is reasonably practicable, an inspection shall be carried out to verify that:

- all equipment and materials used in the installation are of the correct type and comply with the appropriate British Standards or acceptable equivalent
- all parts of the installation have been correctly selected and installed
- no part of the installation is visibly damaged or otherwise defective
- the installation is suitable for the surrounding environmental conditions

Before carrying out the inspection and test of an installation, BS 7671 requires the person carrying out the work to be provided with the following information:

- the maximum demand of the installation expressed in amperes per phase after diversity has been applied
- the number and type of live conductors, both for the source of energy and for each circuit to be used within the installation (e.g., single-phase two-wire a.c. etc.)
- the type of earthing arrangements e.g., TNS, TNCS, TT etc.
- the nominal voltage (U_o)
- the prospective short-circuit current at the origin of the installation (kA)
- the earth-fault loop impedance (Z_e) of that part of the system external to the installation
- the type and rating of the overcurrent device acting at the origin of the installation

The following information should be provided as part of the design information, which should be checked by the person carrying out the inspection. You may have to sign the electrical installation certificate to confirm that the installation has been designed, installed and tested to comply with BS 7671 with reference to:

- the type and composition of circuits, including points of utilization, number and size of conductors and type of cable used, including the installation method
- the method used to meet the requirements for fault protection

- the information to be able to identify each protective device, isolation and switching and its location.
- any circuit or equipment that may be vulnerable to test.

Detailed inspection Requirements

- ✓ **Anticipation of Danger**
  Identify any equipment that may be damaged if subjected to high-test voltages as well as computer equipment as this may include safety systems such as fire or intruder alarms that could well have electronic components susceptible to test voltages.
- ✓ **Joints and connections**
  Provided the switchgear and distribution boards are accessible as required by the Regulations, then a full inspection of all conductor terminations should be carriedout and any signs of overheating or loose connections should be investigated and included in the report. For lighting points and socket outlets a suitable sample should be inspected in the same way
- ✓ **Conductors**
  The means of identification of every conductor, including protective conductors,should be checked and any damage or deterioration to the conductors, their insulation, protective sheathing or armour should be recorded. This inspection should include each conductor at every distribution board within the installation and a suitable sample of lighting points, switching points and socket outlets.
- ✓ **Flexible cables and cords**
  Where flexible cables or cords form part of the fixed installation the inspectionshould include:
  - examination of the cable or cord for damage or deterioration
  - examination of the terminations and anchor points for any defects

  checking the correctness of the installation with regard to additional mechanical protection or the application of heat resistant sleeving where necessary.
- ✓ **Switches**
  The *IEE Guidance Notes 3 (Inspection & Testing)*, recommends that a random sample of at least 10 per cent of all switching devices be given a thorough internal visual inspection to assess their electrical and mechanical condition. Should the inspection reveal excessive wear and tear or signs of damage due to arcing or overheating then, unless it is obvious that the problem is associated with that particular switch, the inspection should be extended to include all remaining switches associated with the installation.

- **Protection against thermal effects**
  the presence of fire barriers and seals should be checked wherever reasonably practicable.
- **Protection against Direct and Indirect contact**
  Separate Extra Low Voltage (SELV) is commonly used as a means of protection against both direct and indirect contact. When inspecting this type of system, the points to be checked include the use of a safety isolating transformer, the need to keep the primary and secondary circuits separate and the segregation of exposed conductive parts of the SELV system from any connection with the earthing of the primary circuit or from any other connection with earth.
- **Basic Protection**

  Inspection of the installation should confirm that all the requirements of the Regulations have been met with regard to basic protection against direct contact with live conductors. This means checking to ensure there has been no damage or deterioration of any of the insulation within the installation, no removal of barriers or obstacles and no alterations to enclosures that may allow access to live conductors.

- **Fault Protection**

  The method used for fault protection must be established and recorded on the Inspection Schedule. Where earthed equipotential bonding and automatic disconnection of the supply is used, a check on the condition of the main equipotential bonding conductor and the satisfactory connection of all other protective conductors with earth are essential.

- **Protective devices**

  A check must be made that each circuit is adequately protected with the correct type, size and rating of fuse or circuit breaker. A check should also be made that each protective device is suitable for the type of circuit it is protecting and the earthing system employed, e.g. will the protective device operate within the disconnection time allowed by the Regulations and is the rating of the protective device suitable for the maximum prospective short circuit current likely to flow under fault conditions?

- **Enclosures and mechanical protection**

  The enclosures of all electrical equipment and accessories should be inspected to ensure that they provide protection not less than IP2X or IPXXB, and where horizontal top surfaces are readily accessible they should have a degree of protection of at least IP4X. IP2X represents the average finger of

12mm diameter and 80mm in length and can be tested by a metal finger of these dimensions. IP4X provides protection against entry by strips greater than 1.0mm thickness or solid objects exceeding 1.0mm in diameter.

Visual Inspection

Inspection Requirements

In order to meet the requirements for the inspection process we should also include the checking of the following relevant items:

1. **Requirements for basic and fault protection**

   Separate extra low voltage (SELV) is the most common method of providing both basic and fault protection. Requirements for this type of system include:

   - an isolated source of supply, e.g. a safety-isolating transformer to BS 3535(also numbered BS EN 60742 1996)
   - electrical separation, which means no electrical connection between the SELV circuit and higher voltage systems
   - no connection with earth or the exposed conductive parts or protective conductors of other systems.

2. **Specialized systems**

3. **Prevention of mutual detrimental influence**

   Account must be taken of the proximity of other electrical services of a different voltage band and of non-electrical services and influences, e.g. fire alarm and emergency lighting circuits must be separated from other cables and from each other, and Band 1 and Band 2 circuits must not be present in the same enclosure or wiring system unless they are either segregated or wired with cables suitable for the highest voltage present. Mixed categories of circuits may be contained in multicore cables, subject to certain requirements. This could also mean checking that water taps have not been fitted directly above a socket outlet. Band 1 circuits are circuits that are nominally extra-low voltage, i.e. not exceeding 50 volts a.c. or 120 volts d.c., such as telecommunications or data and signaling. Band 2 circuits are circuits that are nominally low voltage, i.e. exceeding extra-low voltage but not exceeding 1000 volts a.c. between conductors or 600 volts a.c. between conductors and earth.

4. **Isolating and switching devices**

   BS 7671 requires that effective means suitably positioned and ready to operate should be provided so that all voltage may be cut off from every installation, every circuit within the installation and from all equipment, as may be necessary to prevent or remove danger. This means that switches and/or isolating devices of the correct rating must be installed as appropriate to meet the above requirements. It may be advisable where practicable to carry out an isolation exercise to check that effective isolation can be achieved. This should include switching off, locking-off and testing to verify that the circuit is dead and no other source of supply is present.

5. **Under voltage Protection**

   Suitable precautions must be taken where a loss or lowering of voltage or a subsequent restoration of voltage could cause danger. The most common situation would be where a motor- driven machine stops due to a loss of voltage and unexpectedly restarts when the voltage is restored (unless precautions such as the installation of a motor starter containing a contactor are employed). Regulations require that where unexpected restarting of a motor may cause danger, the provision of a motor starter designed to prevent automatic restarting must be provided.

6. **Selection of equipment appropriate to external influences**

   Items to be considered are ambient temperature, presence of external heat sources, presence of water, likelihood of corrosion, ingress of foreign bodies, impact, vibration, flora, fauna, radiation, building use and structure.

7. **Access to switchgear equipment**

   The Electricity at Work Regulations 1989 and BS 7671 state that every piece of equipment that requires operation or attention must be installed so that adequate and safe means of access and working space are provided.

8. **Presence of Drawings, Charts and other similar information**

   Checks should be made for layout drawings, distribution charts and information on circuits vulnerable to a particular test. All distribution boards should be provided with a distribution board schedule that provides information regarding types of circuits, number and size of conductors and type of wiring etc. These should be attached within or adjacent to each distribution board.

9. **Erection Methods**

   Correct methods of installation should be checked, in particular fixings of switchgear, cables and conduit, etc. which must be adequate and suitable for the environment.

Inspection Checklist

To ensure that all the requirements of the Regulations have been met, inspection checklists should be drawn up and used as appropriate to the type of installation being inspected. Examples of suitable checklists are given in Table

Switchgear (tick if satisfactory)	
Meets requirements of the appropriate BS EN standards	
Securely fixed and suitably labeled	
Suitable glands and gland plates used (526.1)	
Correctly earthed	
Conditions likely to be encountered taken account of, i.e. suitable for the environment	
Correct IP rating	
Suitable as means of isolation	
Complies with the requirements for locations containing a bath or shower	
Need for isolation, mechanical maintenance, emergency and functional switching met	
Fireman switch provided, where required	
Switchgear suitably colored, where necessary	
All connections secure	
Cables correctly terminated and identified	
No sharp edges on cable entries, screw heads etc. which could cause damage to cables	
All covers and equipment in place	
Adequate access and working space	
Wiring accessories (General requirements)(tick if satisfactory)	
All accessories comply with the appropriate British Standard	
Boxes and other enclosures securely fastened	
Metal boxes and enclosures correctly earthed	

Flush boxes not projecting above surface of wall	
No sharp edges which could cause damage to cable insulation	
Non-sheathed cables not exposed outside box or enclosure	
Conductors correctly identified	
Bare protective conductors sleeved green and yellow	
All terminals tight and contain all strands of stranded conductor	
Cord grips correctly used to prevent strain on terminals	
All accessories of adequate current rating	
Accessories suitable for all conditions likely to be encountered	
Complies with the requirements for locations containing a bath or shower	
Cooker control unit sited to one side and low enough for accessibility and to prevent trailing flexes across the radiant plates	
Cable to cooker fixed to prevent strain on connections	
Socket outlet (tick if satisfactory)	
Complies with appropriate British Standard and is shuttered for household and similar installations	
Mounting height above floor or working surface is suitable	
All sockets have correct polarity	
Sockets not installed in bath or shower zones unless they are shaver-type socket or SELV	
Sockets not within 3m of zone 1	
Sockets controlled by a switch if the supply is direct current	
Sockets protected where floor mounted	
Circuit protective conductor connected directly to the earthing terminal of the socket outlet on asheathed wiring installation	
Earthing tail provided from the earthed metal box to the earthing terminal of the socket outlet	
Socket outlets not used to supply a water heater with uninsulated elements	

Lighting controls (tick if satisfactory)	
Light switches comply with appropriate British Standard	
Switches suitably located	
Single-pole switches connected in phase conductor only	
Correct colour-coding of conductors	
Correct earthing of metal switch plates	
Switches out of reach of a person using bath or shower	
Switches for inductive circuits (discharge lamps) de-rated as necessary	
Switches labelled to indicate purpose where this is not obvious	
All switches of adequate current rating	
All controls suitable for their associated luminaire	
Lighting points (tick if satisfactory)	
All lighting points correctly terminated in suitable accessory or fitting	
Ceiling roses comply with appropriate British Standard	
No more than one flexible cord unless designed for multiple pendants	
Devices provided for supporting flex used correctly	
All switch wires identified	
Holes in ceiling above ceiling rose made good to prevent spread of fire	
Ceiling roses not connected to supply exceeding 250 V	
Flexible cords suitable for the mass suspended	
Lamp holders comply with appropriate British Standard	
Conduits (General)(tick if satisfactory)	
All inspection fittings accessible	
Maximum number of cables not exceeded	
Solid elbows used only as permitted	
Conduit ends reamed and bushed	

Adequate number of boxes	
All unused entries blanked off	
Lowest point provided with drainage holes where required	
Correct radius of bends to prevent damage to cables	
Joints and scratches in metal conduit protected by painting	
Securely fixed covers in place adequate protection against mechanical damage	
Rigid metal conduit (tick if satisfactory)	
Complies to the appropriate British standard	
Connected to the main earth terminal	
Line and neutral cables contained within the same conduit	
Conduits suitable for damp and corrosive situations	
Maximum span between buildings without intermediate support	
Rigid non-metallic conduits (tick if satisfactory)	
Complies with the appropriate British Standard	
Ambient and working temperature within permitted limits	
Provision for expansion and contraction	
Boxes and fixings suitable for mass of luminaire suspended at expected temperatures	
Flexible metal conduits (tick if appropriate)	
Complies with the appropriate British Standard	
Separate protective conductor provided	
Adequately supported and terminated	
Trunking (tick if appropriate)	
Complies to the appropriate British Standard	
Securely fixed and adequately protected against mechanical damage	
Selected, erected and rooted so that no damage is caused by ingress of water	
Proximity to non-electrical services	

Internal sealing provided where necessary	
Hole surrounding trunking made good	
Band 1 circuits partitioned from band 2 circuits, or insulated for the highest voltage present	
Circuits partitioned from band one circuits, or wired in mineral-insulated and sheathed cable	
Common outlets for band 1 and band 2 circuits provided with screens, barriers or partitions	
Cables supported for vertical runs	
Metal Trunking (Trunking tick if satisfactory)	
Line and neutral cables contained in the same metal trunking	
Protected against damp corrosion	
Earthed	
Joints mechanically sound, and of adequate earth continuity with links fitted	

Table 5.

Inspection checklist

1.2.1.4 Learning Activities

1.2.1.4.1 Practical activities

An electrical contractor has completed installation for a small private caravan site. The site comprises of 15 dedicated caravan pitches, a toilet and shower block and a combined reception office and a small shop. The building on the site form part of a TN-C-S system supplied at 400\230v with a Ze 0f 0.2 Ω. At the origin of the installation the distribution circuit to the pitch supplies is separated to form a TT system, having an earth electrode resistance of 48Ω and a 500mA RCD as the main isolator. The installation is to be inspected and tested before being placed into services.

a) List all the certification document which particularly relates to the inspection and test for the entire site
b) State the
   i) Statutory document which particularly relates to the inspection and testing process
   ii) Title given to the person carrying out the inspection and test as stated in b(1) above
   iii) Status of a person carrying out the inspection and test

c) List three items of information that should be available to the person carrying out the inspection and test

Self-assessment

1. There are various documents that are relevant to the Inspection and Testing of an installation. State
   a) one statutory item of documentation
   b) two non-statutory items of documentation.
2. List the first three tests that should be carried out during a ***periodic*** inspection andtest of an installation
3. State THREE circumstances that would require a periodic inspection and test to becarried out on an installation.
4. The electrical installation in a small food retail outlet is scheduled for a periodic inspection andtest for local authority licensing.

   a) Describe how the safe isolation of the single-phase distribution board located in the officearea is to be carried out.
   b) Explain why the sequence of testing for this periodic inspection may be different to that given in BS 7671 for initial verification.
5. A periodic inspection is to be undertaken in a large community Centre which is open to the public.

   i) State what must be agreed with the client and recorded before any work isundertaken.

   ii) State who else must be considered by the inspector in respect to their safety whilstcarrying out this work.

   iii) State three actions the inspector must take to ensure the safety of people using thebuilding during the inspection and testing process.

   iv) List three documents that should be available to the inspector in order for theinspection and testing to be carried out safely.

6. One of the competence requirement identified in guidance note 3 (GN3, is for the inspector to have sound knowledge and experience relevant to the nature of the installation being inspected and tested. List three other competence requirement given in GN3
7. List three items related to the nature of the supply which should be made available to an inspector
8. Explain briefly inspection and testing of a new electrical installation should be carried out
9. State three items would need to be inspected during the first fix construction of a PVC conduit installation for lighting in general purpose workshop
10. State the most appropriate human sense used to identify
    a) Terminals are correctly tightened
    b) Terminals are correctly identified
    c) That a motor has been overloaded

Model Answers to self assessment

a) For the TNC-S supplied circuits electrical installation certificate, schedule of inspection, schedule of test results.
For the TT supplied caravan pitches, Electrical installation certificate.
Schedule of inspection, schedule of test results.
b)

i) Electricity at work regulation
ii) Duty holder
iii) The duty holder will be competent person
iv) Ensuring no danger to person's livestock property to compare the test results with design criteria to form a view on the state of installation and advice on remedial works to immediately inform the installation owner (and other interested partner's) if dangerous situation exists.

c. Nominal voltage frequency Ze.

1. Electricity at Work act '89 **or** Health & Safety at Work Act '74

BS 767
On Site Guide
Guidance Notes etc.

2 Continuity of CPC

Polarity
Earth loop impedance

3 End of license (Public buildings)
End of insurance period
Change of ownership
End of recommended period since last test

4 a) Safe Isolation Procedure

1.2.2 Identify the equipment to be worked on and its means of isolation.
1.2.3 Unplug the equipment if possible.
1.2.4 Isolate and lock off.
1.2.5 Prove the voltage tester.
1.2.6 Prove the equipment is dead (phase to neutral and phase to earth).
1.2.7 Re-prove the voltage tester.
1.2.8 Attach temporary earth leads if necessary.
1.2.9 Post caution notices.
1.2.10 Consider the need for additional precautions.

5 Further safety procedures may be set in place. Permits to work come into their own when dealing with an electrical piece of equipment or installation and are part of an overall strategyfor safety, called a 'safe system of work'.

b) The tests need not be carried out in the order as for the initial verification procedure asthe installation will have been in operation for some time.

The same range and level of testing as for initial testing is not necessarily required, orindeed possible. Installations that have been previously tested and for which there arecomprehensive records of test results may not need the same degree of testing as installations for which no such records exist.

The person carrying out the testing should decide which of the above tests areappropriate by using their experience and knowledge of the installation being inspected and tested and by consulting any available records.

The inspector will need to set a sample size for testing. Where a sample test indicatesresults significantly different to those previously recorded, further investigation is necessary. Also, if during the course of testing a sample, significant errors were foundthat would suggest that the same problems may exist in untested items, then the inspector has to take appropriate action.

This action needs to be either increasing the sampling or referring back to the client; itmay be that the inspector recommends that 100 per cent testing is carried out in that area.

2 i) Prior to carrying out the inspection, the inspector will need to meet with the client or the client's representative to outline the scope and nature of the work required and to highlight likely items that require isolation. That is the degree of disconnection which will be acceptable before planning the detailed inspectionand testing must be agreed. Also, the scope, that is, the extent and limitations of the periodic inspection must be agreed, that is, what is to be covered andwhat is not covered.

ii) As required by law, it is the inspector's duty to ensure the safety of himself orherself and that of others during the test procedure.

iii)
- i) The installation must be isolated before disconnecting protectiveconductors.
- ii) Ensure people cannot access exposed/extraneous conductive partswhen using test voltages greater than 50V.
- iii) Use correct test equipment to ensure the test limits are met. For example, limitation of earth fault loop impedance test current to 40ms.

iv)
- Design documentation listing type of supply, earthing arrangements,etc.
- Diagrams.
- Charts or tables identifying isolation and protection devices.
- Previous periodic inspection and test results.

b)
- Correctly identified breakers (circuit details)
- Correct type and rating of main switch and breakers (check ratingsagainst conductor sizes)
- Signs of overheating, thermal damage, etc. (no other visible damage).
- Single pole devices in line conductor

- Manual operation of breakers
- Breakers firmly fixed
- Barrier for IP 2X protection over the busbar
- BS or BS EN markings (or other recognized standard)
- All connections secure, correctly terminated and mechanically sound.

3 Knowledge of relevant regulations
Fully versed in inspection and test procedures
Knowledge and experience to use suitable test equipment

4 Nominal voltage
Frequency
Ze

5 Progressively throughout the different stages of the erection and before being put into service

6 Capacity conduits cables to be installed later
Mechanical protection of conduits where damage

Correct mechanical support of conduits to bear loading by cable

Single pole switch

7 Smell
Touch
Sight

Learning Outcome 3: Perform installation servicing
Presence of storage batteries

Since an emergency occurring in a building may cause the mains supply to fail, the emergency lighting should be supplied from a source which is independent from the main supply. A battery's ability to provide its output instantly makes it a very satisfactory source of standby power. In most commercial, industrial and public service buildings housing essential services, the alternative power supply would be from batteries. The emergency lighting supply must have an adequate capacity and rating for the specific ed duration of time (IEE Regulation 313.2). BS 5266 and BS EN 1838 states that after a battery is discharged by being called into operation for its specified duration of time, it should be capable of once again operating for the specified duration of time following a recharge period of no longer than 24 hours. The duration of time for which the emergency lighting should operate will be specified by a statutory authority but is normally 1–3 hours. The British Standard states that escape lighting should operate for a minimum of 1 hour.

The batteries used for the emergency supply should be suitable for this purpose. The British Standard recommends that the full load should be carried by the emergency supply for at least 1 hour in every 6 months. After testing, the emergency system must be carefully restored to its normal operative state. A record should be kept of each item of equipment and the date of each test by a qualified or responsible person. It may be necessary to produce the record as evidence of satisfactory compliance with statutory legislation to a duly authorized person. Self-contained units are suitable for small installations of up to about 12 units. The batteries contained within these units should be replaced about every 5 years, or as recommended by the manufacturer. Storage batteries are secondary cells. A secondary cell has the advantage of being rechargeable. If the cell is connected to a suitable electrical supply, electrical energy is stored on the plates of the cell as chemical energy. When the cell is connected to a load, the chemical energy is converted to electrical energy.

A lead-acid cell is a secondary cell. Each cell delivers about 2 V, and when six cells are connected in series a 12 V battery is formed. A lead-acid battery is constructed of lead plates which are deeply ribbed to give maximum surface area for a given weight of plate. The plates are assembled in groups, with insulating separators between them. The separators are made of a porous insulating material, such as wood or ebonite, and the whole assembly is immersed in a dilute sulphuric acid solution in a plastic container. The capacity of a cell to store charge is a measure of the total quantity of electricity which it can cause to be displaced around a circuit after being fully charged. It is stated in ampere-hours, abbreviation Ah, and calculated at the 10-hour rate which is the steady load current which would completely discharge the battery in 10 hours. Therefore, a 50 Ah battery will provide a steady current of 5A for 10 hours.

Maintenance of lead-acid batteries

- The plates of the battery must always be covered by dilute sulphuric acid. If the level falls, it must be topped up with distilled water.
- Battery connections must always be tight and should be covered with a thin coat of petroleum jelly.
- The specific gravity or relative density of the battery gives the best indication of its state of charge. A discharged cell will have a specific gravity of 1.150, which will rise to 1.280 when fully charged. The specific gravity of a cell can be tested with a hydrometer.
- To maintain a battery in good condition it should be regularly trickle-charged. A rapid charge or discharge encourages the plates to buckle, and may cause permanent damage. Most batteries used for standby supplies today are equipped with constant voltage chargers. The principle of these is that after the battery has been discharged by it being called into operation, the terminal voltage will be depressed and this enables a relatively large current (1–5A) to fl ow from the charger to recharge the battery. As the battery becomes more fully charged its voltage will rise until it reaches the constant voltage level where the current output from the charger will drop until it is just sufficient to balance the battery's internal losses. The main advantage of this system is that the battery controls the amount of charge it receives and is therefore automatically maintained in a fully charged condition without human intervention and without the use of any elaborate control circuitry.
- The room used to charge the emergency supply storage batteries must be well ventilated because the charged cell gives off hydrogen and oxygen, which are explosive in the correct proportions

Having successfully diagnosed the electrical fault and carried out the necessary repairs or having completed any work in the electro technical industry, we come to the final practical task, leaving the site in a safe and clean condition and the removal of any waste material. This is an important part of company's 'good customer relationships' with the client and having a good attitude to health and safety, working conscientiously and neatly, keeping passageways clear and regularly tidying up the workplace is the sign of a good and competent craftsman. But what do you do with the rubbish that the working environment produces? Well:

- All the packaging material for electrical fittings and accessories usually goes into either your employer's skip or the skip on site designated for that purpose.
- All the off-cuts of conduit, trunking and tray also go into the skip.
- In fact, most of the general site debris will probably go into the skip and the waste disposal company will take the skip contents to a designated local council landfill area for safe disposal. The part coils of cable and any other reusable leftover lengths of conduit, trunking or tray will be taken back to your employer's stores area. Here it will be stored for future use and the returned quantities deducted from the costs allocated to that job.
- What goes into the skip for normal disposal into a landfill site is usually a matter of common sense. However, some substances require special consideration and disposal.

We will now look at asbestos and large quantities of used fluorescent tubes which are classified as ‘special waste’ or ‘hazardous waste’.

Asbestos is a mineral found in many rock formations. When separated it becomes a fluffy, fibrous material with many uses. In the buildings where it was installed some 40 years ago, when left alone, it does not represent a health hazard, but those buildings are increasingly becoming in need of renovation and modernization. It is in the dismantling and breaking up of these asbestos materials that the health hazard increases. Asbestos is a serious health hazard if the dust is inhaled. The tiny asbestos particles find their way into delicate lung tissue and remain embedded for life, causing constant irritation and eventually, serious lung disease. If asbestos is present in situations or buildings where you are expected to work, it should be removed by a specialist contractor before your work commences. Specialist contractors, who will wear fully protective suits and use breathing apparatus, are the only people who can safely and responsibly carry out the removal of asbestos. They will wrap the asbestos in thick plastic bags and store them temporarily in a covered and locked skip. This material is then disposed of in a special landfill site with other toxic industrial waste materials and the site monitored by the local authority for the foreseeable future.

Removing the old fluorescent fittings hanging on chains or fixed to beams and installing a suspended ceiling and an appropriate number of recessed modular fluorescent fittings. These fittings are made of sheet steel, a couple of plastic lampholders, a little cable, a starter and ballast. All of these materials can go into the ordinary skip. However, the fluorescent tubes contain a little mercury and fluorescent powder with toxic elements, which cannot be disposed of in the normal land fill sites. Hazardous Waste Regulations were introduced in July 2005 and under these regulations lamps and tubes are classified as hazardous. The environmentally responsible way to dispose of fluorescent lamps and tubes is to recycle them. The process usually goes like this:

- Your employer arranges for the local electrical wholesaler to deliver a plastic waste container of an appropriate size for the job.
- Expired lamps and tubes are placed whole into the container, which often has a grating inside to prevent the tubes breaking when being transported.
- When the container is full of used lamps and tubes, you telephone the electrical wholesaler and ask them to pick up the filled container and deliver it to one of the specialist recycling centers.
- Your electrical company will receive a ‘Duty of Care Note’ and full recycling documents which ought to be fi led safely as proof that the hazardous waste was recycled safely.
- The charge is approximately 50p for each 1800mm tube and this cost is passed on to the customer through the final account.

NB:

- Clean up before you leave the job.
- Put waste in the correct skip.
- Recycle used lamps and tubes.

- Get rid of all waste responsibly.

Learning outcome 4: Conduct installation tests

Before a completed installation may be connected to the supply a number of tests are required to indicate the general condition of the installation, both with regard to the insulation resistance of the conductors and other current-carrying parts and with regard to the conductance of the earthing system. The tests which are to be made are not a complete guarantee of the quality of the installation for all time, and regular testing is necessary in order that it may be maintained in a proper condition throughout its life.

Insulation resistance.

This is the resistance in ohms between the live parts of the installation and earth, measured through insulating covering of the conductors, etc. In the case of metal-covered wiring or conduit wiring, the term 'earth' means in practice the metallic covering or conduit which itself is connected directly to earth. Additionally, the insulation resistance is measured between lines, that is, between the opposite poles of the installation with lamps or other apparatus disconnected and switches on.

The difference between insulation and conductor resistance is shown in the sketches (Figs. 93 and 94). In measuring the resistance of a

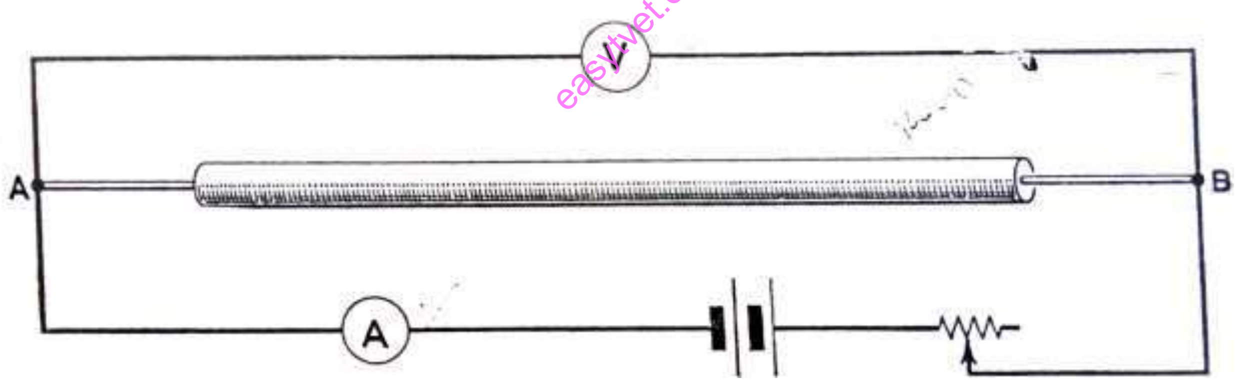


Fig. 1 Measuring conductor resistance

conductor AB, the resistance is measured along the wire from end to end, and increase of conductor length means increase of resistance. In measuring the insulation resistance of the conductor, the measurement is made from the conductor outwards.

The formula for conductor resistance is R =pl where / is the length a of the conductor, a is the cross-sectional area, and p is the resistivity of the conductor material. Using a similar formula for insulation (it is sufficiently true for the purposes of this argument), R' = p'l/a' the thickness of the insulation, a' is proportional to the length of the wire, and p' is the resistivity of the insulating material.

Conduit or metallic covering

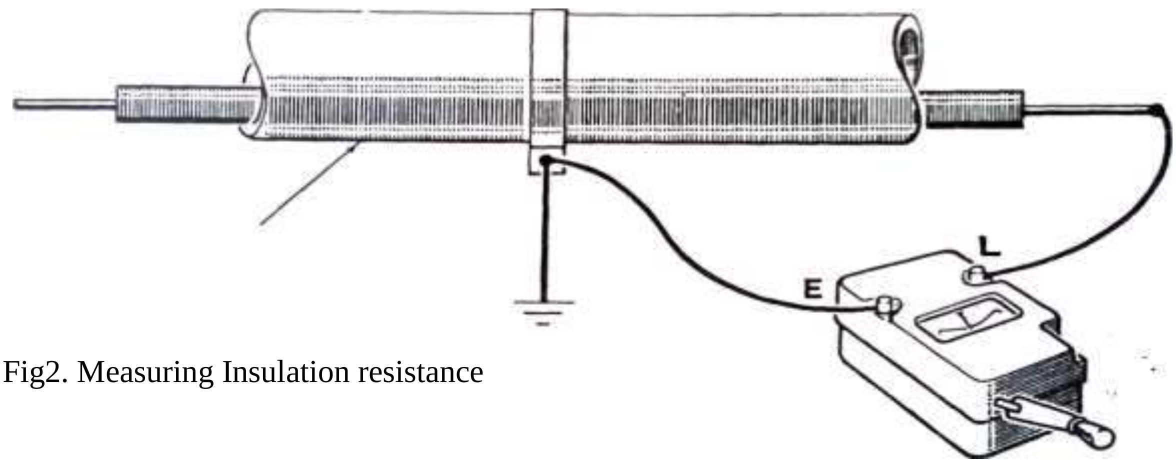


Fig2. Measuring Insulation resistance

Thus, if an insulated wire is increased in length, its conductor resistance increases while its insulation resistance decreases. Therefore, the longer the conductor the less will be its insulation resistance.

Inspection of installations.

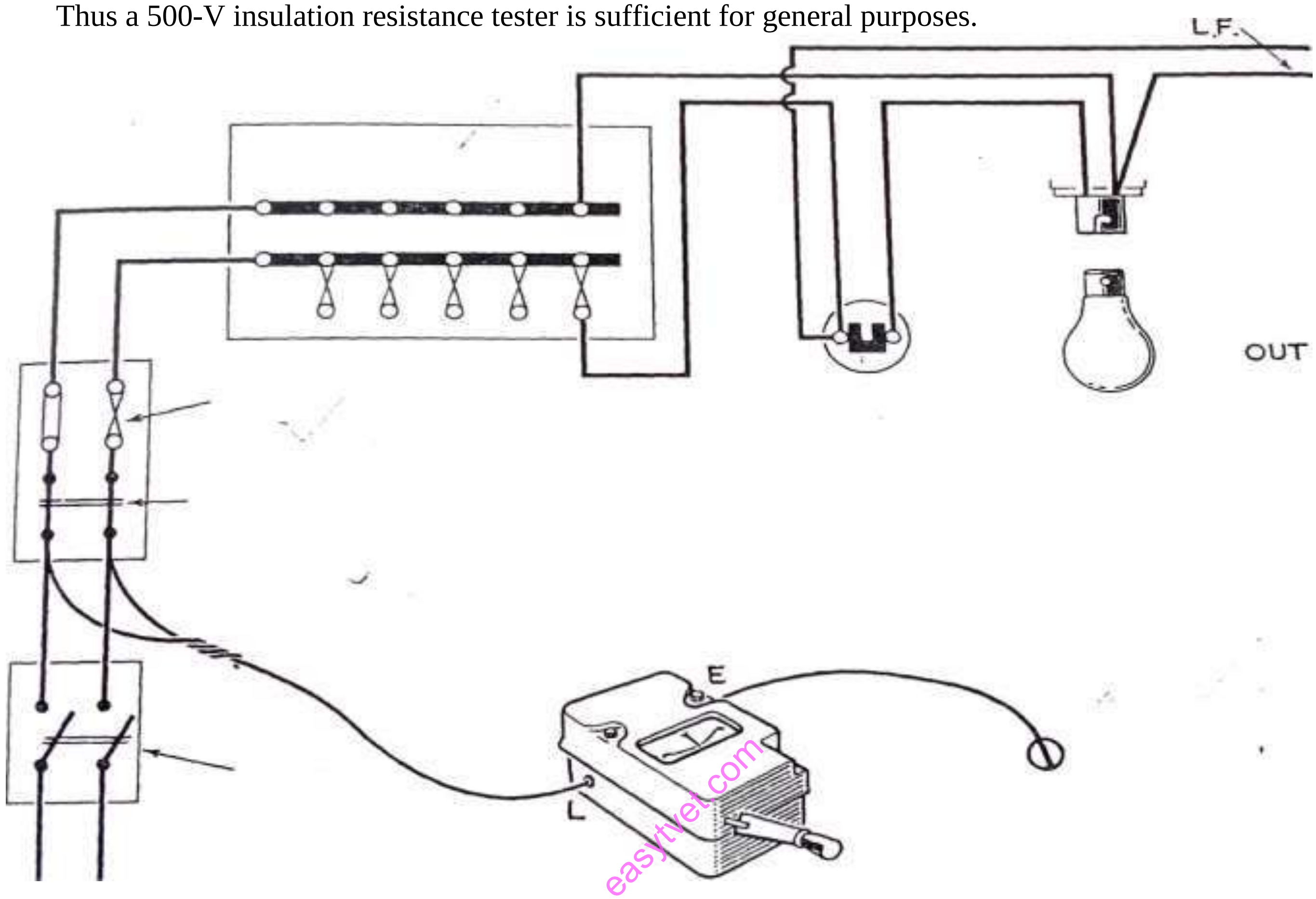
During the fitting of the various parts of an installation some form of inspection by the electrical contractor or his staff is both desirable and necessary, Small faults could be brought to light and corrected thus preventing waste of time during the final testing session. Alternatively, a careful inspection should be made immediately prior to the testing.

Regulations. I.EE.

Regulations EI to E 14 deal with the testing and inspection of installations. These regulations are discussed below, and methods of complying with them are described in detail.

Insulation resistance tests, Regulations E 6 and E 9. The various tests of an installation which follow are to be made before the installation is connected to the supply, For the insulation resistance tests large installations may be divided into groups of not less than 50 outlets. For this purpose, the expression outlet includes every point (position for attachment of lamp, lighting fitting, or current-using appliance) and every switch and socket-outlet. A socket-outlet, appliance or lighting fitting incorporating a switch is regarded as one outlet.

Testing voltage. The voltage used for insulation resistance tests shall be a direct current voltage not less than twice the normal direct current voltage, or in the case of alternating current not less than twice the normal rms. voltage, but it need not exceed 500 V for medium-voltage circuits. Thus a 500-V insulation resistance tester is sufficient for general purposes.



Testing the installation to earth.

The test shall be made with all fuse links in place, all switches including the main switch cloud and, except where earth-concentric wiring is concerned, all poles or phases electrically connected together,

If required, all lamps and appliances may he removed during the test, in which case each piece of apparatus should be separately tested, the measured insulation to earth shall be not less than 1 MΩ. The insulation

S. W S.W TO

NEXT

POINT

LAMPS

FUSES IN SWITCHES CLOSED

SWITCH CLOSED

COMPANY'S

MAIN SWITCH

OFF

EARTH TERMINAL

Fig 3 Testing insulation resistance of completed installation

resistance of each piece of apparatus measured separately shall be not less than 0-5 MM to earth (between live parts and frame), and 05MΩ between poles or phases. The sketch (Fig.) shows the connections for testing the insulation resistance to earth of a completed 2-wire installation with lamps and other apparatus disconnected. The wires of both poles of the supply to the main switch are twisted together and connected to the 'line' terminal of the ohmmeter. The 'earth' terminal of the ohmmeter is connected to the consumer's earthing terminal. The three terminals of 2-way switches should temporarily be connected together.

Testing between conductors.

This test is made between all the conductors connected to any one pole or phase of the supply, and all conductors connected to any other pole or phase of the supply. The insulation resistance is to be not less than 1 MΩ.

All lamps should be removed, all current-using apparatus dis connected and all local switches controlling lamps or apparatus closed. When the removal of lamps and apparatus is not practicable, all local switches should be open. The test does not apply to earthed concentric wiring systems. Figure 97 gives the connections for the test of a 2-wire installation. Only one test is required in this case.

For 3 and 4-wire installations more than one between phases test is necessary. A 3-wire direct current installation will require three tests:

1. between positive line and neutral,

2. between negative line and neutral,

3. between positive and negative lines

L.F

FUSES IN

S.F.

S.W

TO NEXT

POINT

SWITCH CLOSED

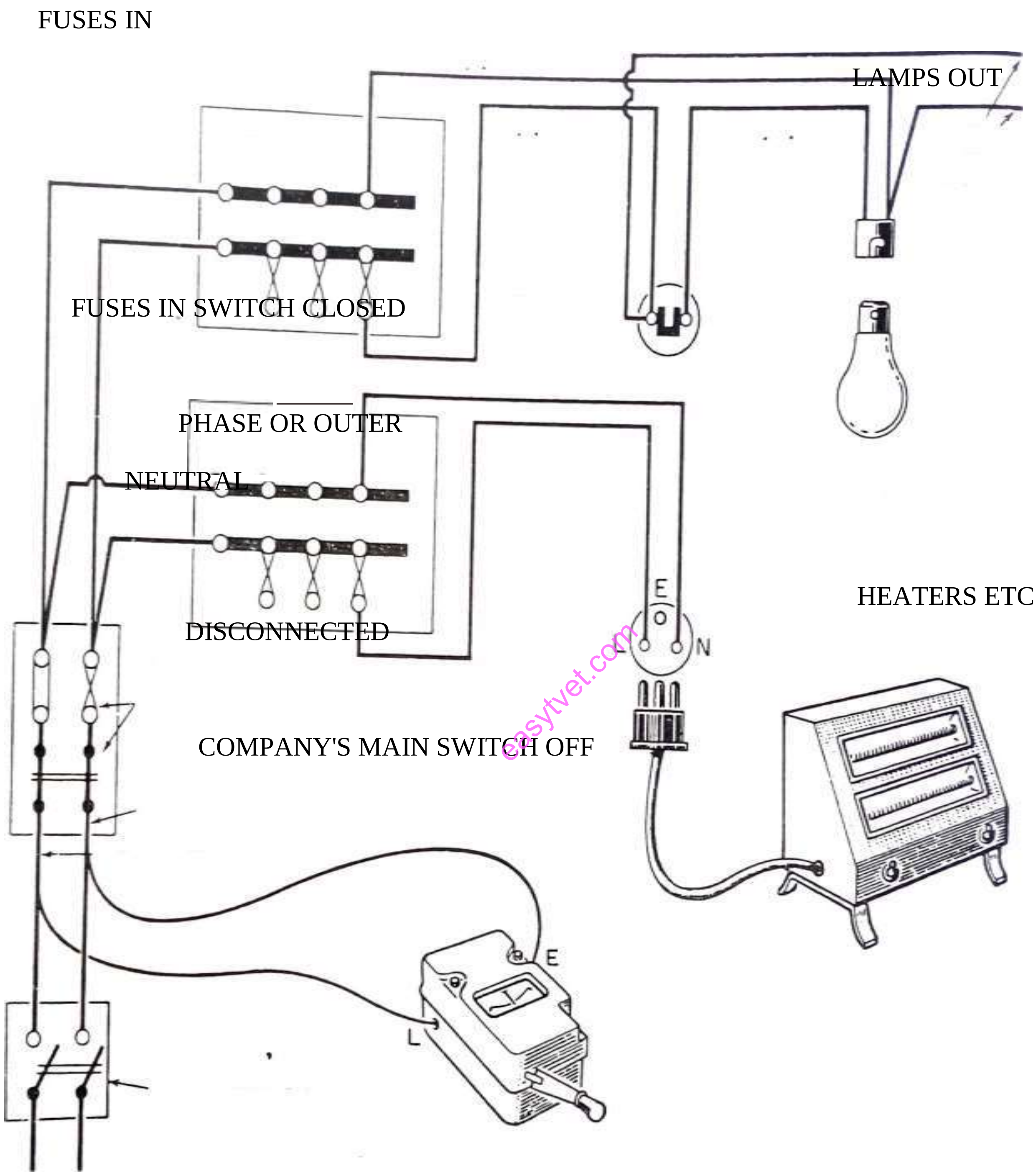

FUSES IN
LAMPS OUT
FUSES IN SWITCH CLOSED
PHASE OR OUTER
NEUTRAL
HEATERS ETC
E
L
N
DISCONNECTED
COMPANY'S MAIN SWITCH OFF
E
L

Figure 4.

A 3-wire 3-phase installation will also require three tests:

1. between lines R and Y,

2. between lines R and B,

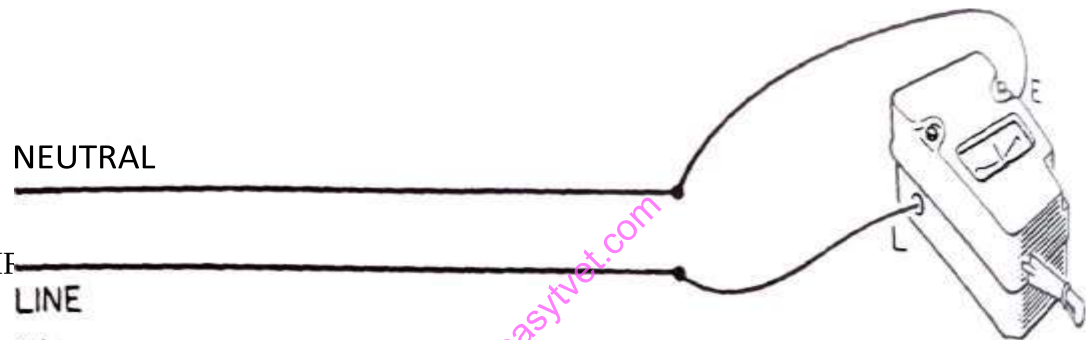
3. between lines Y and B.

A 3-phase 4-wire installation will require six tests:

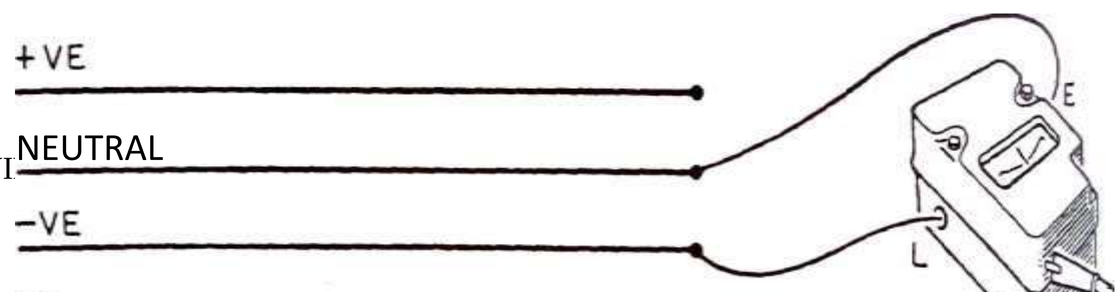
1. three separate tests between pairs of lines, R-Y, R-B, and Y-B.

2. three separate tests, R-neutral, B-neutral and Y-neutral.

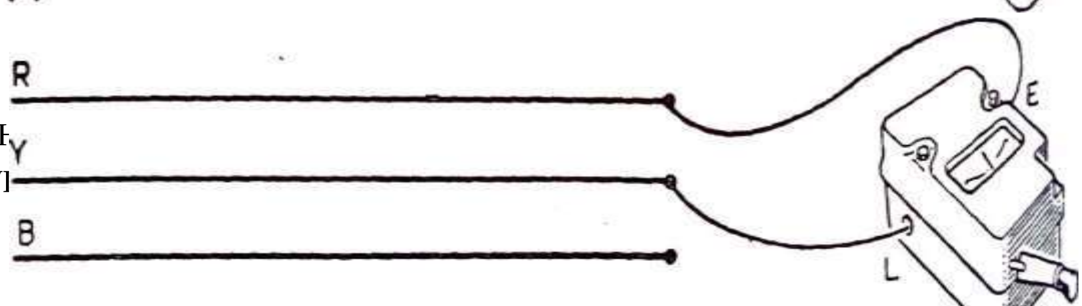
Figures 98 (a) to (d) show the test connections in a simplified form.



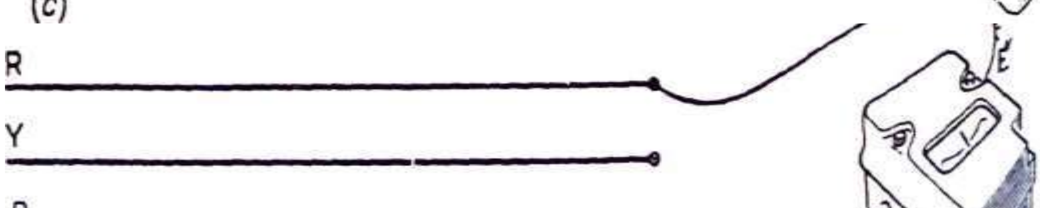
(a)



(b)



(c)



3 - PHASE
4 - WIRE

(d)

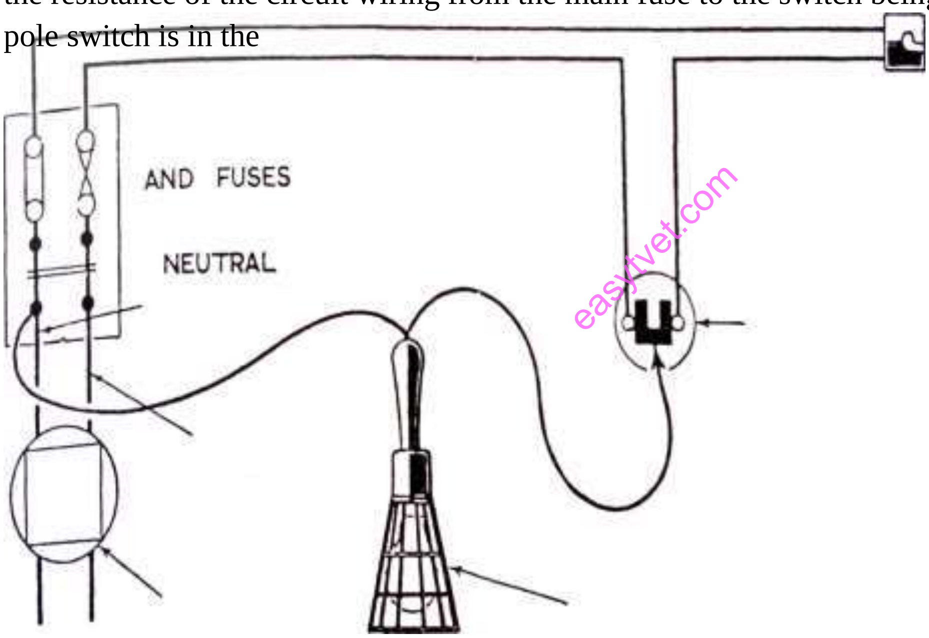
Fig 5 (a) to (d) Simplified diagrams of tests between conductors

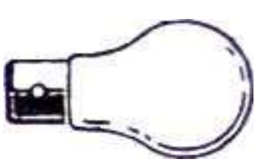
Verification of polarity of single-pole switches, etc. . Regulation E requires that it shall be ensured that all fuses and single-pole control devices are connected in the live conductor only; that the outer contact of Centre-contact bayonet and Edison-type screw lamp holders are C nested to the neutral or earthed conductor; and that plugs and socie outlets have been correctly wired.

On p. 12 it was noted that by I.E.E. Regulation all single-pole or linked switches were to be fitted in the outer or phase conductor. If the proper colored cable is used throughout the installation, i.e., in a2-wi installation, red for switch feeds and switch wires and black for light feeds, no confusion should arise.

Paying for polarity with circuit alive. The simplest way to test is with the circuit alive, switched on the main switch, All single-pole switches would be ON', their covers removed, all lamps should be out, and other Neutral should be disconnected, If the single-pole switches are in the Correct conductor, the phase or outer conductor, they will be alive. A portable lamp with a pair of long insulated leads is used. The leads Should terminate in insulated test prods in the interests of safety. The end of one prod is connected to the known earthed conductor at the main switch, and the other prod is touched to the single-pole switch terminals. The test lamp should light. Should the switch be in the wrong or earthed conductor, the test lamp will not light as the switch will be at earth potential. This procedure is repeated at all the switches in turn. In the case of 2-way switches, the three terminals of the switches should be temporarily connected together for the test. In a large installation the work can be sectionalized by checking the polarity of the busbars at the distribution boards and working from these positions instead of running the test lead back to the main switch. The test should be extended to verify that the three-pin socket outlets are properly connected, that is, with the terminal marked 'L' connected to the outer or phase conductor, In testing screw-type lamp holders to ensure that the outer contact is earthed, one prod should be touched to the live side of the main switch and the other prod to the outer contact of the lamp holder, when the test lamp should light. It must be remembered that the test is being made on a live circuit, and care must be taken, otherwise unpleasant or dangerous shocks may be sustained; Figures above illustrate the tests.

Testing for polarity with circuit dead. Testing instruments are available by which the polarity of the circuit switches can be tested before the installation is connected to the supply. In its simplest form the instrument consists of a direct-reading ohmmeter and a small dry battery contained in a small case, with two terminals to which a pair of test leads with or without testing spikes may be connected. Figure 103 illustrates the test. The main switch and fuses are out, lamps and other apparatus are out or disconnected, and the single-pole switches are on. One lead of the polarity tester is connected to the phase or outer conductor at the outgoing side of the main fuses. The other lead is touched to the terminals of the single-pole switches in turn. Provided the polarity is correct, the instrument reading will be less than I 2 normally, since the instrument is measuring the resistance of the circuit wiring from the main fuse to the switch being tested. If the single-pole switch is in the





CONSUMERS MAIN SWITCH LAMPS OUT

CONDUCTOR

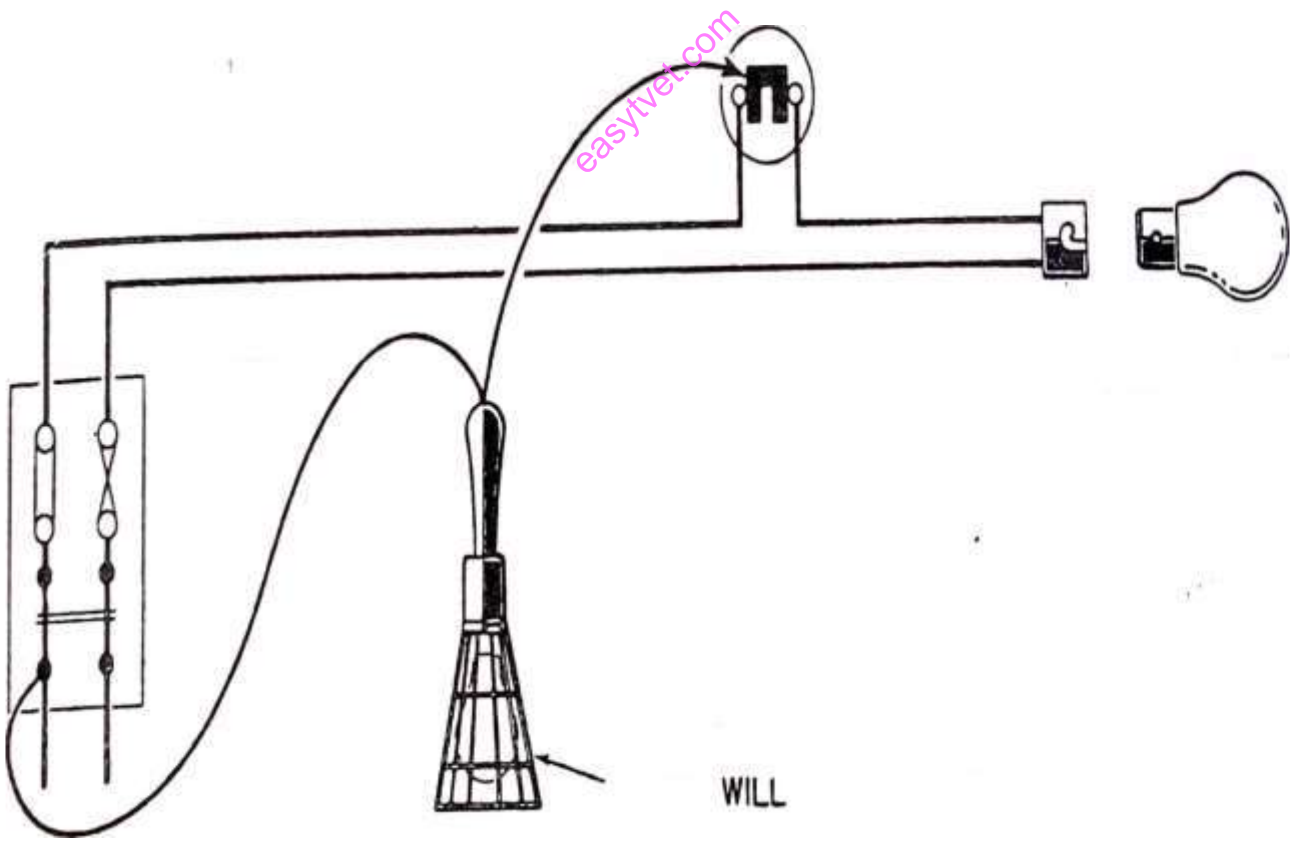
SWITCHES ON

PHASE OR OUTERLAMP WILL LIGHT

CONDUCTOR

METER

Fig5 Testing for polarity of switch, correct



NEUTRAL ↘

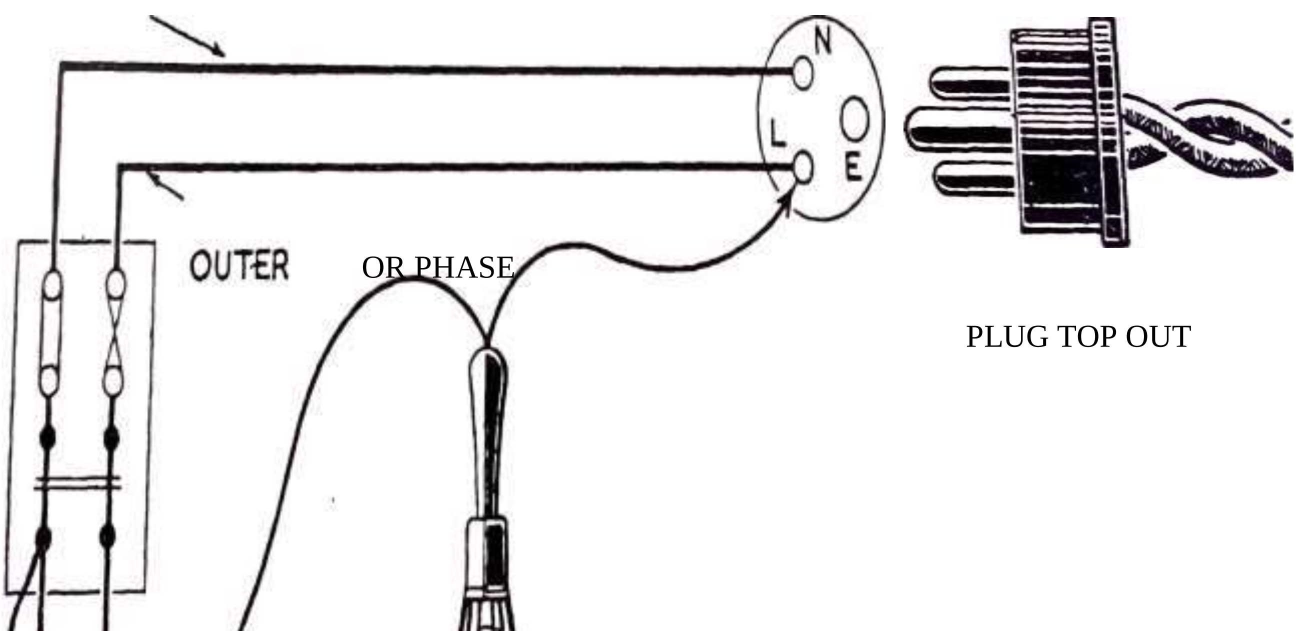
↖PHASE OR OUTER LAMPS

OUT

LAMPS

WILL NOT LIGHT

Fig 6 Testing for polarity of switch, incorrect



LAMP WILL LIGHT

Fig 7 Testing 3-pin socket outlet, correct

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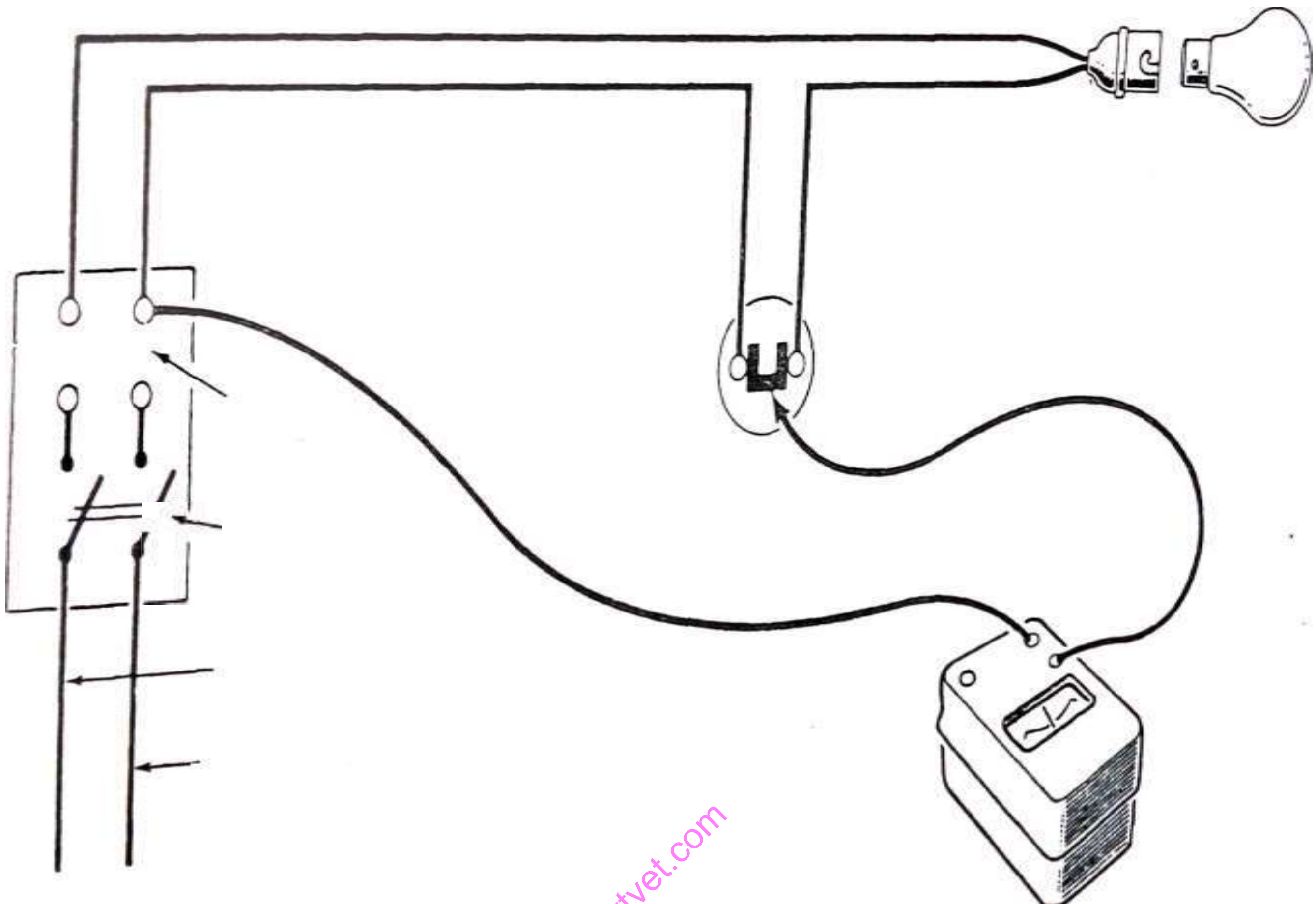


incorrect conductor the instrument reading will be a maximum, i.e., infinity. The polarity of the 3-pin socket outlet is tested in a similar way.

LAMPS OUT

YY FUSES OUT

MAIN SWITCH OPEN

NEUTRAL

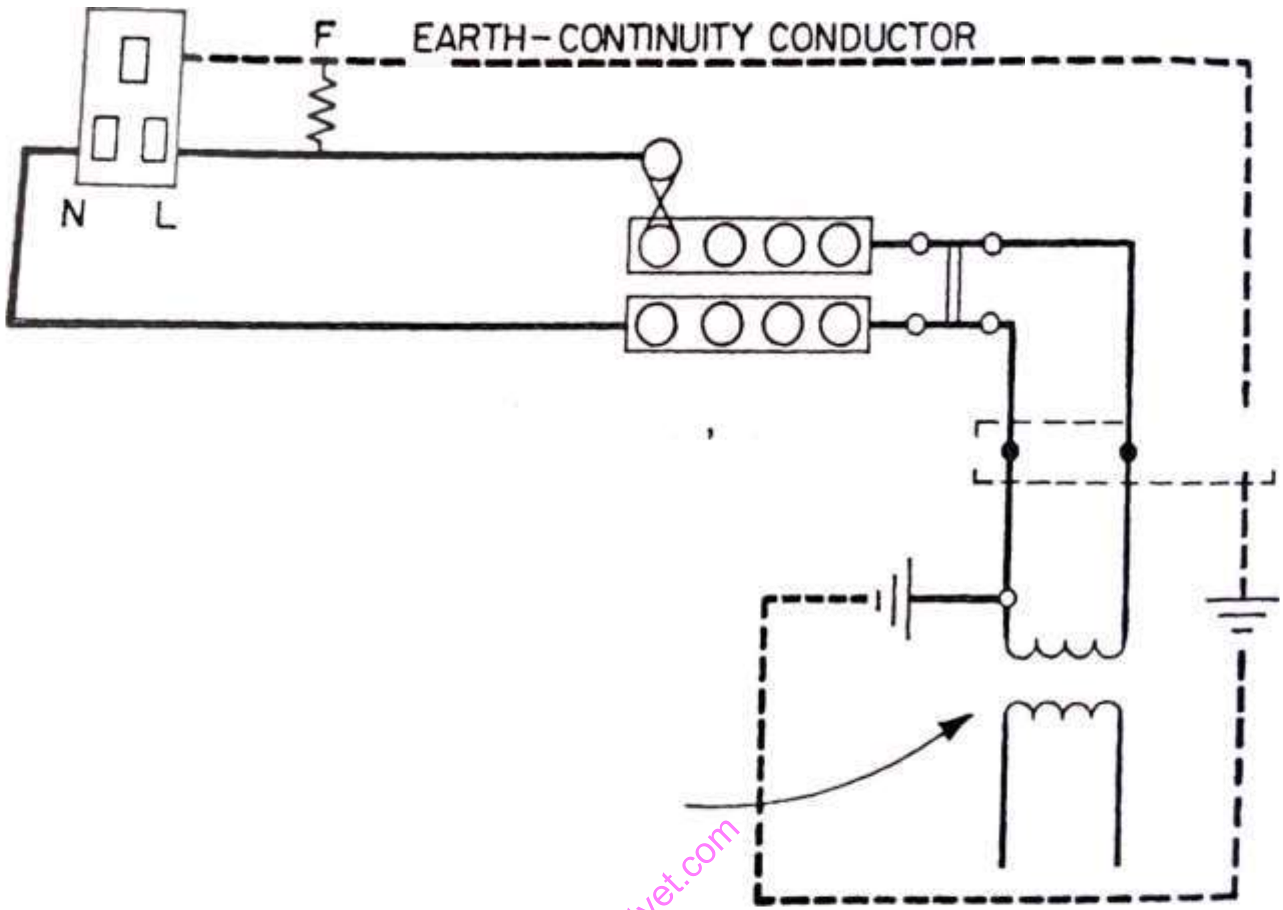
PHASE OR OUTER

Fig. 8 Testing for polarity of switch with circuit dead

Test of earth-leakage circuit-breaker.

In accordance with Regulation E 5, the effectiveness of earth-leakage circuit-breakers is to be verified. The IEE Regulations states that a voltage not exceeding 45 V, obtained from a double-wound transformer connected to the mains supply, shall be applied across the neutral and earth terminals (or neutral and frame terminals of a voltage operated Earth leakage circuit-breaker) and the circuit breaker shall trip instantaneously.

Earth-fault loop testing. Regulation E 4 requires that when earth leakage protection relies on the operation of fuses or excess-current circuit-breakers, the effectiveness of earthing shall be tested by means of an earth-loop impedance test.



CONSUMER'S TERMINALS

SUPPLY AUTHORITY EARTH ELECTRODE

SUPPLY TRANSFORMER

EARTH PATH

Fig 9 .Line-earth loop

The diagram Figure above shows the path of leakage current from an earth fault on a 2-wire final sub-circuit. The path of the leakage current is from the earth fault (F) along the earth-continuity conductor to the consumer's earthing terminal and thence to the consumer's earth electrode. From here the fault current passes through the general mass of earth to the supply authority's earth electrode at the supply trans former, through the transformer winding and along the line through the consumer's wiring to the fault. This path is called the line earth loop, and it is this loop which is to be tested, The Regulations allow the neutral-earth loop to be tested as an alternative.

A line-earth tester such as the Megger line-earth tester would be used. The operation of this instrument is as follows:

The instrument passes a short duration current through the loop, the value of the current depending upon the impedance of the loop as well as upon the voltage of the tester. The current passes through 10 resistors in series with the loop, and the voltage drop across it is measured by means of a ballistic instrument which is calibrated to read directly the loop impedance in ohms. This instrument incorporates a voltmeter and a voltage selection switch, enabling it to be used on supplies of different line-neutral voltages.

Test of earth-continuity conductor.

Regulation E 3 requires that every earth-continuity conductor shall be tested in accordance with Item 1 of Appendix 6. Four methods are given:

- **Alternating current test.**
  It is suggested that one of the current conductors of known resistance shall be disconnected and used as part of the test circuit. At the remote end of the final sub-circuit this cable and the earth-continuity conductor are connected together forming a lead and return. At the other end an alternating current supply not exceeding 40 V at approximately supply frequency is applied to the end of the conductor/e.c.c loop. A current of approximately times the rating of the final sub-circuit is passed through the

loop, with a maximum value of 25 A. The impedance of the e.c.c which is the ratio voltage/current, minus the resistance of the known conductor, should not exceed 1Ω.

- **Alternating current test at reduced current.**
  preferred, a lower value of current may be applied, at approximately supply frequency, The impedance values allowable are, not more than 050 where the e.c.c is partly or wholly of steel conduit or pipe, and I 0 where the e.c.c is wholly of copper, copper alloy, or aluminium.
- **Direct current test of an alternating current installation.**
  Direct current may be used for the test provided that a proper inspection of the e.c.c ensures that there is no inductor incorporated in the e.c.c. The values of impedance are not to exceed 0-5 for steel conduit or pipe, and 1Ω for copper, copper alloy, or aluminium.
- **No current test of direct current installation**
  This test can be made, using say, a secondary battery and rheostat, with a current approaching 1-5 times the rating of the sub-circuit under test, subject to a maximum of 25 A. Alternatively, a hand tester may be used with a reduced current. In each case the resistance obtained by the test should not exceed 1 Ω.

Test of ring-circuit continuity

Regulation E 10 requires that a conductor, including the earth-continuity conductors, shall be verified for continuity, this may be done with a continuity tester, probably a battery type as used for polarity testing on p. 116.

All apparatus must be disconnected from the ring. The ring is the disconnected at the distribution board so that the four ends of the ring conductors are exposed. Touching the continuity tester across the two ends of the line conductor will give a very low reading, showing continuity. The neutral conductor is checked in a similar way.

To check the conductors in the spurs, the ring should remain open with ends exposed. A continuity test would be made across line end neutral from the end socket-outlet on any spur, when the indication should be infinite resistance. This could be repeated at every spur end. If one pair of exposed wires, line and neutral, at the exposed ends be now temporarily short-circuited, continuity readings from each spur end should show very low resistance, thus verifying continuity.

The earth-continuity conductors could be checked for continuity at the same time.

Completion certificate

On completion of a new installation or of a major alteration, and after inspection and testing as described, the installation contractor is required to give a Completion Certificate. This certificate, gives certain details of the installation including the number of appliances, etc., the method of earthing, and the value of the earth-loop impedance. The certificate states that the work has been done in accordance with Regulations. It also recommends periodic testing and inspection.

Inspection certificate

When the installation is re-inspected and tested at a later date, an inspection certificate is completed and handed to the consumer. It gives the results of the full range of tests of the installation.

Practical activities

The test results shown in figure below were obtained from a ring final circuit continuity test. State whether reading for each socket are satisfactory or unsatisfactory. give reason for those reading unsatisfactory.

Note: line, neutral and c.p.c loops =0.8Ω

Socket	L-N	L-c.p.c
A	0.4	0.41
B	Not reading	0.39
C	0.5	0.4
D	0.4	No reading
E	0.41	0.41

Self-assessment

1.

a. Describe in details the test procedure for insulation resistance on the installation

b. The test results indicate an overall value of 1.5Ω. state with reasons what actions if any should be taken

2. A loop impedance test on the lighting circuit is conducted and 6A type B m.c.b trips repeatedly

a. Explain why this is the case

Explain why the problem may be overcome in order to conduct the test

1. Explain briefly the action to be taken if the insulation resistance test of an installation indicates an overall value of 1.25 M-ohms

3. A ring final circuit continuity test revealed incorrect polarity on three socket outlets.The results were

	L to N	L to c.p.c.
Socket A	Open circuit	Correct
Socket B	Correct	Open circuit
Socket C	Open circuit	Open Circuit

State which conductors have reversed polarity in each case.

4. For an insulation resistance test on domestic installation, state the

I. Instrument to be used

II. Resistance range at which this instrument should set

III. Measured value below which each circuit would need to be tested separately

5. A live polarity test is to be conducted. State

i) Why such a test is necessary

ii) The instrument to be used

iii) How neutral-earth polarity is checked

6. Earth fault impedance is to be conducted on a radial circuit during an initial verification. State

i) Where on circuit the circuit should be conducted

ii) Which value measured or corrected should be recorded on the scheduled test results

iii) Why the value in b above may not be the same as Ze + (R1+R2)

2.

7. List

a. Five relevant test including the individual instrument required on the outer house supply cable following the test for continuity protective conduction

b. Five relevant inspection required when inspecting the installation of the outer house supply cable

8.

a. Explain why the earth fault loop impedance test results on lighting circuit in the outer house is likely to be significantly higher than a similar circuit in the main property

b. Explain briefly

i) Why the main switch may operate when testing for earth loop impedance on the lighting circuit in the outer building

ii) How you would overcome the problem encountered in b (1)

Answers to practical Activity

1. As the line, neutral and c.p.c loops are0.8Ω, the outlet readings should be in the order of 0.4Ω +0.05Ω

Socket A L-N reading is acceptable

L-CPC reading is acceptable

Conclusion polarity is correct

Socket B L-N reading is unacceptable- no continuity

L-CPC reading is acceptable

Conclusion Reverse polarity on P/CPC conductors or Neutral is not connected to terminal

Socket C L-N reading is unacceptable- too high (greater than ±0.05Ω)

L-CPC reading is acceptable

Conclusion May indicate a loose connection on the neutral conductor

Socket D L-N reading is unacceptable

L-CPC reading is unacceptable- no continuity

Conclusion reverse polarity on P-N conductors or CPC is not connected

Socket E L-N reading is acceptable

L-CPC reading is acceptable

Conclusion polarity is correct

1. a) isolate the supply and loop off

-all switched closed

-all current using equipment removed

- all fuse/M.C. B's in place\on

-all equipment vulnerable to test should be removed

-test performed at meter tails if possible

Test between live conductors (L&N)

live conductors and earth

b) this could indicate a latent defect. Each circuit should be tested individually and its insulation resistance should be greater than 2Ω.

2.a. As loop impedance tester delivers high current for a short time. It is not.

b. The loop impedance in such cases will have to be determined by a:

- measure Ze (incoming side of device)

- measure R1+R2 for the circuit

-then Z

3. a 1. R1+R2, low reading ohm meter

2. insulation resistance, high reading ohm meter

3.. polarity, low reading ohm meter.

4.. Zs. Earth loop impedance tester.

5. Pfc, prospective fault current faster

b. protection against damages

joint mechanically and electrically sound correct current rating

metal sheaths and armors earthed.

identified at termination

Answers to self-assessment questions

1. Each circuit should be separately tested & its insulation resistance should be greater than 2 MΩ.
2. L & C.P.C.
   L & N
   All **or** N & C.P.C.
3.
   a) . insulation resistance tester
   b) 500 V dc
   c) 2 MΩ

   To prove the correct polarity of the incoming supply

   Approved voltage indicator

4.a. Test across the line and neutral, voltage should be present

b. Test across the line and earth, voltage should be present

c. Test across the neutral and earth conductors, no voltage should be present

5.a. the remote end of the circuit (point furthest away from the source of supply)

b. measured value

c. the R1+R2 value obtained using a d.c test and does not take into account the impedance (a.c resistance) of the circuit conductors. Also when taking a reading of Ze parallel paths may be present which would lead to lower reading than may otherwise be calculating using the values of Ze and R1+R2

Add notes on test result documentation.

CHAPTER 8: ELECTRICAL INSTALLATION MAINTENANCE

Unit of learning code ENG/CU/PO/CR/01/6

Maintain electrical installation systems

8.1 Introduction to the unit of learning

This unit covers the competencies required to carry out maintenance in electrical installation systems. The maintenance includes scheduling, inspection of electrical system, preparation of list of tools, material and equipment, system maintenance and tests.

8.2 Summary of Learning Outcomes

13. Prepare maintenance schedule
14. Inspect electrical installation
15. Perform installation servicing
16. Conduct installation tests

8.2.1 Learning Outcome 1: Prepare maintenance schedule

8.2.1.1 Introduction to learning outcome

This learning outcome entails definition of maintenance, types of maintenance and procedures, Scheduling maintenance based on service manuals as well as Safety precautions to be observed. Information sheet

16.2.1.2 Performance standards

16.2.1.2.1 Type of the system to be maintained is identified
16.2.1.2.2 The maintenance type and scope are defined
16.2.1.2.3 Relevant manual/service instruction is referred to
16.2.1.2.4 Maintenance schedule is developed in accordance with the service checklist
16.2.1.2.5 Relevant maintenance procedures are referred to where applicable

16.2.1.3 Information sheet

Prepare maintenance schedule

Maintenance is the keeping of equipment, building and services of the plant in satisfactory repair and operating conditions.

Importance of Maintenance

- It helps the industry to maintain continuous supply of goods and services.
- Keeps equipment running (operating)
- Keeps the installation efficient

Control of Maintenance Work

In order that there should be some control over the work of maintenance, four rules should be rigidly enforced.

- All requests for maintenance work must be made preferably in writing) to one central control point (maintenance supervisor). No work should be carried out without the knowledge and approval of the maintenance supervisor. Lack strict adherence to this rule will allow a waste of skilled staff and inability to keany schedule of essential work.
- No maintenance work should be undertaken by productive staff unless the operator is seconded to the maintenance department.
- Maintenance stores must be as carefully controlled as any other of the company's stores,as the absence of a vital, part can lead to an expensive plant shut down.
- Records of work carried out, including a statement of materials required, should be kept as those assist in selling rational maintenance, replacement and depreciation policies

Maintenance Policies

Within the context of maintenance, failure is defined as an inability to produce work in the appropriate manner rather than inability to produce any work. Work carried out before failure is said to be overhaul, or planned maintenance work while that carried out after failure is emergency, breakdown or recovery work.

In order to come up with rational policies there is need to collect and analyze maintenance information and data of the installations to actual times taken and work Involved when carrying out maintenance tasks and also maintenance costs. From here a choice can then be made of one or a combination of several of the following five types of maintenance policies

- Time base (‘overhaul every x months’)
- Wok based (‘overhaul when x volume of work is produced’)
- Opportunity based (‘maintain when available’)
- Condition based (‘repair when parameter is at level p’)
- Emergency based (‘continue to operate until plant fails, then maintain)

The new above policy decisions as an address to the following questions

- Should maintenance consist of service or repair or both?
- What should be the timing of service or preventive work in order to involve minimum effort and cost and yet minimize the probability of breakdown resources?
- How should the repair work be conducted?
- What should be the size of maintenance teams?
- How should information be gathered to enable the above question be answered?

Duties of Maintenance

The duties of maintenance can be classified into five

- Inspection
- Engineering

- Production
- Clerical
- Housekeeping

6. **Inspection**

Inspection is concerned with the routine scheduled checks of the plant, building and its equipment and their conditions and to check or needed repairs. On intensively used production equipment Inspection is much more frequent and detailed than function of housing, eg production machines, motors and belting may be inspected once every week, boilers, furnaces and compression equipment every month, overhead cranes may be Inspected every 4 to 6 months.

Facilities will normally be inspected at Intervals in order to determine whether services and\or preventive maintenance is required is likely to be required in the rear future. Such work may Involve visual inspection or the measurement certain of the physical characteristics of a facility. It may Involve the whole facility or simply these parts, which are known to be liable to failure.

A report should be made after such inspection showing the condition of plants, probable reasons for their development and suggested repairs and replacement. A succession of these reports often indicates their weaknesses, which may be developing or may call for change in the inspection interval.

7. **Engineering**

Engineering is concerned with developing changes and improvement in the plant building or the operating equipment. Recurring breakdowns in certain equipment may suggest a need for engineering by the maintenance department to determine what has caused the difficulty. After the study, maintenance would then develop some modification to prevent or at least reduce such future recurrences. In its engineering capacity, for example, maintenance might be deciding to study and develop ways of directing sufficient illumination towards a particular job through stronger fixture brazing arrangement.

8. **Production**

This puts into operation the ideas developed by the engineering phase. It is also concerned with the performing work suggested by inspection function as well as performing other tasks such as servicing and lubricating of equipment. The implementation aspects of maintenance are the part that will the classified under this heading.

9. **Clerical Work**

This is largely keeping records of cost, time progress on jobs etc. It is also responsible for maintaining records to the important features of the plant, equipment and other properties. These may include records of property maps, complete building drawing. Complete writing and power line drawings, maps of underground piping of water, steam, air and similar lines, complete layout drawings of whole machinery, showing types, location and date purchased, spares parts required etc, and records of all inspection, adjustment, repairs, and replacement by department, equipment and date.

10. House keeping

As the name suggest, it means taking care of the detail of the upkeep and cleaning of the buildings, equipment, tools and plant facilities.

These five functions are in essence the total duties of maintenance department.

Types of Maintenance

Fundamentally there are only two types of maintenance,

c. preventive maintenance carried out before failure
d. breakdown maintenance carried out after failure.

Preventive Maintenance

This is also called overhaul, schedule or planned maintenance.

It is generally defined orderly routine of inspecting, cleaning, testing, furnishing, adjusting, and lubricating machines. The main objective of this of program is to avoid or reduce the number of avoidable breakdowns. It is a cores mechanical tear and wear.

A good preventive maintenance program provides for plant shut down during periods of inactivity or least usage for purpose of major overhauls. This ensures continuity of operation and lessens the danger of breakdowns at peak loads.

When preparing routine inspection schedule, it must be recognized that too frequent inspection are a waste time and money and that insufficient inspection places equipment in virtual jeopardy. The frequency of inspection should depend on the equipment' contribution to profitable production, its duty cycle, age, overload etc.

In order to carry out a preventive maintenance schedule it is first necessary to produce an inventory of every item, its service, its role and method required for maintenance, the acceptable frequency of maintenance and attention needed. The selection would be based on the consequences in failure in regard to such factors as safety, productivity and the frequency based on analysis of the past records.

This program is a corrective measure carried out on an item before it fails prevent failure. In most cases, the whole factory would be closed due to overhauls. It embraces type 1 and 3 of maintenance policies.

Planning a preventive maintenance program

A) The most important phase of a preventive maintenance program is the recording and interpretation of data pertinent to each piece of equipment.

B) Maintenance personnel should be selected to the basis of qualification on the job.

C) A skilled maintenance force should be kept abreast of the latest techniques and developments in the field. Files of equipment, manufacturer's bulletins and instructions should be available to all maintenance personnel.

D) Only modern testing equipment, proper tools and latest methods should be used

(e) A carefully selected assortment of spare parts is essential to a good maintenance program and represents insurance against prolonged shutdowns. Overstocking and understocking should be avoided, since overstocking in excessive holding of funds as well as losses due to theft and obsolescence of equipment, while under stocking leads to production in jeopardy if a break down occurs.

F) Safe operation of machines and safety to personnel should the uppermost when planning any maintenance program.

Objectives of Preventive Maintenance

(a) To minimize the possibilities of anticipated production interruption by identifying any condition which might lead to it.

(b) To make plant equipment ad machines available and ready for use.

(C) To reduce the work content of maintenance Jobs that would be occasioned by breakdowns

(d) to ensure safety of employees.

Advantages (Benefits) of Preventive Maintenance(a) A good preventive maintenance ensures co and lessens the chances of breakdown at peak load.

(b) lt enables troubles to be detected in their early stages so that corrective action can be taken before expensive damage is done

(c) The relatively high cost of down time due to equipment failure is avoided particularly in processing plants, assembly.

(e) The total cost of down lime and emergency and clock repairs, which can be staggering are minimized (f) The probability of law suits that may arise from Injury to personnel and failure to meet commitments because of unavoidable break down are eliminated

(g) Leads to better spare parts control leading to minimum Inventory level and reduction in maintenance.

Running Maintenance

This is part of preventive maintenance, which is done more routinely. It involves walking around and inspecting machines through observation while in operation in order to ascertain loose parts like nuts, screws, parts which by their nature require oiling, greasing, etc. and being able to take the necessary action i.e. tightening or replacing loose nuts, rivets, clips, etc., oiling, greasing, adjusting offset parts, etc.

Total Preventive maintenance

This is where you have workers perform preventive maintenance activities. It's based on the machines they operate, rather than use separate personnel for the task. It is a system where employees are given greater responsibility for quality productivity and the general functioning of the system.

Predictive Maintenance

It is an attempt to determine when maintenance activities. It is based on historical records, analysis of technical data to predict when a piece of equipment of a plant is about to fall. The better the predictions of failures are, the more effective preventive maintenance will be. A good preventive maintenance effort relies on complete records for each piece of equipment Records must include information such as data of installation, operating hours, dates and types of insurance and dates and types of repairs

Break Down Maintenance

It is also called corrective, emergency or recovery work. itis typo 4 and 5 of maintenance policies.

This is a maintenance, which is carried out on an item, which has failed in its service. It is repair work, which is carried out through fault diagnosis, analysis and identification to establish its position it is done by repairing the faulty part so as to restore its operation. Some of the worn out or broken parts are removed and replaced.

Repair or breakdown maintenance is remedial; taking place alter an item has ceased to operate. The need to repair is not necessarily that result of inefficient or Insufficient inspection, service or preventive maintenance, since in some cases the cost of repairs will be less than the accumulated cost of preventive work.

Causes of Breakdown

(a) Failure to identity and replace worn out parts

(b) Lack of lubrication.

(C) Inefficient cooling system

(d) difference towards minor faults

(e) Use of standard or wrong fluids.

Disadvantages of Breakdown Maintenance

(a) It is expensive since It results in high cost of down time due to outage for during repair work the equipment is scheduled out of service.

(b) It results to disruption of production and losses thereof, excessive delays or reduction in output.

(c) Failure of machines may cause accident leading to losses and strained industrial relations.

Reasons why breakdowns should be avoided

(a) Avoid production disruptions

(b) Prevent addition to production costs

(c) Maintain high quality products,

(d) Avoid missed delivery dates

Adverse consequences when breakdown occurs

(a) Production capacity is reduced and orders are delayed

(b) There is on production but overheads continue increasing the cost per unit.

(c) There are quality issues, product may be damage

(d) There are safety issues, employees or customers may be injured

Handling Breakdowns

The following are some are some major approaches used to deal with breakdown maintenances.

(a) Have standby or back up and that can be quickly pressed into service.

(b) Have inventories, of spare parts that can be installed as needed, thereby avoiding lead times involved in ordering parts and buffer inventories, so that other equipment will be less likely to be affected by short-term downtime of a particular piece of equipment.

(c) Have operators who are able to perform at least minor repairs on the equipment.

(d) Repair people who are well trained and readily available to diagnose and correct problem with equipment.

2. **Learning Outcome 2:** Inspect electrical installation

1.2.1 Introduction to the learning outcome

This learning outcome specifies the content of competencies required to inspect electrical installation in the electrical installation maintenance. It includes recording of inspection findings, Identification and documentation of maintenance tools, materials and equipment specifications of identified tools, materials and equipment against safety standards Inspection procedure

8. **Performance Standard**
    3. System is inspected according to the established procedure
    4. Instances where the maintenance activities cannot be fully met or where there are defects outside the planned schedule are identified and recorded

1.2.1.3 Information Sheet

Definition of terms

Double installation-insulation comprising both basic (functional) insulation and supplementary (protective) insulation.

Earth fault loop impedance- the impedance (total opposition to flow of current) of the earth fault current loop (phase to earth loop) starting and ending at point of earth fault.

Earthing conductor- a protective conductor which connects a main earthing terminal of an installation to the earth electrode or to the other means of earthing.

Electrical installation-an assembly of associated electrical equipment such as machines, apparatus, writing materials etc. to fulfill a specific purpose within a consumer's premises.

Final circuit- a circuit connected directly to current-using equipment's or sockets-outlets or other outlets points.

Flexible cords-a flexible cable is in which the cross-sectional area of each conductor does not exceeds $4mm^2$.

Isolation-the cutting off circuit or circuits from the source of electrical energy.

Live(alive)-a conductor or object is said to be 'live' when a difference of potential exists between it and earth.

Live part-a conductor or conductive part intended to be energized in normal use, including a neutral conductor but not including a PEN conductor.

Ohmmeter-an indicating instrument for be providing a direct reading of resistance. It's used for measuring conductor resistance and insulation resistance and resistances.

Protective conductor- a conductor for some measure of protection against electric shock and intended for connecting together parts of the system that are exposed and extraneous which are conductive.

Residual current device-a mechanical switching device or Association of devices intended to cause the opening of contacts when device residuals currents attain a given value under specified conditions.

Socket-outlets-a device with protected current-carrying contacts intended to be mounted in affixed position and permanently connected to the fixed wiring of the installation, to enable the connection flexible cord or flexible cables by means of a plug.
Switch gear-apparatus for controlling the distribution of electrical energy or for controlling or protecting electrical circuits, machines and current using appliances.
a **A TN system**-is a system having one or more points of the supply sources directly earthed. There are three systems which fall in this category:

IV. TN-C system- neutral and protective functions combined in a single conductor through the system.
V. TN-S system- neutral and protective conductors separated trough the system.
VI. TN-S-C system-as in (1) above but only in part of the system.

b. **A TT system**-is a system having one point of the supply directly earthed and the exposed conductive parts of installation are connected to an earth electrode which are connected to an earth electrode which is electrically independent of the electrical installation being earthed.
Trunking (for cables) –a fabricated casing for cables normally of rectangular cross sectional of which one side is removable or hinged to allow cable (s) to be laid therein.

In order to make sure that this work is carried out satisfactorily the inspection and test procedure must be carefully planned and carried out and the results correctly documented.

We inspect material after the completion of work for three key reasons to ensure:

- compliance with BS 7671
- compliance with the project specification (commissioning)
- that it is safe to use.

Compliance with BS 7671

BS 7671 Part 6 states that every electrical installation shall, either during construction, on completion, or both, be inspected and tested to verify, so far as is reasonably practicable, that the requirements of the Regulations have been met. In carrying out such inspection and test procedures, precautions must be taken to ensure no danger is caused to any person or livestock and to avoid damage to property and installed equipment.

BS 7671 requires that the following information be provided to the person carrying out the inspection and test of an installation:

- the maximum demand of the installation expressed in amperes per phase
- the number and type of live conductors at the point of supply

- the type of earthing arrangements used by the installation, including details of equipotential bonding arrangements
- the type and composition of circuits, including points of utilization, number andsize of conductors and types of cable installed (this should also include details ofthe 'reference installation method' used)
- the location and description of protective devices (fuses, circuit breakers etc.)
- details of the method selected to prevent danger from shock in the event of an earth fault, e.g. earthed equipotential bonding and automatic disconnection of supply
- the presence of any sensitive electronic devices.

NB: It is important to remember that periodic inspection and testing must be carried outon installations to ensure that the installation has not deteriorated and still meets allrequirements. Tests will also need to be carried out in the event of minor alterationsor additions being made to existing installations.

Compliance with the project specification

Once the installation is complete, we need to test it against the original specification for the work. This is in order to check that the finished installation matches the requirements laid out by the customer and is fit for use in the environment where it will be used. The tasks involved in checking compliance with project specification are as follows.

- **Pre-commissioning** – this involves a full inspection of the installation and the carrying out of all tests required before the installation is energized (continuity,polarity and insulation resistance).
- **Commissioning** – includes all tests which require power to be available, e.g., the measurement of the earth-fault loop impedance and functional testing of residual current devices (RCDs).

As commissioning involves the initial energizing of an installation, this task has to be carried out in a controlled manner with the knowledge of everyone involved. This means that all other persons working on site at the time of the energizing must be informed that power will be applied to the installation, so that all precautions can be taken to prevent danger. The commissioning process is intended to confirm that the installation complies with the designer's requirements. As such, commissioning includes the functional testing of all equipment, isolation, switching, protective devices and circuit arrangements

Safe to use

The final act of the commissioning process is to ensure the safe and correct operation of all circuits and equipment which have been installed, and that the customer's requirements have been met. This will also confirm that the installation works and, more importantly, will work under fault conditions; after all, it is under fault conditions that lives and property will be at risk. The testing of electrical installations can cause some degree of danger; it is the responsibility of the person carrying out the tests to ensure the safety of themselves and others. **Health and Safety Executive Guidance Note GS38 (Electrical test equipment for use by electricians***)* details relevant safety procedures and should be observed in full.

- When using test instruments the following points will help to achieve a safe working environment. The person carrying out the tests must have a thorough understanding of the equipment being used and its rating.
- The person carrying out the tests must ensure that all safety procedures are being followed, e.g. erection of warning notices and barriers where appropriate.
- The person carrying out the tests should ensure that all instruments being used conform to the appropriate British Standard, i.e. BS EN 61010 or older instruments manufactured to BS 5458 (provided these are in good condition and have been recently calibrated).
- The person carrying out the tests should check that test leads including probes and clips are in good condition, are clean and have no cracked or broken insulation. Where appropriate the requirements of GS38 should be observed, including the use of fused test leads.

Purpose of a periodic inspection

Initial inspection and testing is necessary on all newly completed installations. In addition, because all the electrical installations deteriorate due to a number of factors (such as damage, wear and tear, corrosion, excessive electrical loading, ageing and environmental influences) periodic inspection and testing must be carried out at regular intervals. The purpose of a periodic inspection and test is to:

- Confirm the safety of persons and livestock against the effects of electric shock or burns
- Ensure protection against damage to property by fire or heat arising from an installation defect
- Confirm that the installation has not been damaged and has not deteriorated to the extent that it may impair safety
- Identify any defects in the installation or non-conformity with the current edition of the Regulations that may cause danger.

The intervals between tests is determined by the following.

- Legislation requires that all installations must be maintained in a safe condition and therefore must be periodically inspected and tested. Table 8.01 details the maximum period between inspections of various types of installation.
- Licensing authorities, public bodies, insurance companies and other authorities may require public inspection and testing of electrical installations.
- The installation must comply with BS 7671.
- It is also recommended that inspection and testing should occur when there is a change of use of the premises, any alterations or additions to the original installation, any significant change in the electrical loading of the installation, and where there is reason to believe that damage may have been caused to the installation.

Domestic or if change of occupancy	10 years
Highway power supplies	6 years
Churches	5 years
Commercial or if change of occupancy	5 years
Educational premises	5 years
Hotels	5 years
Hospitals	5 years
Laboratories	5 years
Offices	5 years
Public Houses	5 years
Shops	5 years
Village halls	5 years
Agricultural/Horticultural	3 years
Caravans	3 years
Cinemas	3 years
Emergency Lighting	3 years
Industrial	3 years
Leisure Complexes	3 years
Places of public entertainment	3 years
Theaters	3 years
Caravan parks	1 year
Fire alarms	1 year
Fish farms	1 year

Launderettes	1 year
Marinas	1 year
Petrol filling stations	1 year
Residential accommodation or if change of occupancy	1 year
Swimming pool	1 year
Construction sites	3 Months

Table 3 Frequency of Inspection

In the case of an installation that is under constant supervision while in normal use, such as a factory or other industrial premises, periodic inspection and testing may be replaced by a system of continuous monitoring and maintenance of the installation, provided that adequate records of such maintenance are kept.

When carrying out the design of an electrical installation, and particularly when specifying the type of equipment to be installed, the designer should take into account the likely quality of the maintenance programme and the periods between periodic inspection and testing to be specified on the Electrical Installation Certificate. Both Section 6 of the Health and Safety at Work Act and the Construction (Design and Management) Regulations require information on the requirements for routine checks and periodic inspections to be provided. The advice of the Health and Safety Executive in their Memorandum of Guidance on the Electricity at Work Regulations indicates that practical experience of an installation's use may indicate the need for an adjustment to the frequency of checks and inspections, i.e. more often or less frequent depending on the likely deterioration of the installation during its normal use. This would be a matter of judgement for the duty holder.

Routine Checks

Electrical installations should still be routinely checked in the intervening time between periodic inspection and testing. In domestic premises it is likely that the occupier will soon notice any damage or breakages to electrical equipment and will take steps to have repairs carried out. In commercial or industrial installations, a suitable reporting system should be available for users of the installation to report any potential danger from deteriorating or damaged equipment. In addition to this, a system of routine checks should be set up to take place betweenformal periodic inspections. The frequency of these checks will depend entirely on the nature of the premises and the usage of the installation. Routine checks are likelyto include activities such as those listed in Table

Activity	Check

Defect reports	Check that all reported defects have been rectified and that the installation is safe.
Inspection	• Breakages • Wear or deterioration • Signs of overheating • Missing parts (screws & covers) • Switch gear still accessible • Enclosure door secure • Labels still adequate(readable) • Loose fittings
Operations	Check operations of • Switch gear (where reasonable) • Equipment (switching on and off) • RCD (using test buttons)

Table 4: Routine Checks

The recommended period between both routine checks and formal inspections are given in Table above taken from *IEE Guidance Note 3*. The requirements for such inspections are stated in BS 7671 Chapter 62 and specify that all inspections should provide careful scrutiny of the installation without dismantling or with only partial dismantling where absolutely necessary. It is considered that the unnecessary dismantling of equipment or disconnection of cables could produce a risk of introducing faults that were not there in the first place.

In summary, the inspection should ensure that:

- the installation is safe
- the installation has not been damaged
- the installation has not deteriorated so as to impair safety
- any items that no longer comply with the Regulations or may cause danger are identified.

In practical terms the inspector is carrying out a general inspection to ensure that the installation is safe. However, the inspector is required to record and make recommendations with respect to any items that no longer comply with the current edition of the Regulations.

Statutory and Non-Statutory Documentation

These include the following

- The Electricity Supply Regulations (1988).
- The Electricity at Work Regulations.
- BS 5266 Pt. 1 Code of Practice for emergency lighting systems (other than cinemas).Other Regulations and intervals cover testing of batteries and generators.
- BS 5839 Pt. 1 Code of Practice for the design, installation and servicing of fire alarm systems.
- Local authority conditions of license.
- SI 1995 No 1129 (clause 27) The Cinematography (Safety) Regulations.

Inspection Process

In new installations, inspection should be carried out progressively as the installation is installed and must be done before it is energized. As far as is reasonably practicable, an initial inspection should be carried out to verify that:

- all equipment and material is of the correct type and complies with applicable British Standards or acceptable equivalents
- all parts of the fixed installation are correctly selected and erected
- no part of the fixed installation is visibly damaged or otherwise defective
- the equipment and materials used are suitable for the installation relative to the environmental conditions.

The following items must be covered in an inspection.

13. **Connection of conductors:** Every connection between conductors and equipment or other conductors must provide durable electrical continuity and adequate mechanical strength. Requirements for the enclosure and accessibility of connections must be considered.
14. **Identification of each conductor:** BS 7671 provides a schedule of colour identification of each core of a cable and its conductors. It should be checked that each core of a cable is identified as necessary. Where it is desired to indicate a phased rotation or a different function for cores of the same colour, numbered sleeves are permitted.
15. **Routing of cables:** Cable routes shall be selected with regard to the cable's suitability for the environment, i.e. ambient temperature, heat, water, foreign bodies, corrosion, impact, vibration, flora, fauna, radiation, building use and structure. Cables should be routed out of harm's way and protected against mechanical damage where necessary. Permitted cable routes are clearly defined in the *IEE On-Site Guide*; alternatively, cables should be installed in earthed

metal conduit or trunking.

16. **Current-carrying capacity:** Where practicable, the cable size should be assessed against the protective device based upon information provided by the installation designer.

17. **Verification of polarity:** It must be checked that no single pole switch or protective device is installed in any neutral conductor. A check must also be made that all protective devices and switches are connected in the line conductor only (unless the switch is a double pole device) and that the Centre contact of Edison screw lamp holders are connected to the line conductor. No switches are permitted in the Circuit Protective Conductor.

18. **Accessories and equipment:** Correct connection is to be checked. BS 7671 is a schedule of types of plug and socket outlets available, the rating and the associated British Standards. Particular attention should be paid to the requirements for a cable coupler. Lamp holders should comply with BS 5042 and be of temperature rating T2.

19. **Selection and erection to minimize the spread of fire:** A fire barrier or protection against thermal effects should be provided if necessary to meet the requirements of BS 7671. The Regulations require that each ceiling arrangement be inspected to verify that it conforms with the manufacturer's erection instructions. This may be impossible without dismantling the system and it is essential, therefore, that inspection should be carried out at the appropriate stage of the work and that this is recorded at the time for incorporation in the inspection and test documents.

20. **Protection against direct contact:** Direct contact as defined in BS 7671 is the contact of persons or livestock with live parts. Live parts are conductors or conductive parts intended to be energized in normal use including a neutral conductor but by convention not a combined Protective Earthed Neutral (PEN) conductor. Protection is provided using the following methods.

    - **Insulation.** Is the insulation damaged or has too much been removed? Although protection by insulation is the usual method there are other methods of providing basic protection.
    - **Barriers.** Where live parts are protected by barriers or enclosures, these should be checked for adequacy and security. Have all covers, lids and plates been securely fitted?
    - **Obstacles.** Protection by obstacles provides protection only against an intentional contact. If this method is used, the area shall be accessible only to skilled persons or to instructed persons under supervision. Obstacles can include a fence around a transformer sub-station and barbed wire fencing on power pylons.
    - **Out of reach.** Placing out of reach protects against direct contact. Increased distance is necessary where bulky conducting objects are likely to be handled in the vicinity
    - **Fault protection:** Fault protection as defined by BS 7671 is the contact of persons or livestock with exposed conductive parts which have

become live under fault conditions. An exposed conductive part is a conductive part of equipment which can be touched but is not live although it can become live under fault conditions. Examples of exposed conductive parts could include metal trunking, metal conduit and the metal case of an electrical appliance, e.g. a classroom overhead projector.

21. Earthing provides protection against this type of fault. We also need to check that extraneous conductive parts have been correctly bonded with protective conductors. An extraneous conductive part is a conductive part that is liable to introduce a potential, generally earth potential, and not form part of an electrical installation; examples of extraneous conductive parts are metal sink tops and metal water pipes. The purpose of the bonding is to ensure that all extraneous conductive parts which are simultaneously accessible are at the same potential. Methods of fault protection are given in BS 7671 as:

- earthed equipotential bonding and automatic disconnection of supply (most common)
- use of class II equipment
- non-conducting location
- earth-free local equipotential bonding
- electrical separation.

22. **Protective devices:** Have they been set correctly for the load? If rewirable fuses have been fitted, has the correct size of fuse wire been used? If a socket is to be provided for outdoor equipment, has a 30 mA rated RCD been fitted?
23. **Checks on documentation:** Diagrams, schedules, charts, instructions and any other information must be available if inspection and testing is to be carried out in a satisfactory manner.
24. **Checks on warning notices:** These should be fixed to equipment operating in excess of 250 volts where this voltage would not normally be expected.

Preparing for inspection

✓ Where a diagram, chart or tables are not available, a degree of exploratory work may be necessary so that inspection and testing can be carried out safely and effectively. Notes should be made of any known changes in environmental conditions, building structure and alterations, which may have affected the suitability of the wiring for its present load and method of installation.

- ✓ A careful check should be made of the type of equipment on site so that the necessary precautions can be taken, where conditions permit, to disconnect or shortout electronic and other equipment which may be damaged by subsequent testing. Special care must be taken where control and protective devices contain electronic components. It is essential to determine the degree of these disconnections before planning the detailed inspection and testing.
- ✓ For safety, it is necessary to carry out a visual inspection of the installation beforebeginning any tests or opening enclosures, removing covers etc. So far as is reasonably practicable; the visual inspection must verify that the safety of persons, livestock and property is not endangered. A thorough visual inspection should be made of all electrical equipment that is not concealed and should include the accessible internal condition of a sample of the equipment. External conditions should be noted and damage identified or, if the degree of protection has been impaired, the matter should be recorded on the schedule of the report. This inspection should be carried out without power supplies to the installation, wherever possible, in accordance with the Electricity at Work Regulations 1989.
- ✓ The inspection should include a check on the condition of all electrical equipment and materials, taking into account any available manufacturer's information with regard to the following:
    - Safety
    - Damage
    - Age
    - Wear and Tear
    - Excessive loading (overloading)
    - External influences
    - Corrosion
    - Suitability

- ✓ The assessment of condition should take account of known changes in conditions influencing and affecting electrical safety, e.g. extraneous conductive parts, plumbing, structural changes etc. It would not be practicable to inspect all parts ofan installation; thus a random sample should be inspected. This should include:
    - checking that joints and connections are properly secured and that

there is nosign of overheating

- checking switches for satisfactory electrical and mechanical conditions
- checking that protective devices are of the correct rating and type; check for accessibility and damage
- checking that conductors have suffered no mechanical damage and have no signs of overheating
- checking that the condition of enclosures remains satisfactory for the type ofprotection required

Periodic inspection and test

BS 7671 requires that the results of any periodic inspection and test should be recorded on a periodic inspection and test report of the type illustrated in Figure 8.02. The report should include the following:

- a description of the extent of the inspection and tests and what parts of theinstallation were covered.
- any limitations (e.g. portable appliances not covered)
- details of any damage, deterioration or dangerous conditions which were found
- any non-compliance with BS 7671
- schedule of test results.

If any items are found which may cause immediate danger, these should be rectified immediately. If this is not possible then they must be reported to a responsible person without delay.

When inspecting older installations, which may have been installed in accordance with a previous edition of the *IEE Wiring Regulations*, provided that all items which do not conform to the present edition of BS 7671 are reported, the installation may still be acceptable, provided that no risk of shock, fire or burns exists.

Details of the client..

Name……………………………………………………………………………………… …………   Address:……………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… …………………………………………………………….....
Purpose of the report……………………………..
Details of the installation   Occupier……………………………………………………………………………………… …………………   Installation address (if different from)………………………………………………   ……………………………………………………………………………………………… ……………………..   Description of premises: Domestic ☐ commercial ☐ Industrial ☐ Other ☐   Estimated age of the installation……......................................… Years   Evidence of alterations or additions……………………………………… Yes/No   Date of last inspection……………………………………………………………………   Records availability……………………………………………………………………
Extent and the limitations of the inspection   Extent of the installation covered by the report………………………..........................   ……………………………………………………………………………………………… ……………………………………..   ……………………………………………………………………………………………… ……………………………………..

Limitations………………………………………………………………………… ………………………………..   ………………………………………………………………………………… …………………………………   ………………………………………………………………………………… ………………………………..   This inspection has been carried out in accordance with BS 7671(IEE wiring regulations). Cables concealed within trunking and conduit cables concealed under floors buried underground installed in roof spaces or generally hidden within the fabric of the building have not been inspected.
Next inspection   (we recommend that this installation should be further inspected and tested after an interval of not more than………. months\years providing that any observations requiring urgent are attended without delay.
Declaration   Inspected and tested by   Name…………………………………Signature……………………………… ………   For and on behalf of ……………………………Position……………………………………………   Address………………………………………. ……………………………………………………   ……………………………………………………. …………………………………………………………………..   ……………………………………………………. Date……………………………………………………...

Table Periodic inspection and test Report

Statutory and Non-statutory regulations

BS 7671 states that, as far as is reasonably practicable, an inspection shall be carried out to verify that:

- all equipment and materials used in the installation are of the correct type and comply with the appropriate British Standards or acceptable equivalent
- all parts of the installation have been correctly selected and installed
- no part of the installation is visibly damaged or otherwise defective
- the installation is suitable for the surrounding environmental conditions

Before carrying out the inspection and test of an installation, BS 7671 requires the person carrying out the work to be provided with the following information:

- the maximum demand of the installation expressed in amperes per phase after diversity has been applied
- the number and type of live conductors, both for the source of energy and for each circuit to be used within the installation (e.g., single-phase two-wire a.c. etc.)
- the type of earthing arrangements e.g., TNS, TNCS, TT etc.
- the nominal voltage (U_o)
- the prospective short-circuit current at the origin of the installation (kA)
- the earth-fault loop impedance (Z_e) of that part of the system external to the installation
- the type and rating of the overcurrent device acting at the origin of the installation

The following information should be provided as part of the design information, which should be checked by the person carrying out the inspection. You may have to sign the electrical installation certificate to confirm that the installation has been designed, installed and tested to comply with BS 7671 with reference to:

- the type and composition of circuits, including points of utilization, number and size of conductors and type of cable used, including the installation method
- the method used to meet the requirements for fault protection
- the information to be able to identify each protective device, isolation and switching and its location.
- any circuit or equipment that may be vulnerable to test.

Detailed inspection Requirements

- ✓ **Anticipation of Danger**
  Identify any equipment that may be damaged if subjected to high-test voltages as well as computer equipment as this may include safety systems such as fire or intruder alarms that could well have electronic components susceptible to test voltages.
- ✓ **Joints and connections**
  Provided the switchgear and distribution boards are accessible as required by the Regulations, then a full inspection of all conductor terminations should be carried out and any signs of overheating or loose connections should be investigated and included in the report. For lighting points and socket outlets a suitable sample should be inspected in the same way
- ✓ **Conductors**
  The means of identification of every conductor, including protective conductors, should be checked and any damage or deterioration to the conductors, their insulation, protective sheathing or armour should be recorded. This inspection should include each conductor at every distribution board within the installation and a suitable sample of lighting points, switching points and socket outlets.
- ✓ **Flexible cables and cords**
  Where flexible cables or cords form part of the fixed installation the inspection should include:
  - examination of the cable or cord for damage or deterioration
  - examination of the terminations and anchor points for any defects

  checking the correctness of the installation with regard to additional mechanical protection or the application of heat resistant sleeving where necessary.
- ✓ **Switches**
  The *IEE Guidance Notes 3 (Inspection & Testing)*, recommends that a random sample of at least 10 per cent of all switching devices be given a thorough internal visual inspection to assess their electrical and mechanical condition. Should the inspection reveal excessive wear and tear or signs of damage due to arcing or overheating then, unless it is obvious that the problem is associated with that particular switch, the inspection should be extended to include all remaining switches associated with the installation.
- ✓ **Protection against thermal effects**
  the presence of fire barriers and seals should be checked wherever reasonably practicable.
- ✓ **Protection against Direct and Indirect contact**

Separate Extra Low Voltage (SELV) is commonly used as a means of protection against both direct and indirect contact. When inspecting this type of system, the points to be checked include the use of a safety isolating transformer, the need to keep the primary and secondary circuits separate and the segregation of exposed conductive parts of the SELV system from any connection with the earthing of the primary circuit or from any other connection with earth.

- ✓ **Basic Protection**

Inspection of the installation should confirm that all the requirements of the Regulations have been met with regard to basic protection against direct contact with live conductors. This means checking to ensure there has been no damage or deterioration of any of the insulation within the installation, no removal of barriers or obstacles and no alterations to enclosures that may allow access to live conductors.

- ✓ **Fault Protection**

The method used for fault protection must be established and recorded on the Inspection Schedule. Where earthed equipotential bonding and automatic disconnection of the supply is used, a check on the condition of the main equipotential bonding conductor and the satisfactory connection of all other protective conductors with earth are essential.

- ✓ **Protective devices**

A check must be made that each circuit is adequately protected with the correct type, size and rating of fuse or circuit breaker. A check should also be made that each protective device is suitable for the type of circuit it is protecting and the earthing system employed, e.g. will the protective device operate within the disconnection time allowed by the Regulations and is the rating of the protective device suitable for the maximum prospective short circuit current likely to flow under fault conditions?

- ✓ **Enclosures and mechanical protection**

The enclosures of all electrical equipment and accessories should be inspected to ensure that they provide protection not less than IP2X or IPXXB, and where horizontal top surfaces are readily accessible they should have a degree of protection of at least IP4X. IP2X represents the average finger of 12mm diameter and 80mm in length and can be tested by a metal finger of these dimensions. IP4X provides protection against entry by strips greater than 1.0mm thickness or solid objects exceeding 1.0mm in diameter.

Visual Inspection

Inspection Requirements

In order to meet the requirements for the inspection process we should also include the checking of the following relevant items:

10. Requirements for basic and fault protection

Separate extra low voltage (SELV) is the most common method of providing both basic and fault protection. Requirements for this type of system include:

- an isolated source of supply, e.g. a safety-isolating transformer to BS 3535(also numbered BS EN 60742 1996)
- electrical separation, which means no electrical connection between the SELV circuit and higher voltage systems
- no connection with earth or the exposed conductive parts or protective conductors of other systems.

11. Specialized systems

12. Prevention of mutual detrimental influence

Account must be taken of the proximity of other electrical services of a different voltage band and of non-electrical services and influences, e.g. fire alarm and emergency lighting circuits must be separated from other cables and from each other, and Band 1 and Band 2 circuits must not be present in the same enclosure or wiring system unless they are either segregated or wired with cables suitable for the highest voltage present. Mixed categories of circuits may be contained in multicore cables, subject to certain requirements. This could also mean checking that water taps have not been fitted directly above a socket outlet. Band 1 circuits are circuits that are nominally extra-low voltage, i.e. not exceeding 50 volts a.c. or 120 volts d.c., such as telecommunications or data and signaling. Band 2 circuits are circuits that are nominally low voltage, i.e. exceeding extra-low voltage but not exceeding 1000 volts a.c. between conductors or 600 volts a.c. between conductors and earth.

13. Isolating and switching devices

BS 7671 requires that effective means suitably positioned and ready to operate should be provided so that all voltage may be cut off from every installation, every circuit within the installation and from all equipment, as may be necessary to prevent or remove danger. This means that switches and/or isolating devices of the correct rating must be installed as appropriate to meet the above requirements. It may be advisable where practicable to carry out an isolation exercise to check that effective isolation can be achieved. This should include switching off, locking-off and testing to verify that the circuit is dead and no other source of supply is present.

14. Under voltage Protection

Suitable precautions must be taken where a loss or lowering of voltage or a subsequent restoration of voltage could cause danger. The most common situation would be where a motor- driven machine stops due to a loss of voltage and unexpectedly restarts when the voltage is restored (unless precautions such as the installation of a motor starter containing a contactor are employed). Regulations require that where unexpected restarting of a motor may cause danger, the provision of a motor starter designed to prevent automatic restarting must be provided.

15. Selection of equipment appropriate to external influences

Items to be considered are ambient temperature, presence of external heat sources, presence of water, likelihood of corrosion, ingress of foreign bodies, impact, vibration, flora, fauna, radiation, building use and structure.

16. Access to switchgear equipment

The Electricity at Work Regulations 1989 and BS 7671 state that every piece of equipment that requires operation or attention must be installed so that adequate and safe means of access and working space are provided.

17. Presence of Drawings, Charts and other similar information

Checks should be made for layout drawings, distribution charts and information on circuits vulnerable to a particular test. All distribution boards should be provided with a distribution board schedule that provides information regarding types of circuits, number and size of conductors and type of wiring etc. These should be attached within or adjacent to each distribution board.

18. Erection Methods

Correct methods of installation should be checked, in particular fixings of switchgear, cables and conduit, etc. which must be adequate and suitable for the environment.

Inspection Checklist

To ensure that all the requirements of the Regulations have been met, inspection checklists should be drawn up and used as appropriate to the type of installation being inspected. Examples of suitable checklists are given in Table

Switchgear (tick if satisfactory)	
Meets requirements of the appropriate BS EN standards	
Securely fixed and suitably labeled	
Suitable glands and gland plates used (526.1)	
Correctly earthed	
Conditions likely to be encountered taken account of, i.e. suitable for the environment	
Correct IP rating	
Suitable as means of isolation	
Complies with the requirements for locations containing a bath or shower	
Need for isolation, mechanical maintenance, emergency and functional switching met	
Fireman switch provided, where required	
Switchgear suitably colored, where necessary	
All connections secure	
Cables correctly terminated and identified	
No sharp edges on cable entries, screw heads etc. which could cause damage to cables	
All covers and equipment in place	
Adequate access and working space	
Wiring accessories (General requirements) (tick if satisfactory)	
All accessories comply with the appropriate British Standard	
Boxes and other enclosures securely fastened	
Metal boxes and enclosures correctly earthed	
Flush boxes not projecting above surface of wall	
No sharp edges which could cause damage to cable insulation	

Non-sheathed cables not exposed outside box or enclosure	
Conductors correctly identified	
Bare protective conductors sleeved green and yellow	
All terminals tight and contain all strands of stranded conductor	
Cord grips correctly used to prevent strain on terminals	
All accessories of adequate current rating	
Accessories suitable for all conditions likely to be encountered	
Complies with the requirements for locations containing a bath or shower	
Cooker control unit sited to one side and low enough for accessibility and to prevent trailing flexes across the radiant plates	
Cable to cooker fixed to prevent strain on connections	
Socket outlet (tick if satisfactory)	
Complies with appropriate British Standard and is shuttered for household and similar installations	
Mounting height above floor or working surface is suitable	
All sockets have correct polarity	
Sockets not installed in bath or shower zones unless they are shaver-type socket or SELV	
Sockets not within 3m of zone 1	
Sockets controlled by a switch if the supply is direct current	
Sockets protected where floor mounted	
Circuit protective conductor connected directly to the earthing terminal of the socket outlet on asheathed wiring installation	
Earthing tail provided from the earthed metal box to the earthing terminal of the socket outlet	
Socket outlets not used to supply a water heater with uninsulated elements	
Lighting controls (tick if satisfactory)	
Light switches comply with appropriate British Standard	

Switches suitably located	
Single-pole switches connected in phase conductor only	
Correct colour-coding of conductors	
Correct earthing of metal switch plates	
Switches out of reach of a person using bath or shower	
Switches for inductive circuits (discharge lamps) de-rated as necessary	
Switches labelled to indicate purpose where this is not obvious	
All switches of adequate current rating	
All controls suitable for their associated luminaire	
Lighting points (tick if satisfactory)	
All lighting points correctly terminated in suitable accessory or fitting	
Ceiling roses comply with appropriate British Standard	
No more than one flexible cord unless designed for multiple pendants	
Devices provided for supporting flex used correctly	
All switch wires identified	
Holes in ceiling above ceiling rose made good to prevent spread of fire	
Ceiling roses not connected to supply exceeding 250 V	
Flexible cords suitable for the mass suspended	
Lamp holders comply with appropriate British Standard	
Conduits (General)(tick if satisfactory)	
All inspection fittings accessible	
Maximum number of cables not exceeded	
Solid elbows used only as permitted	
Conduit ends reamed and bushed	
Adequate number of boxes	
All unused entries blanked off	

Lowest point provided with drainage holes where required	
Correct radius of bends to prevent damage to cables	
Joints and scratches in metal conduit protected by painting	
Securely fixed covers in place adequate protection against mechanical damage	
Rigid metal conduit (tick if satisfactory)	
Complies to the appropriate British standard	
Connected to the main earth terminal	
Line and neutral cables contained within the same conduit	
Conduits suitable for damp and corrosive situations	
Maximum span between buildings without intermediate support	
Rigid non-metallic conduits (tick if satisfactory)	
Complies with the appropriate British Standard	
Ambient and working temperature within permitted limits	
Provision for expansion and contraction	
Boxes and fixings suitable for mass of luminaire suspended at expected temperatures	
Flexible metal conduits (tick if appropriate)	
Complies with the appropriate British Standard	
Separate protective conductor provided	
Adequately supported and terminated	
Trunking (tick if appropriate)	
Complies to the appropriate British Standard	
Securely fixed and adequately protected against mechanical damage	
Selected, erected and rooted so that no damage is caused by ingress of water	
Proximity to non-electrical services	
Internal sealing provided where necessary	
Hole surrounding trunking made good	

Band 1 circuits partitioned from band 2 circuits, or insulated for the highest voltage present	
Circuits partitioned from band one circuits, or wired in mineral-insulated and sheathed cable	
Common outlets for band 1 and band 2 circuits provided with screens, barriers or partitions	
Cables supported for vertical runs	
Metal Trunking (Trunking tick if satisfactory)	
Line and neutral cables contained in the same metal trunking	
Protected against damp corrosion	
Earthed	
Joints mechanically sound, and of adequate earth continuity with links fitted	

Table 5.

Inspection checklist

7.2.1.4 Learning Activities

7.2.1.4.1 Practical activities

An electrical contractor has completed installation for a small private caravan site. The site comprises of 15 dedicated caravan pitches, a toilet and shower block and a combined reception office and a small shop. The building on the site form part of a TN-C-S system supplied at 400\230v with a Ze 0f 0.2 Ω. At the origin of the installation the distribution circuit to the pitch supplies is separated to form a TT system, having an earth electrode resistance of 48Ω and a 500mA RCD as the main isolator. The installation is to be inspected and tested before being placed into services.

d) List all the certification document which particularly relates to the inspection and test for the entire site
e) State the
    iv) Statutory document which particularly relates to the inspection and testing process
    v) Title given to the person carrying out the inspection and test as stated in b(1) above
    vi) Status of a person carrying out the inspection and test
f) List three items of information that should be available to the person carrying out the inspection and test

Self-assessment

11. There are various documents that are relevant to the Inspection and Testing of an installation. State
    a) one statutory item of documentation
    b) two non-statutory items of documentation.
12. List the first three tests that should be carried out during a ***periodic*** inspection andtest of an installation
13. State THREE circumstances that would require a periodic inspection and test to becarried out on an installation.
14. The electrical installation in a small food retail outlet is scheduled for a periodic inspection andtest for local authority licensing.

    a) Describe how the safe isolation of the single-phase distribution board located in the officearea is to be carried out.
    b) Explain why the sequence of testing for this periodic inspection may be different to that givenin BS 7671 for initial verification.
15. A periodic inspection is to be undertaken in a large community Centre which is open to the public.

    v) State what must be agreed with the client and recorded before any work isundertaken.

    vi) State who else must be considered by the inspector in respect to their safety whilstcarrying out this work.

    vii) State three actions the inspector must take to ensure the safety of people using thebuilding during the inspection and testing process.

    viii) List three documents that should be available to the inspector in order for theinspection and testing to be carried out safely.

16. One of the competence requirement identified in guidance note 3 (GN3, is for the inspector to have sound knowledge and experience relevant to the nature of the installation being inspected and tested. List three other competence requirement given in GN3
17. List three items related to the nature of the supply which should be made available to an inspector
18. Explain briefly inspection and testing of a new electrical installation should be carried out
19. State three items would need to be inspected during the first fix construction of a PVC conduit installation for lighting in general purpose workshop
20. State the most appropriate human sense used to identify
    d) Terminals are correctly tightened
    e) Terminals are correctly identified
    f) That a motor has been overloaded

Model Answers to self-assessment

a) For the TNC-S supplied circuits electrical installation certificate, schedule of inspection, schedule of test results.
For the TT supplied caravan pitches, Electrical installation certificate.

Schedule of inspection, schedule of test results.

b)

v) Electricity at work regulation
vi) Duty holder
vii) The duty holder will be competent person
viii) Ensuring no danger to person's livestock property to compare the test results with design criteria to form a view on the state of installation and advice on remedial works to immediately inform the installation owner (and other interested partner's) if dangerous situation exists.

c. Nominal voltage frequency Ze.

2. Electricity at Work act '89 **or** Health & Safety at Work Act '74

BS 767 On

Site Guide

Guidance Notes etc.

2 Continuity of CPC

Polarity

Earth loop impedance

3 End of license (Public buildings)

End of insurance period

Change of ownership

End of recommended period since last test

4 Safe Isolation Procedure

a) Identify the equipment to be worked on and its means of isolation.
b) Unplug the equipment if possible.
c) Isolate and lock off.
d) Prove the voltage tester.
e) Prove the equipment is dead (phase to neutral and phase to earth).
f) Re-prove the voltage tester.
g) Attach temporary earth leads if necessary.
h) Post caution notices.
i) Consider the need for additional precautions.

5 Further safety procedures may be set in place. Permits to work come into their own when dealing with an electrical piece of equipment or installation and are part of an overall strategyfor safety, called a 'safe system of work'.

b) The tests need not be carried out in the order as for the initial verification procedure asthe installation will have been in operation for some time.

The same range and level of testing as for initial testing is not necessarily required, or indeed possible. Installations that have been previously tested and for which there are comprehensive records of test results may not need the same degree of testing as installations for which no such records exist.

The person carrying out the testing should decide which of the above tests areappropriate by using their experience and knowledge of the installation being inspected and tested and by consulting any available records.

The inspector will need to set a sample size for testing. Where a sample test indicates results significantly different to those previously recorded, further investigation is necessary. Also, if during the course of testing a sample, significant errors were found that would suggest that the same problems may exist in untested items, then the inspector has to take appropriate action.

This action needs to be either increasing the sampling or referring back to the client; it may be that the inspector recommends that 100 per cent testing is carried out in that area.

8 i) Prior to carrying out the inspection, the inspector will need to meet with the client or the client's representative to outline the scope and nature of the work required and to highlight likely items that require isolation. That is the degree of disconnection which will be acceptable before planning the detailed inspectionand testing must be agreed. Also, the scope, that is, the extent and limitations of the periodic inspection must be agreed, that is, what is to be covered andwhat is not covered.

iv) As required by law, it is the inspector's duty to ensure the safety of himself orherself and that of others during the test procedure.

v)
- i) The installation must be isolated before disconnecting protectiveconductors.
- ii) Ensure people cannot access exposed/extraneous conductive partswhen using test voltages greater than 50V.
- iii) Use correct test equipment to ensure the test limits are met. For example, limitation of earth fault loop impedance test current to 40ms.

iv)
- Design documentation listing type of supply, earthing arrangements,etc.
- Diagrams.
- Charts or tables identifying isolation and protection devices.
- Previous periodic inspection and test results.

c)
- Correctly identified breakers (circuit details)
- Correct type and rating of main switch and breakers (check ratingsagainst conductor sizes)
- Signs of overheating, thermal damage, etc. (no other visible damage).
- Single pole devices in line conductor
- Manual operation of breakers
- Breakers firmly fixed
- Barrier for IP 2X protection over the busbar
- BS or BS EN markings (or other recognized standard)
- All connections secure, correctly terminated and mechanically sound.

9 Knowledge of relevant regulations

Fully versed in inspection and test procedures
Knowledge and experience to use suitable test equipment

10 Nominal voltage
Frequency
Ze

11 Progressively throughout the different stages of the erection and before being put into service

12 Capacity conduits cables to be installed later
Mechanical protection of conduits where damage
Correct mechanical support of conduits to bear loading by cable
Single pole switch

13 Smell
Touch
Sight

Learning Outcome 3: Perform installation servicing

Presence of storage batteries

Since an emergency occurring in a building may cause the mains supply to fail, the emergency lighting should be supplied from a source which is independent from the main supply. A battery's ability to provide its output instantly makes it a very satisfactory source of standby power. In most commercial, industrial and public service buildings housing essential services, the alternative power supply would be from batteries. The emergency lighting supply must have an adequate capacity and rating for the specified duration of time (IEE Regulation 313.2). BS 5266 and BS EN 1838 states that after a battery is discharged by being called into operation for its specified duration of time, it should be capable of once again operating for the specified duration of time following a recharge period of no longer than 24 hours. The duration of time for which the emergency lighting should operate will be specified by a statutory authority but is normally 1–3 hours. The British Standard states that escape lighting should operate for a minimum of 1 hour.

The batteries used for the emergency supply should be suitable for this purpose. The British Standard recommends that the full load should be carried by the emergency supply for at least 1 hour in every 6 months. After testing, the emergency system must be carefully restored to its normal operative state. A record should be kept of each item of equipment and the date of each test by a qualified or responsible person. It may be necessary to produce the record as evidence of satisfactory compliance with statutory legislation to a duly authorized person. Self-contained units are suitable for small installations of up to about 12 units. The batteries contained within these units should be replaced about every 5 years, or as recommended by the manufacturer. Storage batteries are secondary cells. A secondary cell has the advantage of being rechargeable. If the cell is connected to a suitable electrical supply, electrical energy is stored on the plates of the cell as chemical energy. When the cell is connected to a load, the chemical energy is converted to electrical energy.

A lead-acid cell is a secondary cell. Each cell delivers about 2 V, and when six cells are connected in series a 12 V battery is formed. A lead-acid battery is constructed of lead plates which are deeply ribbed to give maximum surface area for a given weight of plate. The plates are assembled in groups, with insulating separators between them. The separators are made of a porous insulating material, such as wood or ebonite, and the whole assembly is immersed in a dilute sulphuric acid solution in a plastic container. The capacity of a cell to store charge is a measure of the total quantity of electricity which it can cause to be displaced around a circuit after being fully charged. It is stated in ampere-hours, abbreviation Ah, and calculated at the 10-hour rate which is the steady load current which would completely discharge the battery in 10 hours. Therefore, a 50 Ah battery will provide a steady current of 5A for 10 hours.

Maintenance of lead-acid batteries

- The plates of the battery must always be covered by dilute sulphuric acid. If the level falls, it must be topped up with distilled water.
- Battery connections must always be tight and should be covered with a thin coat of petroleum jelly.
- The specific gravity or relative density of the battery gives the best indication of its state of charge. A discharged cell will have a specific gravity of 1.150, which will rise to 1.280 when fully charged. The specific gravity of a cell can be tested with a hydrometer.
- To maintain a battery in good condition it should be regularly trickle-charged. A rapid charge or discharge encourages the plates to buckle, and may cause permanent damage. Most batteries used for standby supplies today are equipped with constant voltage chargers. The principle of these is that after the battery has been discharged by it being called into operation, the terminal voltage will be depressed and this enables a relatively large current (1–5A) to fl ow from the charger to recharge the battery. As the battery becomes more fully charged its voltage will rise until it reaches the constant voltage level where the current output from the charger will drop until it is just sufficient to balance the battery's internal losses. The main advantage of this system is that the battery controls the amount of charge it receives and is therefore automatically maintained in a fully charged condition without human intervention and without the use of any elaborate control circuitry.
- The room used to charge the emergency supply storage batteries must be well ventilated because the charged cell gives off hydrogen and oxygen, which are explosive in the correct proportions

Having successfully diagnosed the electrical fault and carried out the necessary repairs or having completed any work in the electro technical industry, we come to the final practical task, leaving the site in a safe and clean condition and the removal of any waste material. This is an important part of company's 'good customer relationships' with the client and having a good attitude to health and safety, working conscientiously and neatly, keeping passageways clear and regularly tidying up the workplace is the sign of a good and competent craftsman. But what do you do with the rubbish that the working environment produces? Well:

- All the packaging material for electrical fittings and accessories usually goes into either your employer's skip or the skip on site designated for that purpose.
- All the off-cuts of conduit, trunking and tray also go into the skip.
- In fact, most of the general site debris will probably go into the skip and the waste disposal company will take the skip contents to a designated local council landfill area for safe disposal. The part coils of cable and any other reusable leftover lengths of conduit, trunking or tray will be taken back to your employer's stores area. Here it will be stored for future use and the returned quantities deducted from the costs allocated to that job.
- What goes into the skip for normal disposal into a landfill site is usually a matter of common sense. However, some substances require special consideration and disposal. We will now look at asbestos and large quantities of used fluorescent tubes which are classified as 'special waste' or 'hazardous waste'.

Asbestos is a mineral found in many rock formations. When separated it becomes a fluffy, fibrous material with many uses. In the buildings where it was installed some 40 years ago, when left alone, it does not represent a health hazard, but those buildings are increasingly becoming in need of renovation and modernization. It is in the dismantling and breaking up of these asbestos materials that the health hazard increases. Asbestos is a serious health hazard if the dust is inhaled. The tiny asbestos particles find their way into delicate lung tissue and remain embedded for life, causing constant irritation and eventually, serious lung disease. If asbestos is present in situations or buildings where you are expected to work, it should be removed by a specialist contractor before your work commences. Specialist contractors, who will wear fully protective suits and use breathing apparatus, are the only people who can safely and responsibly carry out the removal of asbestos. They will wrap the asbestos in thick plastic bags and store them temporarily in a covered and locked skip. This material is then disposed of in a special landfill site with other toxic industrial waste materials and the site monitored by the local authority for the foreseeable future.

Removing the old fluorescent fittings hanging on chains or fixed to beams and installing a suspended ceiling and an appropriate number of recessed modular fluorescent fittings. These fittings are made of sheet steel, a couple of plastic lamp holders, a little cable, a starter and ballast. All of these materials can go into the ordinary skip. However, the fluorescent tubes contain a little mercury and fluorescent powder with toxic elements, which cannot be disposed of in the normal land fill sites. Hazardous Waste Regulations were introduced in July 2005 and under these regulations lamps and tubes are classified as hazardous. The environmentally responsible way to dispose of fluorescent lamps and tubes is to recycle them. The process usually goes like this:

- Your employer arranges for the local electrical wholesaler to deliver a plastic waste container of an appropriate size for the job.
- Expired lamps and tubes are placed whole into the container, which often has a grating inside to prevent the tubes breaking when being transported.

- When the container is full of used lamps and tubes, you telephone the electrical wholesaler and ask them to pick up the filled container and deliver it to one of the specialist recycling centers.
- Your electrical company will receive a 'Duty of Care Note' and full recycling documents which ought to be fi led safely as proof that the hazardous waste was recycled safely.
- The charge is approximately 50p for each 1800mm tube and this cost is passed on to the customer through the final account.

NB:

- Clean up before you leave the job.
- Put waste in the correct skip.
- Recycle used lamps and tubes.
- Get rid of all waste responsibly.

Learning outcome 4: Conduct installation tests

Before a completed installation may be connected to the supply a number of tests are required to indicate the general condition of the installation, both with regard to the insulation resistance of the conductors and other current-carrying parts and with regard to the conductance of the earthing system. The tests which are to be made are not a complete guarantee of the quality of the installation for all time, and regular testing is necessary in order that it may be maintained in a proper condition throughout its life.

Insulation resistance.

This is the resistance in ohms between the live parts of the installation and earth, measured through insulating covering of the conductors, etc. In the case of metal-covered wiring or conduit wiring, the term 'earth' means in practice the metallic covering or conduit which itself is connected directly to earth. Additionally, the insulation resistance is measured between lines, that is, between the opposite poles of the installation with lamps or other apparatus disconnected and switches on.

The difference between insulation and conductor resistance is shown in the sketches (Figs. 93 and 94). In measuring the resistance of a

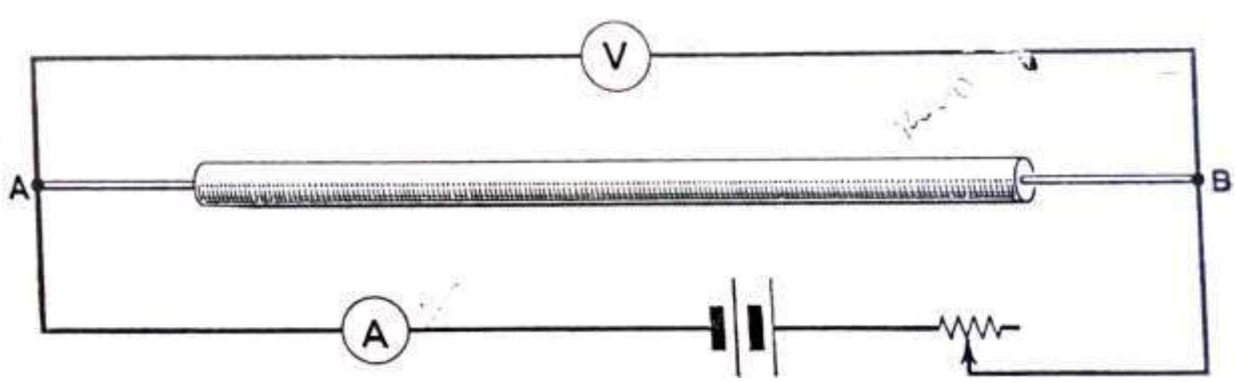


Fig. 1 Measuring conductor resistance

conductor AB, the resistance is measured along the wire from end to end, and increase of conductor length means increase of resistance. In measuring the insulation resistance of the conductor, the measurement is made from the conductor outwards.

The formula for conductor resistance is R =pl where / is the length a of the conductor, a is the cross-sectional area, and p is the resistivity of the conductor material. Using a similar formula for insulation (it is sufficiently true for the purposes of this argument), R' = p'l/a’ the thickness of the insulation, a' is proportional to the length of the wire, and p' is the resistivity of the insulating material.

Conduit or metallic covering

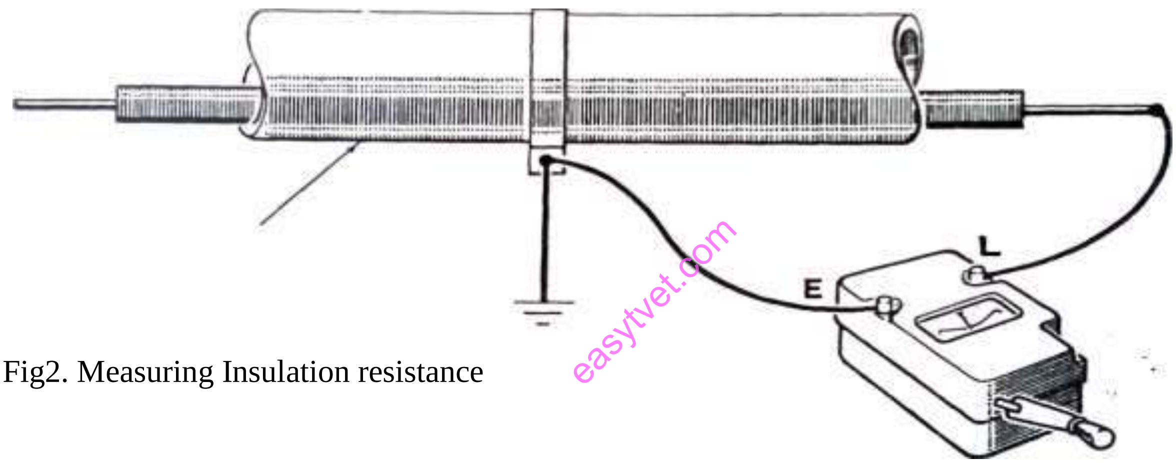


Fig2. Measuring Insulation resistance

Thus, if an insulated wire is increased in length, its conductor resistance increases while its insulation resistance decreases. Therefore, the longer the conductor the less will be its insulation resistance.

Inspection of installations.

During the fitting of the various parts of an installation some form of inspection by the electrical contractor or his staff is both desirable and necessary, Small faults could be brought to light and corrected thus preventing waste of time during the final testing session. Alternatively, a careful inspection should be made immediately prior to the testing.

Regulations. I.EE.

Regulations EI to E 14 deal with the testing and inspection of installations. These regulations are discussed below, and methods of complying with them are described in detail.

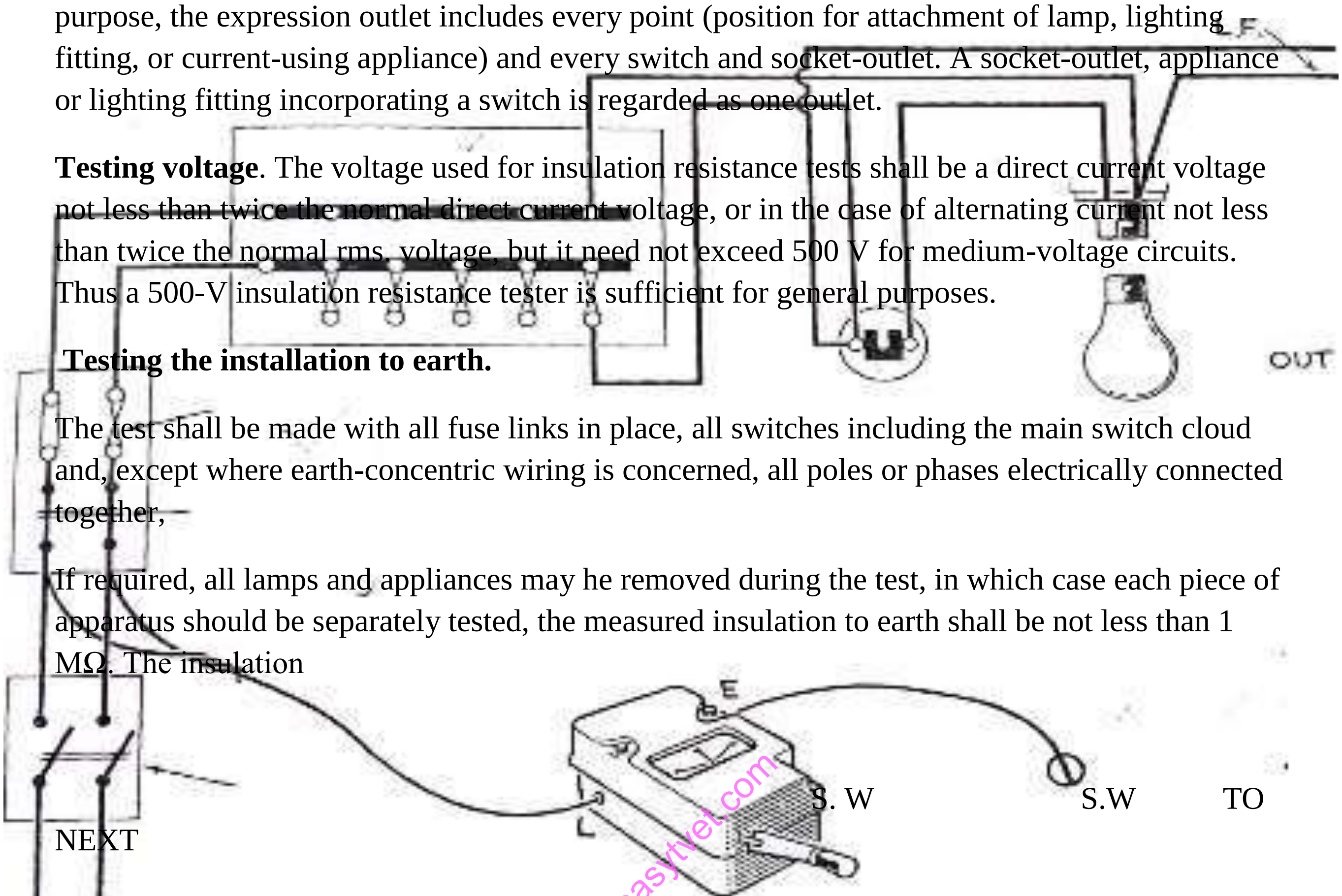
Insulation resistance tests, Regulations E 6 and E 9. The various tests of an installation which follow are to be made before the installation is connected to the supply, For the insulation resistance tests large installations may be divided into groups of not less than 50 outlets. For this purpose, the expression outlet includes every point (position for attachment of lamp, lighting fitting, or current-using appliance) and every switch and socket-outlet. A socket-outlet, appliance or lighting fitting incorporating a switch is regarded as one outlet.

Testing voltage. The voltage used for insulation resistance tests shall be a direct current voltage not less than twice the normal direct current voltage, or in the case of alternating current not less than twice the normal rms. voltage, but it need not exceed 500 V for medium-voltage circuits. Thus a 500-V insulation resistance tester is sufficient for general purposes.

Testing the installation to earth.

The test shall be made with all fuse links in place, all switches including the main switch cloud and, except where earth-concentric wiring is concerned, all poles or phases electrically connected together,

If required, all lamps and appliances may he removed during the test, in which case each piece of apparatus should be separately tested, the measured insulation to earth shall be not less than 1 MΩ. The insulation



S. W S.W TO NEXT

POINT

LAMPS

FUSES IN SWITCHES CLOSED

SWITCH CLOSED

COMPANY’S

MAIN SWITCH

OFF
EARTH TERMINAL

Fig 3 Testing insulation resistance of completed installation

resistance of each piece of apparatus measured separately shall be not less than 0-5 MM to earth (between live parts and frame), and 05MΩ between poles or phases. The sketch (Fig.) shows the connections for testing the insulation resistance to earth of a completed 2-wire installation with lamps and other apparatus disconnected. The wires of both poles of the supply to the main switch are twisted together and connected to the 'line' terminal of the ohmmeter. The 'earth' terminal of the ohmmeter is connected to the consumer's earthing terminal. The three terminals of 2-way switches should temporarily be connected together.

Testing between conductors.

This test is made between all the conductors connected to any one pole or phase of the supply, and all conductors connected to any other pole or phase of the supply. The insulation resistance is to be not less than 1 MΩ.

All lamps should be removed, all current-using apparatus dis connected and all local switches controlling lamps or apparatus closed. When the removal of lamps and apparatus is not practicable, all local switches should be open. The test does not apply to earthed concentric wiring systems. Figure 97 gives the connections for the test of a 2-wire installation. Only one test is required in this case.

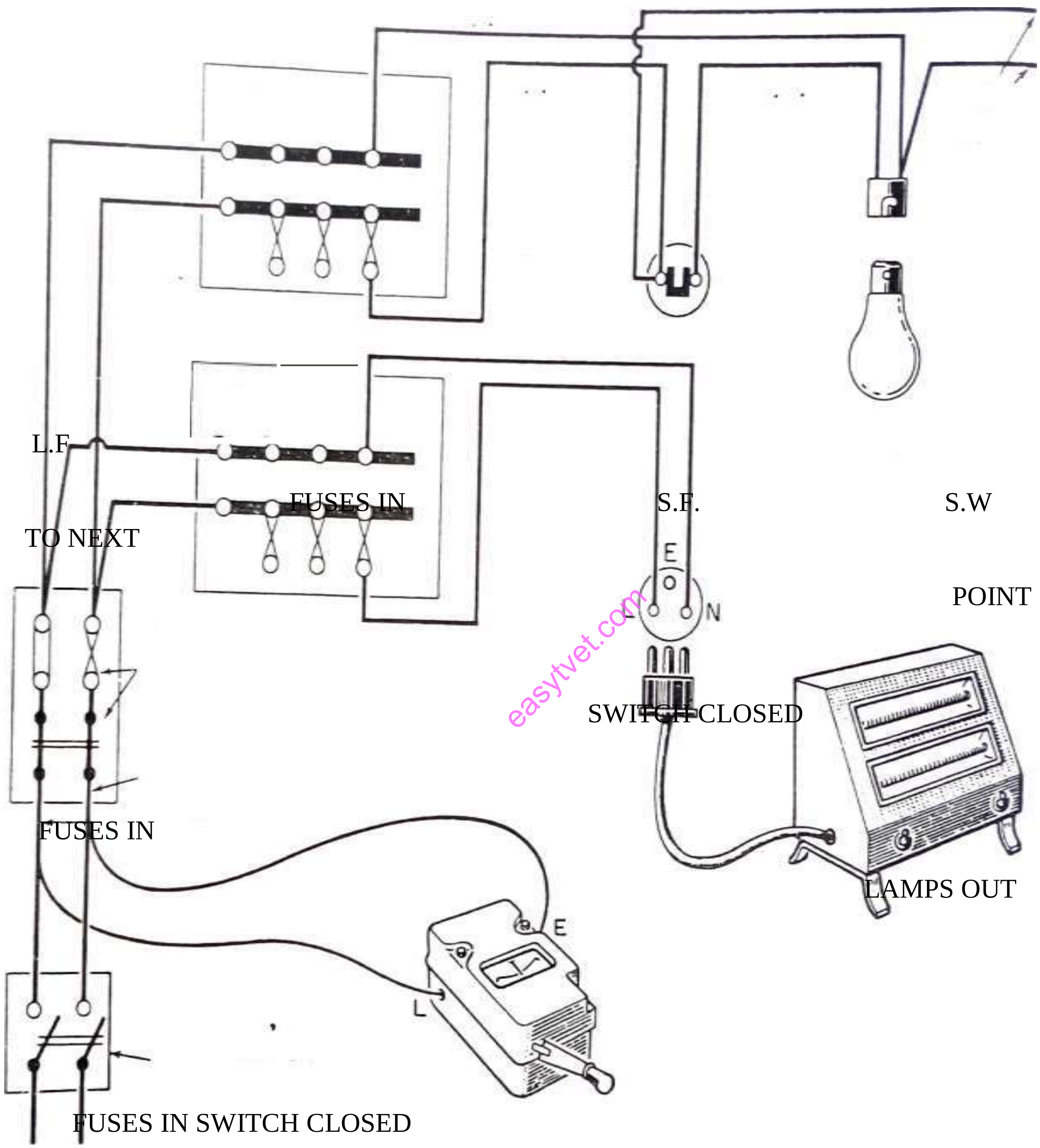
Electrical installation work

For 3 and 4-wire installations more than one between phases test is necessary. A 3-wire direct current installation will require three tests:

1. between positive line and neutral,

2. between negative line and neutral,

3. between positive and negative lines


L.F
FUSES IN
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N
POINT
SWITCH CLOSED
FUSES IN
LAMPS OUT
E
L
FUSES IN SWITCH CLOSED
PHASE OR OUTER
NEUTRAL

HEATERS ETC

DISCONNECTED

COMPANY'S MAIN SWITCH OFF

Figure 4.

A 3-wire 3-phase installation will also require three tests:

1. between lines R and Y,

2. between lines R and B,

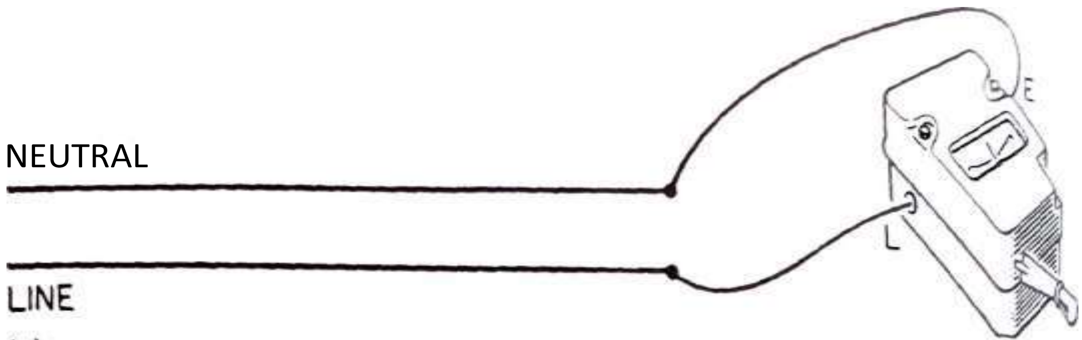
3. between lines Y and B.

A 3-phase 4-wire installation will require six tests:

1. three separate tests between pairs of lines, R-Y, R-B, and Y-B.

2. three separate tests, R-neutral, B-neutral and Y-neutral.

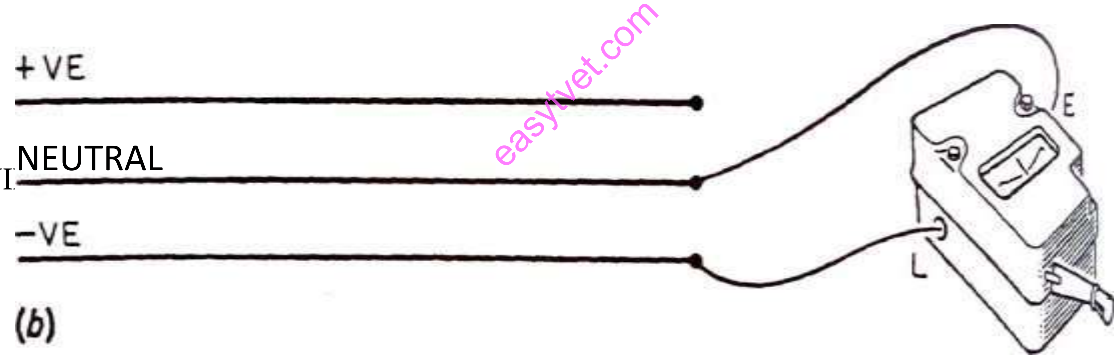
Figures 98 (a) to (d) show the test connections in a simplified form.



(a)

y wIRE

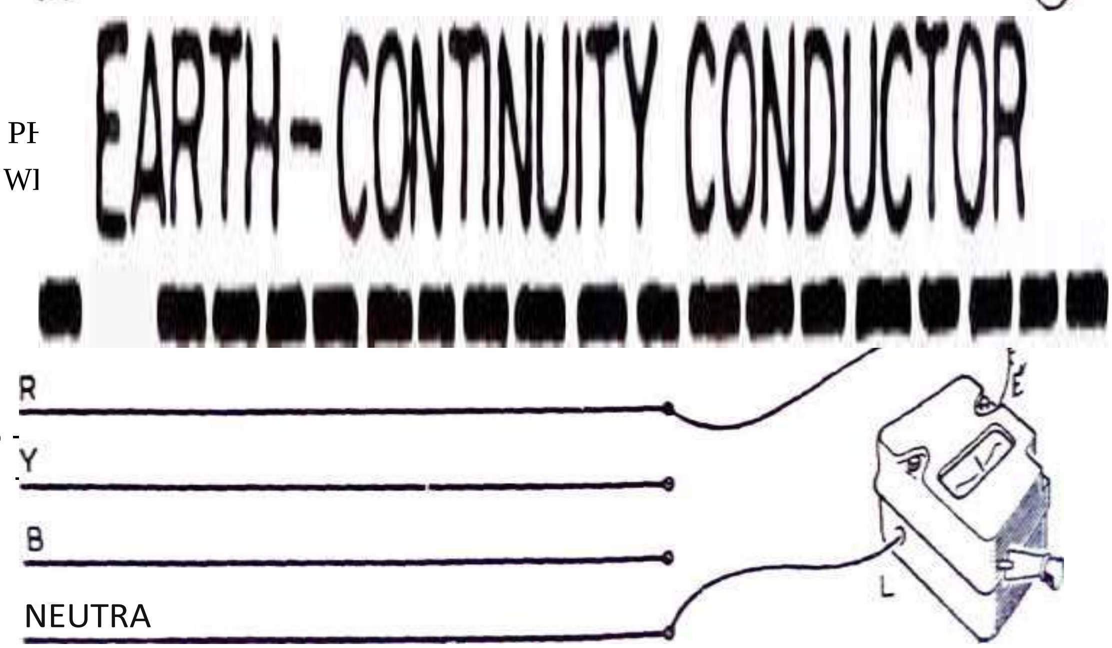
3-WI
d.‹x



(b)

3- PH
3- WI

5 -
6 -



(d)

Fig 5 (a) to (d) Simplified diagrams of tests between conductors

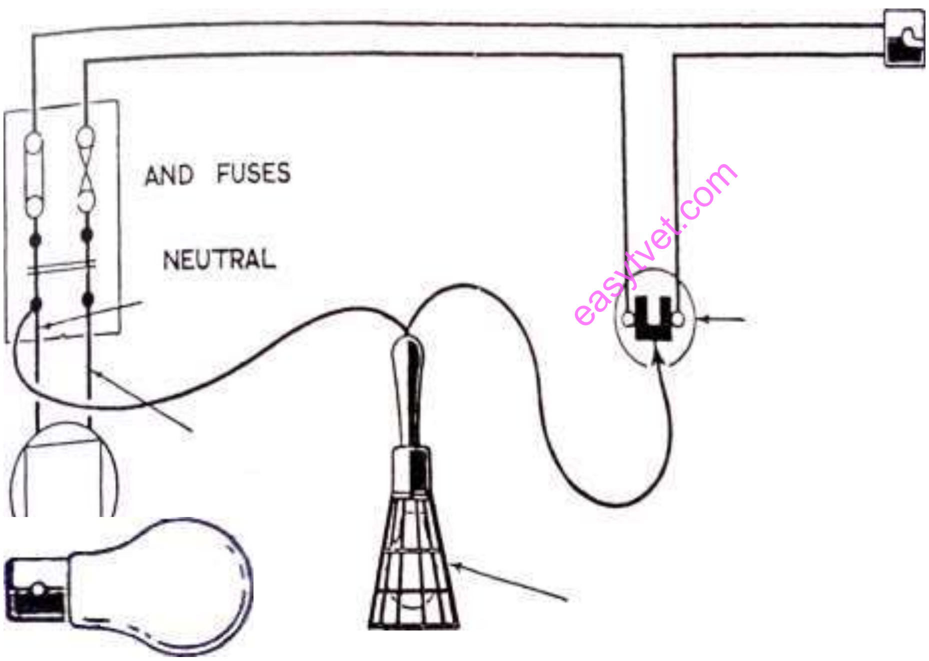
Verification of polarity of single-pole switches, etc. . Regulation E requires that it shall be ensured that all fuses and single-pole control devices are connected in the live conductor only; that the outer contact of Centre-contact bayonet and Edison-type screw lamp holders are C nested to the neutral or earthed conductor; and that plugs and socie outlets have been correctly wired.

On p. 12 it was noted that by I.E.E. Regulation all single-pole or linked switches were to be fitted in the outer or phase conductor. If the proper colored cable is used throughout the installation, i.e., in a2-wi installation, red for switch feeds and switch wires and black for light feeds, no confusion should arise.

Paying for polarity with circuit alive. The simplest way to test is with the circuit alive, switched on the main switch, All single-pole switches would be ON', their covers removed, all lamps should be out, and other Neutral should be disconnected, If the single-pole switches are in the Correct conductor, the phase or outer conductor, they will be alive. A portable lamp with a pair of long insulated leads is used. The leads Should terminate in insulated test prods in the interests of safety. The end of one prod is connected to the known earthed conductor at the main switch, and the other prod is touched to the single-pole switch terminals. The test lamp should light. Should the switch be in the wrong or earthed conductor, the test lamp will not light as the switch will be at earth potential. This procedure is repeated at all the switches in turn. In the case of 2-way switches, the three terminals of the switches should be temporarily connected together for the test. In a large installation the work can be sectionalized by checking the polarity of the busbars at the distribution boards and working from these positions instead of running the test lead back to the main switch. The test should be extended to verify that the three-pin socket outlets are properly connected, that is, with the terminal marked 'L' connected to the outer or phase conductor,

In testing screw-type lamp holders to ensure that the outer contact is earthed, one prod should be touched to the live side of the main switch and the other prod to the outer contact of the lamp holder, when the test lamp should light. It must be remembered that the test is being made on a live circuit, and care must be taken, otherwise unpleasant or dangerous shocks may be sustained; Figures above illustrate the tests.

Testing for polarity with circuit dead. Testing instruments are available by which the polarity of the circuit switches can be tested before the installation is connected to the supply. In its simplest form the instrument consists of a direct-reading ohmmeter and a small dry battery contained in a small case, with two terminals to which a pair of test leads with or without testing spikes may be connected. Figure 103 illustrates the test. The main switch and fuses are out, lamps and other apparatus are out or disconnected, and the single-pole switches are on. One lead of the polarity tester is connected to the phase or outer conductor at the outgoing side of the main fuses. The other lead is touched to the terminals of the single-pole switches in turn. Provided the polarity is correct, the instrument reading will be less than I 2 normally, since the instrument is measuring the resistance of the circuit wiring from the main fuse to the switch being tested. If the single-pole switch is in the



CONSUMERS MAIN SWITCH

LAMPS OUT

CONDUCTOR

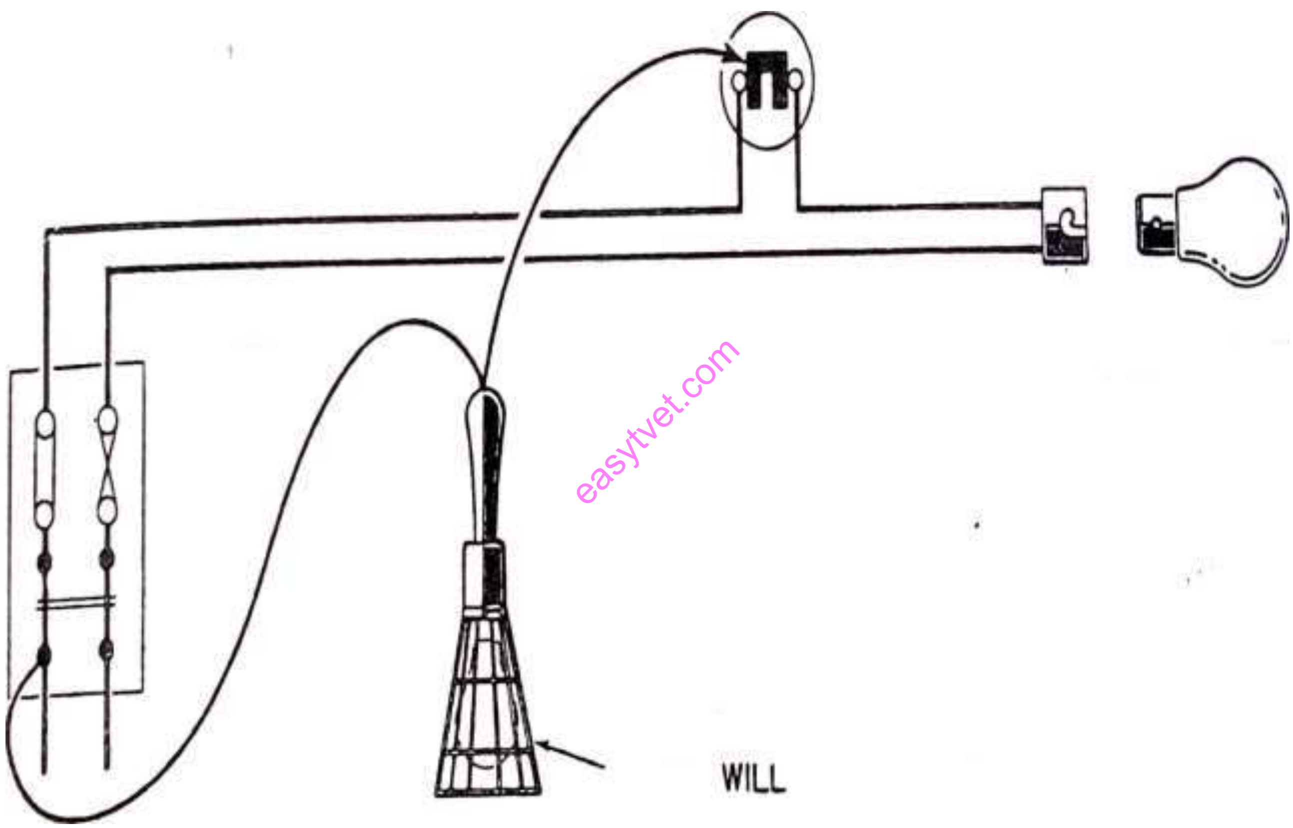
SWITCHES ON

PHASE OR OUTERLAMP WILL LIGHT

CONDUCTOR

METER

Fig5 Testing for polarity of switch, correct



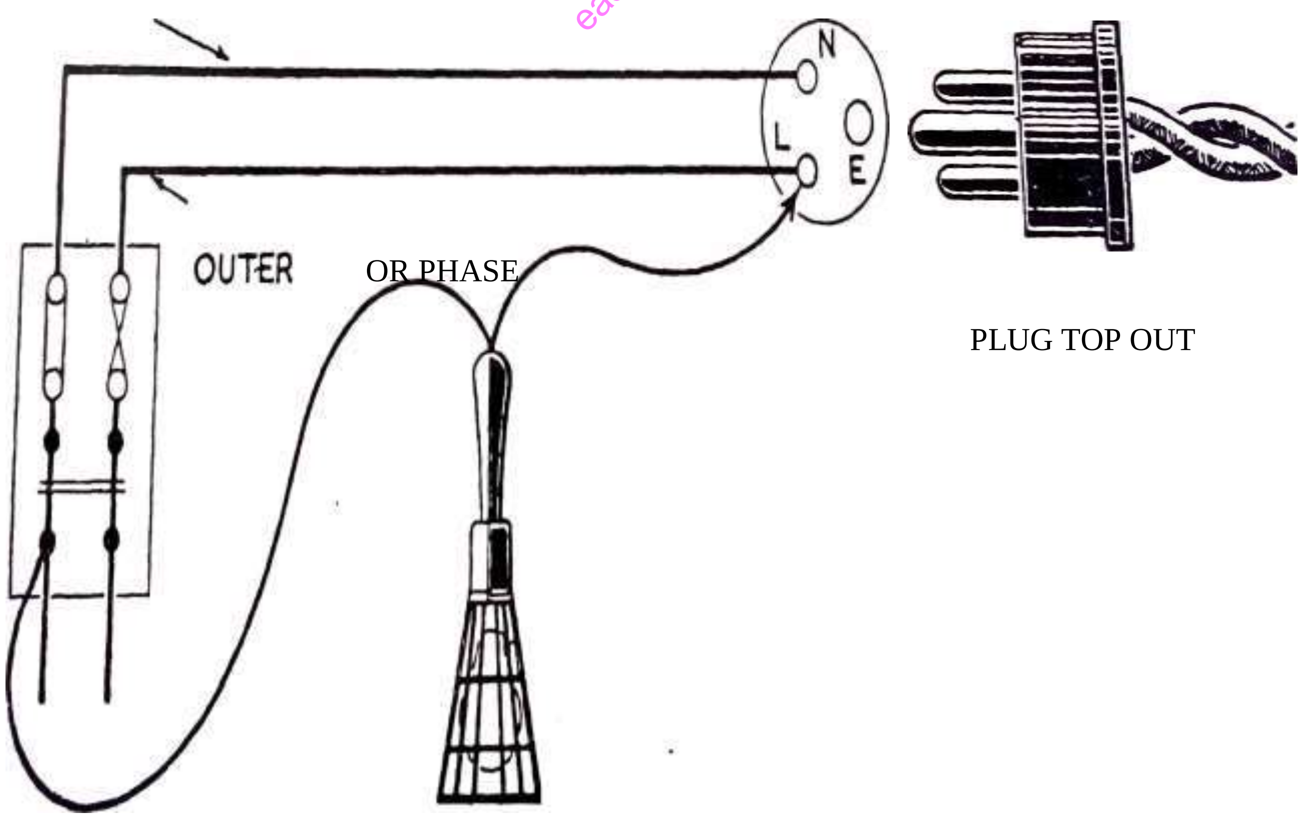
NEUTRAL ↘

↖ PHASE OR OUTER LAMPS OUT

LAMPS

WILL NOT LIGHT

Fig 6 Testing for polarity of switch, incorrect



LAMP WILL LIGHT

Fig 7 Testing 3-pin socket outlet, correct

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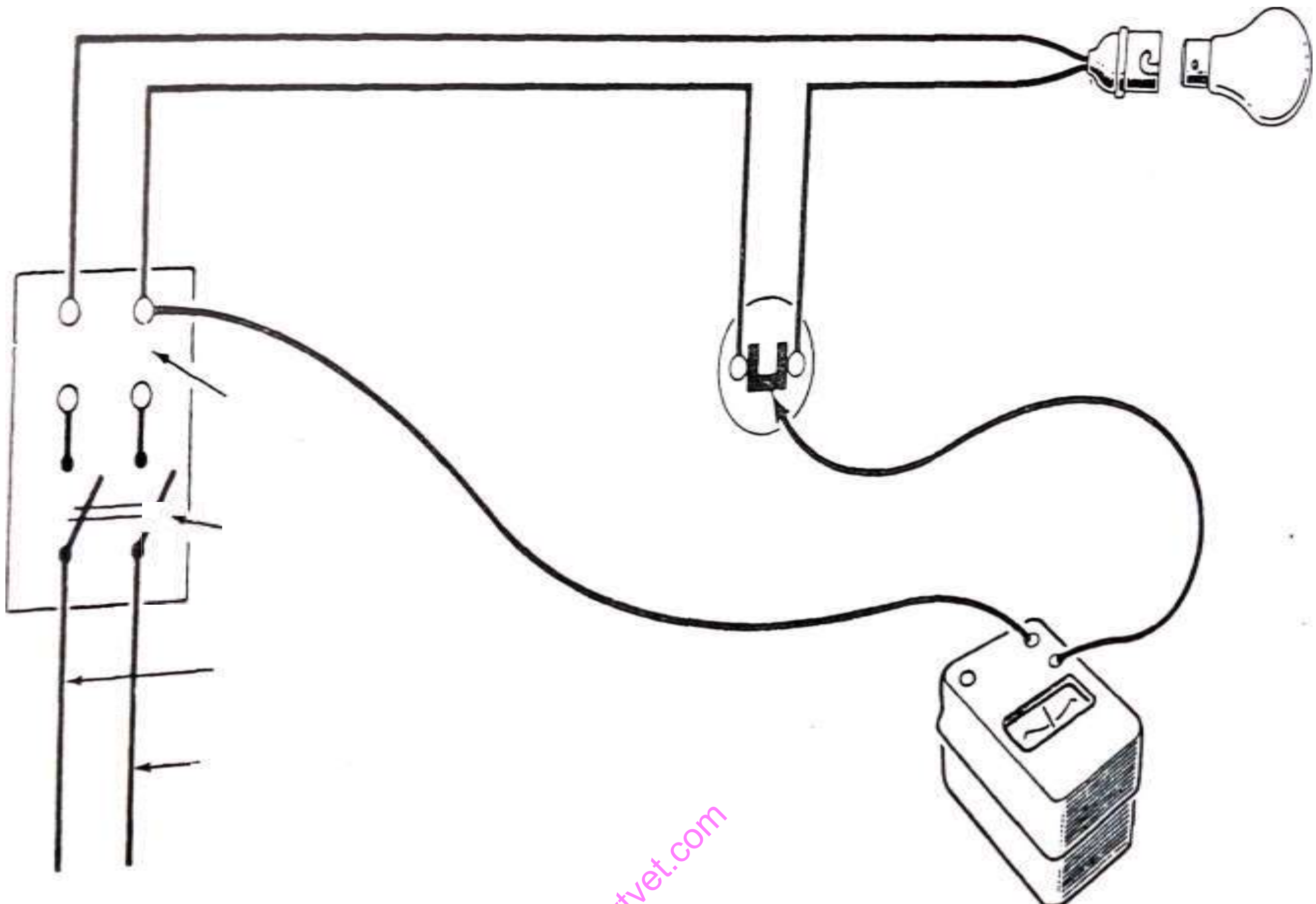


incorrect conductor the instrument reading will be a maximum, i.e., infinity. The polarity of the 3-pin socket outlet is tested in a similar way.

LAMPS OUT

YY FUSES OUT

MAIN SWITCH OPEN

NEUTRAL

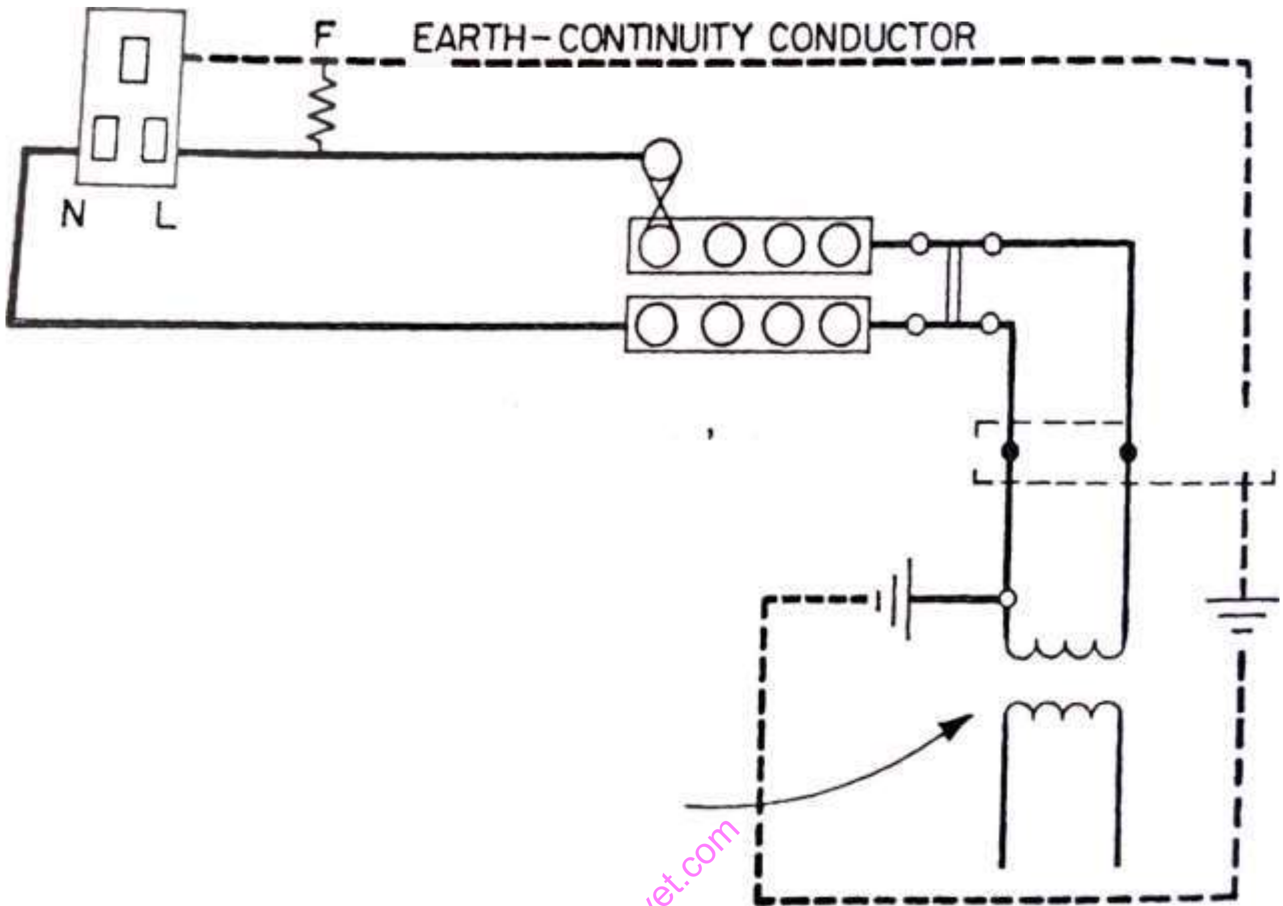
PHASE OR OUTER

Fig. 8 Testing for polarity of switch with circuit dead

Test of earth-leakage circuit-breaker.

In accordance with Regulation E 5, the effectiveness of earth-leakage circuit-breakers is to be verified. The IEE Regulations states that a voltage not exceeding 45 V, obtained from a double-wound transformer connected to the mains supply, shall be applied across the neutral and earth terminals (or neutral and frame terminals of a voltage operated Earth leakage circuit-breaker) and the circuit breaker shall trip instantaneously.

Earth-fault loop testing. Regulation E 4 requires that when earth leakage protection relies on the operation of fuses or excess-current circuit-breakers, the effectiveness of earthing shall be tested by means of an earth-loop impedance test.



CONSUMER'S TERMINALS

SUPPLY AUTHORITY EARTH ELECTRODE

SUPPLY TRANSFORMER

EARTH

PATH

Fig 9 .Line-earth loop

The diagram Figure above shows the path of leakage current from an earth fault on a 2-wire final sub-circuit. The path of the leakage current is from the earth fault (F) along the earth-continuity conductor to the consumer's earthing terminal and thence to the consumer's earth electrode. From here the fault current passes through the general mass of earth to the supply authority's earth electrode at the supply trans former, through the transformer winding and along the line through the consumer's wiring to the fault. This path is called the line earth loop, and it is this loop which is to be tested, The Regulations allow the neutral-earth loop to be tested as an alternative.

A line-earth tester such as the Megger line-earth tester would be used. The operation of this instrument is as follows:

The instrument passes a short duration current through the loop, the value of the current depending upon the impedance of the loop as well as upon the voltage of the tester. The current passes through 10 resistors in series with the loop, and the voltage drop across it is measured by means of a ballistic instrument which is calibrated to read directly the loop impedance in ohms. This instrument incorporates a voltmeter and a voltage selection switch, enabling it to be used on supplies of different line-neutral voltages.

Test of earth-continuity conductor.

Regulation E 3 requires that every earth-continuity conductor shall be tested in accordance with Item 1 of Appendix 6. Four methods are given:

- **Alternating current test.**
  It is suggested that one of the current conductors of known resistance shall be disconnected and used as part of the test circuit. At the remote end of the final sub-circuit this cable and the earth-continuity conductor are connected together forming a lead and return. At the other end an alternating current supply not exceeding 40 V at approximately supply frequency is applied to the end of the conductor/e.c.c loop. A current of approximately times the rating of the final sub-circuit is passed through the

loop, with a maximum value of 25 A. The impedance of the e.c.c which is the ratio voltage/current, minus the resistance of the known conductor, should not exceed 1Ω.

- **Alternating current test at reduced current.**
  preferred, a lower value of current may be applied, at approximately supply frequency, The impedance values allowable are, not more than 050 where the e.c.c is partly or wholly of steel conduit or pipe, and I 0 where the e.c.c is wholly of copper, copper alloy, or aluminium.
- **Direct current test of an alternating current installation.**
  Direct current may be used for the test provided that a proper inspection of the e.c.c ensures that there is no inductor incorporated in the e.c.c. The values of impedance are not to exceed 0-5 for steel conduit or pipe, and 1Ω for copper, copper alloy, or aluminium.
- **No current test of direct current installation**
  This test can be made, using say, a secondary battery and rheostat, with a current approaching 1-5 times the rating of the sub-circuit under test, subject to a maximum of 25 A. Alternatively, a hand tester may be used with a reduced current. In each case the resistance obtained by the test should not exceed 1 Ω.

Test of ring-circuit continuity

Regulation E 10 requires that a conductor, including the earth-continuity conductors, shall be verified for continuity, this may be done with a continuity tester, probably a battery type as used for polarity testing on p. 116.

All apparatus must be disconnected from the ring. The ring is the disconnected at the distribution board so that the four ends of the ring conductors are exposed. Touching the continuity tester across the two ends of the line conductor will give a very low reading, showing continuity. The neutral conductor is checked in a similar way.

To check the conductors in the spurs, the ring should remain open with ends exposed. A continuity test would be made across line end neutral from the end socket-outlet on any spur, when the indication should be infinite resistance. This could be repeated at every spur end. If one pair of exposed wires, line and neutral, at the exposed ends be now temporarily short-circuited, continuity readings from each spur end should show very low resistance, thus verifying continuity.

The earth-continuity conductors could be checked for continuity at the same time.

Completion certificate

On completion of a new installation or of a major alteration, and after inspection and testing as described, the installation contractor is required to give a Completion Certificate. This certificate, gives certain details of the installation including the number of appliances, etc., the method of earthing, and the value of the earth-loop impedance. The certificate states that the work has been done in accordance with Regulations. It also recommends periodic testing and inspection.

Inspection certificate

When the installation is re-inspected and tested at a later date, an inspection certificate is completed and handed to the consumer. It gives the results of the full range of tests of the installation.

Practical activities

The test results shown in figure below were obtained from a ring final circuit continuity test. State whether reading for each socket are satisfactory or unsatisfactory. give reason for those reading unsatisfactory.

Note: line, neutral and c.p.c loops =0.8Ω

Socket	L-N	L-c.p.c
A	0.4	0.41
B	Not reading	0.39
C	0.5	0.4
D	0.4	No reading
E	0.41	0.41

9.

c. Describe in details the test procedure for insulation resistance on the installation

d. The test results indicate an overall value of 1.5Ω. state with reasons what actions if any should be taken

10. A loop impedance test on the lighting circuit is conducted and 6A type B m.c.b trips repeatedly

b. Explain why this is the case

Explain why the problem may be overcome in order to conduct the test

3. Explain briefly the action to be taken if the insulation resistance test of an installation indicates an overall value of 1.25 M-ohms

11. A ring final circuit continuity test revealed incorrect polarity on three socket outlets.The results were

	L to N	L to c.p.c.
Socket A	Open circuit	Correct
Socket B	Correct	Open circuit
Socket C	Open circuit	Open Circuit

State which conductors have reversed polarity in each case.

12. For an insulation resistance test on domestic installation, state the

IV. Instrument to be used

V. Resistance range at which this instrument should set

VI. Measured value below which each circuit would need to be tested separately

13. A live polarity test is to be conducted. State

iv) Why such a test is necessary

v) The instrument to be used

vi) How neutral-earth polarity is checked

14. Earth fault impedance is to be conducted on a radial circuit during an initial verification. State

iv) Where on circuit the circuit should be conducted

v) Which value measured or corrected should be recorded on the scheduled test results

vi) Why the value in b above may not be the same as Ze + (R1+R2)

4.

15. List

c. Five relevant test including the individual instrument required on the outer house supply cable following the test for continuity protective conduction

d. Five relevant inspection required when inspecting the installation of the outer house supply cable

16.

c. Explain why the earth fault loop impedance test results on lighting circuit in the outer house is likely to be significantly higher than a similar circuit in the main property

d. Explain briefly

iii) Why the main switch may operate when testing for earth loop impedance on the lighting circuit in the outer building

iv) How you would overcome the problem encountered in b (1)

Answers to practical Activity

1. As the line, neutral and c.p.c loops are0.8Ω, the outlet readings should be in the order of 0.4Ω +0.05Ω

Socket A L-N reading is acceptable

L-CPC reading is acceptable

Conclusion polarity is correct

Socket B L-N reading is unacceptable- no continuity

L-CPC reading is acceptable

Conclusion Reverse polarity on P/CPC conductors or Neutral is not connected to terminal

Socket C L-N reading is unacceptable- too high (greater than ±0.05Ω)

L-CPC reading is acceptable

Conclusion May indicate a loose connection on the neutral conductor

Socket D L-N reading is unacceptable

L-CPC reading is unacceptable- no continuity

Conclusion reverse polarity on P-N conductors or CPC is not connected

Socket E L-N reading is acceptable

L-CPC reading is acceptable

Conclusion polarity is correct

1. a) isolate the supply and loop off

-all switched closed

-all current using equipment removed

- all fuse/M.C. B's in place\on

-all equipment vulnerable to test should be removed

-test performed at meter tails if possible

Test between live conductors (L&N)

live conductors and earth

b) this could indicate a latent defect. Each circuit should be tested individually and its insulation resistance should be greater than 2Ω.

2.a. As loop impedance tester delivers high current for a short time. It is not.

b. The loop impedance in such cases will have to be determined by a:

- measure Ze (incoming side of device)

- measure R1+R2 for the circuit

-then Z

3. a 1. R1+R2, low reading ohm meter

2. insulation resistance, high reading ohm meter

3.. polarity, low reading ohm meter.

4.. Zs. Earth loop impedance tester.

5. Pfc, prospective fault current faster

b. protection against damages

joint mechanically and electrically sound

correct current rating

metal sheaths and armors earthed.

identified at termination

Answers to self-assessment questions

4. Each circuit should be separately tested & its insulation resistance should be greater than 2 MΩ.
5. L & C.P.C.
   L & N
   All **or** N & C.P.C.
6.
   d) . insulation resistance tester
   e) 500 V dc
   f) 2 MΩ

   To prove the correct polarity of the incoming supply

   Approved voltage indicator

4.a. Test across the line and neutral, voltage should be present

b. Test across the line and earth, voltage should be present

c. Test across the neutral and earth conductors, no voltage should be present

5.a. the remote end of the circuit (point furthest away from the source of supply)

b. measured value

c. the R1+R2 value obtained using a d.c test and does not take into account the impedance (a.c resistance) of the circuit conductors. Also when taking a reading of Ze parallel paths may be present which would lead to lower reading than may otherwise be calculating using the values of Ze and R1+R2

CHAPTER 9: ELECTRICAL INSTALLATION BREAKDOWN MAINTENANCE

Unit of learning code: ENG/CU/EI/CR/05/5

Related Unit of Competency in Occupational Standard: This unit addresses the unit of competency: Conduct Electrical Installation Breakdown Maintenance

9.1 Introduction to the unit of learning

This unit specifies the competencies required to conduct breakdown maintenance of an electrical installation. It includes fault identification, repairing, testing and generating maintenance report.

9.2 Summary of Learning Outcomes

1. Identify system failure
2. Troubleshoot cause of failure
3. Repair the system
4. Test the repaired system

9.2.1 Learning Outcome 1: Identify System Failure

9.2.1.1 Introduction to the learning outcome

This learning outcome requires the trainee to identify why the system has failed it involves visual inspection of the system and carrying out various tests to identify why the system has failed

9.2.1.2 **Performance Standard**

9.2.1.2.1 The necessary information about the failure is obtained from the user, as per set procedures.

9.2.1.2.2 Manuals for the system are referred to identify test points and measured parameters where applicable.

9.2.1.3 **Information Sheet**

- **Breakdown maintenance:** is a form of material or equipment remediation that is performed after the equipment or material has lost its functioning capabilities or property.
- **Failure**: the fact of system not working, or stopping working as well as it should
- **Manual:** a book giving instructions or information
- **Maintenance:** the process of keeping the system in good working condition by checking it regularly and repairing it when necessary
- **Tool:** a piece of equipment that you use with your hands to make or repair a system.
- **Visual inspection**: It is the process of looking over a piece of equipment using the naked eye to look for flaws. It requires no equipment except the naked eye of a trained inspector.
- **Process:** a series of actions or steps taken in order to achieve a particular end

- **System failure:** a breakdown of any system hardware which prevent the accomplishment of the system intended functions
- **Partial failure:** means that the equipment is functioning at less than the set rate that it is required to perform
- **Total failure:** to stop functioning because of breakage or wear
- **as-built drawing:** is a revised set of drawings submitted by a contractor upon completion of a construction project.
- Fault: in an electric power system can be defined as any abnormal condition of the system that involves the electrical failure of the equipment, such as transformers, generators, bursars, etc.
- Short Circuits: A short circuit refers to a specific condition in which electricity strays outside the established pathway of an electrical circuit.

Gathering Information

Principle of operation

Usually, the identification of the symptoms only helps to suspect what items need to be checked for malfunction. To properly identify fault in an electric circuit, you must know how each electrical component in the unit should function and be able to evaluate the performance of each component. Electrical records, prints, schematics, and manufacturers' literature—combined with your knowledge and experience—will help you determine how each component is expected to operate. After determining the expected operating characteristics, the next step is to identify the actual problem by finding the faulty part or component. this may be done by visual inspection or test using instruments.

Some situations also require testing for power, power factor, frequency, phase rotation, inductance, capacitance, and impedance

- Accurately define the problem
- identify all potential failure causes
- Objectively evaluate the likelihood of each failure cause

Visual inspection

Visual Inspection, or Visual Testing (VT), is the oldest and most basic method of inspection

Before actual electrical measurements and tests are considered, the defective equipment should be visually inspected. Sometimes the problem will immediately appear and remedy quickly applied to restore the equipment without much trouble. When conducting visual inspection, the serviceman should look for broken wires, dry joints damaged printed circuits board trucks, burnt or damaged components, displaced fuses and loose connections. Terminals should be inspected and seen to be well secured. Visual inspection may be carried out when power is off and when it is on. Visual inspection can be used for internal and external surface inspection of a variety of equipment types, including storage tanks, pressure vessels, piping, and other equipment.

Interview of users

Many machine operators are responsible for performing safety or quality checks on their equipment prior to putting it to use each day. It there important to interview them to understand the probable cause of the problem questions may include

- Does the machine have a manual?
- How often the does the machine brake
- How often is the machine repaired?
- When was the last maintenance done and the results?
- Has the machine been Overrunning?
- Is there any part that has been replaced replacing worn parts?
- How is the machine stored?

Types of failures

Electrical networks, machines and equipment are often subjected to various types of faults while they are in operation. When a fault occurs, the characteristic values (such as impedance) of the machines may change from existing values to different values till the fault is cleared After all the symptoms have been accurately noted, performance test of the equipment should be carried out. By doing this, the repair serviceman may discover other symptoms that the client may not have known, or been able to communicate on the account of little technical understanding. In some cases, a system may be reported faulty while in fact the failure is the result of incorrect operation due to the customer not being well conversant with his equipment.

Partial Failures

Failure exists in varying degrees but in the most basic terms, Partial failure simply means that some of system, component, or device can no longer produce specific desired results. Even if a piece of manufacturing equipment is still running and producing items, it has failed if it doesn’t deliver the expected quantities.

Total failure

Total failure means that most of the system, component, or device can no longer produce specific desired results. This lead to slow down of operation for the machine can no longer produce

Referring to as-built drawings

As-built drawing: is a revised set of drawings submitted by a contractor upon completion of a construction project. As-built drawings show the dimensions, geometry, and location of all components of the project forming an integral part of a structure)

Manuals

A service manual is a collection of technical data and information for a specific model of equipment. It is compiled and supplied by the manufacture for use when servicing the equipment.

A service manual has the following useful features

- Description of specification
- Performance specifications
- Block diagrams
- Schematic diagrams
- Component's layout
- Hints on maintenance
- Procedures for dismantling, testing, and fault diagnosis
- Fault location guides
- Mechanical layout of the entire equipment
- Spare part lists

NB

Use of a service manual turns what could otherwise be an infuriating guessing game to a quick straight forward repair job

9.2.1.4 Learning activities

a) conduct visual inspection in a defective iron box
b) carry out short circuit test on defective cooker
c) demonstrate how to carry out performance test by simulating faults in an iron box and carrying out performance test

9.2.1.5 Self-Assessment

a) What are the advantages of breakdown maintenance?

b) What are the disadvantages of breakdown maintenance?

c) What are the causes of breakdown maintenance?

d) How do you analyze system failure?

e) Give causes of electrical equipment failure

9.2.1.6 Tools, Equipment, Supplies and Materials

Tools

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

Materials and supplies

- Stationery
- Lubricants
- Service parts

Equipment

- PPE –hand gloves, dust coat, dust masks
- Multimeter

Phase sequence meter

9.2.1.7 References

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9.2.1.8 Model Answers to Self-Assessment

1) Explain what is meant by breakdown maintenance

Ans

- Occurs when an asset completely breaks down and needs repair to resume operation

2) What are the disadvantages of breakdown maintenance?

Ans

- Faster plant deterioration
- Increased chances of accidents or injuries
- Breakdown generally occurs inappropriate times leading to poor and hurried maintenance
- Longer repair time in comparison to any other maintenance type
- It is difficult to find the root cause of breakdown
- costly because it causes downtime and interrupts production

3) What are the advantages of breakdown maintenance?

Ans

- Minimal planning is required
- The process is very simple so it is easy to understand
- Fewer staff are required as less work is done day-to-day

4) What are the causes of system breakdown?

Ans

- Failure to read the operators manual
- Improper maintenance
- Poor electrical connections
- Overrunning machines
- Not replacing worn parts
- Misaligned tighteners
- Improper storage
- Weather related issues
- Ignoring warning signals
- Untrained operators

5) What are the causes of system failure?

Ans

- Short circuit
- Open circuit
- Multiple failure of a part after initial replacement

6) Give causes of electrical equipment failure why systems

Ans

- Loose connection or parts
- Moisture
- Power line disturbance
- Defective or inadequate installation
- Lighting
- Foreign object or short circuit
- Collision
- Overloading or inadequate power capacity

7) Explain visual inspection-

Inspection of equipment and structures using either or all of raw human senses such as vision, hearing, touch and smell and or specialized inspection equipment

9.2.2 Learning Outcome 2: Troubleshoot cause of failure

9.2.2.1 Introduction to the learning outcome

This section requires the trainee to select the right instruments for trouble shooting faulty electrical system. It involves taking the necessary safety procedure and use the correct tools and equipment to diagnose and record failure results

9.2.2.2 Performance Standard

9.2.2.2.1 Safety procedures are applied in accordance with the safety standards

9.2.2.2.2 system trouble shooting is conducted in accordance with the set procedure

9.2.2.2.3 System is diagnosed for failure according to standard operating procedure

9.2.2.2.4 System failure results are recorded as per established procedure.

9.2.2.2.5 Parameters are compared against the standards values

9.2.2.2.6 Decision is made, and recommendations are recorded

9.2.2.3 Information sheet

Trouble shoot: is the process of identifying planning and resolving a problem in a mechanical or electronics system
Failure diagnosis: is the process of tracing a fault by means of its symptoms, applying knowledge, and analyzing test results
Parameters: a limit or boundary which defines a scope or particular process or activity
Systems: a set of things working together as parts of a mechanism or interconnecting network
Failure: the fact of system not working, or stopping working as well as it should
Closed circuit: means a complete electrical connection around which current flows or circulate
Open Circuit - any break (open) in the current path of a series circuit makes the entire circuit inoperative. In a parallel circuit, only the branch effected by the open is inoperative.
Short Circuit - this can be a short-to-ground or short-to-voltage. This may cause a component to continuously operate regardless of switch position, or a fuse to repeatedly blow, depending on the fault

Earth Fault is an inadvertent fault between the live conductor and the earth

Records: a piece of information or a description of an event that is written on paper or store on a computer
Specification: it is made exactly as the person who designed it said it should be done

Conducting fault diagnosis

Introduction

The ability to rapidly diagnose the case of faults in electrical and electronics system is an important skill for every electrician. The use of electrical and electronics equipment in domestic and industrial situations is increasing rapidly. It is therefore important that the electrician or electronic technician be able to repair and service them.

Naturally, fault diagnosis skills are not achieved easily. Trouble shooting and repair should be a logical step by step procedure not a haphazard, hit and miss trial and error practice. A good understanding of component and circuit operation together with sound instruments is prerequisite to successful servicing. in addition, the defective equipment, components and diagnostic tools.

a service technician cannot repair and service electrical gadgets profitably without the appropriate service instruments. However, having the instruments is not enough, the technician must know their specifications and understand their uses. The ability to use measuring instruments and apply appropriate testing methods greatly assist in accurate pinpointing of faults in components and circuits.

The test instruments considered may include multimeter, cathode ray oscilloscope and the megger.

Open Circuits

Current will only flow in a circuit. That is, around a continuous path (or multiple paths) from and back to the source of electromagnetic force (EMF). Any interruption in the circuit, such as an open switch, a break in the wiring, or a component such as a resistor that has changed its resistance to an extremely high value will cause current to cease. The EMF will still be present, but voltages and currents around the circuit will have changed or ceased altogether. The open switch or the fault has caused what is commonly called an open circuit.

Troubleshooting open circuit

Basically, an open circuit fault is any fault that will halt the operation of a machine due to an open component

Find the open by measuring voltage:

1. Measure voltage level at the fuse.
2. Work your way point by point toward the circuit ground.
3. Continue until you find a point where voltage is no longer present. The open is between the last two measured points.

NB

Electrical Troubleshooting an Open Circuit The best method for diagnosing an open circuit is by measuring voltage. When that is not possible, measure resistance following the steps below.

1. Remove the circuit fuse
2. Measure resistance between circuit ground and a circuit point closest to fuse
3. Work your way toward ground, point by point. Continue until you find a point where continuity is present. The open is between the last two measured points. From this point you may have to further isolate.

Short circuit

A short circuit is an electrical circuit that allows a current to travel along an unintended path with no or very low electrical impedance. This results in excessive current flowing through the circuit

Causes of short circuits

There are several causes for short circuits, including three that are most often to blame.

a) faulty circuit wire insulation

Old or damaged insulation may allow neutral and hot wires to touch, which can cause a short circuit. Nail and screw punctures, as well as age, can cause wire casings or insulation to deteriorate and create short circuits. Or, if animal pests such as mice, rats, or squirrels gnaw on circuit wiring, the inner wire conductors can be exposed to cause short circuits.

b) loose wire connections

Attachments can loosen, sometimes allowing neutral and live wires to touch. Fixing faulty wire connections is tricky and is best handled by those thoroughly familiar with wiring work.

c) faulty appliance wiring

When an appliance is plugged into a wall outlet, its wiring effectively becomes an extension of the circuit, and any problems in the appliance wiring become circuit problems. Old or broken appliances can develop inner short circuits over time. Short circuits in appliances can occur in the plugs, in the power cords, or inside the device itself. It’s best to have a technician look at shorts in larger appliances such as ovens and dishwashers. Smaller appliances such as lamps often can be rewired yourself.

Effects

- Abnormal operation of the system
- Danger to the personnel as well as animals

Follow this procedure if you suspect a short circuit:

1. **Locate the tripped circuit breaker:** At the main service panel, look for an individual
2. Circuit breaker with a handle that has snapped to the OFF position. Some breakers may have a red or orange window indicator to make it easy to spot. This tripped breaker will identify the circuit where the problem exists. Leave the circuit breaker OFF as you inspect along the circuit.
3. **Inspect appliance power cords:** Inspect all the power cords plugged into outlets along the circuit that has tripped. If you find any that are damaged or on which the plastic insulation has melted, there is a good chance the short circuit is within the appliance or device itself. Unplug these appliances from the circuit. If you find suspect appliances, switch the circuit breaker back on after unplugging them. If the circuit now remains active without tripping again, it is very certain that your problem existed in the appliance. However, if the circuit breaker trips again immediately, proceed to the next step.
4. **Turn off all light and appliance switches** along the circuit. Then, turn the circuit breaker back to the ON position.
5. **Turn on each light switch or appliance switch**, one at a time. If you reach a switch that causes the circuit breaker to trip again, you have identified the section of circuit wiring where a loose connection or wiring problem exists.
6. **Repair the circuit wiring problem.** This is a step that may require the help of a professional electrician. Do not attempt this unless you are very confident about your knowledge and skill level. This repair will involve shutting off the circuit, then opening up outlet and switch boxes to inspect the wires and wire connections and making any repairs that are necessary.

Earth fault

A transformer circuit consists of a number of subscribers connected to a distribution transformer. The number of subscribers varies depending on size and power output per subscriber. Most instances of earth faults in a transformer circuit are due to insulation faults in the electrical installation of the individual subscriber. Common earth faults include:

- Earth faults in water heaters
- Earth faults in old stoves

- Faults in lighting equipment
- Faults in the fixed installation in the building
- Faults as a result of incorrect connection

A direct earth fault at a given subscriber in a transformer circuit will not normally affect the other subscribers connected to the same circuit provided that the earthing system for the individual installation satisfies current requirements. The individual owner/user is responsible for reporting the fault and having it repaired by an authorized electrical contractor. There is a requirement for earth fault

Causes of earth Fault.

1. Earth faults occur when the hot wire or live wire comes into contact with the ground wire
2. Moisture in the Receptacle Box. The accumulation of moisture is another major cause
3. Overloaded Circuit. Circuit overload occurs when more amperage flows through

Troubleshooting Earth/Ground Faults

i. Locate the problem. Many homes are equipped with ground fault circuit interrupters or GFCI outlets. These outlets detect ground faults and shut off power to the affected circuit. Some model's alert homeowners with a light or by tripping a reset switch on the outlet. Look for these alerts to locate the ground fault. If your home doesn't have GFCI-equipped outlets, look at your breaker box. Tripped breakers will be in the off position. It's important to note that ground faults don't always trip breakers. If your electrical issue is overloading breakers, you could be dealing with an electrical short or too many appliances running on the same circuit.

ii. Disconnect your appliances. Unplug your appliances from the outlet and reset the breaker or GFCI.

iii. Plug in your appliances. Plug each item back into the outlet until it trips again. This will determine which appliance is causing the ground fault. If nothing trips your outlet, or if your outlet doesn't reset, your ground fault is likely located in another part of your home. Call a professional to look. Faults can occur due to other outlets leaking current, problems with exterior circuits, and other faulty appliances.

Mechanical fault

A machine that has been designed and manufactured to perform a certain function, is expected to do so when installed in a plant for its designed life span. However, for reasons beyond one's control, such a machine may fail to do so for several reasons including

i. a faulty design of the machine,
ii. inferior material and workmanship,
iii. incorrect installation and wrong operational procedure,

Excessive component heating are signs that something is going in the wrong direction. In the case of non-typical vibrations, the main causes are:

i. Defective bearings and gears
ii. Electrical and mechanical failures in motors,
iii. Problems caused by misalignments,
iv. Unbalances or unstable bases,
v. Bent shafts, pulley or belt failures
vi. Mechanical gaps,
vii. Aerodynamic or hydraulic problems
viii. Water and oil leaks
ix. Corroded pipes,
x. Smells and abnormal sounds.
xi. Lack of or inadequate lubrication
xii. Not attending equipment
xiii. Safety stops when recommended
xiv. Incorrect operation of the machinery
xv. Lack of or improper maintenance

Electrical Tools and Equipment

Before you tackle any electrical project, having the proper tools is essential to getting the job done efficiently, correctly, and more importantly, safely! The old saying, use the right tool for the job, couldn't be more relevant, especially when it comes to electrical work.

Some of the tools and equipment's are:

Personal protective equipment (PPE)

Your personal safety should be the most important consideration. Goggles and safety glasses, gloves, long-sleeve shirts, long pants or blue jeans, hard hat, etc. A large dose of common sense is required here. Think about the hazards and protect yourself accordingly before taking on any task.

Circuit Testers

You need to have a voltage tester of some type for electrical work, and one that you trust is working properly. The important thing is to ensure that it is working so you can verify that you have the power off on any circuit you may be working with. Check it on a known live source before trusting it to determine if your circuit is dead.

Screwdrivers

It is essential to have a good quality set of screwdrivers. It is best to purchase them in a complete set rather than individually, as this will save you money, and increase the chances that you will have the driver that best fits the need.

Cordless Screwdriver/Drill

If you are going to take on any project beyond the most basic of jobs, such as, for example, changing out an individual receptacle or switch, you should have a good cordless drill and driver tool, along with a complete set of screwdriver bits and drill bits. This will save you a lot of time and when used properly, a power driver can be used in place of a screwdriver for most jobs.
I recommend purchasing a driver and drill instead of a basic cordless screwdriver as the quality is usually better, and one tool will perform both functions. Get the best quality you can afford, and make sure it has a 1/2″drive, and that is has sufficient power to drill a 1″ hole using an auger bit.

If you will be using it a lot as a screwdriver, then give some consideration to the weight and size when selecting the tool.

Electric Drill

For larger projects, with a lot of drilling required (wood studs, etc.), then an electric drill is more practical. A 1/2″ medium duty drill is a minimum for driving a wood auger bit.

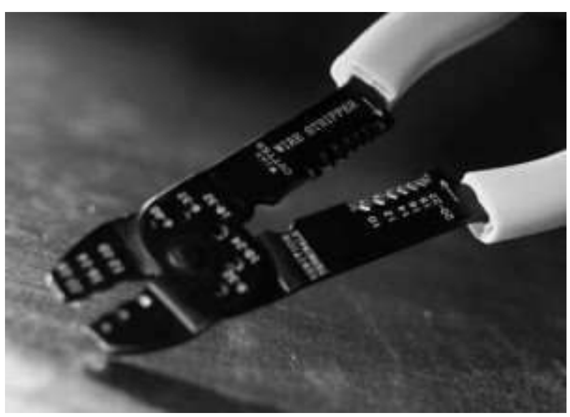
Knife

You will need to have a good knife, and I prefer a standard utility knife for stripping the PVC jacket from Romex, stripping large gauge wire, and for many other jobs as well.

Wire Strippers

Have a good quality wire stripper. I prefer a T-Stripper with a wire cutter, light-duty plier nose, and holes for bending termination loops on wires for most home electrical work. A combination crimper, cutter, stripper, bolt cutter and more, like those found in automotive electrical repair kits can be very handy as well, but the multi-purpose aspect means that the wire stripping function is compromised.

A mechanical wire stripper does a really good job, especially for commercial or industrial applications.



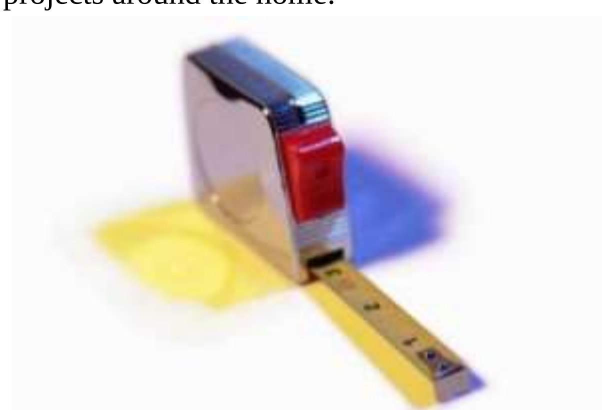
Lineman's Plier

A lineman's plier, or a bull nose plier with a wire cutter, and at least 8″or 9″ handles is also an essential part of the electrical tool list. We use these for cutting, bending, twisting wires, etc.

Standard, Long-Nosed Pliers
Also known as needle-nosed pliers. These tools are also very handy to have as a part of your electrical tool kit. They should have wire cutting knives as well.

Hammer
Have a good quality, 16oz. claw hammer. You will need this for driving staples, nails, etc.

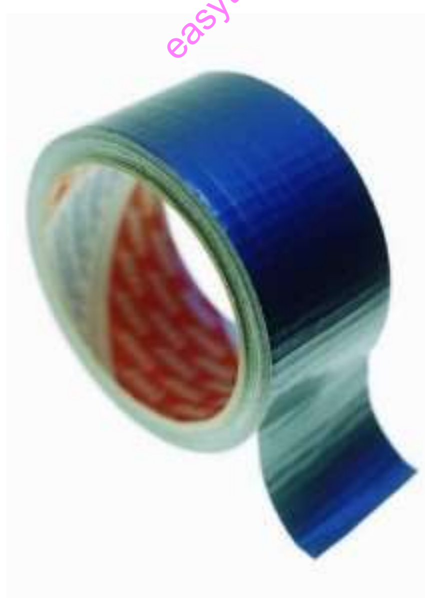
Tape Measure
Have a good quality, locking tape measure and a 25’length, 1″ blade is maybe over-kill, but will come in handy for other projects around the home.



Level
A 6″ plastic torpedo level is essential for levelling outlet boxes, cover plates, wall fixtures, etc. A plastic level is less likely to leave marks.

Always check to make sure the level is indeed "level". Before purchasing, check on a flat surface and note the position of the bubble, even if not quite at center. Then flip the level end for end in the exact same location and see if the bubble is in the same spot. You would be surprised how many you will find that don't pass this test. Especially in the lower quality price range.

Crescent wrench
Have one or two sizes of crescent wrenches in your kit.
Pump Pliers
Very handy, and essential if you are working with conduit, such as, flexible conduit.
Pipe Wrench
Essential if working with conduit
Electrical Tape
Every electrical tool kit should have at least a roll of black electrical tape, and having a few colours like red and blue helps as well for identifying wires, etc.
Duct Tape
Every tool kit, electrical or otherwise, must have the universal repair tool that is a roll of duct tape!



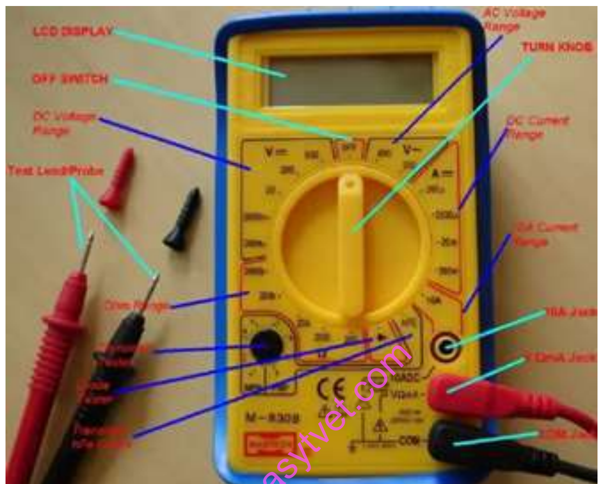
Tool Box or Chest
You need something, even if it's just a big pail, to keep everything together, and to have a place to put all your tools away. It's nice to have a good tool box with many compartments to help you keep organized.

Ladders and Step Stools
They won't fit in your toolbox, but you will need the appropriate size for the height you will be working at.

Bandages
No matter how careful you are, accidents happen. Just do all you can to protect yourself and to minimize the potential for injury. Have a first aid kit handy, just in case!

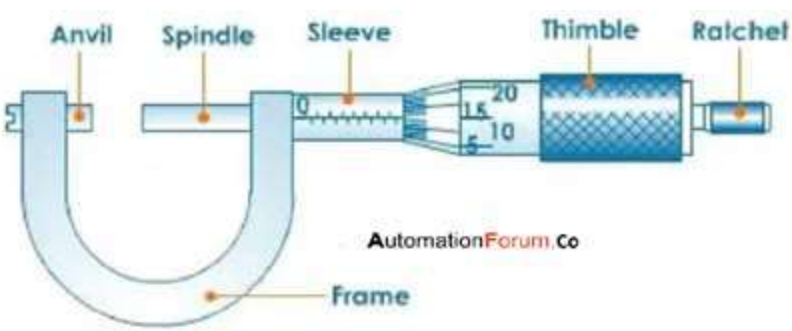
Hacksaw
Critical if working with EMT conduit, flex, etc. If cutting a lot of metal, then an electric reciprocating saw will save you time.

Flashlight/Headlamp
For when you need some extra light for dark places, or when the power is off while working on existing systems.



Micrometer

A micrometer can be used to measure small and large sizes of wires, it is also used to remove the diameter of circular wires. A micrometer can measure the diameter of thin wire accurately or thickness of sheet metal.



Wrenches

Wrenches are instruments that can be used to turn nuts or hold the piece of stock when tightening screws, nuts, and bolts. There are different types of wrenches like adjustable wrenches, pipe wrench, vice grip wrench.

Specification of Tools

Electrical engineers are required to work in hazardous environments near energized equipment. There are certain tools they require to carry out their job effectively and safely without causing any harm to themselves and those around them. Here's a sneak peek into some electrical engineering tools and their uses.

As with any tool purchase, you'll get longer life and better performance from higher-quality tools. Better electrical hand tools, such as wire cutters and linesman pliers, have insulated handles to help guard against shock.

Recording of Installation Failure Results

Fault records are one of the most important pieces of evidence that event analysts can have during system event investigations. They can provide the reasons for premature equipment failure, supply waveforms and status of equipment behavior during an event, and give necessary information to perform post-fault event analysis. Proper use and interpretation of event records can lead to corrective action for a given system problem resulting in improved performance and reliability of any generation, transmission, and distribution system. Fault recording has been used for decades now, and it is generally used for the following purposes:

- Provide the reasons for premature equipment failure
- Supply waveforms and status of equipment behavior during event
- Give necessary information to perform post-fault event analysis

9.2.2.4 Learning Activities

a) Demonstrate the use of ohmmeter in testing for continuity short and open circuits
b) Demonstrate the use of voltmeter in measuring voltages in circuits
c) The trainees to carry out activities involving the use of the multimeter function in carrying various tests

   i. The trainer to construct a single stage amplifier as shown in figure 1 below
   ii. Ascertain the normal working voltages

iii. Simulate the following problems in sequence to demonstrate how the voltages levels will be affected

- R1 0pen circuit
- R2 10pen circuit
- R3 0pen circuit
- R4 0pen circuit
- B-E Junction shorted
- C-B Junction shorted
- Collector

The trainer should record the results and then then help the trainee to interpret the cause of changes in the circuit voltage level

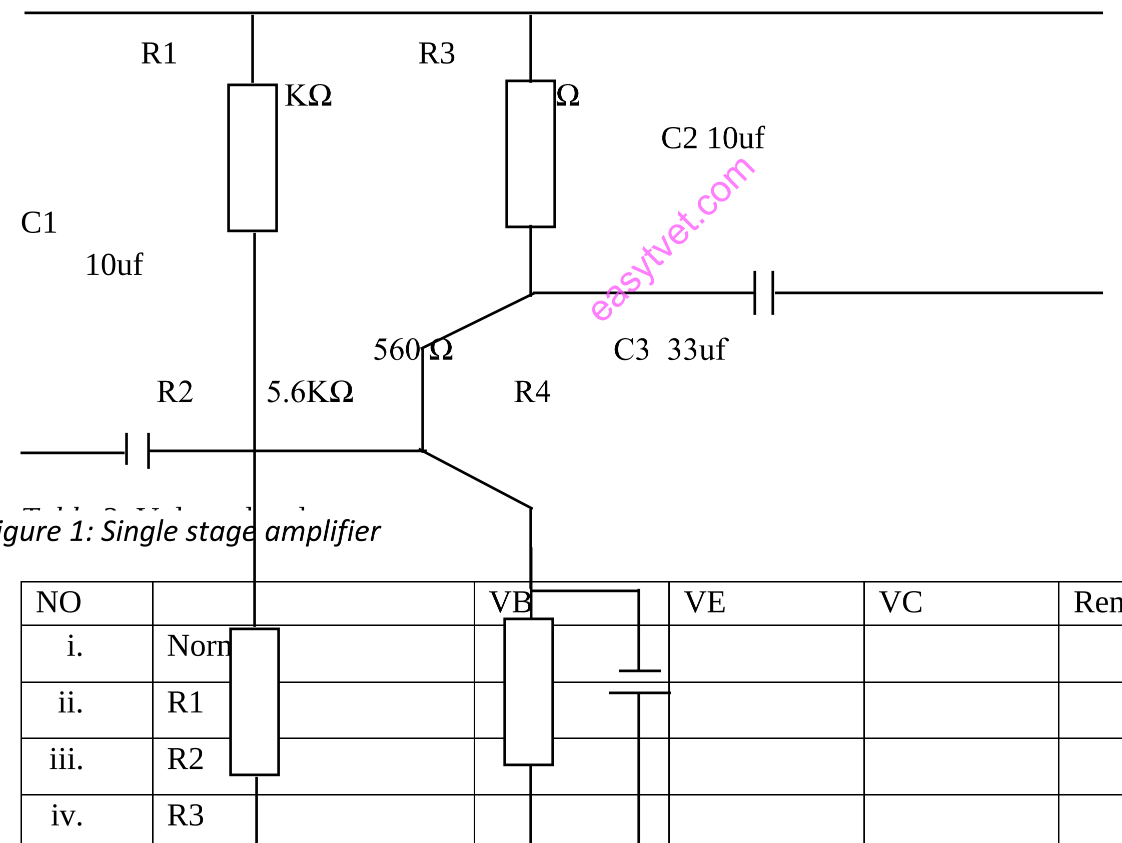


Figure 1: Single stage amplifier

NO		VB	VE	VC	Remarks
i.	Norm				
ii.	R1				
iii.	R2				
iv.	R3				
v.	R4				
vi.	B-E junction shorted				
vii.	C-B junction shorted				
viii.	Collector open				

9.2.2.5 Self-Assessment

a) What are the six steps in the trouble shooting process?
b) What are the common trouble shooting problems?
c) Explain what is meant by PPE
d) Discus how to deduce what actual faults could possibly be
e) Discus the tree functions of a multi meter
f) Discus the appropriate ohmmeter ranges for testing different components

9.2.2.6 Tools, Equipment, Supplies and Materials

Tools

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

Equipment

- PPE –hand gloves, dust coat, dust masks
- Mustimeter
- Clamp meter
- Earth electrode resistance meter
- Phase sequence meter

Materials and supplies

- Stationery
- Electrical component

9.2.2.7 References

Kiameh, P. (2003). *Electrical Equipment Handbook : Troubleshooting & Maintenance.* McGraw-Hill.

KLB. (2010). Trouble Shooting, Repair and Service. In KLB, *KLB Electricity Level 4* (pp. 118-147). Nairobi: KLB.

Moeller, B. M. (1994). *RV Electrical Systems: A Basic Guide to Troubleshooting, Repairing and Improvement.* McGraw-Hill Education.

Patil, M. B. (2004). *Practical troubleshooting of electrical equipment and control circuits 1st Edition.* Newnes.

9.2.2.8 Model Answers to self-assessment

a) What are the six steps in the trouble shooting process?

- Identify the problem
- Establish the theory of the cause
- Test probable cause theory to determine actual cause
- Establish an action plan and execute the plan
- Verify the system functionality
- Document the process

b) What are the common trouble shooting problems?

- Electrical surges
- Overloading
- Switches of light not working
- Flickering light
- Tripping circuit breaker
- Electrical shock

c) Explain what is meant by PPE

It is equipment warn to minimize exposure to a variety of hazards.

d) Examples include such items as gloves, foot and eye protections, protective hearing devices and hats, respirators and full body suits

e) Discus how to deduce what actual faults could possibly be

f)) Discus the tree functions of a multimeter

g) Discus the appropriate ohmmeter ranges for testing different components

9.2.3 Learning Outcome 3: Repair the installation

9.2.3.1 Introduction to the learning outcome

This section requires the trainee to repair a faulty electrical system using the correct set of tools, equipment, materials and observing all the safety procedures

9.2.3.2 Performance Standard

9.2.3.2.1 Maintenance tools, equipment and materials are identified

9.2.3.2.2 Specifications and functionality of tools, equipment and materials are checked in accordance with the applicable technical and safety standards

9.2.3.3 Information Sheet

Repair: restore (damage system, faulty, or worn) to a good condition
Manual: a booklet that instructs on the usage of a particular machine
Procedures: a sequence of actions to be followed in solving a problem or accomplishing task
Activity: a situation in which a lot of things are happening or being done
Planning: is the process of thinking about the activities required to achieve a desired goal.

- Repair/replace
- Meaning of repair

Repair: restore (damaged system, faulty or worn) to a good condition

- Isolating the installation

Prior to beginning work on any installation, regulation 14 of Electricity at work Regulation 1989 require that three conditions must be met These include

- The isolation process which is also known in industry as lockout/tag out and is used to isolate machinery and equipment from energy source. It is important to ensure the isolation of any unsafe machinery/equipment from potential uncontrolled energy sources during repair, service or maintenance work.
- Isolation can be used as a standalone method of ensuring the safety of maintenance staff.
- The isolator should be in locked position (for example by a padlock) and a sign should be used to indicate that maintenance work is in progress.

Any stored energy (hydraulic or pneumatic power for instance) should also be dissipated before work starts. Before working on the equipment, it is essential that the effectiveness of the isolation is verified by a suitably competent person. Minimum safety isolation procedure includes the following:

i. Identification of correct isolation point or device
ii. Check the condition of voltage indicating device such as the test lamb two pole voltage detector
iii. Switch of installation/circuit to be isolated
iv. Verify with voltage indicating device that no voltage is present
v. Reconfirm that voltage indicating device functions correctly
vi. Lock-out device used to isolate installation circuit
vii. Post warning notice- suitable labeling of the disconnected conductors

Conducting repair activities

After the primary work of problem diagnosis and identification has been carried out, the real task of repairing the fault in the system must be undertaken. Appropriate techniques, tools and procedures must be selected for each type of fault or component. The relevant safety precautions must be taken when removing and replacing the faulty components.

Selection of Appropriate Technique

The appropriate methods of repair of equipment often depend on the type of fault, component and its location

Replacing of defective components

When a certain component is found to be defective, it is necessary to first ascertain the cause of the defect before replacing it with a new one. This is especially important in relation to blown fuses, and shorted transistors. It is necessary to clear the fault that caused the fuse to blow or the transistor to short before making the replacement

Fault Finding and Repair

Electrical faults are a health Fault and safety hazard and could be putting your life in danger. Whether in the home or work environment, electrical faults put people at risk of electrocution and electrical fire. The problem must be solved by replacing only defective equipment or components.

Procedure

- Analyse the symptoms of the electrical fault(s).

- Determine the type of electrical fault: open circuit, short circuit, insulation breakdown.
- Design the most effective and efficient strategy to sol
- Explain to the customer exactly what needs fixing and the budget required
- Carry out the work with minimal disruption to the customer's environment.

Recording repair activities

Maintenance workers and their supervisors need to follow some basic rules in order to ensure the safe conduction of the work.

Planning

Maintenance can be seen as either reactive or proactive. Reactive maintenance means engaging in maintenance activity to resolve equipment and machinery which are not functioning properly. Proactive maintenance occurs when steps are taken to maintain, clean and ensure optimum functioning of machinery and equipment to prevent lack of optimum functioning. Maintenance and particularly proactive maintenance are important management issues:

The results of a suitable and sufficient risk assessment should enable to choose which good practice measures are most appropriate in preventing risks in general and also in preventing risks to any individuals identified as

Being particular risk. The implementation may mean making changes to the organisation and working procedures, working environment, equipment and products used. Changes could also be necessary in training management and staff as well as improving communications.

Special issues Qualification

Based on the conducted risk assessment the following issues need special attention:

1. A qualification level has to be determined for the specific repair and maintenance tasks
2. Enough time and appropriate resources have to be allocated.

Providing a safe working area

Only authorised personnel should be allowed to do repair or maintenance work. This becomes all the more important the machines and structures are more sophisticated. Only then can it be guaranteed that the right steps are followed and the correct equipment is used.

Sometimes, it can be necessary to conduct the repair or maintenance work at running machines. In this case special measures have to be taken. The normal safeguards should be in place and should be used.

If that is not possible, special protection devices have to be used (special tools, mobile switches), the speed of the machine has to be reduced, and special covers for dangerous areas have to be provided.

- If this should, in some very special cases, not be possible, special measures have to be taken based on a detailed risk assessment. Supervision must be provided throughout the process.

Work Execution

The work has to be conducted in a safe manner. Only workers with the appropriate qualification should be allowed to conduct specified work (e.g. welders must not repair their welding machines; this must be left to electricians; Site-specific instructions should also be given, which is especially important in the case of contracted out maintenance. That way the workers will be aware of any company specific characteristics.

Safe procedures need to be followed as established in the planning phase, even when under time pressure. Procedures for unexpected events have to be in place: "Part of the safe system of work should be to stop work when faced with an unforeseen problem or a problem exceeding one's own competence

9.2.3.4 Learning Activities

a) Carry out repairs of the following appliances
   - Iron box
   - Cooker
   - Hair drier
   - Electric fan
   - Fluorescent fitting

9.2.3.5 Self-Assessment

a) How do you identify that a machine has a problem?
b) State the general rule to be observed when selecting components for replacement.
c) State importance of running the repaired equipment in its disassembled condition before reassembling.
d) Discus the criteria for selection of specific type of repair technique
e) Discus the considerations taken in the selection of replacement of parts
f) Discus the importance of testing the equipment for proper operation before replacing its covers

9.2.3.6 Tools, Equipment, Supplies and Materials

Tools

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

Materials and supplies

- Stationery
- Cables
- Lubricants
- Service parts and components

Equipment

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

Reference materials

- IEE regulations
- Organizational procedures manual
- charts

9.2.3.7 Reference

Eletrical repair and maintenance- study. Com

Maintenance repair and operations/ EC&M- www.ecmweb.com

EElectrcity level 4 by klb

9.2.3.8 Model Answers to Self-Assessment Questions

a) How do you identify the problem?

- It is identified by finding the faulty part or component through visual inspection or tests using instruments

b) State the general rule to be observed when selecting components for replacement

- The component must have the same or higher performance characteristics

c) What is the importance of testing a repaired equipment?

- To ensure the that the equipment function well at all settings

9.2.4 Learning Outcome 4: Test the repaired system

9.2.4.1 Introduction to the learning outcome

This section requires the trainee to test the repaired system. It involves identifying the test points, carrying out test and recording the results

9.2.4.2 Performance Standard

9.2.4.2.1 Appropriate tests and test points are identified Safety procedures are adhered to

9.2.4.2.2 System is tested as per test procedure

9.2.4.2.3 Test results are recorded according to the established procedures

9.2.4.2.4 Parameters are compared against the standard values

9.2.4.2.5 Maintenance report is prepared according to approved format

9.2.4.3 Information Sheet

A **report**: is a short, sharp, concise document which with respect to the maintenance of the equip

Testing: the means by which the presence, quality or genuineness of anything is determined, a means of trails
Parameters: a numerical or measurable factor forming one of a set that defines a system or sets of conditions of its operation
Standards: something used as a measure norm or model in comparative evaluations

Identification of test and test points

Testing the system's operation once the problem is "fixed" is the last step before signing off the job ticket and walking away from a machine repair.

Before beginning any test, answer the following five questions:

- Is the circuit on or off?
- What is the condition of the fuses or breakers?
- What are the results of a visual inspection?
- Are there bad terminations?
- Is the meter working?

Meters and test equipment, as well as print tools, such as operating logs and schematics, will all help you diagnose and solve electrical problems. The fundamental diagnostic tools and test equipment are the voltmeter, ammeter, and ohmmeter. The basic functions of these meters are combined in a multimeter.

Test point

A **test point** is a location within an electronic circuit that is used to either monitor the state of the circuitry or to inject test signals. Test points have two primary uses:

- During manufacturing they are used to verify that a newly assembled device is working correctly. Any equipment that fails this testing is either discarded or sent to a rework station to attempt to repair the manufacturing defects.
- After sale of the device to a customer, test points may be used at a later time to repair the device if it malfunctions, or if the device needs to be re-calibrated after having components replaced.

Test points can be labelled and may include pins for attachment of alligator clips or may have complete connectors for test clips.

Modern miniature surface-mount electronics often simply have a row of unlabeled, tinned solder pads. The device is placed into a test fixture that holds the device securely, and a special surface-contact connector plate is pressed down onto the solder pads to connect them all as a group.

4-Step Approach to Utilizing Test Points

An excellent approach to implementing the use of test points is to follow the following 4-step approach. It provides a systematic, organized methodology that will enable consistency in utilizing test points across a range of different applications.

1. **Define** – The first step is to define a test point. A standard set of test point guidelines should be developed which can be used to verify which artefacts/objects are determined to be test points. And to help standardize the process of defining test points, test point detail & summary templates should be created.
2. **Create** – This step involves identifying potential test points at detail level.
3. **Validate and refine** – The procedure of creating and implementing test points should regularly be reviewed and refined. Creating firm timelines for the validation process — once every quarter, for example, or upon the release of every 6 service packs — can help assure consistency in the validate/refine process.
4. **Implement and Measure** – Implementing test points for a defined release should involve conducting an impact analysis. It’s also a time to look for ways to improve the process – searching for opportunities to increase test coverage, for example, or identifying opportunities for improving test productivity. It can also be helpful to incorporate metric impacts in a release scorecard.

Test parameters

It is the job of a test technician to know which piece of test equipment to use for the task at hand and also understand the limitations of the test equipment they are using

Electrical testing in its most basic form is the act of applying a voltage or current to a circuit and comparing the measured value to an expected result. Electrical test equipment verifies the math behind a circuit and each piece of test equipment is designed for a specific application.

Electrical test equipment should be considered a source of lethal electrical energy. Technicians must observe all safety warnings and follow all practical safety precautions to prevent contact with energized parts of the equipment and related circuits, including the use of appropriate Personal Protective Equipment.

Tests

The correct tests need to be carried out in the following order:

a) Visual Inspection This is very important as approximately 90% of faults can be found by this inspection alone. The Visual Inspection is not just an inspection; it basically is *'everything but* 'what is done during the actual electrical testing process. This part of the testing process may involve:

- Smelling
- Pulling on leads
- Tapping the appliance
- Shaking
- Turning some part/s
- Checking by trying to see that retractable guards actually retract and all manner of other things may be done to ensure that it is safe to operate.

b) Earth Continuity Test
c) Insulation Resistance Test
d) Leakage Test
e) Further tests have to be performed on leads, RCDs etc

Test parameters

The use of test parameters is a powerful practice to enhance your testing scenarios. In other words, the concept of parameters in testing is that your test cases may define and likewise use some parameters. Scaling up your test cases effectively usually involves the practice of parametrization.

10 Voltage

The a.c voltmeter may be used to test the presence and level of a.c supply and signal in electric circuit. Care must be to use the correct range. In the case of mains voltages, all necessary safety precautions must be observed to prevent electric shocks.

The d.c voltmeter functions used for testing voltage levels in electronic circuits, most components failure in electronic circuits alter the d.c operating conditions of the circuit. intensity in the range of 10 A with the accuracy of 1 μA, voltages in the range of 1 kV with the accuracy of 1 μV

11 Resistance

The ohmmeter is useful for testing continuity of heating elements, stator, coils, armature winding and operation of switches.

When tested with an ohmmeter, switches should show continuity in closed position. the resistance of a closed circuit is zero. The resistance of an open switch is infinity. Any intermediate resistance reading between switch contacts would indicate loose contact, the presence of dirt or moisture.

12 Current

Just like the voltmeter the ammeter can be used to infer faults in system. In case of fault the ammeter shows a higher-than-normal charge for longer, even though you know you have not used more electricity

Testing

A final test should be done to ascertain that the equipment is functioning by the client. This is done by connecting power supply to the equipment and manipulating its controls to ensure that the equipment functions well at all settings

Documenting results

Maintenance and repair documentation must be updated frequently to reflect equipment upgrades and technology advances, as well as changes in safety standards. For this reason, tracking previous versions of documentation is yet another key consideration.

The aim of documentation is to give those carrying out the works the information they need. Documents are also used to prepare cost estimates and to obtain tenders from potential contractors. Documentation should be prepared by qualified specialists. The key to good documentation is to correctly identify the problem to be solved, and hence to specify an appropriate solution. The nature and extent of the work must then be clearly conveyed to those who will do it. This information sheet discusses firstly what to document and secondly how. The central maintenance and repair record can be used to keep track of all other maintenance, including maintenance done by the in-house team, by vendors, or by service agents. The information captured should include the date, the equipment reference number, what was done, who did the work, and when next maintenance is due

Maintenance report writing

A report is a short, sharp, concise document which is written for a particular purpose and audience. It generally sets outs and analyses a situation or problem, often making recommendations for future action. It is a factual paper, and needs to be clear and well-structured.

5 Steps to Create a Maintenance Report in MS Word

Step 1: Create the Cover Page

The title should contain the information as to what the maintenance report is being created. Write the name of your company and enter the logo as well. Write down the details as well, like the address the contact details, email, etc.

Step 2: Cover Letter

On the next page include the cover letter. The person, depending on who your client is, might not be able to make sense of the technical information that you might be presenting later. That is why, in the cover letter, write down, in brief, the results of the checking. Mention what needs repairing and other such basic details.

Step 3: Device Information

In the next section, write down in detail all the information related to the device or machine. List out all the components and write down what condition they are in. You might want to make a table for the purpose as it will help you to present and record the information in a much more efficient way.

Step 4: New Parts Cost Details

Write down the parts that need repairing. Some of the parts might need a full replacement. In each case, there will be a charge incurred. It is convenient, just to put the information in this document. Mention each of the charges clearly and separately. Write the total cost involved and consider putting it in the cover letter as well.

Step 5: Suggestions and Signature

Despite repairing certain parts, there might be something on the client's end that he can do to squeeze some extra performance out of the machine. Also, you might have noticed some negligence on the client's part, which you might want to point out to him so that his machine lasts longer. Finally, put your name and signature at the bottom.

Maintenance Report Form Template

Contact Details	
Name	
Date	
Property Address	
Description of maintenance issue:	
For office use:	
Date Received	
Action Taken	
Works Completed	

9.2.4.4 Learning Activities

a) Demonstrate how to carry out the final test after the equipment has been reassembled

b) Perform the final test on the repaired equipment

c) Prepare a report on the repair carried out

9.2.4.5 Self-Assessment

1. What is testing in electrical equipment?
2. Name types of test carried
3. What is the basic instrument for testing?

9.2.5.6 Tools, Equipment, Supplies and Materials

Tools

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

Materials and supplies

- Stationery
- Cables
- Lubricants
- Service parts and components

Equipment

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

9.2.5.7 References

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9.2.5.7 Model Answers to Self-Assessments Questions

Self-Assessment

1. What is testing in electrical equipment –it makes sure that system work the way they are supposed to
2. Name types of test carried

- -visual inspection,
- earth continuity
- insulation resistance,
- earth leakage, polarity
- loop impedance functional

3. What are the basic instrument for testing?

- Multimeter
- Oscilloscope
- Signal generators
- Signal tracers
- The megger

CHAPTER 9: ELECTRICAL INSTALLATION BREAKDOWN MAINTENANCE

Unit of learning code: ENG/CU/EI/CR/05/5

Related Unit of Competency in Occupational Standard: This unit addresses the unit of competency: Conduct Electrical Installation Breakdown Maintenance

9.1 Introduction to the unit of learning

This unit specifies the competencies required to conduct breakdown maintenance of an electrical installation. It includes fault identification, repairing, testing and generating maintenance report.

9.2 Summary of Learning Outcomes

5. Identify system failure
6. Troubleshoot cause of failure
7. Repair the system
8. Test the repaired system

9.2.1 Learning Outcome 1: Identify System Failure

9.2.1.1 Introduction to the learning outcome

This learning outcome requires the trainee to identify why the system has failed it involves visual inspection of the system and carrying out various tests to identify why the system has failed

9.2.1.2 Performance Standard

- The necessary information about the failure is obtained from the user, as per set procedures.
- Manuals for the system are referred to identify test points and measured parameters where applicable.

9.2.1.3 Information Sheet

9.2.1.3.1 Definitions of Terms,

- **Breakdown maintenance:** is a form of material or equipment remediation that is performed after the equipment or material has lost its functioning capabilities or property.
- **Failure**: the fact of system not working, or stopping working as well as it should
- **Manual:** a book giving instructions or information
- **Maintenance:** the process of keeping the system in good working condition by checking it regularly and repairing it when necessary
- **Tool:** a piece of equipment that you use with your hands to make or repair a system.

- **Visual inspection**: It is the process of looking over a piece of equipment using the naked eye to look for flaws. It requires no equipment except the naked eye of a trained inspector.
- **Process:** a series of actions or steps taken in order to achieve a particular end
- **System failure:** a breakdown of any system hardware which prevent the accomplishment of the system intended functions
- **Partial failure:** means that the equipment is functioning at less than the set rate that it is required to perform
- **Total failure:** to stop functioning because of breakage or wear
- **as-built drawing:** is a revised set of drawings submitted by a contractor upon completion of a construction project.
- Fault: in an electric power system can be defined as any abnormal condition of the system that involves the electrical failure of the equipment, such as transformers, generators, bursars, etc.
- Short Circuits: A short circuit refers to a specific condition in which electricity strays outside the established pathway of an electrical circuit.

9.2.1.3.2 Gathering Information

Principle of operation

Usually, the identification of the symptoms only helps to suspect what items need to be checked for malfunction. To properly identify fault in an electric circuit, you must know how each electrical component in the unit should function and be able to evaluate the performance of each component. Electrical records, prints, schematics, and manufacturers' literature—combined with your knowledge and experience—will help you determine how each component is expected to operate. After determining the expected operating characteristics, the next step is to identify the actual problem by finding the faulty part or component. this may be done by visual inspection or test using instruments.

Some situations also require testing for power, power factor, frequency, phase rotation, inductance, capacitance, and impedance

- Accurately define the problem
- identify all potential failure causes
- Objectively evaluate the likelihood of each failure cause

Visual inspection

Visual Inspection, or Visual Testing (VT), is the oldest and most basic method of inspection

Before actual electrical measurements and tests are considered, the defective equipment should be visually inspected. Sometimes the problem will immediately appear and remedy quickly applied to restore the equipment without much trouble. When conducting visual inspection, the serviceman should look for broken wires, dry joints damaged printed circuits board trucks, burnt or damaged components, displaced fuses and loose connections. Terminals should be inspected and seen to be well secured. Visual inspection may be carried out when power is off and when it is on. Visual inspection can be used for internal and external surface inspection of a variety of equipment types, including storage tanks, pressure vessels, piping, and other equipment.

Interview of users

Many machine operators are responsible for performing safety or quality checks on their equipment prior to putting it to use each day. It there important to interview them to understand the probable cause of the problem questions may include

- Does the machine have a manual?
- How often the does the machine brake
- How often is the machine repaired?
- When was the last maintenance done and the results?
- Has the machine been Overrunning?
- Is there any part that has been replaced replacing worn parts?
- How is the machine stored?

Types of failures

Electrical networks, machines and equipment are often subjected to various types of faults while they are in operation. When a fault occurs, the characteristic values (such as impedance) of the machines may change from existing values to different values till the fault is cleared After all the symptoms have been accurately noted, performance test of the equipment should be carried out. By doing this, the repair serviceman may discover other symptoms that the client may not have known, or been able to communicate on the account of little technical understanding. In some cases, a system may be reported faulty while in fact the failure is the result of incorrect operation due to the customer not being well conversant with his equipment.

Partial Failures

Failure exists in varying degrees but in the most basic terms, Partial failure simply means that some of system, component, or device can no longer produce specific desired results. Even if a piece of manufacturing equipment is still running and producing items, it has failed if it doesn't deliver the expected quantities.

Total failure

Total failure means that most of the system, component, or device can no longer produce specific desired results. This lead to slow down of operation for the machine can no longer produce

Referring to as-built drawings

As-built drawing: is a revised set of drawings submitted by a contractor upon completion of a construction project. As-built drawings show the dimensions, geometry, and location of all components of the project forming an integral part of a structure)

Manuals

A service manual is a collection of technical data and information for a specific model of equipment. It is compiled and supplied by the manufacture for use when servicing the equipment.

A service manual has the following useful features

- Description of specification
- Performance specifications
- Block diagrams
- Schematic diagrams
- Components layout
- Hints on maintenance
- Procedures for dismantling, testing, and fault diagnosis
- Fault location guides
- Mechanical layout of the entire equipment
- Spare part lists

NB
Use of a service manual turns what could otherwise be an infuriating guessing game to a quick straight forward repair job

9.2.1.4 Learning activities

d) conduct visual inspection in a defective iron box

e) carry out short circuit test on defective cooker
f) demonstrate how to carry out performance test by simulating faults in an iron box and carrying out performance test

9.2.1.5 Self-Assessment

f) What are the advantages of breakdown maintenance?
g) What are the disadvantages of breakdown maintenance?
h) What are the causes of breakdown maintenance?
i) How do you analyze system failure?
j) Give causes of electrical equipment failure

9.2.1.6 Tools, Equipment, Supplies and Materials

Tools

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

Materials and supplies

- Stationery
- Lubricants
- Service parts

Equipment

- PPE –hand gloves, dust coat, dust masks
- Multimeter

Phase sequence meter

9.2.1.7 References

KLB. (2010). Trouble Shooting, Repair and Service. In KLB, *KLB Electricity Level 4* (pp. 118-147). Nairobi: KLB.

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White, J. R. (2015). *Circuit Breakers: A Technician's Guide to Low- and Medium-voltage Circuit Breakers.* American Technical Publishers.

Answers for Self-Assessment

8) Explain what is meant by breakdown maintenance

Ans

- Occurs when an asset completely breaks down and needs repair to resume operation

9) What are the disadvantages of breakdown maintenance?

Ans

- Faster plant deterioration
- Increased chances of accidents or injuries
- Breakdown generally occurs inappropriate times leading to poor and hurried maintenance
- Longer repair time in comparison to any other maintenance type
- It is difficult to find the root cause of breakdown
- costly because it causes downtime and interrupts production

10) What are the advantages of breakdown maintenance?

Ans

- Minimal planning is required
- The process is very simple so it is easy to understand
- Fewer staff are required as less work is done day-to-day

11) What are the causes of system breakdown?

Ans

- Failure to read the operators manual
- Improper maintenance
- Poor electrical connections
- Overrunning machines
- Not replacing worn parts
- Misaligned tighteners
- Improper storage
- Weather related issues
- Ignoring warning signals

- Untrained operators

12) What are the causes of system failure?

Ans

- Short circuit
- Open circuit
- Multiple failure of a part after initial replacement

13) Give causes of electrical equipment failure why systems

Ans

- Loose connection or parts
- Moisture
- Power line disturbance
- Defective or inadequate installation
- Lighting
- Foreign object or short circuit
- Collision
- Overloading or inadequate power capacity

14) Explain visual inspection-

ans

Inspection of equipment and structures using either or all of raw human senses such as vision, hearing, touch and smell and or specialized inspection equipment

9.2.2 Learning Outcome 2: Troubleshoot cause of failure

9.2.2.1 Introduction to the learning outcome

This section requires the trainee to select the right instruments for trouble shooting faulty electrical system. It involves taking the necessary safety procedure and use the correct tools and equipment to diagnose and record failure results

9.2.2.2 Performance Standard

- Safety procedures are applied in accordance with the safety standards
- system trouble shooting is conducted in accordance with the set procedure
- System is diagnosed for failure according to standard operating procedure
- System failure results are recorded as per established procedure.
- Parameters are compared against the standards values
- Decision is made, and recommendations are recorded

9.2.2.3 Information sheet

Definitions of terms

Trouble shoot: is the process of identifying planning and resolving a problem in a mechanical or electronics system
Failure diagnosis: is the process of tracing a fault by means of its symptoms, applying knowledge, and analyzing test results
Parameters: a limit or boundary which defines a scope or particular process or activity
Systems: a set of things working together as parts of a mechanism or interconnecting network
Failure: the fact of system not working, or stopping working as well as it should
Closed circuit: means a complete electrical connection around which current flows or circulate
Open Circuit - any break (open) in the current path of a series circuit makes the entire circuit inoperative. In a parallel circuit, only the branch effected by the open is inoperative.
Short Circuit - this can be a short-to-ground or short-to-voltage. This may cause a component to continuously operate regardless of switch position, or a fuse to repeatedly blow, depending on the fault

Earth Fault is an inadvertent fault between the live conductor and the earth

Records: a piece of information or a description of an event that is written on paper or store on a computer
Specification: it is made exactly as the person who designed it said it should be done

Conducting fault diagnosis

Introduction

The ability to rapidly diagnose the case of faults in electrical and electronics system is an important skill for every electrician. The use of electrical and electronics equipment in domestic and industrial situations is increasing rapidly. It is therefore important that the electrician or electronic technician be able to repair and service them.

Naturally, fault diagnosis skills are not achieved easily. Trouble shooting and repair should be a logical step by step procedure not a haphazard, hit and miss trial and error practice. A good understanding of component and circuit operation together with sound instruments is prerequisite to successful servicing. in addition, the defective equipment, components and diagnostic tools.

a service technician cannot repair and service electrical gadgets profitably without the appropriate service instruments. However, having the instruments is not enough, the technician must know their specifications and understand their uses. The ability to use measuring instruments and apply appropriate testing methods greatly assist in accurate pinpointing of faults in components and circuits.

The test instruments considered may include multimeter , cathode ray oscilloscope and the megger.

Open Circuits

Current will only flow in a circuit. That is, around a continuous path (or multiple paths) from and back to the source of electromagnetic force (EMF). Any interruption in the circuit, such as an open switch, a break in the wiring, or a component such as a resistor that has changed its resistance to an extremely high value will cause current to cease. The EMF will still be present, but voltages and currents around the circuit will have changed or ceased altogether. The open switch or the fault has caused what is commonly called an open circuit.

Troubleshooting open circuit

Basically, an open circuit fault is any fault that will halt the operation of a machine due to an open component

Find the open by measuring voltage:

4. Measure voltage level at the fuse.
5. Work your way point by point toward the circuit ground.
6. Continue until you find a point where voltage is no longer present. The open is between the last two measured points.

NB

Electrical Troubleshooting an Open Circuit The best method for diagnosing an open circuit is by measuring voltage. When that is not possible, measure resistance following the steps below.

4. Remove the circuit fuse
5. Measure resistance between circuit ground and a circuit point closest to fuse
6. Work your way toward ground, point by point. Continue until you find a point where continuity is present. The open is between the last two measured points. From this point you may have to further isolate.

Short circuit

A short circuit is an electrical circuit that allows a current to travel along an unintended path with no or very low electrical impedance. This results in excessive current flowing through the circuit

Causes of short circuits

There are several causes for short circuits, including three that are most often to blame.

d) faulty circuit wire insulation

Old or damaged insulation may allow neutral and hot wires to touch, which can cause a short circuit. Nail and screw punctures, as well as age, can cause wire casings or insulation to deteriorate and create short circuits. Or, if animal pests such as mice, rats, or squirrels gnaw on circuit wiring, the inner wire conductors can be exposed to cause short circuits.

e) loose wire connections

Attachments can loosen, sometimes allowing neutral and live wires to touch. Fixing faulty wire connections is tricky and is best handled by those thoroughly familiar with wiring work.

f) faulty appliance wiring

When an appliance is plugged into a wall outlet, its wiring effectively becomes an extension of the circuit, and any problems in the appliance wiring become circuit problems. Old or broken appliances can develop inner short circuits over time. Short circuits in appliances can occur in the plugs, in the power cords, or inside the device itself. It’s best to have a technician look at shorts in larger appliances such as ovens and dishwashers. Smaller appliances such as lamps often can be rewired yourself.

Effects

- Abnormal operation of the system
- Danger to the personnel as well as animals

Follow this procedure if you suspect a short circuit:

7. **Locate the tripped circuit breaker:** At the main service panel, look for an individual
8. Circuit breaker with a handle that has snapped to the OFF position. Some breakers may have a red or orange window indicator to make it easy to spot. This tripped breaker will identify the circuit where the problem exists. Leave the circuit breaker OFF as you inspect along the circuit.
9. **Inspect appliance power cords:** Inspect all the power cords plugged into outlets along the circuit that has tripped. If you find any that are damaged or on which the plastic insulation has melted, there is a good chance the short circuit is within the appliance or device itself. Unplug these appliances from the circuit. If you find suspect appliances, switch the circuit breaker back on after unplugging them. If the circuit now remains active without tripping again, it is very certain that your problem existed in the appliance. However, if the circuit breaker trips again immediately, proceed to the next step.
10. **Turn off all light and appliance switches** along the circuit. Then, turn the circuit breaker back to the ON position.
11. **Turn on each light switch or appliance switch**, one at a time. If you reach a switch that causes the circuit breaker to trip again, you have identified the section of circuit wiring where a loose connection or wiring problem exists.
12. **Repair the circuit wiring problem.** This is a step that may require the help of a professional electrician. Do not attempt this unless you are very confident about your knowledge and skill level. This repair will involve shutting off the circuit, then opening up outlet and switch boxes to inspect the wires and wire connections and making any repairs that are necessary.

Earth fault

A transformer circuit consists of a number of subscribers connected to a distribution transformer. The number of subscribers varies depending on size and power output per subscriber. Most instances of earth faults in a transformer circuit are due to insulation faults in the electrical installation of the individual subscriber. Common earth faults include:

- Earth faults in water heaters

- Earth faults in old stoves
- Faults in lighting equipment
- Faults in the fixed installation in the building
- Faults as a result of incorrect connection

A direct earth fault at a given subscriber in a transformer circuit will not normally affect the other subscribers connected to the same circuit provided that the earthing system for the individual installation satisfies current requirements. The individual owner/user is responsible for reporting the fault and having it repaired by an authorized electrical contractor. There is a requirement for earth fault

Causes of earth Fault.

4. Earth faults occur when the hot wire or live wire comes into contact with the ground wire
5. Moisture in the Receptacle Box. The accumulation of moisture is another major cause
6. Overloaded Circuit. Circuit overload occurs when more amperage flows through

Troubleshooting Earth/Ground Faults

iv. Locate the problem. Many homes are equipped with ground fault circuit interrupters or GFCI outlets. These outlets detect ground faults and shut off power to the affected circuit. Some models alert homeowners with a light or by tripping a reset switch on the outlet. Look for these alerts to locate the ground fault. If your home doesn’t have GFCI-equipped outlets, look at your breaker box. Tripped breakers will be in the off position. It’s important to note that ground faults don’t always trip breakers. If your electrical issue is overloading breakers, you could be dealing with an electrical short or too many appliances running on the same circuit.

v. Disconnect your appliances. Unplug your appliances from the outlet and reset the breaker or GFCI.

vi. Plug in your appliances. Plug each item back into the outlet until it trips again. This will determine which appliance is causing the ground fault. If nothing trips your outlet, or if your outlet doesn’t reset, your ground fault is likely located in another part of your home. Call a professional to look. Faults can occur due to other outlets leaking current, problems with exterior circuits, and other faulty appliances.

Mechanical fault

A machine that has been designed and manufactured to perform a certain function, is expected to do so when installed in a plant for its designed life span. However, for reasons beyond one's control, such a machine may fail to do so for several reasons including

iv. a faulty design of the machine,
v. inferior material and workmanship,
vi. incorrect installation and wrong operational procedure,

Excessive component heating are signs that something is going in the wrong direction. In the case of non-typical vibrations, the main causes are:

xvi. Defective bearings and gears
xvii. Electrical and mechanical failures in motors,
xviii. Problems caused by misalignments,
xix. Unbalances or unstable bases,
xx. Bent shafts, pulley or belt failures
xxi. Mechanical gaps,
xxii. Aerodynamic or hydraulic problems
xxiii. Water and oil leaks
xxiv. Corroded pipes,
xxv. Smells and abnormal sounds.
xxvi. Lack of or inadequate lubrication
xxvii. Not attending equipment
xxviii. Safety stops when recommended
xxix. Incorrect operation of the machinery
xxx. Lack of or improper maintenance

Electrical Tools and Equipment

Before you tackle any electrical project, having the proper tools is essential to getting the job done efficiently, correctly, and more importantly, safely! The old saying, use the right tool for the job, couldn't be more relevant, especially when it comes to electrical work.

Some of the tools and equipment's are:

Personal protective equipment (PPE)

Your personal safety should be the most important consideration. Goggles and safety glasses, gloves, long-sleeve shirts, long pants or blue jeans, hard hat, etc. A large dose of common sense is required here. Think about the hazards and protect yourself accordingly before taking on any task.

Circuit Testers

You need to have a voltage tester of some type for electrical work, and one that you trust is working properly. The important thing is to ensure that it is working so you can verify that you have the power off on any circuit you may be working with. Check it on a known live source before trusting it to determine if your circuit is dead.

Screwdrivers

It is essential to have a good quality set of screwdrivers. It is best to purchase them in a complete set rather than individually, as this will save you money, and increase the chances that you will have the driver that best fits the need.

Cordless Screwdriver/Drill

If you are going to take on any project beyond the most basic of jobs, such as, for example, changing out an individual receptacle or switch, you should have a good cordless drill and driver tool, along with a complete set of screwdriver bits and drill bits. This will save you a lot of time and when used properly, a power driver can be used in place of a screwdriver for most jobs.

I recommend purchasing a driver and drill instead of a basic cordless screwdriver as the quality is usually better, and one tool will perform both functions. Get the best quality you can afford, and make sure it has a 1/2″drive, and that is has sufficient power to drill a 1″ hole using an auger bit.

If you will be using it a lot as a screwdriver, then give some consideration to the weight and size when selecting the tool.

Electric Drill

For larger projects, with a lot of drilling required (wood studs, etc.), then an electric drill is more practical. A 1/2″ medium duty drill is a minimum for driving a wood auger bit.

Knife

You will need to have a good knife, and I prefer a standard utility knife for stripping the PVC jacket from Romex, stripping large gauge wire, and for many other jobs as well.

Wire Strippers

Have a good quality wire stripper. I prefer a T-Stripper with a wire cutter, light-duty plier nose, and holes for bending termination loops on wires for most home electrical work. A combination crimper, cutter, stripper, bolt cutter and more, like those found in automotive electrical repair kits can be very handy as well, but the multi-purpose aspect means that the wire stripping function is compromised.

A mechanical wire stripper does a really good job, especially for commercial or industrial applications.

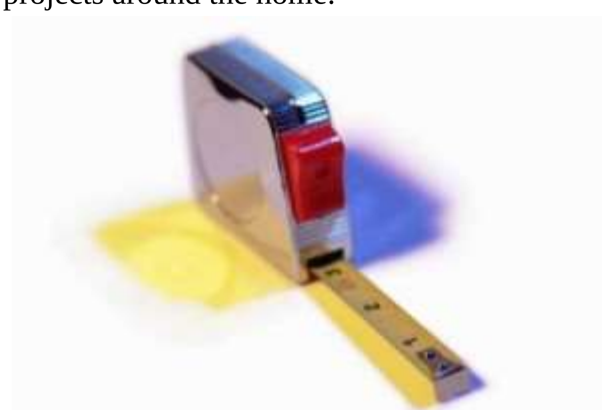
Lineman's Plier

A lineman's plier, or a bull nose plier with a wire cutter, and at least 8″or 9″ handles is also an essential part of the electrical tool list. We use these for cutting, bending, twisting wires, etc.

Standard, Long-Nosed Pliers
Also known as needle-nosed pliers. These tools are also very handy to have as a part of your electrical tool kit. They should have wire cutting knives as well.

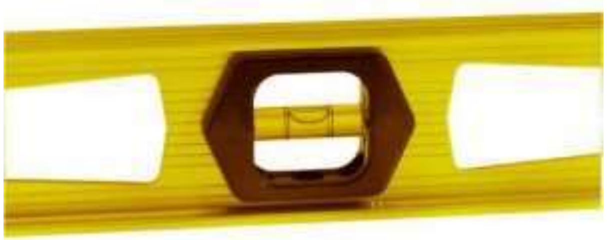
Hammer
Have a good quality, 16oz. claw hammer. You will need this for driving staples, nails, etc.

Tape Measure
Have a good quality, locking tape measure and a 25’length, 1″ blade is maybe over-kill, but will come in handy for other projects around the home.

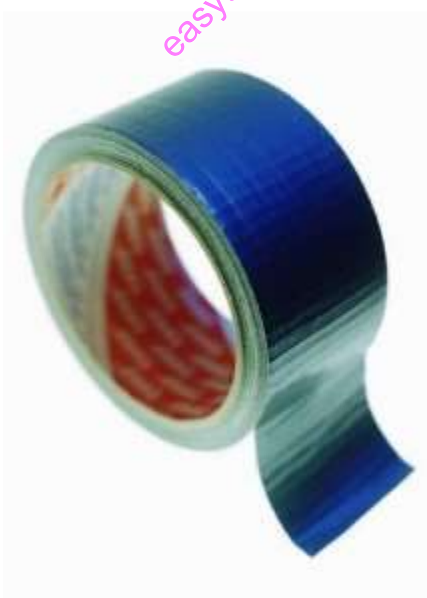


Level
A 6″ plastic torpedo level is essential for levelling outlet boxes, cover plates, wall fixtures, etc. A plastic level is less likely to leave marks.

Always check to make sure the level is indeed “level”. Before purchasing, check on a flat surface and note the position of the bubble, even if not quite at center. Then flip the level end for end in the exact same location and see if the bubble is in the same spot. You would be surprised how many you will find that don’t pass this test. Especially in the lower quality price range.



Crescent wrench
Have one or two sizes of crescent wrenches in your kit.
Pump Pliers
Very handy, and essential if you are working with conduit, such as, flexible conduit.
Pipe Wrench
Essential if working with conduit
Electrical Tape
Every electrical tool kit should have at least a roll of black electrical tape, and having a few colours like red and blue helps as well for identifying wires, etc.
Duct Tape
Every tool kit, electrical or otherwise, must have the universal repair tool that is a roll of duct tape!



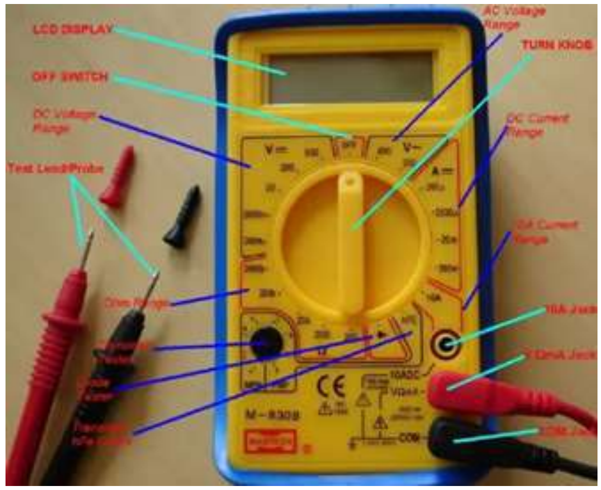
Tool Box or Chest
You need something, even if it’s just a big pail, to keep everything together, and to have a place to put all your tools away. It’s nice to have a good tool box with many compartments to help you keep organized.

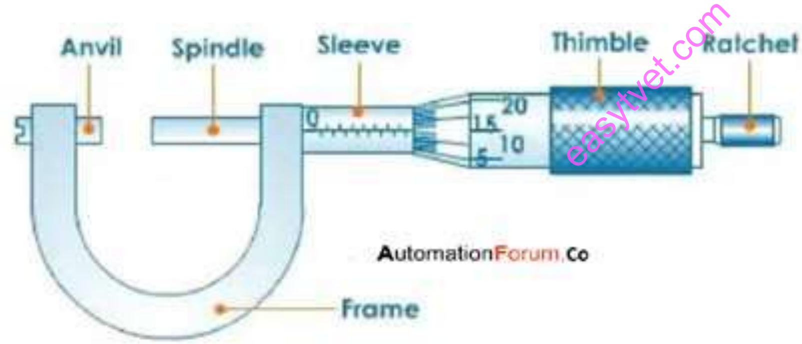
Ladders and Step Stools
They won't fit in your toolbox, but you will need the appropriate size for the height you will be working at.

Bandages
No matter how careful you are, accidents happen. Just do all you can to protect yourself and to minimize the potential for injury. Have a first aid kit handy, just in case!

Hacksaw
Critical if working with EMT conduit, flex, etc. If cutting a lot of metal, then an electric reciprocating saw will save you time.

Flashlight/Headlamp
For when you need some extra light for dark places, or when the power is off while working on existing systems.





Micrometer

A micrometer can be used to measure small and large sizes of wires, it is also used to remove the diameter of circular wires. A micrometer can measure the diameter of thin wire accurately or thickness of sheet metal.

Wrenches

Wrenches are instruments that can be used to turn nuts or hold the piece of stock when tightening screws, nuts, and bolts. There are different types of wrenches like adjustable wrenches, pipe wrench, vice grip wrench.

Specification of Tools

Electrical engineers are required to work in hazardous environments near energized equipment. There are certain tools they require to carry out their job effectively and safely without causing any harm to themselves and those around them. Here's a sneak peek into some electrical engineering tools and their uses.

As with any tool purchase, you'll get longer life and better performance from higher-quality tools. Better electrical hand tools, such as wire cutters and linesman pliers, have insulated handles to help guard against shock.

Recording of Installation Failure Results

Fault records are one of the most important pieces of evidence that event analysts can have during system event investigations. They can provide the reasons for premature equipment failure, supply waveforms and status of equipment behavior during an event, and give necessary information to perform post-fault event analysis. Proper use and interpretation of event records can lead to corrective action for a given system problem resulting in improved performance and reliability of any generation, transmission, and distribution system. Fault recording has been used for decades now, and it is generally used for the following purposes:

- Provide the reasons for premature equipment failure
- Supply waveforms and status of equipment behavior during event
- Give necessary information to perform post-fault event analysis

9.2.2.4 Learning Activities

d) Demonstrate the use of ohmmeter in testing for continuity short and open circuits
e) Demonstrate the use of voltmeter in measuring voltages in circuits
f) The trainees to carry out activities involving the use of the multimeter function in carrying various tests

iv. The trainer to construct a single stage amplifier as shown in figure 1 below
v. Ascertain the normal working voltages
vi. Simulate the following problems in sequence to demonstrate how the voltages levels will be affected

- R1 0pen circuit
- R2 10pen circuit
- R3 0pen circuit
- R4 0pen circuit
- B-E Junction shorted

- C-B Junction shorted
- Collector

The trainer should record the results and then then help the trainee to interpret the cause of changes in the circuit voltage level

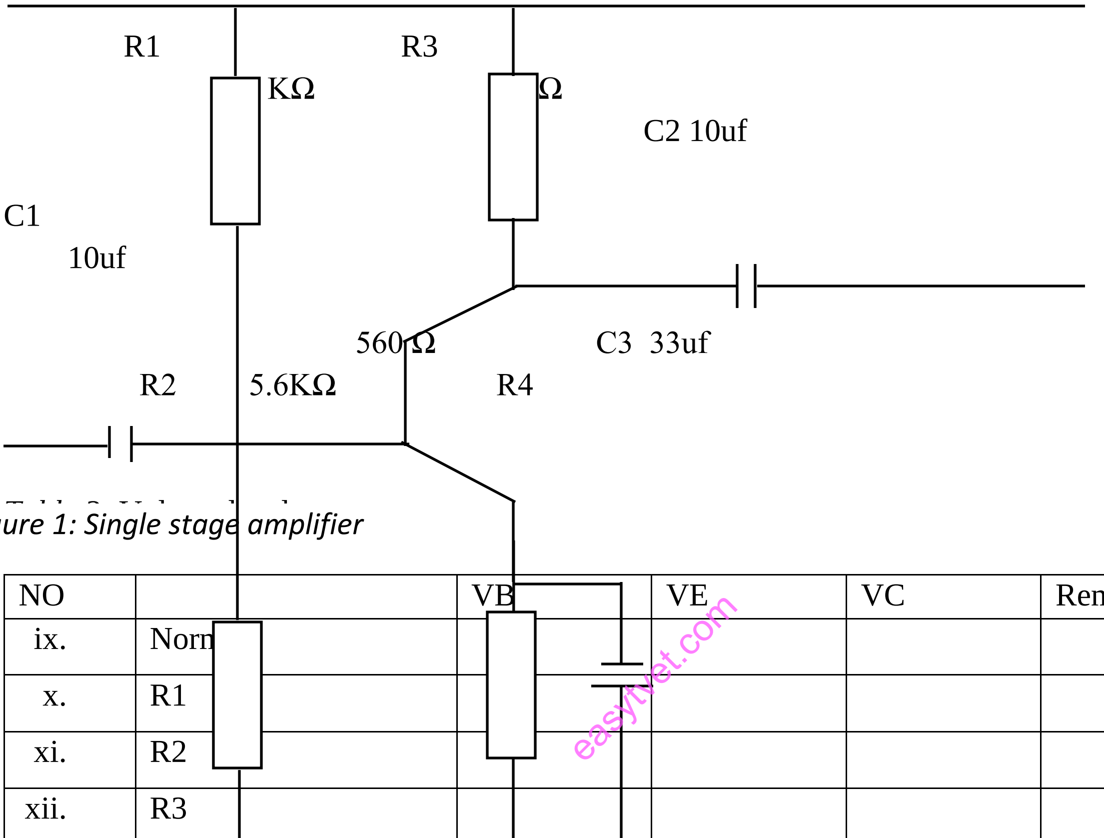


Figure 1: Single stage amplifier

NO		VB	VE	VC	Remarks
ix.	Norn				
x.	R1				
xi.	R2				
xii.	R3				
xiii.	R4				
xiv.	B-E junction shorted				
xv.	C-B junction shorted				
xvi.	Collector open				

9.2.2.5 Self-Assessment

g) What are the six steps in the trouble shooting process?

h) What are the common trouble shooting problems?

i) Explain what is meant by PPE

j) Discus how to deduce what actual faults could possibly be

k) Discus the tree functions of a multi meter

l) Discus the appropriate ohmmeter ranges for testing different components

9.2.2.6 Tools, Equipment, Supplies and Materials

Tools

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

Equipment

- PPE –hand gloves, dust coat, dust masks
- Mustimeter
- Clamp meter
- Earth electrode resistance meter
- Phase sequence meter

Materials and supplies

- Stationery
- Electrical component

9.2.2.7 References

Kiameh, P. (2003). *Electrical Equipment Handbook : Troubleshooting & Maintenance.* McGraw-Hill.

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Answers to self-assessment

h) What are the six steps in the trouble shooting process?
   - Identify the problem
   - Establish the theory of the cause
   - Test probable cause theory to determine actual cause
   - Establish an action plan and execute the plan
   - Verify the system functionality
   - Document the process

i) What are the common trouble shooting problems?

- Electrical surges
- Overloading
- Switches of light not working
- Flickering light
- Tripping circuit breaker
- Electrical shock

j) Explain what is meant by PPE

It is equipment warn to minimize exposure to a variety of hazards.

k) Examples include such items as gloves, foot and eye protections, protective hearing devices and hats, respirators and full body suits

l) Discus how to deduce what actual faults could possibly be

m)) Discus the tree functions of a multimeter

n) Discus the appropriate ohmmeter ranges for testing different components

9.2.3 Learning Outcome 3: Repair the installation

9.2.3.1 Introduction to the learning outcome

This section requires the trainee to repair a faulty electrical system using the correct set of tools, equipment, materials and observing all the safety procedures

9.2.3.2 Performance Standard

1. Maintenance tools, equipment and materials are identified
2. Specifications and functionality of tools, equipment and materials are checked in accordance with the applicable technical and safety standards

5.2.3.3 Information Sheet

Definitions of terms

Repair: restore (damage system, faulty, or worn) to a good condition
Manual: a booklet that instructs on the usage of a particular machine
Procedures: a sequence of actions to be followed in solving a problem or accomplishing task
Activity: a situation in which a lot of things are happening or being done
Planning: is the process of thinking about the activities required to achieve a desired goal.

- Repair/replace
- Meaning of repair

Repair: restore (damaged system, faulty or worn) to a good condition

- Isolating the installation

Prior to beginning work on any installation, regulation 14 of Electricity at work Regulation 1989 require that three conditions must be met These include

- The isolation process which is also known in industry as lockout/tag out and is used to isolate machinery and equipment from energy source. It is important to ensure the isolation of any unsafe machinery/equipment from potential uncontrolled energy sources during repair, service or maintenance work.
- Isolation can be used as a standalone method of ensuring the safety of maintenance staff.
- The isolator should be in locked position (for example by a padlock) and a sign should be used to indicate that maintenance work is in progress.

Any stored energy (hydraulic or pneumatic power for instance) should also be dissipated before work starts. Before working on the equipment, it is essential that the effectiveness of the isolation is verified by a suitably competent person. Minimum safety isolation procedure includes the following:

viii. Identification of correct isolation point or device
ix. Check the condition of voltage indicating device such as the test lamb two pole voltage detector
x. Switch of installation/circuit to be isolated
xi. Verify with voltage indicating device that no voltage is present
xii. Reconfirm that voltage indicating device functions correctly
xiii. Lock-out device used to isolate installation circuit
xiv. Post warning notice- suitable labeling of the disconnected conductors

Conducting repair activities

After the primary work of problem diagnosis and identification has been carried out, the real task of repairing the fault in the system must be undertaken. Appropriate techniques, tools and procedures must be selected for each type of fault or component. The relevant safety precautions must be taken when removing and replacing the faulty components.

Selection of Appropriate Technique

The appropriate methods of repair of equipment often depend on the type of fault, component and its location

Replacing of defective components

When a certain component is found to be defective, it is necessary to first ascertain the cause of the defect before replacing it with a new one. This is especially important in relation to blown fuses, and shorted transistors. It is necessary to clear the fault that caused the fuse to blow or the transistor to short before making the replacement

Fault Finding and Repair

Electrical faults are a health Fault and safety hazard and could be putting your life in danger. Whether in the home or work environment, electrical faults put people at risk of electrocution and electrical fire. The problem must be solved by replacing only defective equipment or components.

Procedure

- Analyse the symptoms of the electrical fault(s).

- Determine the type of electrical fault: open circuit, short circuit, insulation breakdown.
- Design the most effective and efficient strategy to sol
- Explain to the customer exactly what needs fixing and the budget required
- Carry out the work with minimal disruption to the customer's environment.

Recording repair activities

Maintenance workers and their supervisors need to follow some basic rules in order to ensure the safe conduction of the work.

Planning

Maintenance can be seen as either reactive or proactive. Reactive maintenance means engaging in maintenance activity to resolve equipment and machinery which are not functioning properly. Proactive maintenance occurs when steps are taken to maintain, clean and ensure optimum functioning of machinery and equipment to prevent lack of optimum functioning. Maintenance and particularly proactive maintenance are important management issues:

The results of a suitable and sufficient risk assessment should enable to choose which good practice measures are most appropriate in preventing risks in general and also in preventing risks to any individuals identified as

Being particular risk. The implementation may mean making changes to the organisation and working procedures, working environment, equipment and products used. Changes could also be necessary in training management and staff as well as improving communications.

Special issues Qualification

Based on the conducted risk assessment the following issues need special attention:

3. A qualification level has to be determined for the specific repair and maintenance tasks
4. Enough time and appropriate resources have to be allocated.

Only authorised personnel should be allowed to do repair or maintenance work. This becomes all the more important the machines and structures are more sophisticated. Only then can it be guaranteed that the right steps are followed and the correct equipment is used.

Sometimes, it can be necessary to conduct the repair or maintenance work at running machines. In this case special measures have to be taken. The normal safeguards should be in place and should be used.

If that is not possible, special protection devices have to be used (special tools, mobile switches), the speed of the machine has to be reduced, and special covers for dangerous areas have to be provided.

- If this should, in some very special cases, not be possible, special measures have to be taken based on a detailed risk assessment. Supervision must be provided throughout the process.

Work Execution

The work has to be conducted in a safe manner. Only workers with the appropriate qualification should be allowed to conduct specified work (e.g. welders must not repair their welding machines; this must be left to electricians; Site-specific instructions should also be given, which is especially important in the case of contracted out maintenance. That way the workers will be aware of any company specific characteristics.

Safe procedures need to be followed as established in the planning phase, even when under time pressure. Procedures for unexpected events have to be in place: "Part of the safe system of work should be to stop work when faced with an unforeseen problem or a problem exceeding one's own competence

9.2.3.4 Learning Activities

b) Carry out repairs of the following appliances

- Iron box
- Cooker
- Hair drier
- Electric fan
- Fluorescent fitting

9.2.3.5 Self-Assessment

g) How do you identify that a machine has a problem?
h) State the general rule to be observed when selecting components for replacement.
i) State importance of running the repaired equipment in its disassembled condition before reassembling.
j) Discus the criteria for selection of specific type of repair technique
k) Discus the considerations taken in the selection of replacement of parts
l) Discus the importance of testing the equipment for proper operation before replacing its covers

9.2.3.6 Tools, Equipment, Supplies and Materials

Tools

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

Materials and supplies

- Stationery
- Cables
- Lubricants
- Service parts and components

Equipment

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

Reference materials

- IEE regulations
- Organizational procedures manual
- charts

9.2.3.7 Reference

1. Eletrical repair and maintenance- study. Com
2. Maintenance repair and operations/ EC&M- www.ecmweb.com
3. EElectrcity level 4 by klb

Answers to Self-Assessment Questions

d) How do you identify the problem?

- It is identified by finding the faulty part or component through visual inspection or tests using instruments

e) State the general rule to be observed when selecting components for replacement

- The component must have the same or higher performance characteristics

f) What is the importance of testing a repaired equipment?

- To ensure the that the equipment function well at all settings

9.2.4 Learning Outcome 4: Test the repaired system

9.2.4.1 Introduction to the learning outcome

This section requires the trainee to test the repaired system. It involves identifying the test points, carrying out test and recording the results

9.2.4.2 Performance Standard

- Appropriate tests and test points are identified Safety procedures are adhered to
- System is tested as per test procedure
- Test results are recorded according to the established procedures
- Parameters are compared against the standard values
- Maintenance report is prepared according to approved format

9.2.4.3 Information Sheet

Definitions of terms

A **report**: is a short, sharp, concise document which with respect to the maintenance of the equip

Testing: the means by which the presence, quality or genuineness of anything is determined, a means of trails

Parameters: a numerical or measurable factor forming one of a set that defines a system or sets of conditions of its operation

Standards: something used as a measure norm or model in comparative evaluations

Identification of test and test points

Testing the system's operation once the problem is "fixed" is the last step before signing off the job ticket and walking away from a machine repair.

Before beginning any test, answer the following five questions:

- Is the circuit on or off?
- What is the condition of the fuses or breakers?
- What are the results of a visual inspection?
- Are there bad terminations?
- Is the meter working?

Meters and test equipment, as well as print tools, such as operating logs and schematics, will all help you diagnose and solve electrical problems. The fundamental diagnostic tools and test equipment are the voltmeter, ammeter, and ohmmeter. The basic functions of these meters are combined in a multimeter.

Test point

A **test point** is a location within an electronic circuit that is used to either monitor the state of the circuitry or to inject test signals. Test points have two primary uses:

- During manufacturing they are used to verify that a newly assembled device is working correctly. Any equipment that fails this testing is either discarded or sent to a rework station to attempt to repair the manufacturing defects.
- After sale of the device to a customer, test points may be used at a later time to repair the device if it malfunctions, or if the device needs to be re-calibrated after having components replaced.

Test points can be labelled and may include pins for attachment of alligator clips or may have complete connectors for test clips.

Modern miniature surface-mount electronics often simply have a row of unlabeled, tinned solder pads. The device is placed into a test fixture that holds the device securely, and a special surface-contact connector plate is pressed down onto the solder pads to connect them all as a group.

4-Step Approach to Utilizing Test Points

An excellent approach to implementing the use of test points is to follow the following 4-step approach. It provides a systematic, organized methodology that will enable consistency in utilizing test points across a range of different applications.

5. **Define** – The first step is to define a test point. A standard set of test point guidelines should be developed which can be used to verify which artefacts/objects are determined to be test points. And to help standardize the process of defining test points, test point detail & summary templates should be created.
6. **Create** – This step involves identifying potential test points at detail level.
7. **Validate and refine** – The procedure of creating and implementing test points should regularly be reviewed and refined. Creating firm timelines for the validation process — once every quarter, for example, or upon the release of every 6 service packs — can help assure consistency in the validate/refine process.
8. **Implement and Measure** – Implementing test points for a defined release should involve conducting an impact analysis. It’s also a time to look for ways to improve the process –

searching for opportunities to increase test coverage, for example, or identifying opportunities for improving test productivity. It can also be helpful to incorporate metric impacts in a release scorecard.

Test parameters

It is the job of a test technician to know which piece of test equipment to use for the task at hand and also understand the limitations of the test equipment they are using

Electrical testing in its most basic form is the act of applying a voltage or current to a circuit and comparing the measured value to an expected result. Electrical test equipment verifies the math behind a circuit and each piece of test equipment is designed for a specific application.

Electrical test equipment should be considered a source of lethal electrical energy. Technicians must observe all safety warnings and follow all practical safety precautions to prevent contact with energized parts of the equipment and related circuits, including the use of appropriate Personal Protective Equipment.

Tests

The correct tests need to be carried out in the following order:

f) Visual Inspection This is very important as approximately 90% of faults can be found by this inspection alone. The Visual Inspection is not just an inspection; it basically is *'everything but* 'what is done during the actual electrical testing process. This part of the testing process may involve:

- Smelling
- Pulling on leads
- Tapping the appliance
- Shaking
- Turning some part/s
- Checking by trying to see that retractable guards actually retract and all manner of other things may be done to ensure that it is safe to operate.

g) Earth Continuity Test
h) Insulation Resistance Test
i) Leakage Test

j) Further tests have to be performed on leads, RCDs etc

Test parameters

The use of test parameters is a powerful practice to enhance your testing scenarios. In other words, the concept of parameters in testing is that your test cases may define and likewise use some parameters. Scaling up your test cases effectively usually involves the practice of parametrization.

- Voltage

The a.c voltmeter may be used to test the presence and level of a.c supply and signal in electric circuit. Care must be to use the correct range. In the case of mains voltages, all necessary safety precautions must be observed to prevent electric shocks.

The d.c voltmeter functions used for testing voltage levels in electronic circuits, most components failure in electronic circuits alter the d.c operating conditions of the circuit. intensity in the range of 10 A with the accuracy of 1 μA, voltages in the range of 1 kV with the accuracy of 1 μV

- Resistance

The ohmmeter is useful for testing continuity of heating elements, stator, coils, armature winding and operation of switches.

When tested with an ohmmeter, switches should show continuity in closed position. the resistance of a closed circuit is zero. The resistance of an open switch is infinity. Any intermediate resistance reading between switch contacts would indicate loose contact, the presence of dirt or moisture.

- Current

Just like the voltmeter the ammeter can be used to infer faults in system. In case of fault the ammeter shows a higher than normal charge for longer, even though you know you have not used more electricity

Testing

A final test should be done to ascertain that the equipment is functioning by the client. This is done by connecting power supply to the equipment and manipulating its controls to ensure that the equipment functions well at all settings

Documenting results

Maintenance and repair documentation must be updated frequently to reflect equipment upgrades and technology advances, as well as changes in safety standards. For this reason, tracking previous versions of documentation is yet another key consideration.

The aim of documentation is to give those carrying out the works the information they need. Documents are also used to prepare cost estimates and to obtain tenders from potential contractors. Documentation should be prepared by qualified specialists. The key to good documentation is to correctly identify the problem to be solved, and hence to specify an appropriate solution. The nature and extent of the work must then be clearly conveyed to those who will do it. This information sheet discusses firstly what to document and secondly how. The central maintenance and repair record can be used to keep track of all other maintenance, including maintenance done by the in-house team, by vendors, or by service agents. The information captured should include the date, the equipment reference number, what was done, who did the work, and when next maintenance is due

Maintenance report writing

A report is a short, sharp, concise document which is written for a particular purpose and audience. It generally sets outs and analyses a situation or problem, often making recommendations for future action. It is a factual paper, and needs to be clear and well-structured.

5 Steps to Create a Maintenance Report in MS Word

Step 1: Create the Cover Page

The title should contain the information as to what the maintenance report is being created. Write the name of your company and enter the logo as well. Write down the details as well, like the address the contact details, email, etc.

Step 2: Cover Letter

On the next page include the cover letter. The person, depending on who your client is, might not be able to make sense of the technical information that you might be presenting later. That is why, in the cover letter, write down, in brief, the results of the checking. Mention what needs repairing and other such basic details.

Step 3: Device Information

In the next section, write down in detail all the information related to the device or machine. List out all the components and write down what condition they are in. You might want to make a table for the purpose as it will help you to present and record the information in a much more efficient way.

Step 4: New Parts Cost Details

Write down the parts that need repairing. Some of the parts might need a full replacement. In each case, there will be a charge incurred. It is convenient, just to put the information in this document. Mention each of the charges clearly and separately. Write the total cost involved and consider putting it in the cover letter as well.

Step 5: Suggestions and Signature

Despite repairing certain parts, there might be something on the client's end that he can do to squeeze some extra performance out of the machine. Also, you might have noticed some negligence on the client's part, which you might want to point out to him so that his machine lasts longer. Finally, put your name and signature at the bottom.

Maintenance Report Form Template

Contact Details	
Name	
Date	
Property Address	

Description of maintenance issue:

For office use:

Date Received	

Action Taken

Works Completed

9.2.4.4 Learning Activities

d) Demonstrate how to carry out the final test after the equipment has been reassembled

e) Perform the final test on the repaired equipment

f) Prepare a report on the repair carried out

9.2.4.5 Self-Assessment

4. What is testing in electrical equipment?
5. Name types of test carried

6. What are the basic instrument for testing?

9.2.4.6 Tools, Equipment, Supplies and Materials

Tools

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

Materials and supplies

- Stationery
- Cables
- Lubricants
- Service parts and components

Equipment

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

9.2.4.7 References

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Answers to Self-Assessments Questions

Self-Assessment

4. What is testing in electrical equipment –

- it makes sure that system work the way they are supposed to

5. Name types of test carried

- -visual inspection,
- earth continuity
- insulation resistance,
- earth leakage, polarity
- loop impedance functional

6. What are the basic instrument for testing?

- Multimeter
- Oscilloscope
- Signal generators
- Signal tracers
- The megger