CHAPTER 3: SCIENTIFIC PRINCIPLES

Unit of learning code: CON/CU/PL/CC/03/5/A

Related Unit of Competency in Occupational Standard: Apply Scientific Principles

3.1. Introduction to the unit of learning

This unit describes the competence in applying scientific principles. It involves applying principles of: units of measurements, force, work, energy and power, friction, heat, acoustics, pressure in fluids, mechanical properties of materials and electrical.

3.2. Summary of Learning Outcomes

1. Apply principles of units of measurements
2. Apply principles of Force, work, energy and power
3. Apply principles of Friction
4. Apply principles of heat
5. Apply principles of acoustics
6. Apply principles of pressure in fluids
7. Apply mechanical properties of materials
8. Apply electrical principles

3.2.1. Learning Outcome 1: Apply principles of units of measurements

3.2.2.1 Introduction to the learning outcome

This unit describes the competence in principles of units of measurements, identification and their conversion.

3.2.2.2 Performance Standard

1.1 Units of measurements are identified based on task given

1.2 Units are converted based on standard conventions.

3.2.2.3 Information Sheet

Definitions of terms

- *Base quantity* - physical quantity chosen by convention and practical considerations such that all other physical quantities can be expressed as algebraic combinations of them
- *Conversion factor*- a ratio that expresses how many of one unit are equal to another unit
- *Derived quantity*- physical quantity defined using algebraic combinations of base quantities
- *Derived units*- units that can be calculated using algebraic combinations of the fundamental units
- *Dimension*- expression of the dependence of a physical quantity on the base quantities as a product of powers of symbols representing the base quantities.
- *English units* - system of measurement used in the United States; includes units of measure such as feet, gallons, and pounds
- *Estimation*- using prior experience and sound physical reasoning to arrive at a rough idea of a quantity's value
- *Law*- description, using concise language or a mathematical formula, of a generalized pattern in nature supported by scientific evidence and repeated experiments
- *Metric system*- system in which values can be calculated in factors of 10 model representation of something often too difficult (or impossible) to display directly
- *Physics*- science concerned with describing the interactions of energy, matter, space, and time; especially interested in what fundamental mechanisms underlie every phenomenon
- *Precision*- the degree to which repeated measurements agree with each other second the SI unit for time, abbreviated s
- *SI units* - the international system of units that scientists in most countries have agreed to use; includes units such as meters, liters, and grams

Introduction to Measurement

Consider a plumber expected to measure the required length of pipe for a piece of work and a carpet installer checking to see the length and width of a room. These are examples of measurement.

Measurement is defined as the action of determining the size or amount of something. This is usually done by using an acceptable measurement tool such as a scale rule. For example, the carpet installer uses a tape measure as his choice of measurement tool to see how long and wide a particular room is whereas the Plumber will use a scale rule is the length of pipe required is less than 300mm long or a tape measure for lengths longer than that.

When measuring weight, The Kilogram (Kg) is used. When measuring the size of a room, feet are used. You can say that a room is 20 feet long, a box weighs 45 pounds, and your computer screen measures 17 inches on its diagonal.

Systems of units are built up from a small number of base units which are defined by accurate and precise measurements of conventionally chosen base quantities. Other units are then derived as algebraic combinations of the base units

Two commonly used systems of units are English units and SI units. All scientists and most of the other people in the world use SI, whereas some use English units.

- The SI base units are international system of units that scientists in most countries have agreed to use. They include;
  - Length – meter (m)
  - Mass - kilogram(kg)
  - time - second(s)

SI units are a metric system of units, meaning values can be calculated by factors of 10. Metric prefixes may be used with metric units to scale the base units to sizes appropriate for almost any application.

- English units – is a system of measurement used in the United States; includes units of measurement such as feet, gallons, and pounds

1. Basic SI Units of Measurement

The International System of Units, or SI, is based on base units from which all other measurement units are derived. These are:

Base Units

SI Base Units common to the Building Services Industry

Base quantity	SI base unit		Description
	Name	Symbol	
Length	Metre	m	The metre is either divided or multiplied by 1000 for greater or smaller units i.e multiplied by 1000 to become kilometres (km) or divided by 1000 to become millimetres (mm). We do not use centimetres (cm) in the construction industry.
Mass	Kilogram	kg	Mass is measured in kilograms. This is not weight, as weight is measured in Newtons. The mass of an object refers to the amount of matter an object contains.
Time	Second	S	The second is the base unit of time. Derivatives of time are measured in multiples of 60, ie. 60 seconds in a minute and 60 minutes in an hour.
Electric current	Ampere	A	Referred to as the amp, this is the unit of electrical current equal to one coulomb per second.
Temperature	Kelvin	K	The kelvin is a unit of measure for temperature based upon an absolute scale. Absolute 0 K is equal to -273°C.
Pressure	Pascals	pa	The Pascal is the SI Unit of pressure. It is defined as 1 Newton per

2. Derived SI Units

We can derive many units from the seven SI base units. For example, we can use the base unit of length to define a unit of volume, and the base units of mass and length to define a unit of density.

Derived units are units that may be stated in terms of base units by means of mathematical symbols of multiplication and division as shown below:

Derived Units

Examples of SI derived units expressed in terms of base units

Derived Quantity	***SI derived unit***		**Description**
	Name	**Symbol**	
Area	**square metre**	**m^2**	The m^2 is derived from multiplying length and width. It is 2-dimensional.
Volume	**cubic metre**	**m^3**	The m^3 is derived from multiplying length, width and height. It is 3-dimensional.
Speed, velocity	**metre per second**	**m/s**	The m/s is the distance travelled over time in a straight line and at a constant speed.
Acceleration	**metre per second squared**	**m/s^2**	The m/s^2 is the distance travelled over time that includes speeding up, slowing down and changing direction.
Density	**Kilograms per metre cubed**	**Kg/m^3**	The kilogram per meter cubed (kg/m^3) is the standard unit of material density in the International System of Units (SI). Material density is expressed directly in base SI units, and cannot be further reduced.
Capacity	**Litre**	**l**	Capacity is measured in litres (l). A litre is a measurement of 1000 centimetres cubed (cm^3).
Area	**square metre**	**m^2**	The m^2 is derived from multiplying length and width. It is 2-dimensional.

Unit conversion

- **Length**

The standard unit of length in both the SI and original metric systems is the meter (m). One meter is about 39.37 inches or 1.094 yards.

Longer distances are often reported/ represented in kilometers

1 km = 1000 m = 10^3 m

whereas shorter distances can be reported in centimeters or millimeters

1 cm = 0.01 m = 10^{-2} m

1 mm = 0.001 m = 10^{-3} m.

Most working drawings have measurement given in mm.

- **Mass**

The standard unit of mass in the SI system is the kilogram (kg). A kilogram was originally defined as the mass of a liter of water in a cube of water with an edge length of exactly 0.1 meter. One kilogram is about 2.2 pounds.

One gram (g) is exactly equal to 1/1000 or 10^{-3} kg.

Pipes laid below the ground floor level may collapse due to heavy loads if the load bearing capacity is exceeded.

- **Temperature**

Temperature is an intensive property. The SI unit of temperature is the kelvin (K). The IUPAC convention is to use kelvin (all lowercase) for the word, K (uppercase) for the unit symbol. Celsius degrees are the same magnitude as those of kelvin, but the two scales place their zeros in different places.

Water freezes at 273.15 K (0 °C) and boils at 373.15 K (100 °C) by definition, and normal human body temperature is approximately 310 K (37 °C).

It is important to use a given pipe material for the task its specified for. Pipes meant for cold water supply should specifically be used for that task since they may fail if used to supply or carry hot water since they have a smaller wall thickness.

- **Time**

The SI base unit of time is the second (s). Time intervals can be expressed with the appropriate prefixes; for example;

3 microseconds = 0.000003 s = 3×10^{-6}

5 mega seconds = 5,000,000 s = 5×10^{6} s.

Alternatively, hours, days, and years can be used.

When determining the capacity of a storage tank, it is important to ensure that the stored water is enough to serve the occupants for a period of 24hours after the direct water supply is cut off or being maintained.

(It is important to give practical examples of instances where these units of measurement are applied in Plumbing to enhance the relevance of this learning outcome to the trainee)

3.2.2.4 Learning Activities

Practical activity

With the assistance of your trainer, measure the length of a given path.
Example measure the length of administration block to the main gate and indicate the length in;

a) Metres
b) Kilometres
c) Centimetres

Materials Required

- Measuring tape
- Markers
- Pencil
- Drafting book

3.2.2.5 Self-Assessment

1. Convert 35.9 kL to liters.
2. How many cubic centimeters are in 0.883 m^3?

3. A rectangular plot in a garden has the dimensions 36.7 cm by 128.8 cm. What is the area of the garden plot in square meters? Express your answer in the proper number of significant figures.

4. Suppose that you drive the 10.0 km from your Institute to home in 20.0 min. Calculate your average speed
   a) in kilometers per hour (km/h) and
   b) in meters per second (m/s). (Note: Average speed is distance traveled divided by time of travel.)
5. Convert 88.4 m/min to meters/second.

3.2.2.6 Tools, Equipment, Supplies and Materials

- Scale rule
- Pencils
- Eraser
- Drawing paper
- Drawing board
- T-square

3.2.2.7 References

Hibbeler, R. (2015). *Engineering Mechanics: Dynamics* (14th ed.). Pearson.

Meriam, J. L., Kraige, L. G., & Bolton, J. N. (2015). *Engineering Mechanics: Dynamics* (8th ed.). Wiley.

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3.2.3.1 Responses

1. **Convert 35.9 kL to liters.**

Solution

1 kL = 1,000 L.

$$35.9\ \cancel{kL} \times \frac{1000\ L}{1\ \cancel{kL}} = 35900\ L$$

2. **How many cubic centimeters are in 0.883 m^3?**

Solution

$$0.833\ \cancel{m}^3 \times \frac{100\ cm}{1\ \cancel{m}} \times \frac{100\ cm}{1\ \cancel{m}} \times \frac{100\ cm}{1\ \cancel{m}} = 883000\ cm^3 = 8.83 \times 10^5\ cm^3$$

3. **A rectangular plot in a garden has the dimensions 36.7 cm by 128.8 cm. What is the area of the garden plot in square meters? Express your answer in the proper number of significant figures.**

Solution

$$36.7\ \cancel{cm} \times 128.8\ \cancel{cm} \times \frac{1\ m}{100\ \cancel{cm}} \times \frac{1\ m}{100\ \cancel{cm}} = 0.472696\ m^2 = 0.473\ m^2$$

4. **Suppose that you drive the 10.0 km from your Institute to home in 20.0 min. Calculate your average speed.**
   a) in kilometers per hour (km/h) and
   b) in meters per second (m/s). (Note: Average speed is distance traveled divided by time of travel.)

Solution

average speed = distance/time

average speed= 10.0 km20.0 min=0.500 km min

average speed=0.500 kmmin×60 min1 h=30.0kmh.

5. Convert 88.4 m/min to meters/second.

Solution

$$\frac{88.4\ m}{\cancel{min}} \times \frac{1\ \cancel{min}}{60\ s} = 1.47\ m/s$$

3.2.2. Learning outcome 3: Apply principles of Friction

3.2.3.1. Introduction to the learning outcome

This unit describes the competence in applying principles of friction and its application based on scientific principles.

3.2.3.2. Performance Standard

1. Friction is defined and interpreted based on standard conventions
2. The advantages and disadvantages of friction are identified based on scientific principles
3. Simple problems on friction are solved based on task requirements

3.2.3.3. Information Sheet

Definitions of terms

- *Friction* is a force which opposes or tends to oppose the relative motion of two surfaces in contact with each other.
- *Coefficient of friction* is defined as the ratio of the force needed to overcome friction
- *Viscosity* this is the internal friction of a fluid

Force of friction equation

The formula that lets you calculate the friction force is:

$$F = \mu N$$

where:

- F is the force of friction, measured in Newtons;
- μ is the dimensionless coefficient of friction; and
- N is the normal force (perpendicular to the ground surface), expressed in Newtons.

How to find force of friction

1. Choose the normal force acting between the object and the ground. Let's assume a normal force of 250 N.
2. Determine the friction coefficient. We can choose a coefficient of friction equal to 0.13.
3. Multiply these values by each other: (250 N) * 0.13 = 32.5 N.
4. You just found the force of friction! Perhaps you want to check what work it performs?

Types of friction.

- **Static** is between two surfaces when neither are moving (with respect to each other).
- **Sliding** is between two objects sliding over each other (oddly enough) - like when you slide over a wooden floor in your socks.
- **Rolling** is between a surface and a rollable object (wheel, ball, etc.).
- **Fluid friction** is the friction between an object in movement and the medium it's traveling through, e.g., a plane through the air or a fish through water
- **Static friction** acts when the object remains stationary. Imagine you try to pull a heavy box. If we don't take friction into account, even the smallest force should cause some acceleration of the box, according to Newton's second law. In reality, you need to pull quite hard for the box to start moving because of the static friction force.
- **Kinetic friction** acts on a moving object or, in other words, on an object with nonzero kinetic energy. If there were no kinetic friction, any object that you nudge (for example, a toy car) would never stop moving, as, according to Newton's first law, no force would act on it, so it would keep on going with a constant velocity.

How to measure the coefficient of friction

There are two easy methods of estimating the coefficient of friction: by measuring the angle of movement and using a force gauge. The coefficient of friction is equal to tan(θ), where θ is the angle from the horizontal where an object placed on top of another starts to move. For a flat surface, you can pull an object across the surface with a force meter attached. Divide the Newtons required to move the object by the object's mass to get the coefficient of friction.

The SI unit of friction

Like all forces, the unit for friction is the Newton, which is equal to 1 kg·m·s-2. In Imperial, the force unit is the pound of force, lbf, 1 of which is roughly 4.45 N. The coefficient of friction is dimensionless, and therefore has no units.

Laws of friction

It is difficult to perform experiments involving friction and thus the following statements should therefore be taken merely as approximate descriptions: -

1. Friction is always parallel to the contact surface and in the opposite direction to the force tending to produce or producing motion.
2. Friction depends on the nature of the surfaces and materials in contact with each other.
3. Sliding (kinetic) friction is less than static friction (friction before the body starts to slide).
4. Kinetic friction is independent of speed.
5. Friction is independent of the area of contact.
6. Friction is proportional to the force pressing the two surfaces together.

Measuring frictional forces

We can relate weight of bodies in contact and the force between them. This relationship is called coefficient of friction. Coefficient of friction as the ratio of the force needed to overcome friction Ff to the perpendicular force between the surfaces Fn. Hence

$\mu = Ff / Fn$

Examples

1. A box of mass 50 kg is dragged on a horizontal floor by means of a rope tied to its front. If the coefficient of kinetic friction between the floor and the box is 0.30, what is the force required to move the box at uniform speed?

   Solution

   $Ff = \mu Fn$

   $Fn = \text{weight} = 50 \times 10 = 500$ N

   $Ff = 0.30 \times 500 = 150$ N

2. A block of metal with a mass of 20 kg requires a horizontal force of 50 N to pull it with uniform velocity along a horizontal surface. Calculate the coefficient of friction between the surface and the block. (take g = 10 m/s)

   Solution

Since motion is uniform, the applied force is equal to the frictional force

Fn = normal reaction = weight = 20 ×10 = 200 N

Therefore, μ =Ff / Fn = 50/ 200 = 0.25.

Applications of friction

1. Match stick
2. Chewing food
3. Brakes
4. Motion of motor vehicles
5. Walking

(Plumbing Applications- Rotation of moving parts in different Plumbing machines- (Electric Diestocks, Drills, Hydraulic Machines, During cutting of steel pipes)

Methods of reducing friction

1. Rollers
2. Ball bearings in vehicles and machines
3. Lubrication / oiling
4. Air cushioning in hovercrafts

(Give different Plumbing Examples)

Lubrication of moving parts-The electric Diestock is manufactured with its own oil drum that keeps recycling and supplying the oil to the moving parts as it is in use.

To easen the cutting and threading processes, one is required to spray or oil the pipe with a suitable lubricant to reduce friction between the pipe and the cutting/ threading tool.

Viscosity

Viscosity of a liquid decreases as temperature increases. When a body is released in a viscous fluid it accelerates at first then soon attains a steady velocity called terminal velocity. Terminal velocity is attained when F + U = mg where F is viscous force, U is upthrust and mg is weight.

Advantages of friction:

1. Friction enables us to walk freely.
2. It helps to support ladder against wall.

3. It becomes possible to transfer one form of energy to another.

4. Objects can be piled up without slipping.

5. Breaks of vehicles work due to friction

Disadvantages of friction:

1. It always resists the motion, so extra energy is required to overcome it.
2. It causes wear and tear of machines.
3. It decreases the life expectancy of moving parts of vehicles.
4. Since friction is very useful in some cases while harmful in some cases, friction is called a necessary evil.

3.2.3.4. Learning Activities

Practical activity

a) Pull a heavy box on a fairly flat surface and note down your findings.
b) Suggest ways you can make the box move easily and apply them

Materials and Supplies

- A relatively heavy box
- A flat surface/floor
- Rollers
- Rope

3.2.3.5. Self-Assessment

1. A wooden box of mass 30 kg rests on a rough floor. The coefficient of friction between the floor and the box is 0.6. Calculate
2. What are the five advantages of friction?

3. Which four day-to-day operations do we apply friction?
4. A block of metal with a mass of 20 kg requires a horizontal force of 50 N to pull it with uniform velocity along a horizontal surface. Calculate the coefficient of friction between the surface and the block. (take g = 10 m/s)
5. Discuss any five types of friction.

3.2.3.6. Tools, Equipment, Supplies and Materials

- A relatively heavy box
- A flat surface/floor
- Rollers
- Rope

3.2.3.7. Reference

Hibbeler, R. (2015). *Engineering Mechanics: Dynamics* (14th ed.). Pearson.

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Trumbauer, L. (2004). *What Is Friction? (Rookie Read-About Science: Physical Science: Previous Editions)* (Illustrated ed.). Children's Press.

3.2.3.8. Model Answers

1. **A wooden box of mass 30 kg rests on a rough floor. The coefficient of friction between the floor and the box is 0.6. Calculate**
   a) The force required to just move the box
   b) If a force of 200 N is applied the box with what acceleration will it move?

2. **What are the five advantages of friction?**

   a) Friction enables us to walk freely.
   b) It helps to support ladder against wall.
   c) It becomes possible to transfer one form of energy to another.
   d) Objects can be piled up without slipping.
   e) Breaks of vehicles work due to friction.

3. **Which four day-to-day operations do we apply friction?**
   a) Match stick
   b) Chewing food
   c) Brakes
   d) Motion of motor vehicles
   e) Walking

4. **A block of metal with a mass of 20 kg requires a horizontal force of 50 N to pull it with uniform velocity along a horizontal surface. Calculate the coefficient of friction between the surface and the block. (take g = 10 m/s)**

   Solution
   Since motion is uniform, the applied force is equal to the frictional force

   F_n = normal reaction = weight = $20 \times 10 = 200$ N

   Therefore, $\mu = F_f / F_n = 50/200 = 0.25$.

5. **Discuss any five types of friction.**

- Static is between two surfaces when neither are moving (with respect to each other).
- Sliding is between two objects sliding over each other (oddly enough) - like when you slide over a wooden floor in your socks.
- Rolling is between a surface and a rollable object (wheel, ball, etc.).
- Fluid friction is the friction between an object in movement and the medium it's traveling through, e.g., a plane through the air or a fish through water.
- Static friction acts when the object remains stationary
- **Kinetic friction** acts on a moving object or, in other words, on an object with nonzero kinetic energy. If there were no kinetic friction, any object that you nudge (for example, a toy car) would never stop moving, as, according to Newton's first law, no force would act on it, so it would keep on going with a constant velocity.

3.2.3. Learning outcome 2: **Apply principles of Force, work, energy and power**

3.2.2.1. Introduction to the learning outcome

This unit describes the competence in applying principles of force, work, energy and power based on standard conventions. It also involves the various forms of energy and its conversion to other forms and scientific calculations involving energy.

3.2.2.2. Performance Standard

1. Force, work, energy and power are defined based on standard conventions
2. Forms of energy are described based on the state of the matter
3. Energy is converted according to scientific principles
4. Simple calculations on work, energy and power are solved based on the task requirements

3.2.2.3. Information Sheet

Definitions of terms

- *Work* is said to be done when a body or object moves with the application of external force.
- *Power* can be defined as the rate at which work is done i.e. energy converted.
- *Energy* is the ability to perform work
- A *force* is a push or pull upon an object resulting from the object's interaction with another object

Introduction to principles of Force, work, energy and power

Energy, force, heat and power are closely linked. It is almost impossible to have one without the other.

The first law of thermodynamics states that: 'Energy can neither be created nor destroyed. Energy is transferred from one form to another.'

The SI Units

- The unit of power - The watt is the SI unit for power. It is equivalent to one joule per second (1 J/s) or in electrical units, one volt ampere (1 V·A) (DC circuits).
- The unit of heat - The Joule is unit of heat. 4.186 joule of heat energy (equals one calorie) is required to raise the temperature of 1 g of water from 0oC to 1oC. This is usually rounded up to 4.19j/g for calculation purposes.
- The Unit of energy – also the joule (see above)

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1. Forms of energy.

a) Chemical energy: - this is found in foods, oils charcoal firewood etc.

b) Mechanical energy: - there are two types;

  i. Potential energy – a body possesses potential energy due to its relative position or state

  ii. Kinetic energy – energy possessed by a body due to its motion i.e. wind, water

  iii. Wave energy – wave energy may be produced by vibrating objects or particles i.e. light, sound or tidal waves.

  iv. Electrical energy – this is energy formed by conversion of other forms of energy i.e. generators.

Transformation and conservation of energy

Any device that facilitates energy transformations is called transducer. Energy can be transformed from one form to another i.e. mechanical – electrical – heat energy. The law of conservation of energy states that "energy cannot be created or destroyed; it can only be transformed from one form to another".

2. Work

Work is done when a force acts on a body and the body moves in the direction of the force.

Work done = force × distance moved by object

$W = F \times d$

Work is measured in Nm. 1 Nm = 1 Joule (J)

Examples

1. Calculate the work done by a stone mason lifting a stone of mass 15 kg through a height of 2.0 m. (take g=10N/kg)

   Solution

   Work done = force × distance

   = (15× 10) × 2 = 300 Nm or 300 J

2. A girl of mass 50 kg walks up a flight of 12 steps. If each step is 30 cm high, calculate the work done by the girl climbing the stairs.

   Solution

   Work done = force × distance

   = (50× 10) × (12 ×30) ÷ 100 = 500 × 3.6 = 1,800 J

3. Power

Power is the time rate of doing work or the rate of energy conversion.

Power (P) = work done / time

P = W / t

The SI unit for power is the watt (W) or joules per second (J/s).

Examples

1. A person weighing 500 N takes 4 seconds to climb upstairs to a height of 3.0 m. what is the average power in climbing up the height?

   Solution

   Power = work done / time = (force × distance) / time

   = (500 ×3) / 4 = 375 W

4. Machines

A machine is any device that uses a force applied at one point to overcome a force at another point. Force applied is called the effort while the resisting force overcome is called load. Machines makes work easier or convenient to be done. Three quantities dealing with machines are;-

a) Mechanical advantage (M.A.) - this is defined as the ratio of the load (L) to the effort (E). It has no units.

   M.A = load (L) / effort (E)

b) Velocity ratio – this is the ratio of the distance moved by the effort to the distance moved by the load

   V.R = distance moved by effort/ distance moved by the load

c) Efficiency – is obtained by dividing the work output by the work input and the getting percentage

   Efficiency = (work output/work input) × 100

= (M.A / V.R) × 100

= (work done on load / work done on effort) × 100

Examples

1. A machine; the load moves 2 m when the effort moves 8 m. If an effort of 20 N is used to raise a load of 60 N, what is the efficiency of the machine?

   Solution

   Efficiency = (M.A / V.R) × 100   M.A = load/effort =60/20 = 3

   V.R =DE/ DL = 8/2 = 4

   Efficiency = ¾ × 100 = 75%

Some simple machines

a) Levers – this is a simple machine whose operation relies on the principle of moments
b) Pulleys – this is a wheel with a grooved rim used for lifting heavy loads to high levels. The can be used as a single fixed pulley, or as a block-and-tackle system.

These machines are used in the lifting of heavy equipment or materials on site.

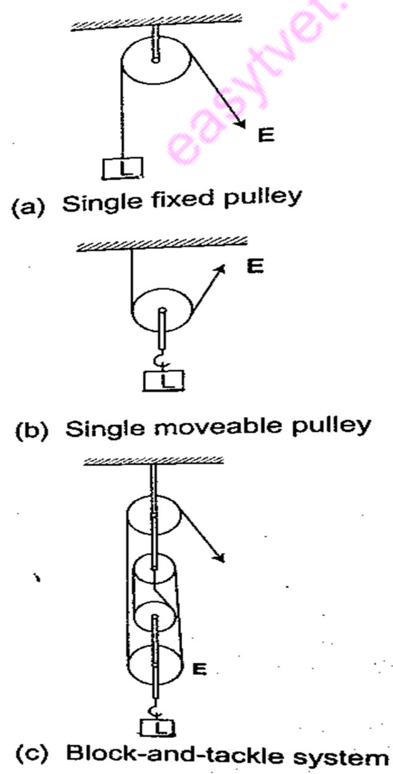

Figure 101:Pulleys

M.A = Load/ Effort

V.R = no. of pulleys/ no. of strings supporting the load

Example

A block and tackle system has 3 pulleys in the upper fixed block and two in the lower moveable block. What load can be lifted by an effort of 200 N if the efficiency of the machine is 60%?

Solution

V.R = total number of pulleys = 5

Efficiency = (M.A /V.R) × 100 = 60%

0.6 = M.A/ 5 =3, but M.A = Load/Effort

Therefore, load = 3 ×200 = 600 N

c) Wheel and axle – consists of a large wheel of big radius attached to an axle of smaller radius.

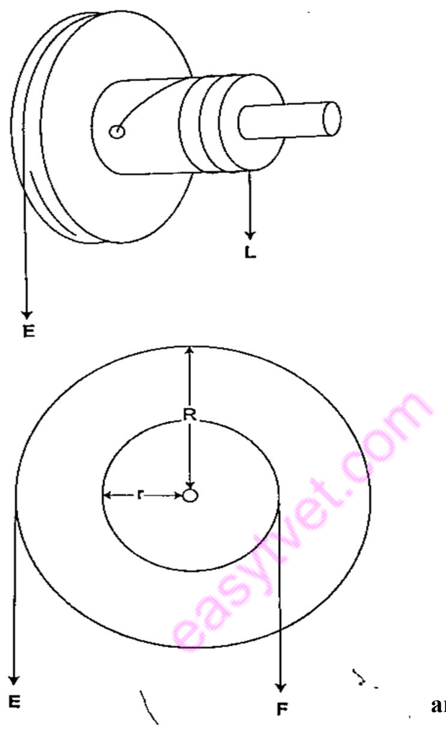

Figure 102: Wheel and axle

V.R = R/r and M.A = R/r

Example

A wheel and axle is used to raise a load of 280 N by a force of 40 N applied to the rim of the wheel. If the radii of the wheel and axle are 70 cm and 5 cm respectively. Calculate the M.A, V.R and efficiency.

Solution

M.A = 280 / 40 = 7

V.R = R/r = 70/5 = 14

Efficiency = (M.A/ V.R) × 100 = 7/14 × 100 = 50 %

d) Inclined plane: -

V.R = 1/ sin θ   M.A = Load/ Effort

Example

A car weighing 1,600 kg is lifted with a jack-screw of 11 mm pitch. If the handle is 28 cm from the screw, find the force applied.

Solution

Neglecting friction M.A = V.R

V.R = $2\pi r$ /P = M.A = L / E

1,600 / E = $(2\pi \times 0.28) / 0.011$

E = $(1,600 \times 0.011 \times 7) / 22\times2\times0.28$ =10 N

e) Gears: - the wheel in which effort is applied is called the driver while the load wheel is the driven wheel.

V.R = revolutions of driver wheel / revolutions of driven wheel

Or

V.R = no. of teeth in the driven wheel/ no. of teeth in the driving wheel

f) Pulley belts: -these are used in bicycles and other industrial machines

V.R = radius of the driven pulley / radius of the driving pulley

g) Hydraulic machines

V.R = R2 / r2 where R- radius of the load piston and r- radius of the effort piston

Example

The radius of the effort piston of a hydraulic lift is 1.4 cm while that of the load piston is 7.0 cm. This machine is used to raise a load of 120 kg at a constant velocity through a height of 2.5 cm. given that the machine is 80% efficient, calculate;

a) The effort needed
b) The energy wasted using the machine

Solution

a) V.R = R2 / r2 = $(7\times7) / 1.4 \times 1.4 = 25$

Efficiency = M.A / V.R = $(80 /100) \times 25 = 20$

But M.A = Load / Effort = $(120\times10) / 20 = 60$ N

b) Efficiency = work output / work input = work done on load (m g h) /80

= $(120 \times 10\times 2.5)$ / work input

80 / 100 = 3,000 / work input

Work input = $(3,000 \times 100) /80 = 3,750$ J

Energy wasted = work input – work output

= 3,750 – 3,000 = 750

3.2.2.4. Learning Activities

Practical activity

Assemble a single fixed pulley system on a higher surface and safely lift various masses as shown below.

Materials and Supplies needed for the practical activity

- Pulley
- Rope
- A convenient mass
- Nails
- Timber
- Claw hammer

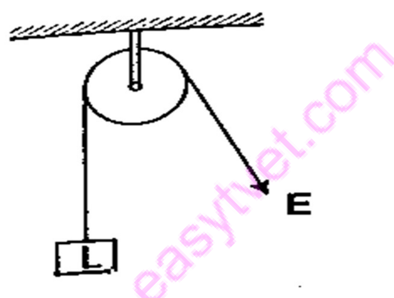

Figure 103: Single fixed pulley

3.2.2.5. Self-Assessment

1. A force of 7.5 N stretches a certain spring by 5 cm. How much work is done in stretching this spring by 8.0 cm?
2. A car travelling at a speed of 72 km/h is uniformly retarded by an application of brakes and comes to rest after 8 seconds. If the car with its occupants has a mass of 1,250 kg. Calculate;
   a) The breaking force
   b) The work done in bringing it to rest
   c) Work done
3. A spring constant k = 100 Nm is stretched to a distance of 20 cm. calculate the work done by the spring.

4. A box of mass 500 kg is dragged along a level ground at a speed of 12 m/s. If the force of friction between the box and floor is 1200 N. Calculate the power developed.
5. A man uses an inclined plane to lift a 50 kg load through a vertical height of 4.0 m. the inclined plane makes an angle of 300 with the horizontal. If the efficiency of the inclined plane is 72%, calculate;
   a) The effort needed to move the load up the inclined plane at a constant velocity.
   b) The work done against friction in raising the load through the height of 4.0 m. (take g= 10 N/kg)

3.2.2.6. Tools, Equipment, Supplies and Materials

- Pulley
- Rope
- A convenient mass
- Nails
- Timber
- Claw hammer

3.2.2.7. References

Hibbeler, R. (2015). *Engineering Mechanics: Dynamics* (14th ed.). Pearson.

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3.2.2.8. Model Answers

1. **A force of 7.5 N stretches a certain spring by 5 cm. How much work is done in stretching this spring by 8.0 cm?**

   Solution

   A force of 7.5 produces an extension of 5.0 cm.

   Hence 8.0 cm = (7.5 ×8)/ 5 = 12.0 N

   Work done = ½ × force × extension

   = ½ × 12.0 × 0.08 = 0.48 J

2. **A car travelling at a speed of 72 km/h is uniformly retarded by an application of brakes and comes to rest after 8 seconds. If the car with its occupants has a mass of 1,250 kg. Calculate;**

   a) **The breaking force**

   b) **The work done in bringing it to rest**

   c) **Work done**

   Solution

   F = ma and a = v – u/t

   But 72 km/h = 20m/s

   a = 0 -20/8 = - 2.5 m/s

   Retardation = 2.5 m/s

   Braking force F = 1,250 × 2.5

   = 3,125 N

   Work done = kinetic energy lost by the car

   = ½ mv2 – ½ mu2

   = ½ × 1250 × 02 – ½ × 1250 × 202

   = - 2.5 × 105 J

3. **A spring constant k = 100 Nm is stretched to a distance of 20 cm. calculate the work done by the spring.**

   Solution

   Work = ½ ks2

   = ½ × 100 × 0.22

   = 2 J

4. **A box of mass 500 kg is dragged along a level ground at a speed of 12 m/s. If the force of friction between the box and floor is 1200 N. Calculate the power developed.**

   Solution

Power = F v

= 2,000 × 12

= 24,000 W = 24 kW.

5. **A man uses an inclined plane to lift a 50 kg load through a vertical height of 4.0 m. the inclined plane makes an angle of 300 with the horizontal. If the efficiency of the inclined plane is 72%, calculate;**
   a) **The effort needed to move the load up the inclined plane at a constant velocity.**
   b) **The work done against friction in raising the load through the height of 4.0 m. (take g= 10 N/kg)**

   Solution

   a) V.R = 1 / sin C = 1/ sin 300 = 2 M.A = efficiency × V.R = (72/100)× 2 = 1.44

      Effort = load (mg) / effort (50×10)/ 1.44 = 347.2 N

   b) Work done against friction = work input – work output

      Work output = m g h = 50×10×4 = 2,000 J

      Work input = effort × distance moved by effort

      347.2 × (4× sin 300) = 2,777.6 J

      Therefore work done against friction = 2,777.6 – 2,000 = 777.6 J

3.2.4. Learning outcome 4: Apply principles of heat

3.2.4.1. Introduction to the learning outcome

This unit describes the competence in applying principles of heat, methods of heat transfer, sources of heat and their effects.

3.2.4.2. Performance Standard

1. Sources of heat are identified based on scientific principles
2. Effects of heat on matter is identified based on scientific principles
3. Methods of heat transfer are identified and interpreted based on scientific principles

3.2.4.3. Information Sheet

Definitions of terms

- *Temperature* represents the amount of thermal energy available
- *Heat* is the form of energy that is transferred between systems or objects with different temperatures
- *Heat flow* represents the movement of thermal energy from place to place

Basics of Heat Transfer

In the simplest of terms, the discipline of heat transfer is concerned with only two things: temperature, and the flow of heat.

On a microscopic scale, thermal energy is related to the kinetic energy of molecules. The greater a material's temperature, the greater the thermal agitation of its constituent. Several material properties serve to modulate the heat transferred between two regions at differing temperatures.

Everything on Earth and in space is made of matter. Matter can exist in 3 states:

1. Liquid
2. Solid
3. Gas

Each of these states can be changed by the addition or removal of heat. For example, if heat is applied to ice (solid), it becomes water (liquid) and if more heat is applied, the water will evaporate to become steam (gas). These transitions will also work in reverse when heat is taken away – steam to water to ice. Each of these phases is given a name:

- Ice (solid) to water (liquid) = melting
- Water (liquid) to steam (gas) = evaporation/vaporisation
- Steam (gas) back to a water (liquid) = condensation
- Water (liquid) to ice (solid) = (solidification)

Under certain conditions, it is possible to miss out certain states. For instance, ice under controlled conditions will go straight from ice to a gas, completely missing out the liquid water stage:

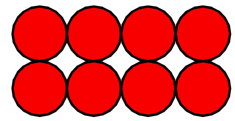
- Solid to gas = sublimation

- Gas to solid = deposition

Solids

The table shows some of the properties of solids:

Property	Reason
Solids have a fixed shape and cannot flow	The particles cannot move from place to place
Solids cannot be compressed or squashed	The particles are close together and have no space to move into

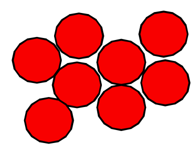


Examples : Different Pipe materials (Galvanized Iron, Copper, P.V.C Plastic e.t.c.

Liquids

The table shows some of the properties of liquids:

Property	Because
Liquids flow and take the shape of their container	The particles can move around each other
Liquids cannot be compressed or squashed	The particles are close together and have no space to move into



Examples Lubricating oil

Gases

The table shows some of the properties of gases:

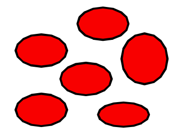
Property	Because
Gases flow and take the shape	of

their container

Gases can be compressed or squashed

The particles can move quickly in any direction

The particles are far apart and can move into any space



Examples Carbon (iv) oxide gas - used for fire fighting

Difference between latent heat and sensible heat

Table 5: Latent heat vs sensible heat

Sensible heat	**Latent heat**
When heat is directly applied to water, its temperature will rise until it reaches its boiling point. The resulting increase in the heat of the water is known as sensible heat because the application of heat has led to hotter water: Water @ 0ºC to water @ 100ºC = a change in temperature due to the application of heat. **There is no change of state.**	Changes of state are also a result of heat added but here, the added heat leads to a change in state **without** an increase in temperature. Latent heat does not affect the waters temperature. Water @ 100ºC to Steam at 100ºC = a change in state due to the application of heat. **There is no change in temperature** The process is reversible.

Heat energy is needed to increase the temperature of an object. The amount of energy needed depends on the mass of the object, the type of material it is made from, and the temperature increase.
Heat energy is also absorbed when substances melt or boil, but the temperature does not alter during a change of state. The amount of energy needed to melt or boil something depends upon the mass of the object and the type of material it is made from.

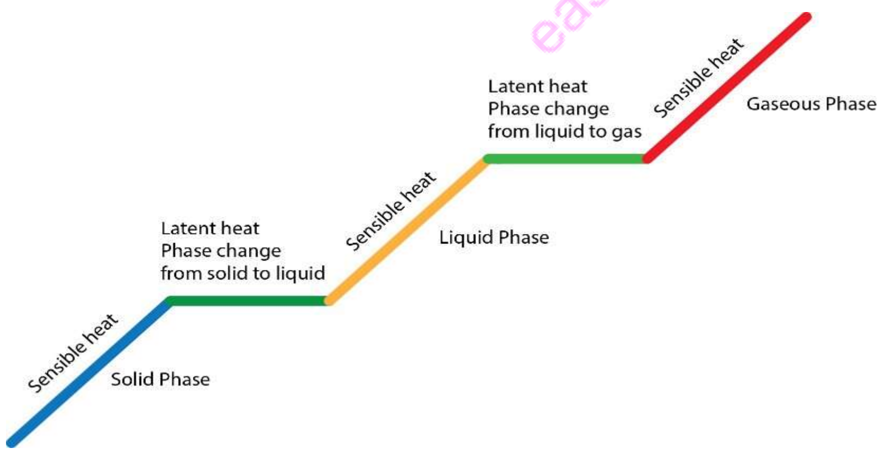


Figure 104: Heat phase Diagram

Methods of heat transfer

- Conduction
- Convection
- Radiation

Heat can be transferred from one place to another by three methods: conduction in solids, convection of fluids (liquids or gases) and radiation through anything that will allow radiation to pass. The method used to transfer heat is usually the one that is the most efficient.

Conduction

Conduction occurs when heat travels through a substance, the heat passing directly from one molecule to another.

If a piece of copper tube is heated at one end, the heat will quickly be felt at the other end. This occurs because kinetic energy in the form of heat is directly transferred from one copper atom to another very quickly.

The same principle can be applied to the conduction of electricity, as good conductors of heat are generally also good conductors of electricity.

The rate at which a material will conduct heat is known as the coefficient of thermal conductivity. It is measured in W/m2K.

$$Thermal\ conductivity = \frac{heat\ x\ distance}{area\ x\ temperature\ difference\ (\Delta t)} = W$$

The table below shows the coefficient of thermal conductivity of some common materials.

Table 6: Thermal conductivity

Thermal Conductivity of Materials	
Material	Thermal Conductivity W/m/K
Silver	406.0
Copper	397.0
Gold	317.0
Aluminum	225.0
Brass	109.0
Steel	50.2
Lead	34.7
Polyethylene HD	0.5

Wood	0.113

Convection

Convection occurs when heat is transferred through a fluid i.e. a gas or a liquid. Convection takes place because the warm fluid is less dense than the cool fluid. As the lighter, warm fluid rises, it releases heat into the surrounding environment. As this happens, the warm fluid loses its heat, becomes denser and falls by the effect of gravity, to begin the process again.

In a hot water system, this is known as gravity circulation as hot water rises and cooler water moves down to replace it, causing a circular motion.

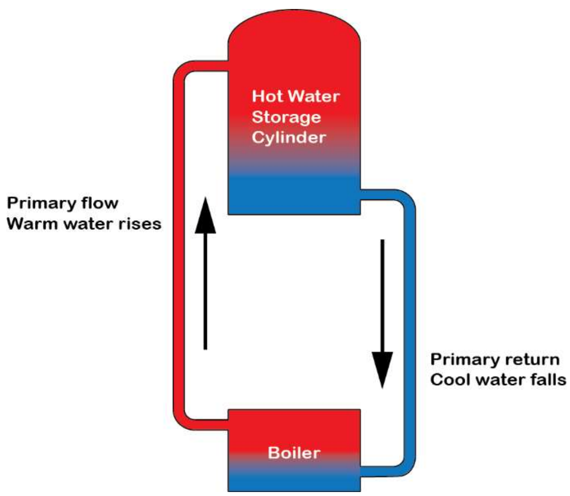


Figure 105: Convection

Radiation

On Earth, we get the heat to warm our planet from the Sun. The Sun's heat travels over 90,000,000 miles through the cold vacuum of space to warm the Earth's surface. The heat is felt because it travels objects will transmit and receive heat in the form of thermal radiation (often called infrared radiation). The hotter an object is the more thermal radiation it will emit.

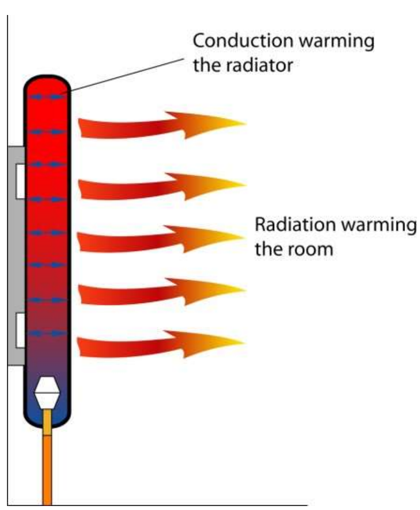


Figure 106: Radiation

How SI units of energy, heat and power are Related and Derived

- Energy – Joules (J) - the SI unit of work or energy, equal to the work done by a force of one newton when its point of application moves one metre in the direction of the force. It is equivalent to one 3600th of a watt-hour.
- Specific Heat Capacity (kJ/kg/°C) – This is the amount of energy required (in joules or kilojoules) to increase the temperature of 1kg of a substance by 1°C. Water, for example, has a SHC of 4.19 kJ/kg/°C. This means that it takes 4190joules of energy to raise the temperature of 1kg of water by 1°C.
- Power – Watts (W) - The watt (abbreviated W) is the International System of Units standard unit of power (or energy per unit time). It is the equivalent of one joule per second. The watt is used to specify the rate at which energy is dispersed, or the rate at which electro-magnetic energy is radiated, absorbed, or dissipated. The Watt can be used to describe electrical power or heat power.

To recap, the S.I. units of measurement of energy, heat and power are:

- Energy — The Joule (J)
- Heat — The Joule (J)
- Power — The Watt (W)
- Specific Heat Capacity — kilojoules per kilogram per degree Celsius (kJ/kg/°C)

The Specific Heat Capacity of water is 4.19kJ/kg/OC

Calculations using the Specific Heat Capacity of Water

Example 1 - How many kilojoules would it take to heat 200 litres of water from 40°C to 80°C? The formula for this is:

$$L\ x\ \Delta t\ x\ SHC\ of\ water$$

Where:

L = litres

□t = temperature difference SHC of water = 4.19

Therefore

200 x (80 – 40) x 4.19 = $\mathbf{33520kJ}$

3.2.4.4. References

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3.2.4.5.Model Answers

1. Discuss the three Methods of heat transfer
   - Conduction
   - Convection
   - Radiation
2. Calculate how many kilowatts it would take to raise the temperature of the 200 litres water by 40°C assume that you require 200 litres of water at 80°C in 2 hours' time:

   2 x (60 x 60) = 7200

   200 x (80 − 40) x 4.19 = 4.65 kW

This shows that to increase the temperature of 200 litres of water from 40°C to 80°C in 2 hours would take 4.65 kW of heat.

3. Which are the three states of matter giving two properties for each.

- Liquid
- Solid
- Gas

4.How many hours would it take for 200 litres of water to be heated by 40°C using a 6kW of power?

Water has a specific heat capacity of 4.19 kJ/kg/°C and that 1 W = 1 J/s. The formula for this is:

$$l\ x\ t\ x\ SHC$$
$$kW$$

Where:

L	=	litres
t	=	Temperature
kW	=	kilowatts
SHC	=	Specific Heat Capacity

Therefore:

$$200x\ 40\ x\ 4.19 = 5586.666667\ seconds$$

5. How many kilojoules would it take to heat 200 litres of water from 40°C to 80°C? The formula for this is:

$$L\ x\ \Delta t\ x\ SHC\ of\ water$$

temperature difference SHC of water = 4.19

$200\ x\ (80 - 40)\ x\ 4.19 = \mathbf{33520kJ}$.

3.2.5. Learning outcome 5: Apply principles of pressure in fluids

3.2.5.1. Introduction to the learning outcome

This unit describes the competence in applying principles of pressure in fluids based on scientific laws. It also involves simple scientific calculations for pressure in liquids.

3.2.5.2. Performance Standard

1. Density and variation of pressure is defined based on scientific principles
2. Laws are identified based on scientific principles
3. Simple calculations on pressure in liquids are performed based on scientific principles

3.2.5.3. Information Sheet

Definitions of terms

- *Pressure - Physics defines pressure as force per unit area.*
- *Force* - is the influence on a static object that causes the motion of the object to change. If the object is subjected to force, it will begin to move.
- *Flow rate*- is the volume of fluid, which passes per unit time

INTRODUCTION TO PRESSURE

Pressure is defined as the force acting normally (perpendicularly) per unit area.

The SI units for pressure is newton per metre squared (N/m2). One Nm-2 is known as one Pascal(Pa).

Pressure = normal force / area or pressure = thrust / area. Another unit for measuring

pressure is the bar. 1 bar = 105 N/m2. 1millibar = 100 N/m2.

Calculating pressure

Example

A rectangular brick of weight 10 N, measures 50 cm × 30 cm × 10 cm. calculate the values of the maximum and minimum pressures which the block exert when resting on a horizontal table.

Solution

Area of the smallest face = 0.3 × 0.1 = 0.03 m2.

Area of the largest face = 0.5 × 0.3 = 0.15 m2.

Maximum pressure = 10 N / 0.03 = 3.3 × 102 N/m2.

Minimum pressure = 10 N / 0.15 = 67 N/m2.

PRESSURE IN LIQUIDS.

The following formula is used to determine pressure in liquids.

Pressure = h ρ g, where h – height of the liquid, ρ – density and g – is force of gravity.

Example

A diver is 10 m below the surface of water in a dam. If the density of water is 1,000 kgm^3 determine the pressure due to the water on the diver. (Take g = 10 Nkg-1)

Solution

Pressure = h ρ g = 10 × 1000 × 10 = 100,000 Nm-2.

Ways of measurement of pressure in fluids

U-tube manometer

It is a transparent tube bent into U-shape. When a liquid is poured into a u-tube it settles at equal level since pressure depends on height and they share the same bottom.

Consider the following diagrams;

For the levels to differ the pressure P1 must be greater than P2, hence

P1 = P2 + hρg.

If P1 is the lung pressure, P0 is the atmospheric pressure, then if the difference is ‘h’ then lung pressure can calculated as follows.

P1 = P0 + hρg.

Example

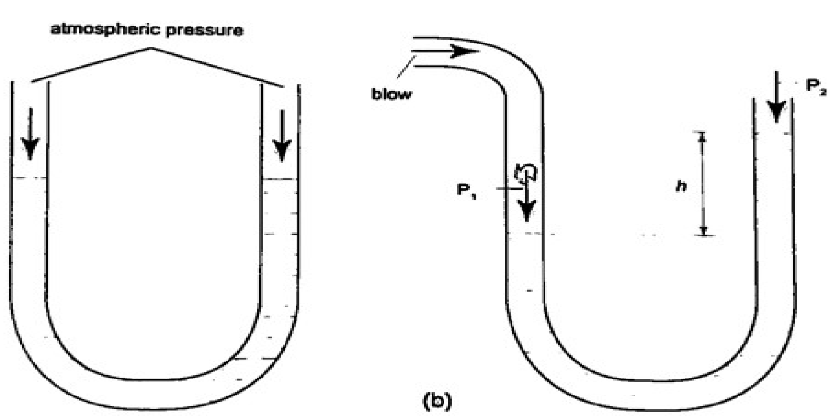
A man blows into one end of a U-tube containing water until the levels differ by 40.0 cm. if the atmospheric pressure is 1.01 × 105 N/m2 and the density of water is 1000 kg/m3, calculate his lung pressure.

Solution

Lung pressure = atmospheric Pressure + liquid pressure

P1 = P0 + hρg. Hence P1 = (1.01 × 105) + (0.4 × 10 × 1000) = 1.05 × 105 N/m2.

Measuring pressure



1. Simple mercury barometer– it is constructed using a thick walled glass tube of length 1 m and closed at one end. Mercury is added into the tube then

inverted and dipped into a dish containing more mercury. The space above the mercury column is called torricellian vacuum. The height ‘h’ (if it is at sea level) would be found to be 760 mm. Atmospheric pressure can be calculated as,

$P = \rho g h$ =>where ρ (mercury)- 1.36×104 kg/m3, g- 9.81 N/kg, h- 0.76 m.

Then $P = (1.36 \times 104) \times 9.81 \times 0.76 = 1.014 \times 105$ Pa.

This is the standard atmospheric pressure, sometimes called one atmosphere. It is approximately one bar.

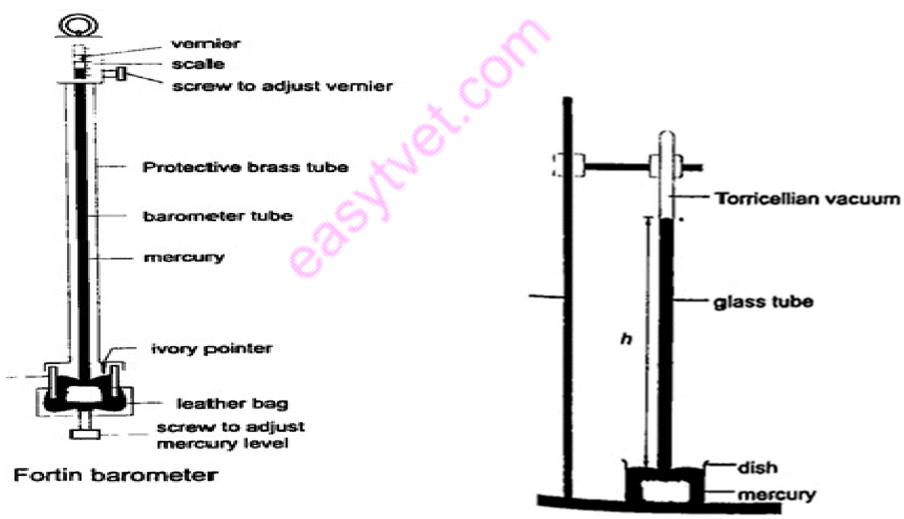


Figure 107:Mercury Barometer

2. Fortin barometer–this is a more accurate mercury barometer. The adjusting screw is adjusted first to touch the mercury level in the leather bag.
3. Aneroid barometer– increase in pressure causes the box to contract, the movements are magnified by the system of levers and is transmitted to the pointer by the fine chain and this causes the pointer to move. The scale is suitably calibrated to read pressure. Since pressure falls or rises as altitude falls or rises, the pointer can also be calibrated to read altitude.

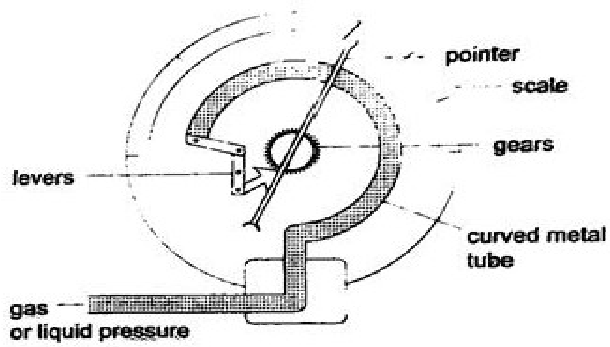


Figure 108:Aneroid Barometer

Examples

The height of the mercury column in a barometer is found to be 67.0 cm at a certain place. What would be the height of a water barometer at the same place? (densities of mercury- 1.36 × 104 kg/m3 and water- 1.0 × 103 kg/m3).

Solution

Let the pressure due to water be h1 ρ1 g1 and that of water be h ρ g. Then

h1 ρ1 g1 = h ρ g. Hence h1 = (6.7 × 10-1) × (1.36 × 104) / 1.0 × 103 = 911.2 cm or 9.11 m.

Application of pressure in gases and liquids.

1. Rubber sucker– this is a shallow rubber cap. Before use it is moistened to get a good seal then pressed firmly on a smooth surface so that the air inside is pushed out. The atmospheric pressure will then hold it firmly against the surface as shown below. They are used by printing machines to lift papers, lifting glass panes, heavy metal sheets etc.
2. Drinking straw– when a liquid is drawn using a straw air is sucked through the straw to the lungs. This leaves the space in the straw partially evacuated. The atmospheric pressure pushing down the liquid in the container becomes greater than the pressure inside the straw and this forces the liquid into your mouth.

3. The syringe– they work in the principle as the straw. They are used by the doctors in hospitals for giving injections. Bicycle pump– it uses two valves, one in the pump (greasy leather) and the other in the tire. When the handle is pushed in, the pressure inside the barrel becomes greater than the one in the tire and this pushes air inside. The valve in the tire is made such that air is locked inside once pumped.
4. The siphon– it is used to empty tanks which may not be easy to empty by pouring their contents out. The tubing must be lowered below the base of the tank. The liquid flows out due to pressure difference caused by the difference in height (h ρ g).
5. Lift pump.
6. Force pump.

Applications of pressure in Plumbing Systems

Positioning of tanks at high levels

The use of pumps to pump water to the storage vessels because it is against gravity.

Flowrate

In plumbing and heating, the volumetric. The SI unit is m^3/s: in other words, the volume of water (in m3) that flows every second (s). However, since we know that 1m3 of water has a mass of 1000kg and that 1 kg of water is equal to 1 litre, then the flow rate can also

be represented in various other ways too:

- m^3/s
- l/s
- kg/s

For example, if a tap discharges $0.3m^3/s$, then:

$0.3m^3/s = 300\ li\ =\ 300kg$

In this case, the flow rate could be quoted as $0.3m^3/s$ or 300l/s or 300kg/s.

The Application of Pressure and Flow Rate Measurements

Pressure and flow rate are the key points that any plumbing system will be measured by. If the flow rate or the pressure is poor, then this can be the result of poor design, poor installation or both. Good plumbing design and installation will deliver the desired pressure and flow rate for a given specification. However, we must also be aware that too much pressure or too high a flow rate can be detrimental as they can cause noise and erosion problems in pipework and fittings and this may lead to breakdown or failure of the pipework or components.

Force

If the object is subjected to force, it will begin to move. Consider the following example:

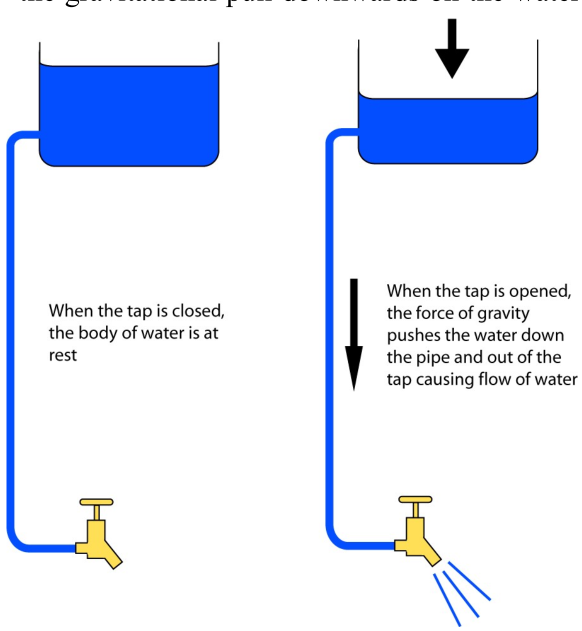
A pipe is connected to a cistern at one end and a tap at the other. The cistern is situated in the roof space and the tap is in the bathroom. While the tap is closed, the water can be said to be at rest because it is not moving. When the tap is opened, the water moves from the cistern, down the pipe and out of the tap. The water is being acted upon by the force of gravity causing it to move. We can calculate the amount of force acting downwards on the cistern that causes the water to flow.

The cistern contains 100 litres of water. Since 1 litre = 1 kg, then the mass of the cistern is 100kg. Therefore:

$Kg\ x\ 9.81 = N\ 100\ x\ 9.81 = 981N$

So, the force acting on the water is 981 N.

Force, however, does not give the pressure of the water at the tap. Force only gives an indication of the gravitational pull downwards on the water. Water pressure is calculated slightly differently and



this will be discussed in Part C, a little later in the unit.

Figure 109: Force in Water

Pressure

The weight of, say, a cistern sitting on a platform in a roof space is measured in N/m2 or Newtons per square metre. If the cistern was of equal dimensions (length, width and height), then the weight being exerted onto the platform would be the same irrespective of whether the cistern was on its bottom, side or end.

If the cistern has unequal dimensions for the length, width and height, then different pressures will be exerted depending on which of the sides is face down.

Example:

A cistern measuring 0.9m long x 0.8m wide x 0.7m high is to be installed on a platform in a roof space. What pressure would it exert on the platform if:

- The cistern was placed on its bottom (length x width)
- The cistern was placed on its side (length x height)
- The cistern was placed on its end (width x height)

Before we can attempt these calculations, we must first determine the mass of the cistern in kg. The formula for this is:

Mass = $Length\ x\ width\ x\ height$ = $volume\ in\ m$Y $0.9\ x\ 0.8\ x\ 0.7$

= $0.504m$Y

Then, we must convert the volume into mass of water. To do this we must multiply the volume by 1000 to convert the mass into litres.

$Volume\ x\ 1000 = litres\ 0.504\ x\ 1000 = 504\ litres$

Since 1 litre of water has a mass of 1 kg, then:

$Litres = kg$

$504\ litres = 504\ kg$

From an earlier calculation we know that:

So:

$Kg\ x\ 9.81 = N$

$$504\ x\ 9.81 = 4944.24\ N$$

Therefore, the cistern has a force of 4494.24 N

The formula for finding the pressure exerted is:

$$\text{Pressure} = Force \div A\ rea = Pressure$$

- Area of the bottom of the cistern:

$$0.9\ x\ 0.8 = 0.72m'$$

$$4944.24 \div 0.72 = 6867N\ pressure$$

- Area of the side of the cistern:

$$0.9\ x\ 0.7 = 0.63m'$$

$$4944.24 \div 0.63 = 7848N\ pressure$$

- Area of the end of the cistern:

$$0.8\ x\ 0.7 = 0.56m'$$

$$4944.24 \div 0.56 = 8829N\ pressure$$

From these calculations we can see that the greater the surface area for a known mass of water, then the less force is exerted by the mass on to the platform. This is very important when we are deciding on where to place large cisterns that will contain a lot of water. The greater area we can present to the platform, the better the spread of the weight across the platform, creating less stress on the structure.

Water Pressure

Water pressure can be measured when the water is flowing and when it is not flowing. These methods are known as:

1. Static pressure (head) – Water that is not flowing
2. Dynamic pressure – Water that is flowing
3. Static pressure (head) – Water that is not flowing

The image shows a cistern full of water with a pipe connected to a tap. It is the distance between the cistern and the tap (measured from the bottom of the cistern to the outlet of the tap) that creates the water pressure. It is measured in Pascals (pa). This is known as the 'static head' or 'head of water'. Every metre of height (or head) between the two increases the water pressure by 10 Kpa (kilopascals):

As we have seen previously, water pressure is also measured in bar and psi.

methods are known as:

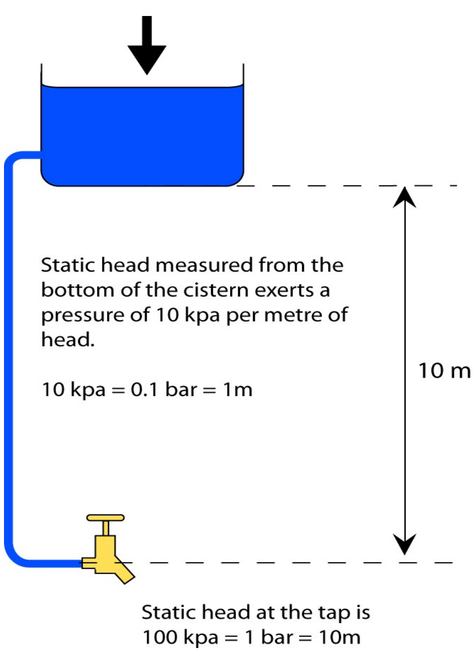


Figure 110: Demonstration of water pressure

The image shows a cistern full of water with a pipe connected to a tap. It is the distance between the cistern and the tap (measured from the bottom of the cistern to the outlet of the tap) that creates the water pressure. It is measured in Pascals (pa). This is known as the 'static head' or 'head of water'. Every metre of height (or head) between the two increases the water pressure by 10 Kpa (kilopascals):

As we have seen previously, water pressure is also measured in bar and psi.

$1m\ of\ head = 10kpa = 0.1\ bar$

So:

$10m\ head = 100\ kpa = 1\ bar$

Dynamic Pressure – Water that is Flowing

Dynamic pressure is also known as working pressure. It is the pressure of the water when it is flowing. This will generally be less than the static pressure because it is affected by other factors:

If the static pressure of the water is increased, then the effect would be that the flow rate of the water and is velocity would also increase.

The relationship between velocity, pressure and flow rate in systems

- Increasing the static water pressure will increase the velocity of the water, and therefore the flow rate, because the water is flowing with more force through the pipe.

- Decreasing the static pressure will also decrease the water velocity and therefore reduce the flow rate.
- Decreasing the pipe size will reduce the flow rate and increase the velocity because of the Bernoulli Effect

The Bernoulli effect

The Bernoulli Effect describes the relationship between flow velocity and pressure of a fluid, i.e. water. It states that when the water passes through a reduction in pipe size, then the velocity of horizontal flow will increase and the pressure will decrease.

This effect was discovered by Daniel Bernoulli in 1738.

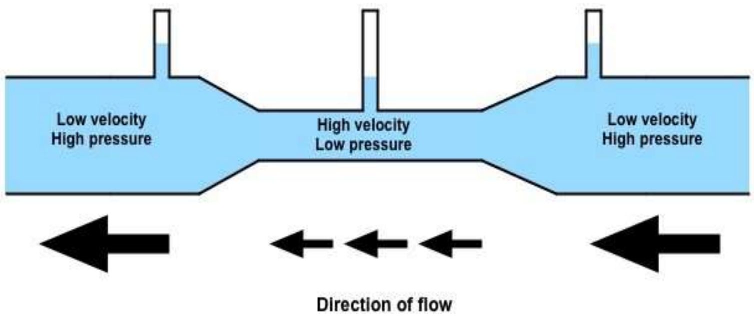


Figure 111: The Bernoulli effect

If the water is moving uniformly through the pipe, then the only forces acting on the water are its own weight and the static pressure of the water itself. If the pipe reduces in size, the water must speed up, because the same amount of water is trying to flow through a smaller space. The only way the water will move faster is if the pressure behind the fluid is greater than the pressure in front. Thus, the pressure must decrease as velocity increases.

Increasing the pipe size has a reverse Bernoulli Effect and this increases the pressure and reduces the velocity.

Reasons why pipework restricts the flow of liquids and gases

The material of the pipe

Different materials offer different resistance to the flow of water. Copper tubes and plastics are smooth internally and give little resistance to the flow of water. Low Carbon Steel, by contrast, is very rough internally and offers a greater resistance. This in turn decreases the pressure.

Changes of direction

Elbows, bends and the junction of tee fittings also offer resistance to flow and this too will reduce the pressure. An elbow, for example, has the same resistance as around 0.5m of pipe (0.3m of pipe if machine made bends are used). So if the pipe run has 6 elbows (or 6 changes of direction), this is equivalent to an extra 3m of pipe.

Length of pipe run

Again, the greater the length of pipe, the more resistance is encountered. This will effectively reduce the pressure and the flow rate of both water and gases

Pipe size

The bigger the pipe, the greater the volume of water or gases.

Restrictions such as valves and stop taps

These reduce both pressure and flow rate because they offer resistance to smooth water flow.

Reductions in pipe size

A pipe size reduction reduces the pressure and the flow rate BUT increases the velocity. It is known as the Bernoulli Effect.

Roughness of material surface

The rougher the pipe material, the greater the resistance to flow.

Principles of a Siphon

The principle of a siphon is to move water from a high place to a low place using only atmospheric pressure and the cohesive properties of water.

3.2.5.4. Learning Activities

Practical activity

a) Assemble a water closet with a siphonic flush, Test the WC and note the pressure application.

Materials and Supplies

- A complete WC

- Caulk
- Safety gear
- Adjustable spanner
- Water hose

5.1.1.4.1. Self-Assessment

1. Discuss the five factors why pipework restricts the flow of liquids and gases
2. A man of mass 84 kg stands upright on a floor. If the area of contact of his shoes and the floor is 420 cm^2, determine the average pressure he exerts on the floor. (Take g =10 N/Kg)
3. The density of mercury is 13,600 kgm-3. Determine the liquid pressure at a point 76 cm below the surface of mercury. (Take g = 10 Nkg-1)

4. The height of the mercury column in a barometer is found to be 67.0 cm at a certain place. What would be the height of a water barometer at the same place? (Densities of mercury and water are 1.36 × 104 kg/m3 and 1.0 × 103 kg/m3 respectively.)
5. Which three types of water pressure are you familiar with

3.2.5.5. Tools, Equipment, Supplies and Materials

- A complete WC
- Caulk
- Safety gear
- Adjustable spanner
- Water hose

3.2.5.6. References

Hibbeler, R. (2015). *Engineering Mechanics: Dynamics* (14th ed.). Pearson.

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3.2.5.7. Model Answers

1. **Discuss the five factors why pipework restricts the flow of liquids and gases**

The material of the pipe

Different materials offer different resistance to the flow of water. Copper tubes and plastics are smooth internally and give little resistance to the flow of water.

Changes of direction

Elbows, bends and the junction of tee fittings also offer resistance to flow and this too will reduce the pressure.

Length of pipe run

The greater the length of pipe, the more resistance is encountered. This will effectively reduce the pressure and the flow rate of both water and gases

Pipe size

The bigger the pipe, the greater the volume of water or gases.

Restrictions such as valves and stop taps

These reduce both pressure and flow rate because they offer resistance to smooth water flow.

Reductions in pipe size

A pipe size reduction reduces the pressure and the flow rate BUT increases the velocity. It is known as the Bernoulli Effect.

2. **A man of mass 84 kg stands upright on a floor. If the area of contact of his shoes and the floor is 420 cm^2, determine the average pressure he exerts on the floor. (Take g =10 N/Kg)**

Solution

Pressure = force / area = 840 / 0.042 = 20,000 Nm-2.

3. **The density of mercury is 13,600 kgm-3. Determine the liquid pressure at a point 76 cm below the surface of mercury. (Take g = 10 Nkg-1)**

Solution

Pressure = h ρ g = 0.76 × 13,600 × 10 = 103,360 Nm-2.

4. **The height of the mercury column in a barometer is found to be 67.0 cm at a certain place. What would be the height of a water barometer at the same place? (Densities of mercury and water are 1.36 × 104 kg/m3 and 1.0 × 103 kg/m3 respectively.)**

Solution

Let the pressure due to water be h1ρ1g1 = h ρ g, hence;

h1 = h ρ / ρ1= (6.7 × 10-1) × (1.36 × 104) = 911.2 cm or 9.11 m.

5. **Which three types of water pressure are you familiar with**

- Static pressure (head) – Water that is not flowing
- Dynamic pressure – Water that is flowing
- Static pressure (head) – Water that is not flowing

3.2.6. Learning outcome 6: Apply principles of acoustic

3.2.6.1. Introduction to the learning outcome

This unit describes the competence in applying principles of sound and their effects on the surroundings. It also lays emphasis on the effective methods of sound proofing and insulation.

3.2.6.2. Performance Standard

1. Sources of sound are identified based on scientific principles
2. Effects of sound on surrounding areas is identified based on scientific principles
3. Methods of sound insulation are identified and interpreted based on scientific principles

3.2.6.3. Information Sheet

Introduction

The main application of acoustics is to make the music or speech sound as good as possible. It is achieved by reducing the sound barriers and increasing the factors that help in proper transmission of sound waves. Initially, acoustics was used only in industries which are based on sound like an auditorium, theatre but today, the application of acoustics has spread to many fields like medicine, warfare, architectural industries, etc.

Definitions of terms

- *Acoustics* - the science that deals with the study of sound and its production, transmission, and effects.
- *Acoustician*- a scientist or researcher who studies acoustics
- *Acoustic energy* – is the disturbance of energy which passes through matter in the form of a wave.
- *Transduction* - the process in which some other form of energy is converted into sonic energy producing a sound wave
- *decibel (dB)* – Is the unit of measuring the amplitude of sound. The more amplitude a sound has, the louder it is.

Sound is created by vibration in an elastic medium such as air, water, and solids such as building materials. Sound travels outward through air molecules at a speed of about 1130 feet per second, quite slow in relation to the speed of light, which is about 186,000 miles per second. The vibration of the air particles in a sound wave sets the eardrums in motion. Sound is a series of pressure variations in air that take the form of periodic compressions and rarefactions. Sound travelling in air exhibits a longitudinal wave motion.

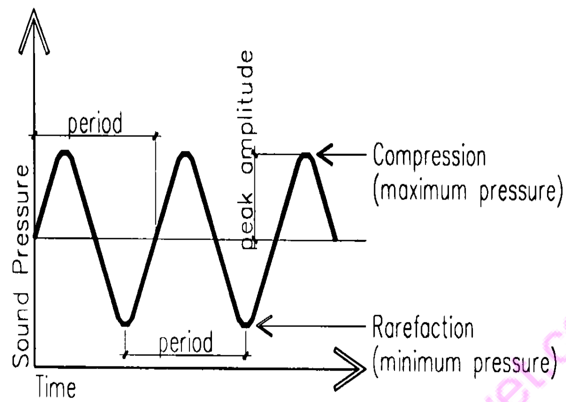

Figure 112:Vibration of Particle in Air.

- ✓ The number of complete to-and-fro vibrations that the source makes in one second is called the **frequency** of vibration.
- ✓ The time required for one complete vibration cycle is called the **period**. Consequently, the reciprocal of frequency is period.
- ✓ The greater the number of complete cycles, the higher the frequency. Frequency is measured in hertz,
- ✓ which represents cycles per second.
- ✓ **Wavelength** is the distance a sound wave travels during one cycle of vibration. The relationship between wavelength, frequency, and velocity (or speed) of sound is expressed as:

$$\lambda = c/f$$

where λ = wavelength, c = velocity of sound in feet per second, and f = frequency of the sound in hertz. Low-frequency sounds are characterized by long wavelengths and high frequency sounds are characterized by short wavelengths. While sound travels relatively slew in air, it may travel as fast as 16,000 feet per second along steel pipes and duct walls or through other building materials. It is therefore crucial to block or isolate paths where sound energy can travel through building materials to sensitive areas, even great distances away, where it can be regenerated as airborne sound.

Acoustic Energy

In other words, it is the energy concerning the mechanical vibrations from its components is called Acoustic Energy. Any acoustic event has the following stages.

- Cause or Generating Mechanism
- Acoustic wave propagation
- Reception Effect

Sound waves carry energy throughout the propagating medium. The acoustic wave equation is the fundamental equation that describes sound wave propagation. Wave propagation is the key process in any of the acoustic event. Sound propagates in liquids as a pressure wave and in solids as longitudinal or transverse waves.

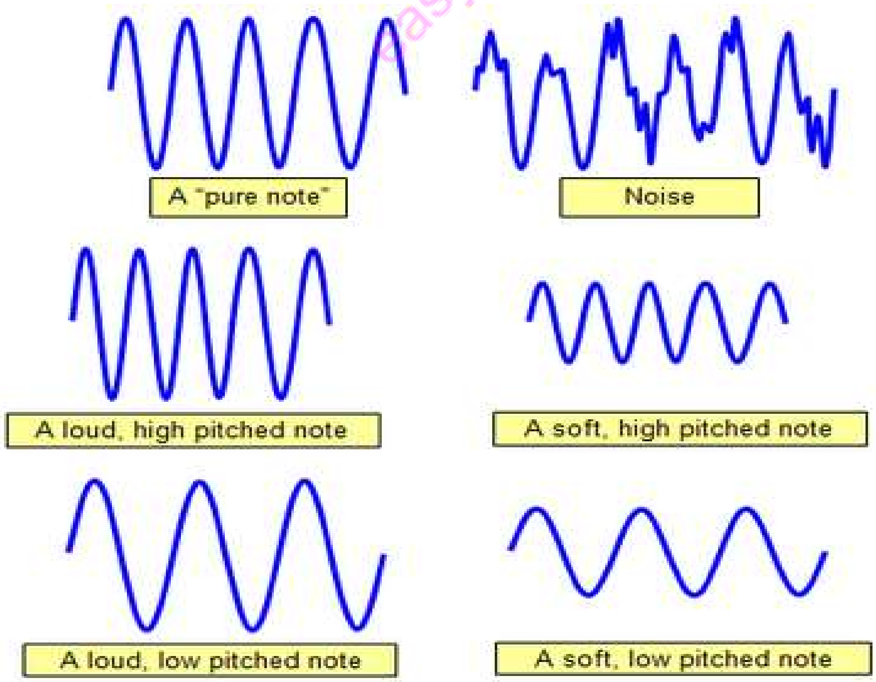

Figure 113:Sub-disciplines of Acoustics

TYPES OF ACOUSTICS

1. **Environmental Noise**

Environmental Acoustics is concerned with vibration and noise caused by roadways. Railways, aircraft and general activities that are related to the environment. The main goal of these is to reduce vibration and noise that affects the environment.

2. **Ultrasounds**

Ultrasounds are the sounds with a frequency greater than the human audible limit. However, there is no difference in physical properties when compared to normal sound. Ultrasound is used in many fields. Ultrasonic devices are used in measuring distances and in detecting objects. Ultrasound imaging is used in physics.

3. **Infrasounds**

Infrasounds are the sounds with a frequency of less than 20 Hz. The study of such sounds is called infrasonics. Applications include detection of petrol formation under the earth and the possibility of earthquakes.

4. **Vibration and Dynamics**

It is the study of how mechanical systems vibrate and interact with their environment. Applications include Vibration control which helps to protect a building from earthquakes and ground vibrations used in railways.

PRINCIPLES OF ACOUSTICS

In order to improve acoustic performance there are a number of items that can be considered.

1. The Mass Law. Essentially one of the most effective ways in enhancing acoustic performance on a frontage is to increase the mass or weight of its main surface components. Going by the Mass Law, for every doubling of weight of a material, it equates to a 6dB improvement.

Therefore, a 12mm thick glass will give a 6dB improvement in performance, over a 6mm thick glass.

2. Separating the elements in a front build up. The separating of the elements disrupts the pattern of the sound waves as they pass through the front and makes it harder for them to reach the inside surface. Including different materials in the frontage build up can be used as a method for controlling sound. Different materials will absorb and block different sounds, so a variety of materials can work together to achieve the required result.

3. The glass specifications themselves, by using laminated glass, especially one with an acoustic interlayer, you can often achieve the marginal gains that are often required.

4. When using double glazed units on a project, consider using different thicknesses / compositions of glass for the inner and outer panes, as the different thicknesses will resonate at different frequencies.

SOUND INSULATION

Sound insulation relates to the total ability of a building element or building structure to lower the sound transmission through it. Two types of sound insulation might be referred to – airborne sound insulation and impact sound insulation. It's crucial to keep in mind that the weakest link in the construction has a large impact on the overall sound insulation.

The level of sound insulation relies on the following general principles:

- flexibility/rigidity
- efficiency
- mass
- isolation.

The efficiency of each strategy of insulation can vary with the kind of sound, however in the majority of constructions all the principles of insulation matter.

- **Mass**

For example, the typical SRI of a brick wall increases from 45 dB to 50 dB when the thickness is increased from 102.5 mm to 215 mm. This doubling of mass does not need to be achieved by a doubling of thickness as the mass of a wall for sound insulation purposes is specified by its surface density determined in kilograms per square metre (rather than per cubic metre). Concrete blocks of different densities can produce the very same surface area density by differing the densities of the blocks.

- **Resonance.**

The Mass Law states that the sound insulation of a single-leaf partition has a linear relationship with the surface density (mass per system area) of the partition, and increases with the frequency of the sound.

Windows and doors are necessary parts of a building however a knowledge of the uniformity concept can prevent effort being lost on the insulation of the wrong locations. To enhance the insulation of a composite structure the component with the most affordable insulation must be improved first off. Walls dealing with loud roads need to consist of the minimum of windows and doors, and they must be well insulated.

Any doubling of frequency is a change of one octave. For example, a brick wall provides about 10 dB more insulation against 400 Hz sounds than versus 100 Hz noises. This modification, from 100 to 200 Hz and after that 200 to 400 Hz, is a rise of two octaves.Sound insulation increases by roughly 5 dB whenever the mass is doubled.

For increasing sound insulation typically involve increasing the thickness of masonry, plaster and glass. Where a construction does not obey the Mass Law it is due to the fact that other factors such as airtightness, stiffness and isolation have an effect.

- **Efficiency.**

Single-leaf construction includes composite construction such as plastered brickwork, as long as the layers are bonded together. Theory predicts an insulation increase of 6 dB for each doubling of mass, however for practical constructions the following working rule is preferable.

Typical air gaps:

- Wall– floor gaps.
- Gaps around doors.
- Poor window seals.
- Unsealed pipe runs.
- Unsealed cable runs.
- Permeable blockwork.

- **Isolation.**

Loss of insulation by resonance occurs if the event sound waves have the exact same frequency as the natural frequency of the partition. The increased vibrations that take place in the structure are handed down to the air therefore the insulation is reduced. Resonant frequencies are usually low and probably to trigger problem in the air areas of cavity construction.

- **Airtightness.**

The overall sound insulation of a construction is considerably reduced by small locations of poor insulation. An unsealed door occupying 25 per cent of the area of a half-brick wall lowers the average sound insulation of that wall from around 45 dB to 23 dB. The final sound insulation is affected by relative locations but is always closer to the insulation of the poorer part than to the better component.

The effectiveness of sound insulation depends upon frequency and the Mass Law likewise predicts the list below impact on frequency.

- **Flexibility**

Heavyweight structures with high mass transmit less sound energy than lightweight structures. The high density of heavyweight materials restricts the size of the sound vibrations inside the material so that the final face of the structure, such as the inside wall of a room, vibrates with less movement than for a light-weight material.

Flexible (non-stiff) materials, integrated with a high mass, are best for high sound insulation. Flexibility is not usually a preferable structural property in a wall or a floor.

3.2.6.4. Learning Activities

Practical activity

- Tie a 4foot piece of string to a table leg.
- Pull it tight and pluck it.
- Repeat this with a different kind of string.

Materials and Supplies

- 3 pieces of string, each 4 feet long (different kinds)
- 2 large paper clips
- Paper towels

3.2.6.5. Self-Assessment

1. What do you understand with the following terms;
   a) Frequency
   b) Period
   c) Wavelength
2. Discuss the crucial factors considered when carrying out insulation of a given room
3. In your own understanding, highlight the five types of acoustics and give an application for each.
4. Which are the three stages for the generation of acoustic Energy.
5. Briefly discuss the principles of acoustics

3.2.6.6. Tools, Equipment, Supplies and Materials

- 3 pieces of string, each 4 feet long (different kinds)
- 2 large paper clips
- Paper towels

3.2.6.7. References

Hibbeler, R. (2015). *Engineering Mechanics: Dynamics* (14th ed.). Pearson.

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3.2.6.8. Response

1. What do you understand with the following terms;

   a) **Frequency** - The number of complete to-and-fro vibrations that the source makes in one second

   b) Period - the time required for one complete vibration cycle is called the. Consequently, the reciprocal of frequency is period.

   c) Wavelength -is the distance a sound wave travels during one cycle of vibration

2. Discuss the crucial factors considered when carrying out insulation of a given room

   - flexibility/rigidity
   - efficiency
   - mass
   - isolation.

3. In your own understanding, highlight the five types of acoustics and give an application for each.

i. Environmental Noise

Environmental Acoustics is concerned with vibration and noise caused by roadways. Railways, aircraft and general activities that are related to the environment.

ii. Musical Acoustics

Musical acoustics is concerned with the study of physics of music i.e., how sounds are used to make music. Areas of study include human voice, musical instruments, and music therapy.

iii. Ultrasounds

Ultrasounds are the sounds with a frequency greater than the human audible limit.. Ultrasound is used in many fields. Ultrasonic devices are used in measuring distances and in detecting object

iv. Infrasounds

Infrasounds are the sounds with a frequency of less than 20 Hz. The study of such sounds is called infrasonics. Applications include detection of petrol formation under the earth and the possibility of earthquakes.

v. Vibration and Dynamics

It is the study of how mechanical systems vibrate and interact with their environment. Applications include Vibration control which helps to protect a building from earthquakes and ground vibrations used in railways.

4. Which are the three stages for the generation of acoustic Energy.

- Cause or Generating Mechanism
- Acoustic wave propagation
- Reception Effect

5. Briefly discuss the principles of acoustics

i. The Mass Law. Essentially one of the most effective ways in enhancing acoustic performance on a frontage is to increase the mass or weight of its main surface components. Going by the Mass Law, for every doubling of weight of a material, it equates to a 6dB improvement.

ii. Separating the elements in a front build up. The separating of the elements disrupts the pattern of the sound waves as they pass through the front and makes it harder for them to reach the inside surface. Including different materials in the frontage build up can be used as a method for controlling sound. Different materials will absorb and block different sounds, so a variety of materials can work together to achieve the required result.

iii. The glass specifications themselves, by using laminated glass, especially one with an acoustic interlayer, you can often achieve the marginal gains that are often required.

iv. When using double glazed units on a project, consider using different thicknesses / compositions of glass for the inner and outer panes, as the different thicknesses will resonate at different frequencies.

3.2.7. Learning outcome 7: Apply mechanical properties of materials

3.2.7.1. Introduction to the learning outcome

This unit describes the competence in applying principles of mechanical properties for materials and the respective tests involved for various materials to ascertain their mechanical properties.

3.2.7.2. Performance Standard

1.Mechanical properties are identified and interpreted based on type of material
2.Advantages and disadvantages of materials are identified based on use of materials
3.Materials are tested based on type of material.

3.2.7.3. Information Sheet

Definitions of terms

- *Mechanical properties* are physical properties that a material exhibits upon the application of forces
- *Test* - the determination of the technological and operational properties of materials, primarily by the use of machines and instruments

INTRODUCTION

The mechanical properties are those which affect the mechanical strength and ability of a material to be molded in suitable shape. Some of the typical mechanical properties show huge applications in space and automobile industries. These properties are associated with the capability of the materials to resist mechanical forces and load and they are measured in terms of the behavior of the material when subjected to a force. Mechanical properties may be determined to provide either design data for the engineer or as a check on the standard of raw materials. Mechanical properties may be changed by heat treatment process and the working temperature. Mostly, the strength, toughness and hardness of materials are to be measured after the metal forming process.

- **Stiffness**

It is the ability of a material to resist deformation under stress. Modulus of elasticity is the measure of stiffness. Material which suffers slight deformation under load has a high degree of stiffness or rigidity. Steel beam is stiffer or more rigid than aluminium beam. Finally, it means that the ability of material to resist elastic deflection is known as stiffness.

- **Elasticity**

It is the property of materials to regain its original shape after deformation when the external forces are removed. Example is the extension or compression of a spring. This property is desirable for Materials used in tools and machines. Steel is more elastic than rubber. Elasticity is a tensile property of the material. Proportional limit and elastic limit indicate elasticity. It is also known as Non-Permanent deformation. It consists of two sub properties within this elastic region. They are proportional limit and elastic limit. Proportional limit is the maximum stress under which a material will maintain a perfectly uniform rate of strain to stress. Proportional limit applications are precision instruments, springs etc... The greatest stress that a material can endure without taking up some permanent set is called elastic limit. Beyond the elastic limit, material does not regain its original form and permanent set occurs.

- **Plasticity**

It is the ability of material to undergo some degree of permanent deformation without rupture or failure. That means, this is the property of a material to deform permanently under the application of a load. Plastic deformation will take place only after the elastic range has been exceeded by the process of slipping when the shear stress on the slip plane reaches a critical value. Displacement caused by slipping is permanent and the crystal planes do not return to their original positions even after the removal of the stresses. Applications are forming, shaping, extruding, hot & cold working process, forging, ornamental work, stamping, rolling, drawing, pressing, etc. Aluminum is a good plasticity material.

- **Ductility**

It is the property of a material which enables it to draw out into thin wire with the application of a tensile force. Ductile material must be both strong and plastic. Ductile materials are gold (most ductile material), mild steel, copper, aluminium, nickel, zinc, tin. Ductility usually measured by the terms, percentage elongation and percentage reduction in area. Ductility is thought of as a tensile quality. Ductile material combines the properties of plasticity and tensile strength. It is also mentioned as a capacity of a material to undergo deformation under tension without rupture or the ability of a material to withstand cold deformation without fracture. Ductility of a material is to stretch under the application of tensile load and retain the deformed shape on the removal of the load. If subjected to a shock load the material would yield and become deformed. Ductile material can be worked into a shape without loss of strength. All materials which are formed by drawing are required to be ductile, e.g. drawing into wire form.

- **Brittleness**

Breaking of a material with little permanent distortion simply states the property of brittleness. Brittle materials when subjected to tensile loads snap off without giving any sensible elongation. Usually the tensile strength of brittle materials is only a fraction of their compressive strength. Examples of brittle materials are glass, bricks, cast iron etc… It is also a tendency of a material to fracture when subjected to shock loading or a blow. Material that shatters is also a brittle material.

- **Malleability**

It is the ability of materials to be rolled, flattened or hammered into thin sheets without cracking by hot or cold working. Malleable material should be plastic but it is not essential to be strong and malleability is considered as a compressive quality. Examples for malleability Al, Cu, Sn, Pb, soft steel, wrought iron. This is the property of a material to deform permanently under the application of a compressive load. A material which is forged to its final shape is required to be malleable. Forging, Rolling processes are malleability.

- **Toughness and Testing**

It is the ability of a material to withstand bending without fracture due to high impact loads. Toughness of material decreases when it is heated. It is also measured by the amount of energy that a unit volume of the material has absorbed after being stressed up to failure point and is the area under stress strain curve. For example, if a load is suddenly applied to a piece of mild steel and then to a piece of glass, the mild steel will absorb much more energy before failure occurs. Thus mild steel is said to be much tougher than a glass. This property is desirable in parts subjected to shock and impact loads. Notch toughness is the measure of the metal's resistance to brittle fracture in presence of flaw or notch and fast loading conditions. Examples are Mn-steel, wrought iron, MS, etc…it can be also defined as property of absorbing energy before fracture. To the opposite of brittleness, the ability of a material is to resist fracture under shock loading.

- **Resilience**

The property of a material to absorb energy and to resist shock and impact loads are known as resilience. Generally, it is mentioned by the amount of energy absorbed per unit volume within elastic limit. This is essential for spring materials. Two kind of resilience are available. Proof resilience: Maximum energy which can be stored in a body up to elastic limit is called the proof resilience. But the Proof resilience per unit volume is called modulus of resilience.

- **Creep**

When a part is subjected to a constant stress at high temperature for a long period of time, it will undergo a slow and permanent deformation called creep. Property is considered in designing IC engines, boilers, turbines. Simplest type of creep deformation- viscous flow Plastics, rubber and amorphous materials are very temperature sensitive to creep. Stress for a specified rate of strain at a constant temperature is called creep strength. When a material sustains steady loads for long periods of time, the material may continue to deform until they may tend to fracture under the same load. This is called creep. If a load is applied and left on the sample for months or years, the sample will slowly extend.

- **Fatigue**

It is a failure of materials under cyclic loads. When a part is subjected to a repeated or fluctuating stresses, the fracture takes place under a stress whose maximum value is less than the tensile strength of the material. For instance, the components of high speed aero and turbine engine are of this type. This is the property of a material to withstand continuously varying and alternating loads. If a part is loaded once to a stress near the yield stress, it will not break. However, if it is loaded repeatedly to this level, it will eventually break. This failure is called fatigue. Fatigue is an important goal in the design of moving machinery. Basically three stages of fatigue processes are

i) Initial fatigue
damage which leads to crack nucleation and crack initiation.
ii) Progressive cyclic growth of a
crack, this is the crack propagation stage, until the remaining un-cracked cross section of a part becomes too weak to withstand the loads applied.
iii) Final stage is the sudden fracture.

- **Hardness**

Property of a material to resist penetration by another material is known as hardness. It embraces many different properties such as resistance to wear, scratching, deformation etc.. Hardness of materials can be meant like resistance to abrasion, deformation or indentation.

- **Machinability**

Machinability is defined as the ease with which a material can be machined such as drill, lathe work, Cutting. Machinability of metal is indicated by percentage (%) that is known as machinability index. Standard metal used for the 100% machinability rating is the free-cutting steel. Materials with good machinability may be cut with relatively little power and low cost. Alloys containing more than 10% Si are the most difficult to machine because hard particles of free silicon cause rapid tool wear.

Mechanical property	Testing method
Elasticity, plasticity	Tensile test, compression test, bending test, torsion test
Stiffness, material behaviour under static load	
Creep behaviour	Creep rupture test
Hardness	Brinell, Rockwell, Vickers
Toughness	Impact test
Fatigue behaviour, fatigue strength	Wöhler fatigue test

- **Tensile Strength -** The maximum force a material can withstand when being pulled apart. Some materials such as plastics and some metals will stretch when subjected to tensile strength, while other materials like cast iron and concrete will simply snap with no deformation of shape.
- **Compressive strength -** The maximum force a material can withstand when being crushed
- **Shear strength -** The maximum force a material can withstand when being ripped.
- **Torsion strength -** The maximum force a material can withstand when being twisted (see above).
- **Heat and Electrical Conductivity -** The measure of how well a material conducts heat or electricity.
- **Heaviness -** The denseness of a material. A dense material will be heavy in relation to its size.
- **Strength -** The measure of how materials withstand heavy loads without breaking.

MATERIALS TESTING

Materials testing studies the behaviour of materials under different loads. In particular, the relationship between the acting in quality assurance. There is a range of standardized testing methods to characterize the mechanical properties of materials

Figure 114: Material testing

1. **Compression test to determine flow curves**

Compression tests are less significant for testing metallic materials compared to tensile tests. However, when studying building materials such as natural stone, brick, concrete, wood etc., the compression test is fundamentally import- ant. A standardized specimen with a known cross section is loaded uniformly with low increasing force in the longitudinal direction. A uniaxial stress state prevails in the specimen. The ratio of stress to compression can be shown from the plotted force-path diagram. The stress-compression diagram shows clearly the different behaviour of the various separate materials and provides the characteristic values for compression strength, 0,2% offset yield point and the compression yield stress.

2. **Bending tests for the study of deformation behaviour**

The most frequently studied bending load in materials testing is the three-point bending test. Using this method, a beam mounted on two supports is studied under a single force applied to the centre. The bending test demonstrates the relationship between the load of a bending beam and its elastic deformation. The effects of modulus of elasticity and second moment of area are shown.

3. **Shear test to study the load capacity against shearing**

The shear test is applied when testing screws, rivets, pins and parallel keys in order to determine the shear strength of the material or the behaviour of the material under shear strain. To do this, the shear stresses are produced in the specimen by means of external shear forces until the specimen shears off. The resistance of a material against the shear stress can be determined by two different methods, the single-shear and the double-shear testing method.

4. **Torsion test to study the plastic behaviour of materials**

Sheets and strips are subject to high demands in terms of their cold formability for deep drawing. No cracks are allowed to occur when working with these thin sheets.

The cupping test checks the cold formability in sheets. Components that are subjected to rotary movements are twisted. This twisting is referred to as torsion. The torsional stiffness determined in the torsion test serves as orientation for the load capacity of the material. This method is applied in shafts, axles, wires and springs and to assess the impact behaviour of tool steels.

5. **Impact test to determine the toughness property**

The impact test is a method with sudden loading and is suit- able primarily for determining the cleavage fracture tendency or toughness property of a material. This test method does not provide any values of material characteristics. The determined values of the impact test, the notched-bar impact strength, do not fit directly into calculations on strength. Rather, they help only with a rough selection of materials for a specific task.
The deformation behaviour is often an important criterion for the selection of materials. It can be used to identify quickly which of the selected materials are brittle or tough.

6. **Fatigue strength test**

Materials behave differently under lasting static loads at increased temperatures than they do under the same load at without an increase in load lead to a slow but steady irreversible plastic deformation, also known as creep.

The fatigue strength defines the load limit up to which a material that is loaded dynamically withstands without breaking. Moving machine parts in particular are subject to dynamic loads, caused by vibrations for example. In this case, a fracture occurs after a high number of load cycles with stresses that are far below the yield point and far below the fracture stress.

7. **Principle of the creep rupture test**

In the creep rupture test, a specimen is subjected to load at constant stress and constant temperature. This experiment is performed multiple times with different stresses, but always at the same temperature. The plastic deformations are measured in continuous intervals. All measured values can then be transferred to a creep diagram. The measured elongation shows long, even load time, this leads to fracture of the specimen. A characteristic curve, which is known as the creep curve. The creep rupture test determines the characteristic values for the creep strength and the various strain values.

APPLICATIONS OF MECHANICAL PROPERTIES

The mechanical properties of materials are fundamentally important in terms of materials science. Every mechanical property has specific applications in designing components in manufacturing automobile, forging, power plant, aerospace etc. Some of the applications and its properties are given in the table below.

Table 8. Properties and applications

Sl.no.	Properties	Applications
1	Proportional limit	Precision instruments, springs
2	Plasticity	forming, forging, shaping, extruding, hot & cold working, ornamental work, stamping, rolling, drawing, pressing
3	Elasticity	Desirable for materials used in tools and machines.
4	Malleability	rolling, hammering
5	Toughness	Desirable for shock & impact loads.
6	Resilience	Springs
7	Creep	in designing IC engines, boilers, turbines
8	Hardness	resistance to wear, scratching, deformation

9	Fatigue	high speed aero and turbine engine

3.2.7.4. Learning Activities

Practical activity

With the help of your trainer, undertake a compression test on a building stone or on a concrete block and determine the compressive strength.

Include a test for tensile strength

Materials and Supplies

- Compression testing machine
- A building stone
- Writing materials

3.2.7.5. Self-Assessment

1. Discuss at least eight properties of materials
2. Which are the three stages of fatigue processes?
3. Highlight the application of the following tests;

   i. Plasticity
   ii. Elasticity
   iii. Malleability
   iv. Toughness

4. Briefly explain the procedure of undertaking the Fatigue strength test

5. Discuss the principle of the creep rupture test.

3.2.7.6. Tools, Equipment, Supplies and Materials

- Compression testing machine
- A building stone
- Writing materials

3.2.7.7. References

Hibbeler, R. (2015). *Engineering Mechanics: Dynamics* (14th ed.). Pearson.

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3.2.7.8. Responses

1. Discuss at least eight properties of materials

- Hardness - The resistance of material to being cut, deformed or bent.
- Toughness - The amount of energy a material can absorb without breaking or fracturing.
- Tensile Strength - The maximum force a material can withstand when being pulled apart. Some materials such as plastics and some metals will stretch when subjected to tensile

strength, while other materials like cast iron and concrete will simply snap with no deformation of shape.

- Compressive strength - The maximum force a material can withstand when being crushed
- Shear strength - The maximum force a material can withstand when being ripped.
- Torsion strength - The maximum force a material can withstand when being twisted (see above).
- Malleability - The amount of hammering and shaping a material can withstand without breaking, splitting or cracking. Malleability is particularly desirable in metals such as sheet lead.
- Ductility - The amount that a material can be pulled, pushed, stretched or deformed without breaking. It is often characterized by a material's ability to be stretched into a wire. Copper is a very ductile metal because it can be easily bent and formed into different shapes.

2. Which are the three stages of fatigue processes?

i. Initial fatigue
ii. Damage which leads to crack nucleation and crack initiation.
iii. Progressive cyclic growth of a crack, this is the crack propagation stage, until the remaining un-cracked cross section of a part becomes too weak to withstand the loads applied.
iv. Final stage is the sudden fracture.

3. Highlight the application of the following tests;

i. Plasticity - forming, forging, shaping, extruding, hot & cold working, ornamental work, stamping, rolling, drawing, pressing
ii. Elasticity - Desirable for materials used in tools and machines.
iii. Malleability - rolling, hammering
iv. Toughness - Desirable for shock & impact loads.

4. Briefly explain the procedure of undertaking the Fatigue strength test

Materials behave differently under lasting static loads at increased temperatures than they do under the same load at without an increase in load lead to a slow but steady irreversible plastic deformation, also known as creep.

The fatigue strength defines the load limit up to which a material that is loaded dynamically withstands without breaking. Moving machine parts in particular are subject to dynamic loads, caused by vibrations for example. In this case, a fracture occurs after a high number of load cycles with stresses that are far below the yield point and far below the fracture stress.

5. **Discuss the principle of the creep rupture test.**

   In the creep rupture test, a specimen is subjected to load at constant stress and constant temperature. This experiment is performed multiple times with different stresses, but always at the same temperature. The plastic deformations are measured in continuous intervals

3.2.8. Learning outcome 8: Apply electrical principles

3.2.8.1. Introduction to the learning outcome

This unit involves identifying, applying and interpretation of electrical principles based on international standards while observing occupational safety and health practices. It also involves identification and installation of simple electrical circuits.

3.2.8.2. Performance Standard

1. Electrical principles are identified based on scientific principles
2. Electrical standards are interpreted based on international standards
3. Occupational safety and health practices are identified based on statutory and sector regulations.
4. Simple electrical circuits are identified based on international standards.

3.2.8.3. Information Sheet

Definitions of terms

- *Atom* - the smallest particle of a chemical element that can exist.
- *Neutron* - a subatomic particle of about the same mass as a proton but without an electric charge, present in all atomic nuclei
- *Proton* - a stable subatomic particle occurring in all atomic nuclei, with a positive electric charge equal in magnitude to that of an electron.
- *Nucleus* - the positively charged central core of an atom, consisting of protons and neutrons and containing nearly all its mass.
- *Conductivity* – how well a material allows electron movement
- *Resistivity* - how well a material resists electron flow is called
- *Voltage* - the difference in electron concentration. Also known as the potential difference
- *Resistance* is the opposition to electron movement through a conductor
- *Current* - is The rate at which electricity flows through an appliance
- *Power* - when electricity is converted into other forms of energy, such as light, heat or mechanical

The basic principles of electron flow theory

Everything on Earth is made up of atoms. Atoms are not solid. At the centre of every atom is a nucleus, which consists of an equal number of positively (+) charged protons and negatively (-) charged neutrons, making the atom electrically neutral. The neutrons play no role in the electrical properties of atoms. Their sole purpose is to hold the nucleus together. Without them, the nucleus would fly apart. Revolving around the nucleus is the electron. These too have a negative (-) charge.

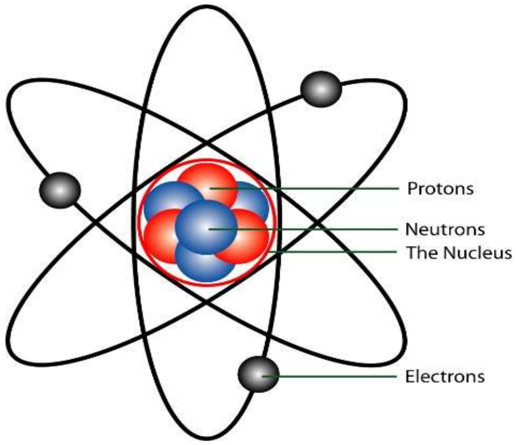


Figure 115:The nucleus of an atom

As can be seen from the image, the atom is very similar to a mini solar system, with electrons orbiting the nucleus like the planets around the sun, and, just like a solar system, those electrons nearer the nucleus orbit more quickly than those further away. The electrons that are furthest away are less attracted to the atom and are easily deflected from their weak orbits, to be attracted by other atoms. It is this constant movement of electrons from one atom to another that makes electricity possible. Materials that allow the free movement of electrons are called conductors. Those that prevent movement are called insulators.

Measurements of Electrical Flow

Electricity is measured in two ways:

1. By the number of electrons flowing. This is called the current and it is measured in Amperes or Amps.
2. By the amount of pressure, or the push, which causes the current to flow. This is measured in Volts.

Voltage is created by the electrons which, being negatively charged, repel each other. When electrons are concentrated in one place, they will flow freely away provided the path is clear for them to do so. It is the Voltage (or push) that makes them move. If there are lots of electrons in one place, the Voltage is high and many electrons will flow through the conductor. The more electrons that flow, the better the conductor.

The direction of movement of the negatively charged electrons is random unless a force acts upon them to move them in the same direction. This is Electro-Motive Force (EMF), better known as electricity.

Material Conductivity and Resistance

- **Conductivity** – conductivity is the ability of the material to allow the movement of electricity. A good conductor allows free movement of electrons; whereas a poor conductor resists the flow of electrons. Silver is the best conductor of electricity with copper a close second. However, copper is much cheaper to manufacture into electrical cables and has less mass (silver = 10490kg/m3: copper = 8960kg/m3).
- **Resistivity** – resistivity is the opposition to electron flow. It is the resistance of the material against the flow of electricity. When a metal resists the flow of electricity, the energy can be transformed into other forms of energy, such as heat and light. For example, when electricity passes through the resistance of a heating element in an electric kettle, the water will eventually boil. Similarly, when electricity passes through the filament of a light lamp, light is generated. The amount of resistance will depend on the material.

Types of Current

There are two different types of electricity:

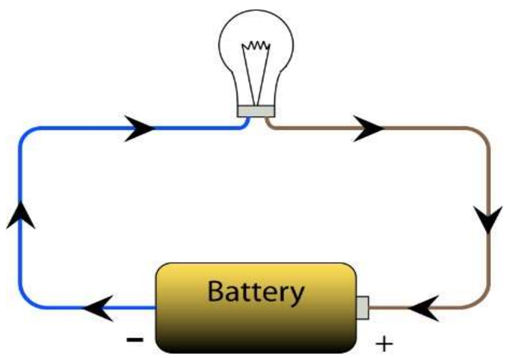
Direct Current (DC)

Direct Current is generated by a number of sources. It can be generated by photo-voltaic (PV) panels or as a result of an electrochemical reaction. DC current can be stored in cells and batteries.

In a DC circuit, the electrons will always flow from the negative (-) pole to the positive (+) pole. The

direction of the electrons, known as the polarity, never changes. The negative electrons will seek the positive. It never reverses

Figure 116:A simple DC circuit



The symbol for DC Current

Alternating Current (AC)

Alternating Current does not travel in one direction. It reverses its direction of travel from positive to negative and from negative to positive, constantly. In other words, it alternates. AC current alternates 50 times every second. This is known as the frequency and is measured in Hertz.

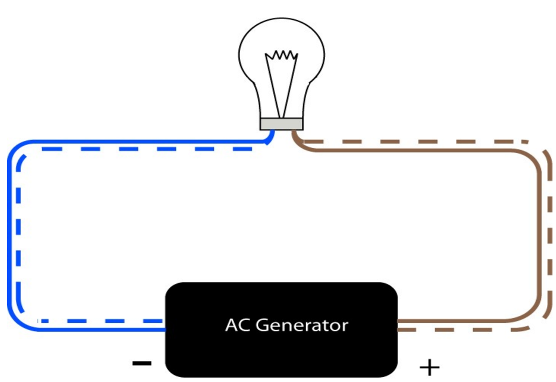


Figure 117:A simple AC circuit

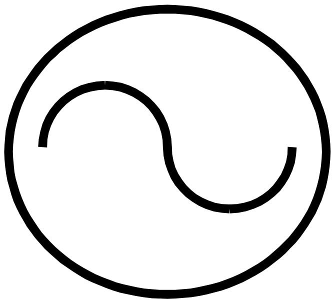


Figure 118: The symbol for AC Current

Below is a table of the advantages and disadvantages of AC current:

The advantages and disadvantages of AC current	
Advantages	Disadvantages
• Voltages can be transformed easily from one voltage to another. DC voltage is hard to transform. • AC current can be transported over long distances without excessive voltage loss making it much more efficient than DC voltage.	• AC current cannot be stored. It is generated at power stations and bulky portable generators. • AC power tools need long cables, which can be a trip hazard. DC power tools use battery power and are much more portable than AC power tools.

Voltage (volts)

In a circuit where there are more electrons in one part of the circuit than the other, the electrons will flow from the area of concentration to the area where they are absent. The higher the voltage, then it can be assumed that there is a greater imbalance and the harder the electrons will repel each other. This leads to greater current or flow (in amps) in the circuit.

The voltage in a circuit can be calculated:

$Amps\ (I)\ x\ Resistance\ (\Omega\ or\ R)$

Resistance

Every electrical circuit has resistance. Some circuits have more resistance than others. In some circuits, resistance is necessary to reduce the amount electrons flowing, whilst in others as little resistance as possible will ensure high current flow.

The interaction between current (or electron flow), voltage (current flow) and resistance is shown in Ohm's Law. As the voltage increases, more electrons will flow. Increasing the voltage leads to an increase in current. However, if the resistance is increased, this reduces the current flow and the amps in the circuit.

The resistance in a circuit can be calculated:

$$Voltage\ (V) \div Amps\ (I) = Ohms\ (Resistance)(\Omega)$$

Current

Is measured in amps. The easiest way to understand current is through a water analogy.

A 15mm pipe at 2 bar pressure will deliver a set flow rate. If we want to increase that flow rate, we would need a bigger pipe. If we increased the pipe size to 22mm, then the pressure would be the same but the flow rate would be greater.

In electrical terms, the voltage is the pressure and the current is the flow rate. If we increase the cable size, the voltage remains at 230V but the current is greater.

The SI unit of measurement of electrical current is the Ampere or amp (i). The current in a circuit can be calculated:

$$Voltage\ (V) \div Ohms\ (Resistance)(\Omega\ or\ R) = Amps\ (I)$$

Power

When electricity is converted into other forms of energy, such as light, heat or mechanical, it is called power. It is equal to the sum of the current and the voltage.

An immersion heater, rated at 3kW simply means that the electrical energy is converted into heat to warm the water. Electrical power is the rate at which electrical energy is consumed and is defined as 1 joule per second.

The SI unit of measurement of electrical power is the Watt (W). The power in a circuit can be calculated:

$$Amps\ (I)\ x\ Volts\ (V) = Watts$$

Carrying out simple electrical calculations

Ohm's law states:

'The current through a conductor between two points is equal to the voltage across the two points, and inversely proportional to the resistance between them.'

It defines the relationship current, voltage, resistance and power.

According to Ohm's law:
'1 Ohm is the resistance through which 1 volt will maintain a current of 1 amp.'

In theory, if we have 2 electrical values, then we can calculate a third. In the following calculations:

$$\boldsymbol{I} = current \quad \boldsymbol{V} = voltage$$
$$\boldsymbol{R} = resistance \quad \boldsymbol{P} = power$$

The diagrams below show Ohm's triangle and the power triangle. By covering the Unit you are calculating with your finger, the remaining units are needed in the calculation. For example, if we are calculating voltage, cover the 'V' and we are left with $I\ x\ R$. If we are calculating resistance, cover the 'R' and we are left with:

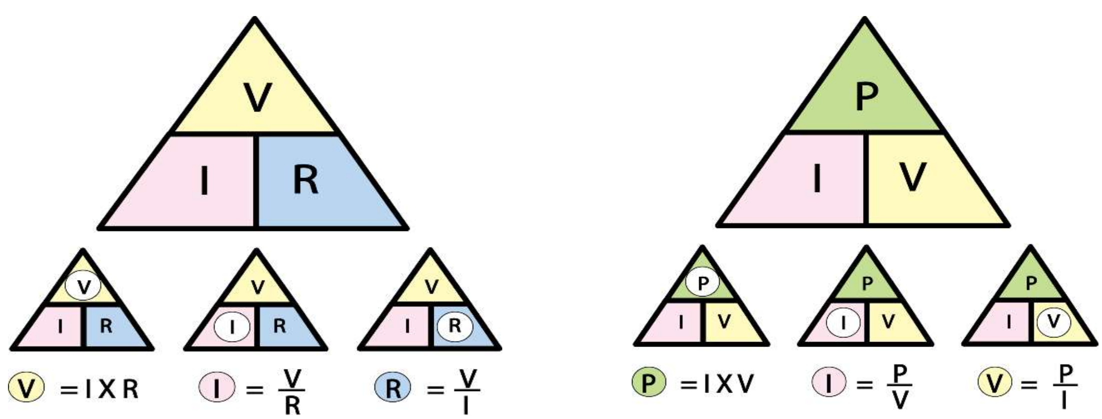


Figure 119:Ohm's Law equations

Simple calculations using Ohm's Law

Example 1 – What size of over current protection device will be needed to protect a circuit that has a 3kW immersion heater installed on a 230V supply?

The formula for this is:

$$I = P \div V$$

Therefore:

First, convert the kilowatts to watts by multiplying by 1000:

$\mathbf{3}\boldsymbol{kw} = \mathbf{3000}$

$\mathbf{3000} \div \mathbf{230}$

$= \mathbf{13}\ \boldsymbol{amps}$

Voltage, current and resistance in series and parallel circuits

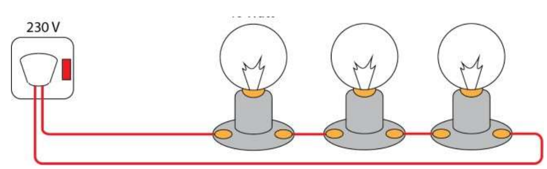
There two types of circuit:

A. Series

B. Parallel

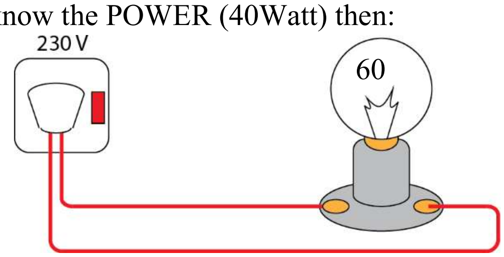
Series Circuits

A series circuit has only one path from the power source through the circuit loads and back to the power source. In this instance, the current MUST flow through ALL of the loads.



This circuit depends upon all of the lamps working perfectly. If one of the lamps fails, then the whole circuit will fail and none of the lamps will light up. This is because the current flows from one lamp to the next. It is the ONLY path from the power source and back again.

Consider the circuit to the right. The circuit has one lamp connected to a 230V electricity supply. The lamp will glow at full brightness simply because it is receiving all of the current. To find the resistance in the circuit, we must first find the current (I). Since we know the POWER (40Watt) then:



The current (amps) is:

$$\frac{60}{230} = 0.26087\ amps$$

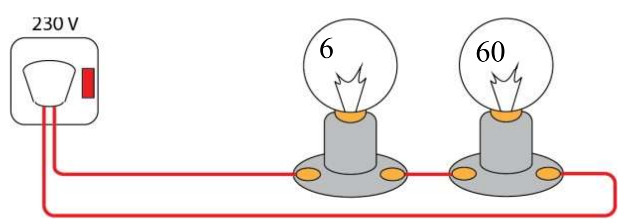
Now, we can apply Ohm's law to find the resistance:

$$R = \frac{V}{I}$$

Therefore:

$$\frac{230}{0.26087} = 881.6651\ Ohms$$

If a second lamp with the same 40 Watts is added to the circuit, then the resistance in the circuit will double and the current flow is half that when there was only one lamp. The voltage is now only 115V to each lamp and this halves the brightness emitting from each lamp. Both lamps have the same voltage drop.



Again, firstly, we must find the current:

Therefore, the current (amps) is:

$$I = \frac{W}{V}$$

$$Bulb\ 1 = \frac{60}{230} = 0.26087\ amps$$

$$Bulb\ 2 = \frac{60}{230} = 0.26087\ amps$$

Now, we can apply Ohm's law to find the resistance of each light lamp:

$$R = \frac{V}{I}$$

Now the total resistance of the circuit:

$$RT = R1 + R2$$

$$RT = 881.6651 + 881.6651 = 1763.3307\ Ohms$$

To find the current across the circuit using the total resistance:

$$I = \frac{V}{R}$$

Therefore:

$$\frac{230}{1763.3307} = 0.13043\ amps$$

To find the voltage, since each lamp is 40 Watts with a resistance of 1763.3307 Ohms and the total circuit current is 0.13043 amps, to find the voltage to each lamp:

$$V = I\ x\ R$$

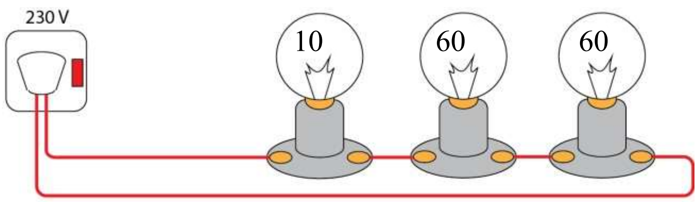
$$0.13043\ x\ 881.6651 = 114.99V$$

Because each lamp is only drawing 115V, each lamp will only glow with half its potential brightness. To find out how many Watts is being generated:

$$\boldsymbol{P = I \; x \; V}$$

Therefore:

$$\mathbf{0.13043} \; \boldsymbol{x} \; \mathbf{230 = 29.999} \; \boldsymbol{Watts}$$



We must find the current to each light lamp:

$$I = W/V$$

$$Lamp\ 1 = \frac{10}{230} = 0.043479\ amps$$

$$Lamp\ 2 = \frac{60}{230} = 0.26087\ amps$$

$$Lamp\ 3 = \frac{60}{230} = 0.26087\ amps$$

Now, we can apply Ohm's law to find the resistance of each light lamp:

$$R = \frac{V}{I}$$

Therefore :

$$R1 = \frac{230}{0.043479} = 5289.91\ Ohms$$

$$R2 = \frac{230}{0.26087} = 881.6651\ Ohms$$

$$R3 = \frac{230}{0.26087}$$

$$= 881.6651\ Ohms$$

Now find the total resistance of the circuit:

$$RT = R1 + R2 + R3$$

$$RT = 5289.91 + 881.6651 + 881.6651$$

$$= 7053.2402\ Ohms$$

To find the current across the circuit using the total resistance:

$$I = \frac{V}{R}$$

Therefore:

$$\frac{230}{7053.2402} = 0.03261\ amps$$

To find the voltage to each lamp:

$V = I \ x \ R$

$$Volts\ @\ Lamp\ 1 = 0.03261\ x\ 5289.91 = 172.503\ Volts$$

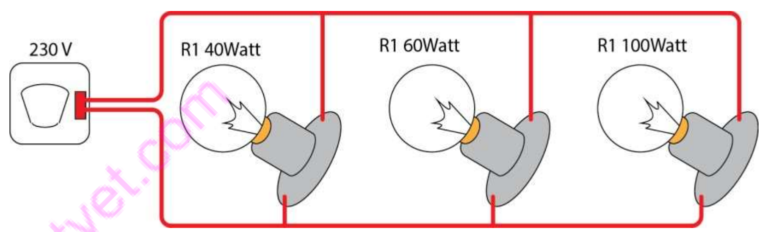
$$Volts\ @\ Lamp\ 2 = 0.03261\ x\ 881.6651 = 28.75\ Volts$$

$$Volts\ @\ Lamp\ 3 = 0.03261\ x\ 881.6651 = 28.75\ Volts$$

Because each lamp is drawing less voltage, each lamp will only glow with a fraction of its potential brightness.

Parallel Circuits

A parallel circuit has at least 2 independent paths in the circuit.



In a parallel circuit, each light lamp has its own independent path to the power source. This means that the lamps are unaffected by each other. If one lamp fails, the other two will continue to work. Voltage is equal across all components. However, the current increases when more light lamps are added and if too many are installed, then the circuit will overload.

3.2.8.4. Learning Activities

Practical activity

Assemble a circuit in a series as shown in the diagram below

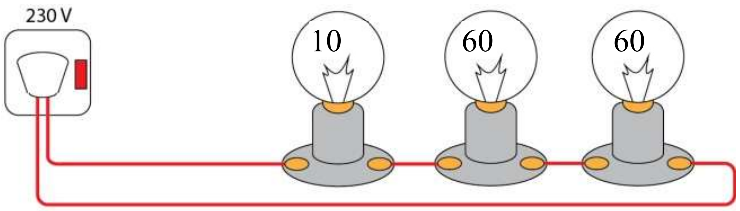


Figure 120: A series circuit

Materials and Supplies

- Battery
- Bulbs (10W, 60W x 2)
- Connecting wires
- Pliers
- Clips

3.2.8.5. Self-Assessment

1. Using the Ohm's Law Formula calculate the voltage in a circuit which has a resistance of 115 Ohms and a current of 2 amps.

$$V = I \; x \; R$$

$$115 \ x \ 2 = 230 \ volts$$

2. Calculate the resistance in a circuit when the voltage is 110V and the current is 45 amps.

$$\Omega = V \div I$$

$$110 \div 45 = 2.44 \ \mathrm{Ohms}$$

3. What are the two advantages of AC over DC voltage?
    - AC voltages can be transformed easily from one voltage to another. DC voltage is hard to transform.
    - AC current can be transported over long distances without excessive voltage loss making it much more efficient than DC voltage.
4. Distinguish between conductivity and resistivity giving an example.
    - Conductivity is the ability of the material to allow the movement of electricity. A good conductor allows free movement of electrons; whereas a poor conductor resists the flow of electrons. Silver is the best conductor of electricity with copper a close second.
    - Resistivity is the opposition to electron flow. It is the resistance of the material against the flow of electricity. When a metal resists the flow of electricity, the energy can be transformed into other forms of energy, such as heat and light. For example, when electricity passes through the resistance of a heating element in an electric kettle, the water will eventually boil.
5. In your own understanding, discuss how voltage is created.

    Voltage is created by the electrons which, being negatively charged, repel each other. When electrons are concentrated in one place, they will flow freely away provided the path is clear for them to do so. It is the Voltage (or push) that makes them move. If there are lots of electrons in one place, the Voltage is high and many electrons will flow through the conductor

3.2.8.6. Tools, Equipment, Supplies and Materials

- Battery
- Bulbs (10W, 60W x 2)
- Connecting wires
- Pliers
- Clips

3.2.8.7. References

Hibbeler, R. (2015). *Engineering Mechanics: Dynamics* (14th ed.). Pearson.

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3.2.8.8. Responses

1. Using the Ohm's Law Formula calculate the voltage in a circuit which has a resistance of 115 Ohms and a current of 2 amps.

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$$115 \; x \; 2 = 230 \; volts$$

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3. What are the two advantages of AC over DC voltage?
   - **AC voltages can be transformed easily from one voltage to another. DC voltage is hard to transform.**
   - **AC current can be transported over long distances without excessive voltage loss making it much more efficient than DC voltage.**
4. Distinguish between conductivity and resistivity giving an example.
   - **Conductivity is the ability of the material to allow the movement of electricity. A good conductor allows free movement of electrons; whereas a poor conductor resists the flow of electrons. Silver is the best conductor of electricity with copper a close second.**
   - **Resistivity is the opposition to electron flow. It is the resistance of the material against the flow of electricity. When a metal resists the flow of electricity, the energy can be transformed into other forms of energy, such as heat and light. For example, when electricity passes through the resistance of a heating element in an electric kettle, the water will eventually boil.**
5. In your own understanding, discuss how voltage is created.

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When electrons are concentrated in one place, they will flow freely away provided the path is clear for them to do so. It is the Voltage (or push) that makes them move. If there are lots of electrons in one place, the Voltage is high and many electrons will flow through the conductor