



Senior 4 General Science (New curriculum)

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Senior 4

Term 2

THEME: SCIENCE AND ENERGY

TOPIC 5: SOUND WAVES

Competency: The learner investigates the properties of transverse and longitudinal wave form and appreciates that waves transmit energy

Waves

Waves are **disturbances that transfer energy from one point to another without the transfer of matter**. They are fundamental in physics and occur in many forms in daily life.

Types of Waves

(i) Mechanical Waves

Require a medium (solid, liquid, or gas) to travel.

Examples: water waves, sound waves, seismic waves.

Subtypes:

- **Transverse waves:** Particles vibrate perpendicular to wave direction (e.g., water waves, light waves).
- **Longitudinal waves:** Particles vibrate parallel to wave direction (e.g., sound waves).

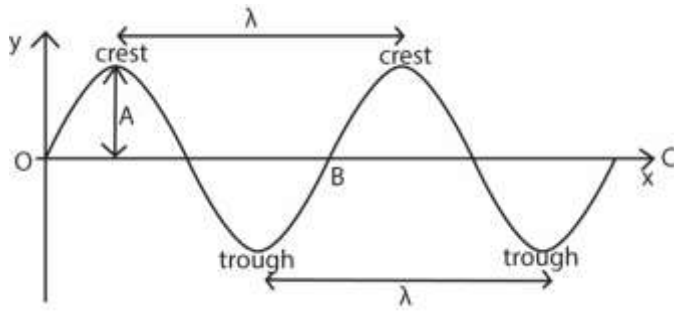
(ii) Electromagnetic Waves

Do not need a medium; can travel through vacuum.

Examples: light, radio waves, X-rays, microwaves.

Consist of oscillating electric and magnetic fields at right angles.

General presentation of a wave



A wave can be represented graphically by a sine wave. The curve is drawn by plotting displacement of particles, y against distance of the particle from the source of the wave, x .

Definition of terms

- (i) OC is the equilibrium/resting/mean position.
- (ii) **Displacement** is a distance of any particle at any point of the wave from equilibrium position.
- (iii) **Amplitude (A)** is a maximum displacement of a particle from its rest position on a wave.
- (iv) **Crest** is the point on the wave profile with maximum positive displacement.
- (v) **Trough** is the point on the wave profile with maximum negative displacement.
- (vi) **Cycle or oscillation:** This is a complete to and fro motion of a wave. It is equivalent to moving from O to B along the wave profile.
- (vii) **Wavelength (λ):** Distance between two successive crests/troughs.

The SI unit of wavelength is meters.

- (viii) **Period, T:** This is the time taken by a wave to perform one complete cycle or oscillation.
S.I. unit of period is Hertz (Hz) or per second.
- (i) **Frequency (f):** Number of waves passing a point per second. Or number of oscillations per second.
- (ix) **Ray** is a line perpendicular to wave front which shows the direction of travel of a wave.

Relationship between T and f

Consider a wave motion in which n cycle are made in time t seconds. One oscillation will be made in $\frac{t}{n}$ seconds.

$$\Rightarrow T = \frac{t}{n}$$

Also in 1 second, $\frac{n}{t}$ oscillations are made.

$$\Rightarrow f = \frac{n}{t}$$

$$\text{But } \frac{n}{t} = \frac{1}{\frac{1}{t}}$$

$$\therefore f = \frac{1}{T}$$

Importance of Waves in Daily Life

- (i) **Communication:** Radio, TV, mobile phones use electromagnetic waves.
- (ii) **Medicine:** Ultrasound waves for scanning, X-rays for imaging.
- (iii) **Navigation:** SONAR uses sound waves to detect underwater objects.
- (iv) **Energy transfer:** Ocean waves harnessed for electricity.
- (v) **Entertainment:** Music and speech transmitted via sound waves.

Progressive Waves

Definition: Waves that travel forward through a medium, transferring energy from one point to another.

Characteristics:

- Crests and troughs (or compressions and rarefactions) move forward.
- Energy is carried along the medium.
- Particles oscillate but the disturbance moves.

Examples: Sound waves in air, water waves, light waves.

Stationary Waves

Definition: Waves formed when two identical progressive waves travel in opposite directions and interfere, producing nodes and antinodes.

Characteristics:

- No net transfer of energy.
- Nodes (points of no vibration) and antinodes (points of maximum vibration) are fixed.
- The wave pattern appears to “stand still.”

Examples: Vibrations on a guitar string, air column in a flute.

Comparison Table

Aspect	Progressive Wave	Stationary Wave
Energy transfer	Yes, energy moves forward	No net energy transfer
Particle motion	Oscillates, disturbance moves	Oscillates, disturbance fixed
Pattern	Crests/troughs move	Nodes & antinodes fixed
Examples	Sound, water, light	Guitar string, organ pipe

Speed of waves

The **speed of a wave** is the distance a wave travels per unit time. It depends on the type of wave and the medium through which it moves.

Formula for Wave Speed

$$v = f \cdot \lambda$$

Where:

- v = speed of the wave
- f = frequency (number of oscillations per second)
- λ = wavelength (distance between two successive crests/troughs or compressions/rarefactions)

Factors Affecting Wave Speed

(i) Medium

Sound travels faster in solids than in liquids, and faster in liquids than in gases.

Light travels slower in denser media (like glass) compared to air or vacuum.

(ii) **Elasticity of Medium**

More elastic materials transmit waves faster.

(iii) **Density of Medium**

Higher density can slow down mechanical waves, but for electromagnetic waves, density affects refractive index.

Example 1

A source produces waves which travel a distance of 140cm in 0.08s, if the distance between successive crests is 20cm, find the frequency of the source.

Solution

$$V = \frac{D}{t} = \frac{1.4}{0.08} = 17.5 \text{ms}^{-1}$$

$$f = \frac{v}{\lambda} = \frac{17.5}{0.2} = 87.5 \text{Hz}$$

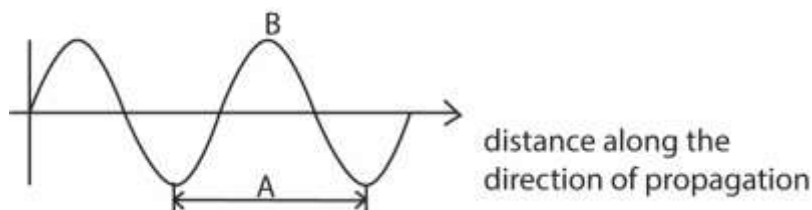
Example 2

Sound is produced by a source vibrator at a frequency of 50Hz. Given that the speed is 330ms^{-1} in air, its wavelength is

$$\lambda = \frac{v}{f} = \frac{330}{50} = 6.6 \text{m}$$

Exercise 5.1

1. A vibrator produces a sound that travels 900m in 3 seconds. If the wavelength of the wave is 10m, find the frequency of vibrator. [30Hz]
2. Sound waves travel a distance of 48cm in 8s. If the separation between successive compressions is 3.0cm, find the frequency of the waves. [2Hz]
3. (a) What is meant by a transverse wave?
(b) the diagram below represents a wave travelling in water



- (i) Name part labelled B
 - (ii) If distance represented by A is 20cm and the speed of the wave is 8.0ms^{-1} . What is the frequency of a wave? [40Hz]
4. The distance between ten successive crests is 18cm. If the frequency of the wave is 40Hz. Calculate the velocity of the waves. [0.8m/s]
 5. In a ripple tank, the distance between 10 successive crests is 18cm and the frequency of the ripples is 50Hz. Find the speed of the ripples. [1.0m/s]

Particle Theory and Sound

Sound is a mechanical wave: It requires a medium (air, water, or solid) to travel.

Particles vibrate: When an object (like a guitar string or vocal cords) vibrates, it causes nearby particles in the medium to oscillate.

Compression and rarefaction:

- Vibrating particles push neighboring particles closer together → **compression** (high pressure region).
- Then they move apart → **rarefaction** (low pressure region).
- These alternating compressions and rarefactions move outward as a **longitudinal wave**, carrying energy but not matter.

Diagram showing motion of particles for longitudinal wave.



C is compression region, **R** is rarefaction region.

Sound travels at a speed of 343ms^{-1} .

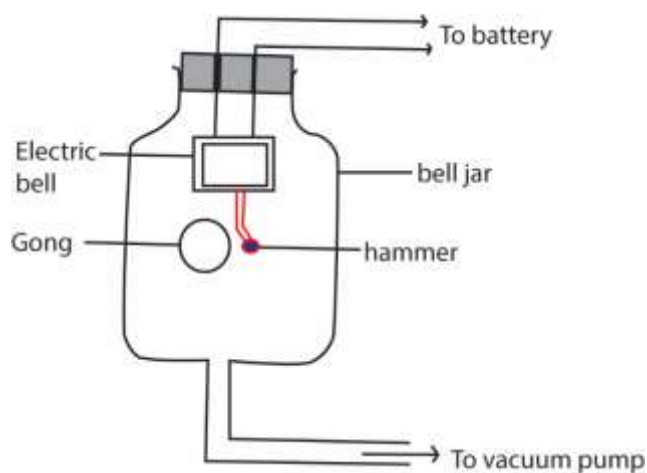
Everyday Examples

- (i) **Speaking:** Vocal cords vibrate, pushing air particles to create compressions and rarefactions → sound waves.
- (ii) **Drums:** The drum skin vibrates, disturbing air particles.
- (iii) **Radio speakers:** The diaphragm vibrates back and forth, producing sound waves in air.

Summary Table

Step	Particle Action	Result
Object vibrates	Disturbs nearby particles	Sound initiated
Compression	Particles pushed together	High pressure
Rarefaction	Particles spread apart	Low pressure
Wave propagation	Disturbance moves forward	Sound travels

Experiment to show that sound needs a material medium for the transmission



- (i) **Switch on the electric bell:** Switching on the electric bell, a loud sound is heard
- (ii) **Removal of air gradually:** On gradually removing the air by a vacuum pump, the loudness of sound gradually dies away.
- (iii) No sound is heard when all the air has been completely removed though the hammer is seen hitting the gong.

Conclusion

This shows sound waves need material medium like air, liquid or solid for transmission.

Exercise 5.2

Describe an experiment to show that sound does not travel in a vacuum

Reasons why sound moves at different speed in different media/states of matter

Sound moves at different speeds in different media because of how **particles are arranged and interact** in solids, liquids, and gases.

Particle Theory Explanation

Sound is a mechanical wave: It travels by vibrating particles.

Speed depends on particle density and elasticity:

- **Elasticity:** How quickly particles return to their original position after being disturbed.
- **Density:** How closely packed the particles are.

Speeds in Different Media

(i) Solids

- Particles are tightly packed and highly elastic.
- Vibrations pass quickly from one particle to the next.
- Sound travels fastest (e.g., ~5000 m/s in steel).

(ii) Liquids

- Particles are less tightly packed than solids but still close enough to transmit vibrations efficiently.
- Sound travels slower than in solids but faster than in gases (e.g., ~1500 m/s in water).

(iii) Gases

- Particles are far apart, so vibrations take longer to pass along.
- Sound travels slowest (e.g., ~343 m/s in air at room temperature).

Summary Table

Medium	Particle Arrangement	Speed of Sound	Reason
Solids	Tightly packed, highly elastic	Fastest (~5000 m/s in steel)	Quick particle vibration transfer
Liquids	Moderately packed	Medium (~1500 m/s in water)	Efficient but slower than solids
Gases	Widely spaced	Slowest (~343 m/s in air)	Longer time for vibrations to pass

Exercise 5.3

Give reasons why sound travels at different speed in different state of matter.

Factors Affecting Velocity of Sound in Air

(i) Temperature

As temperature increases, air molecules move faster.

This increases the rate at which vibrations are passed along.

Higher temperature → higher speed of sound.

Example: At 0°C, speed $\approx$ 331 m/s; at 20°C, speed $\approx$ 343 m/s.

(ii) Air Pressure

Surprisingly, air pressure has little effect when temperature is constant.

This is because both pressure and density change proportionally, canceling out their effect.

So, at a given temperature, sound speed is independent of pressure.

(iii) Air Density

Denser air (due to humidity or altitude changes) affects sound speed.

Humidity increases speed: Water vapor is lighter than nitrogen/oxygen, reducing air density and allowing sound to travel faster.

High altitude decreases speed: Air is thinner, so sound travels slower.

(iv) Composition of Air

Normal air is mostly nitrogen and oxygen.

If composition changes (e.g., more carbon dioxide or helium), the speed of sound changes because molecular mass and elasticity differ.

Summary Table

Factor	Effect on Sound Speed
Temperature	Higher temp → faster sound
Pressure	No effect (at constant temp)
Density	Higher humidity → faster; thinner air → slower
Composition	Different gases → different speeds

Exercise 5.4

Give reasons why sound travels at different speed in different state of matter.

Loudness, pitch, and noise of sound

Loudness

Definition: Loudness is the perception of how strong or intense a sound is.

Cause: Determined by the **amplitude** of the sound wave — larger amplitude = louder sound.

Example: A drum hit hard produces a louder sound than a gentle tap.

Pitch

Definition: Pitch is the perception of how high or low a sound is.

Cause: Determined by the **frequency** of the sound wave — higher frequency = higher pitch.

Example: A whistle has a high pitch, while a bass guitar produces a low pitch.

Noise

Definition: Noise is an unpleasant, irregular, or unwanted sound.

Cause: Produced by irregular vibrations that lack a definite frequency or pattern.

Example: Traffic sounds, construction work, or a loud crowd.

Summary Table

Aspect	Definition	Cause	Example
Loudness	Intensity of sound	Amplitude of wave	Loud drumbeat
Pitch	Highness/lowness of sound	Frequency of wave	Whistle vs bass
Noise	Unpleasant/irregular sound	Irregular vibrations	Traffic, machines

Exercise 5.5

Distinguish between loudness, pitch of sound and noise

Reflection of Sound

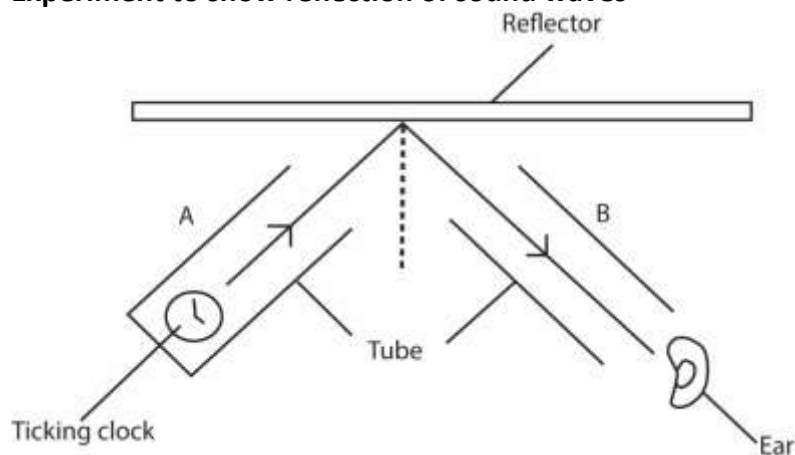
Definition: Sound waves bounce back when they hit a hard surface.

Law: Angle of incidence = angle of reflection (same as light).

Examples:

- **Echo:** Reflection of sound from a distant wall or cliff.
- **Sonar:** Ships use reflected sound to detect underwater objects.

Experiment to show reflection of sound waves



- (a) **Producing sound waves:** Sound waves produced by the clock at the end of tube A are reflected at the hard surface reflector.
- (b) **Moving tube B:** The ear is put at the end of the tube B and the tube B is moved until the ticks of the clock are loudest. This is the direction of reflected sound wave.

Note: Hard surfaces reflect sound waves while soft surfaces absorb sound waves.

Applications of Reflection of Sound

- (i) **Echo sounding:** Used in ships to measure the depth of water by timing the reflected sound pulse.
- (ii) **Sonar (Sound Navigation and Ranging):** Submarines and ships use reflected sound waves to detect underwater objects.
- (iii) **Medical ultrasound:** Reflected sound waves create images of internal organs and unborn babies.
- (iv) **Acoustics in buildings:** Reflection is controlled to improve sound quality in auditoriums and theaters.
- (v) **Communication with bats/dolphins:** These animals use echolocation (sound reflection) to navigate and hunt.

Echoes

An echo is reflected sound waves

Echoes are produced by the reflection of sound from a hard surface. Echoes are often heard in the neighborhoods of large houses, high walls, cliffs etc.

Echoes are often heard in the big churches, halls etc. They are not heard in a small room or class-room because the reflected sound waves return very quickly and mix up with the original sound wave.

Echoes are troublesome in lecture halls, cinema etc. To reduce echoes in such places, the walls are covered with soft thick porous materials.

Furniture and people in halls also reduce echoes. So many echoes are produced in empty halls compared to one filled with people because bodies of people are soft so they absorb some of the sound.

Reverberation

If the reflecting surface is nearer, the echo joins the original sound which then seems to become prolonged. This is called reverberation.

To some degree, reverberation is desirable in concert halls to stop the hall sounding dead so that hearing in such places is improved.

However, too much reverberation causes confusion.

The time taken by a particular intensity of sound to die away is the reverberation time.

For echo

$$\text{Velocity} = \frac{2 \times \text{distance}}{\text{time taken}}$$

Example 3

A man stands at a distance of 990m away from a tall building and makes a loud sound. He hears the echo after 6 seconds. Calculate the speed of sound.

$$\text{For echo: Speed} = \frac{2 \times \text{distance}}{\text{time taken}} = \frac{2 \times 990}{6} = 330 \text{ms}^{-1}$$

Example 4

A man stands between two walls, but nearer one of them and makes a loud sound. If he hears the third echo after 6 seconds, calculate the distance between the two walls, (speed of sound in air is 330ms^{-1}).

$$V = 330 \text{ms}^{-1} \quad d = ? \quad t = 6 \text{ seconds}$$

$$\text{Velocity} = \frac{2d}{t}$$

$$330 = \frac{2 \times d}{6}$$

$$d = 330 \times 3 = 990 \text{m}$$

Example 5

A sound of frequency 150Hz is produced 45m away from a cliff. Calculate the

(i). wavelength

$$\text{From } V = \lambda f$$

$$\lambda = \frac{v}{f} = \frac{330}{150} = 2.2 \text{m}$$

(ii). Time it takes the sound wave to travel to and from the cliff
(speed of sound in air = 330ms^{-1}).

$$\text{Time} = \frac{\text{distance to and fro}}{\text{speed}} = \frac{45 \times 2}{330} = 0.27 \text{s}$$

Example 6

A man stands between two cliffs and makes a loud sound. If he hears the first echo after 1.5s and second echo after 2s, find the distance between the two cliffs. Speed of sound in air is 300ms^{-1} .

Diagram to be drawn

Using Velocity = $\frac{2 \times \text{distance}}{\text{time taken}}$

First echo

$$t = 1.5\text{s}$$

$$V = 300\text{ms}^{-1}$$

$$X = ?$$

$$V = \frac{2X}{t}$$

$$300 = \frac{2X}{1.5} \quad 300 = \frac{2Y}{2}$$

$$X = \frac{300 \times 1.5}{2} = 225\text{m}$$

Second echo

$$t = 2\text{s}$$

$$V = 300\text{ms}^{-1}$$

$$Y = ?$$

$$V = \frac{2Y}{t}$$

$$Y = \frac{300 \times 2}{2} = 300\text{m}$$

Distance between the two cliffs = $225 + 300 = 525\text{m}$

Exercise 5.6

1. A boy standing 150m from a vertical cliff claps his hand and hears an echo 0.85 seconds later. Find the speed of sound in air. [353m/s]
2. A man standing in front of a tall wall makes a loud sound and hears the echo after $1\frac{1}{2}$ s. how far is he from the wall if the velocity of sound in air is 330ms^{-1} . [247.5m]
3. An echo sounder in a boat emits a pulse of sound which returns 0.2s later after reflection from the sea bed. If sound travels at 1500ms^{-1} in sea water, how deep is water? [150m]
4. (a) What is an echo?
Echo is reflected sound
(a) (i) Describe an experiment to measure the speed of sound in air.
 - Measure a distance X in meters from a point of experiment to a tall wall more than 17.5m
 - Make a sharp clapping sound by bringing two blocks of wood together at such an interval that each clap coincides with its echo.
 - Using a stop clock determine time, t, for 20 claps
 - Velocity of light $v = \frac{2x}{\frac{t}{20}} = \frac{40x}{t} \text{ms}^{-1}$
 -

- (i) State the probable source of error in this experiment.
- From timing
 - Variation of speed of sound with change in temperature, humidity and wind

Refraction of Sound

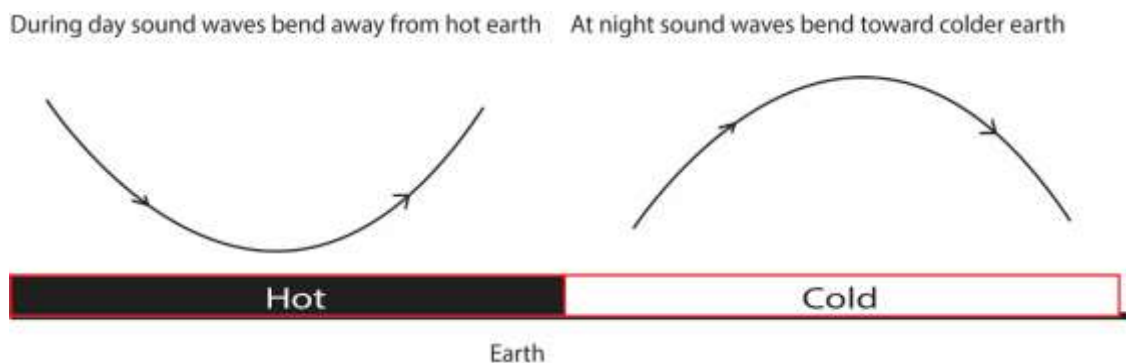
Definition: Bending of sound waves when they pass through regions of different air densities or temperatures.

Examples:

- Sound travels farther at night because cooler air near the ground bends sound waves back toward Earth.
- Underwater communication: sound bends when moving between water layers of different temperatures.

Applications of Refraction of Sound

- (i) **Sound focusing:** Refraction in layers of air can bend sound waves, making them audible over long distances.
- (ii) **Night-time sound travel:** Cooler air near the ground bends sound waves back toward Earth, so sounds travel farther at night.



- (iii) **Underwater communication:** Sound bends when moving between water layers of different temperatures, helping in submarine communication.
- (iv) **Seismology:** Refraction of seismic sound waves helps scientists study Earth's interior.
- (v) **Medical diagnosis:** Refraction principles are used in ultrasound scanning to focus sound waves on specific tissues.

Ultrasonic

Sound waves with frequencies above 20 kHz are called ultrasonic waves. They are emitted by bats. Sound of high frequency that human ear cannot detect is described as ultrasonic.

Applications of ultrasonic sound

- (i) Ultrasonic enable bats to judge the distance of an object from the time taken by the reflected wave to return.
- (ii) Ultrasonic are used in spectacles for blind to judge distances of an object from the time taken by reflected waves to return. Such spectacles contain ultrasonic sender and receiver.
- (iii) In sonar (echo-sounding system) of ships use ultrasonic wave to measure the depth of sea and to detect shoals of fish.
- (iv) In industry, ultrasonic waves are used to reveal flaws in welded joints and also holes are cut in glass and steel by ultrasonic drills.

Note:

In an echo sounder (sonar, ultrasonic waves are used because they:-

- (i) Cannot be confused with engine sound and other sound made ship,
- (ii) Can penetrate sea water to a large distance without undue loss of energy.
- (iii) They are not much detracted.

Frequency and audio frequency range.

The human ear has a range of sound frequencies which it can hear. The lowest limit of audibility is about 30Hz and the upper limit audibility for most people is between 20 kHz and 30 kHz.

In daily life, a dog is more able than a human being to detect the presence of a thief tiptoeing at night. A thief tiptoeing at night produces sound of low frequency that can only be detected by dog ears not human being ears because the dog has wider ears than human being ears.

Musical notes

Musical notes are regular vibrations of sound waves.

Properties of musical notes

Musical notes have three properties namely:

Pitch, loudness and quality

Quality or tone (timbre) of a musical note

The same note on different instruments sounds different, the notes are said to differ in quality or timbre. The difference arises because no instruments except a tuning fork and

single generator can emit a pure note i.e. of one frequency but they produced notes consisting of main or fundamental frequency mixed with overtones.

Overtone frequencies are exact multiples of the fundamental. The number and strength of overtones determine the quality of a note.

A violin has more and stronger higher overtones than a piano.

Waves in strings and pipes

Factors on which the frequency of a wave in a vibrating string depends

- Length of the string.
- Tension in the string.
- Mass per unit length of the string.

A stationary wave can be set up in a string which has both ends fixed.

Resonance

Resonance occurs when a body or system is set into vibrations with its own natural frequency by a nearby body or system vibrating with the same frequency.

The vibrations combine to produce a larger vibration with larger amplitude.

Thus, resonance occurs when a body is set into vibration with its own natural frequency by another nearby body which vibrates with the same frequency.

Exercise 5.7

- (i) Sound waves travel a distance of 48cm in 8s. If the separation between successive compressions is 3.0cm, find the frequency of the waves.

A. 0.5Hz **B. 2.0Hz** C. 18.0Hz D. 128.0Hz

$$\text{Velocity} = \frac{\text{Distance}}{\text{time}} = \frac{48}{8} = 6.0 \text{ cm s}^{-1}$$

$$\text{Wavelength} = 3.0 \text{ cm}$$

$$\lambda = \frac{\text{velocity}}{\text{wavelength}} = \frac{6}{3} = 2 \text{ Hz}$$

- (ii) Describe a simple echo method of determining the speed of sound in air.

- ✓ Clap at such a rate that each clap coincides with the echo from a tall wall at a distance D from the experimenter.

- ✓ Using a stop clock, measure the time, t , for a given number of claps, n .
- ✓ Average time for one clap = $\frac{t}{n}$ is the time taken for the wave to travel from experimenter to the wall and back
- ✓ The velocity of sound in air = $\frac{2D}{t/n} = \frac{2nD}{t}$

(iii) (a) What is an echo?

Echo is reflected sound

(b) (i) Describe an experiment to measure the speed of sound in air.

- Measure a distance X in meters from a point of experiment to a tall wall more than 17.5m
- Make a sharp clapping sound by bringing two blocks of wood together at such an interval that each clap coincides with its echo.
- Using a stop clock determine time, t , for 20 claps
- Velocity of light $v = \frac{2x}{\frac{t}{20}} = \frac{40x}{t} \text{ ms}^{-1}$

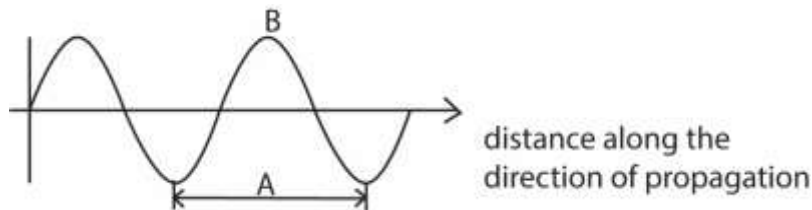
(ii) State the probable source of error in this experiment.

- From timing
- Variation of speed of sound with change in temperature, humidity and wind

(iv) (a) What is meant by a transverse wave?

Is one in which particles in a medium vibrate perpendicular to the direction of travel of the wave.

(b) the diagram below represents a wave travelling in water



(iii) Name part labelled B
crest

(iv) If distance represented by A is 20cm and the speed of the wave is 8.0 ms^{-1} .
What is the speed of a wave?

$$f = \frac{v}{\lambda} = \frac{8}{0.2} = 40 \text{ Hz}$$

(v) (a) state three differences between sound and light waves

Sound wave	Light waves
- Need material medium for propagation - Propagate at relatively low speed - Have longer wavelength - Particles vibrate in direction is same direction as that of a wave	- Can propagate in vacuum - Propagate as very high speed - Shorter wavelength - Particles vibrate perpendicular to the direction of travel of the wave.

(b) (i) explain how stationary wave is formed

When two waves of the same frequency, equal wavelength and equal amplitude are propagating in the same medium in opposite direction they meet and superpose; the resultant displacement of particles in medium at any point is the sum of displacements due to each of the waves at that point.

(ii) State three main characteristics of a wave

- Amplitude of a wave varies from place to place along the profile.
- Wave energy is not transmitted along the profile.
- At certain points called nodes, the particles are permanently at rest
- Has nodes and antinodes.

(c) (i) Define the terms frequency and wavelength as applied to sound.

(ii) Describe an experiment to demonstrate resonance in sound.

(d) The velocity and frequency of sound in air at a certain time were 320ms^{-1} and 200Hz respectively. At later time, the air temperature changed and velocity of sound in air was found to be 340ms^{-1} . Determine the change in wavelength of sound.

(vi) (a) What is meant by sound?

Sound is a form of energy that travels in form of longitudinal waves from one point to another than enable us to hear.

(b) Describe an experiment to show that sound waves require a material medium for transmission.

Electric bell hung from rubber bands inside a bell jar is used.

- A loud sound is heard when the bell is switched on
- When air is removed, the sound disappear

(c) Explain the following

- (i) A dog is more able than human beings to detect the presence of a thief tiptoeing at night
A tip toeing thief produced low frequency (ultrasonic) sound which cannot be detected by human but can be detected by dog's ears
- (ii) An approaching train can easily be detected by human ears placed close to the rail.
Because sound travels faster in solids than in air.
- (d) A sound of frequency 250Hz is produced 120m away from a high wall.
Calculate
- (i) Wavelength
- (ii) Time it takes sound wave to travel to and from the wall (speed of sound in air = 320ms^{-1})
- (vii) (a) What is reverberation?
Reverberation is when echo joins up with original sound which seems a prolonged sound and occurs when the reflecting surface is less than 15m from the source.
- (a) State two factors which affect frequency of a vibrating string
Length of string
Tension of string
- (b) A sound wave of frequency 440Hz has a velocity 330Hz. Calculate its wavelength.
$$\lambda = \frac{v}{f} = \frac{330}{440} = 0.75\text{m}$$
- (viii) (a) (i) Define an echo?
An echo is reflected sound
- (ii) State one application of echoes
- Measurement of velocity of sound in air
 - In medicine field to give an image of internal structure of the body
 - In speaking tubes to send messages from one point to another
 - In Radar aerials to send out radio waves into space
- (iii) State the conditions required for a standing wave to be formed.
The two waves should have the same frequency and nearly equal amplitude moving in opposite direction
- (a) List the factors on which the frequency of vibrating string depends
- Tension in string
 - Length of string
- (b) A child stands between two cliffs and makes loud sound. If he hears the first echo after 1.5s and the second echo after 2.0s. find the distance between the two cliffs (speed of sound in air = 320ms^{-1})

$$\text{Distance} = (\text{velocity} \times \text{time})/2 = (320 \times 1.5 + 320 \times 2)/2 = 560\text{m}$$

(ix) (a) What is an echo?

Echo is reflected sound.

(b) An echo sounder on a boat send down a pulse through the water and receives its echo 0.9s later. Calculate the water depth. (speed of sound in water = 1450ms^{-1})

$$\text{Depth} = \frac{1}{2}vt = \frac{1}{2} \times 1450 \times 0.9 = 652.5\text{m}$$

(c) State two factors which determine the frequency of a note produced when a guitar string vibrates. (1mark)

- Tension in string
- Length of the string

(x) (a) State any two difference between sound and light waves.

Sound waves	Light waves
Are longitudinal	Are transverse
Slow	Fast
Do not travel in vacuum	Travel in vacuum

(b)(i) Describe a simple experiment to determine the velocity of sound in air.

- A long glass tube is filled with water.
- A tuning fork of frequency f is sounded and held close to the open end of the tube.
- Water in the tube is slowly drained until a loud sound is heard.
- Length, L , of the air column is measured
- The velocity of sound $v = 4Lf$.

(ii) Explain why the speed of sound is higher in solids than air.

The molecules of solids are closely packed, hence vibrations are easily transmitted from one atom to another, than in air.

(c) Two people X and Y, stand in a line at a distances of 330m, and 660m respectively from high wall. Find the time interval taken for X to hear the first and second sounds when y makes a loud sound. (speed of sound in air = 330ms^{-1})

$$\text{Time taken to hear first sound} = \frac{\text{distance}}{\text{velocity}} = \frac{330}{300} = 1\text{s}$$

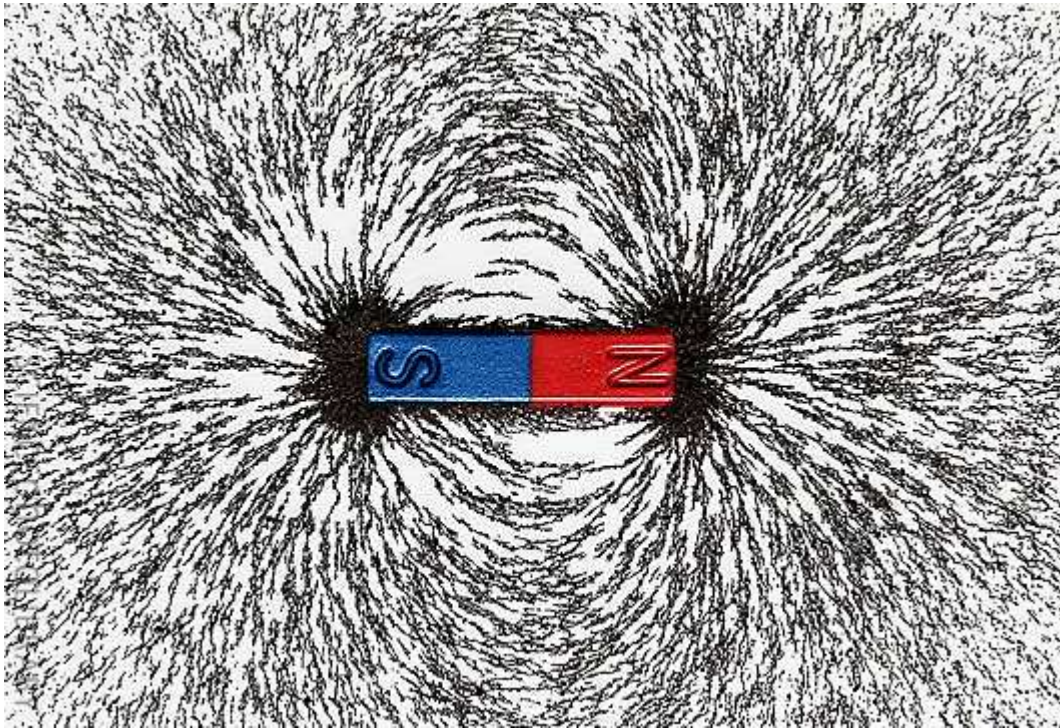
The second sound is an echo is heard when travel 660m or 330 to and fro

$$\text{Time} = \frac{\text{distance}}{\text{velocity}} = \frac{660}{300} = 2\text{s}$$

THEME: SCIENCE AND TECHNOLOGY

TOPIC 6: MAGNETISM AND ITS APPLICATIONS

Competency: The learner knows the properties of magnets and appreciate the earth is magnet itself.



Magnet

A **magnet** is a material or object that produces a magnetic field, which can attract or repel other materials, especially metals like iron, nickel, and cobalt.

Uses of magnets

- (i) In construction of cycle dynamos, telephones, loud speaker, electric meters, current measuring instruments.
- (ii) To remove metal splinters from oil engine
- (iii) For door closures
- (iv) Electric bell
- (v) Magnetic ink
- (vi) Computer memory cards.
- (vii) Electric motor
- (viii) Magnets are used in hospitals to remove iron pieces from the eye of patient.
- (ix) Making magnetic tapes used in audio and video recorders.

Types of Magnets

(i) Permanent Magnets

Retain magnetism for a long time.

Examples: bar magnets, horseshoe magnets.

(ii) Temporary Magnets

Become magnetic only when placed in a magnetic field.

Example: soft iron used in electromagnets.

(iii) Electromagnets

Created by passing electric current through a coil of wire around a soft iron core.

Strength can be controlled by adjusting current.

Used in motors, transformers, cranes.

Properties of Magnets

- (i) Attract certain metals (iron, nickel, cobalt).
- (ii) Have two poles: **North (N)** and **South (S)**.
- (iii) Like poles repel, unlike poles attract.
- (iv) Magnetic field lines flow from North to South outside the magnet.

Applications of Magnets

Daily life: Fridge doors, magnetic clips, compasses.

Industry: Lifting heavy scrap metal, separating metals from non-metals.

Medicine: MRI machines use strong magnets.

Technology: Loudspeakers, electric motors, data storage devices.

Summary Table

Type	Feature	Example
Permanent	Always magnetic	Bar magnet
Temporary	Magnetic only in field	Soft iron
Electromagnet	Magnetism from electric current	Crane magnet

Exercise 6.1

- (a) What is a magnet?
- (b) Mention Three properties of a magnet

Magnetic Materials

Definition: Materials that are attracted to a magnet.

Examples: Iron, steel, nickel, cobalt.

Simple Test: Bring a magnet close to the material. If it is pulled toward the magnet, it is magnetic.

Observation: Strong attraction, often sticks firmly to the magnet.

Non-Magnetic Materials

Definition: Materials that are not attracted to a magnet.

Examples: Wood, plastic, glass, rubber, copper, aluminum.

Simple Test: Bring a magnet close to the material. If there is no movement or attraction, it is non-magnetic.

Observation: No effect, remains in place.

Summary Table

Category	Examples	Test Result
Magnetic materials	Iron, steel, nickel, cobalt	Attracted to magnet
Non-magnetic materials	Wood, plastic, glass, rubber, copper	Not attracted

Exercise 6.2

Explain a test that can be carried out to distinguish between magnetic and nonmagnetic substances

Ferromagnetic Materials

Meaning: Materials with strong, permanent magnetism. Their atomic dipoles align spontaneously into domains, producing a large net magnetic field.

Cause: Exchange interaction between unpaired electrons aligns spins in the same direction.

Examples: Iron (Fe), Nickel (Ni), Cobalt (Co), and their alloys.

Properties:

- Strong attraction to magnets.
- Can retain magnetism (high retentivity).
- Exhibit hysteresis (lag between magnetisation and demagnetisation).

Applications

- (i) **Permanent magnets** (used in compasses, speakers, motors).
- (ii) **Electromagnet cores** (transformers, generators).
- (iii) **Data storage** (hard drives, magnetic tapes).
- (iv) **Magnetic levitation** (maglev trains).
- (v) **Medical imaging** (MRI machines use ferromagnetic materials in magnets).

Paramagnetic Materials

Meaning: Materials weakly attracted to magnets. They do not retain magnetism once the external field is removed.

Cause: Presence of unpaired electrons gives atoms a small magnetic moment, but thermal motion randomizes them.

Examples: Aluminium (Al), Platinum (Pt), Manganese (Mn), Oxygen (O₂).

Properties:

- Weak attraction to external magnetic fields.
- Susceptibility decreases with increasing temperature (Curie's Law).
- No permanent magnetism.

Applications

- (i) **MRI contrast agents** (gadolinium-based compounds enhance imaging).
- (ii) **Alloys** (used to modify magnetic properties in engineering).
- (iii) **Scientific research** (studying magnetic susceptibility and quantum effects).
- (iv) **Cryogenics** (paramagnetic salts used in magnetic refrigeration).

Comparison Table

Aspect	Ferromagnetic	Paramagnetic
Attraction strength	Strong	Weak
Retains magnetism	Yes (permanent)	No
Examples	Iron, Nickel, Cobalt	Aluminium, Platinum, Oxygen
Applications	Motors, transformers, permanent magnets	MRI contrast, alloys, refrigeration

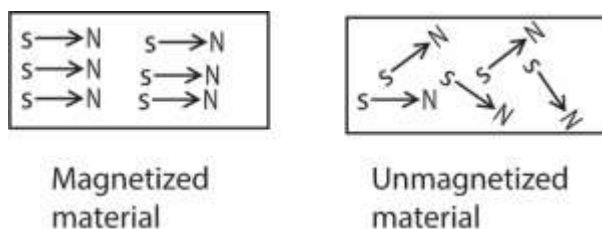
Exercise 6.3

- (a) Using examples distinguish between ferromagnetic and paramagnetic substances.
- (b) state two applications each of ferromagnetic and paramagnetic substances.

Magnetic domain theory

A magnet is made up of tiny molecular magnets called dipole arranged in groups called magnetic domains, lined up with their N-poles pointing in the same direction.

In nonmagnetic materials, the domains are randomly mixed and their magnetic effect cancel each out.



Magnetization

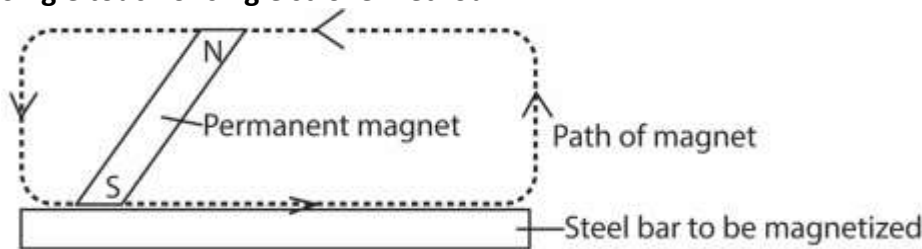
This is a process by which randomly arranged molecular magnet of a ferromagnetic material are arranged to point in one direction.

Methods of magnetization

These include:

- Single touch method.
- Double touch method.
- Electrical method using direct current (d.c.).

Single touch or single stroke method



Single stroking

A steel bar (Ferromagnetic material) is stroked several times from end to end using a bar magnet. The stroking is done in the same direction and using the same pole of bar magnet.

Molecular magnets explanation

The stroking of the magnet pulls the randomly molecular magnets to face in one direction thus material becomes magnetic.

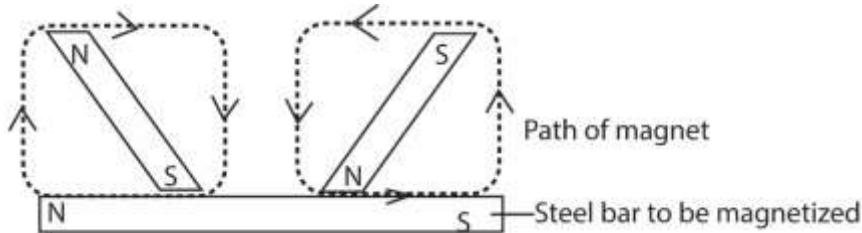
Disadvantage of single stroke method

The magnet produced has one pole nearer to the end as compared to the other pole

Identification of a pole

The pole of the bar magnet being used for stroking should be the same pole induced at the end of the steel bar from where stroking starts.

Double touch method or double stroke method



This uses two bar magnets placed at the centre of the steel bar with unlike poles as in the diagram. The stroking begins in the middle of the steel bar and ends at the opposite ends. The magnets are raised high at the end of each stroke before another one begins. This prevents reversing the acquired magnetism.

Molecular magnet

As stroking is done, the molecular magnets are pulled to face in one direction therefore creating poles at the ends of the steel bar.

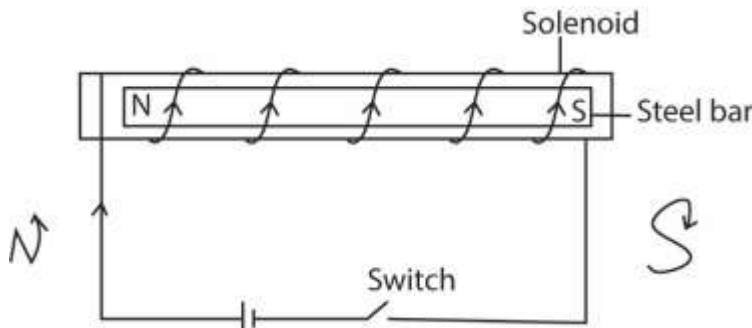
Advantage of a double touch method over a single touch method

All poles are at both ends while for single touch method one pole is nearer to end than the other.

Disadvantages of double touch method over a single touch method

Double touch method is more expensive and tiresome.

Electrical method



The steel bar to be magnetized is placed inside a solenoid connected to the cells. When direct current is switched on for some time, the bar will be magnetized

Note that with a.c. current the bar is not magnetized

Polarity of steel bar

The polarity of the steel bar depends on the direction in which the current is flowing. Current flows from positive to negative, so if on looking at the end of solenoid, current is flowing in a clock wise direction, that end will be South Pole but if it is flowing anti clockwise the end will be a north pole.

Induction method

When a magnetic material is kept close to a magnet for long time it gets magnetized.

Magnetic saturation

This is the maximum level of magnetization when the resultant magnetic axes of all domains in magnetic material are aligned with the magnetizing field.

Exercise 6.4

Explain the following methods of making a magnet

- (i) single stroke
- (ii) electrical method

Demagnetization

Demagnetization is the process through which magnets lose their magnetism. Demagnetization results in scattering molecular magnets to face in random directions.

Methods of demagnetization

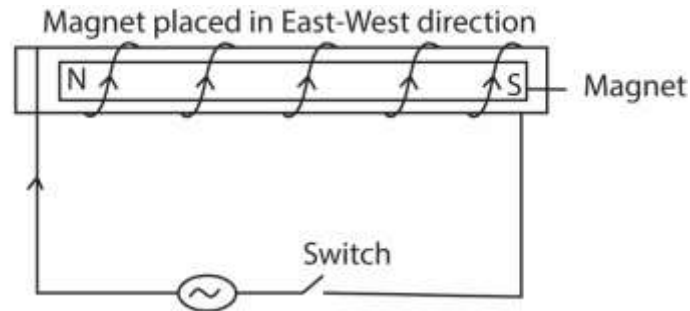
(i) By Heating:

Heating a magnetized material makes it lose its magnetism. This is because the temperature rise causes the vibrations of molecular magnets to become so great that their ordinary arrangement is destroyed.

(ii) By hammering:

Hammering a magnetized material placed in east-west direction, makes it lose most of its magnetism. This is because when a magnet is hammered, the vibrations of the molecular magnets increase which result in random arrangement.

(iii) By electrical method using alternating current



Here an alternating current is supplied to the solenoid in which the magnet is placed in east-west direction.

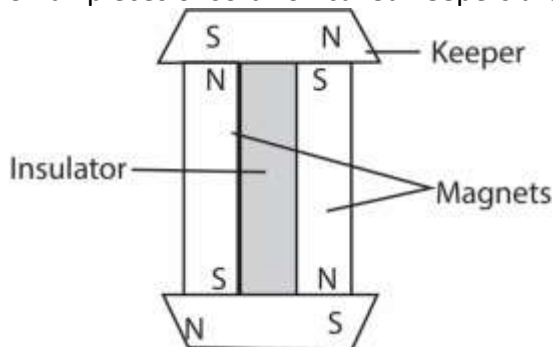
The alternating current (a.c.) causes the molecular magnet to change from orderly to random arrangement as current changes direction of flow every half cycle. The demagnetized magnet should be removed from solenoid and stored along east-west direction to avoid magnetization due to earth's field.

Exercise 6.5

List methods by which a magnet can be made to lose its magnetism.

Storing magnets

Small pieces of soft iron called keepers are placed across opposite **poles** of two bar magnets



These iron keepers become induced magnets and their poles neutralize the poles of the magnets. This ensures that there is no magnetic loss.

Soft and hard magnetic substances

Soft magnetic materials are substance that are easily magnetized and easily lose magnetism, e.g. soft iron.

Soft magnetic materials are used in making soft-iron core in transformers, dynamos, e.t.c.

Hard magnetic material are materials that are difficult to magnetize but retain their magnetism for long, e.g. steel.

Hardmagneticmaterials are used in loud spears.

THEME: SCIENCE AND TECHNOLOGY

TOPIC 7: BASIC ELECTRICITY

Competency: The learner appreciates how electric current is generated and the limitations associated with the methods of generating electricity



Nalubale power station

Electric Cell

Meaning: An electric cell is a device that converts chemical energy into electrical energy.

Structure: Consists of two electrodes (positive and negative) immersed in an electrolyte.

Function: When connected in a circuit, chemical reactions at the electrodes produce a flow of electrons, generating current.

Examples: Dry cell (used in torches), car battery (lead-acid cell).

Electromotive Force (EMF)

Meaning: EMF is the energy supplied per unit charge by a source of electrical energy (like a cell or battery).

Definition: It is the potential difference across the terminals of a cell when no current is flowing.

Formula:

$$\text{EMF} = \frac{\text{Work done}}{\text{Charge}}$$

Unit: Volt (V).

Note: EMF is not a force but a measure of energy per charge.

Sources of EMF

(i) Chemical sources

Electric cells and batteries (dry cell, lead-acid battery, lithium-ion battery).

(ii) Magnetic sources

Generators (induced EMF by electromagnetic induction).

(iii) **Solar sources**

Solar cells convert light energy into electrical energy.

(iv) **Thermal sources**

Thermocouples produce EMF when two different metals are joined and heated.

(v) **Piezoelectric sources**

Crystals like quartz generate EMF when mechanically stressed.

Summary Table

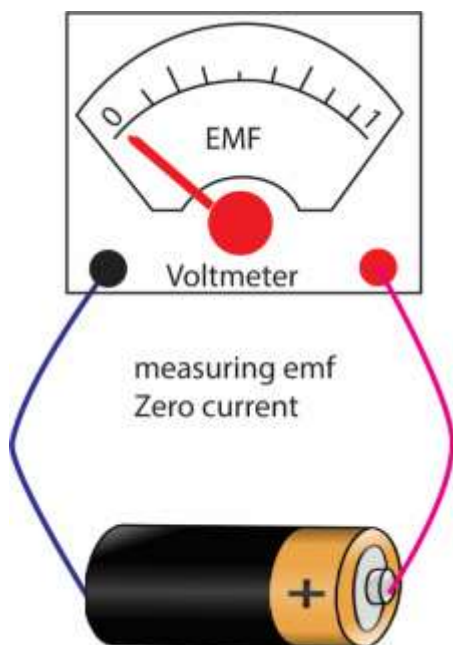
Concept	Meaning	Examples
Electric Cell	Device converting chemical → electrical energy	Dry cell, lead-acid battery
EMF	Energy per unit charge supplied by source	Measured in volts
Sources of EMF	Devices that produce EMF	Cells, generators, solar cells, thermocouples

Measuring EMF

Definition Reminder: EMF (Electromotive Force) is the potential difference across the terminals of a cell when no current is flowing.

Measurement of emf

Voltmeter Method



- (i) Connect a **high-resistance voltmeter** across the terminals of the cell.
- (ii) Since the voltmeter draws negligible current, the reading gives the EMF directly.

Potentiometer Method

A more accurate method.

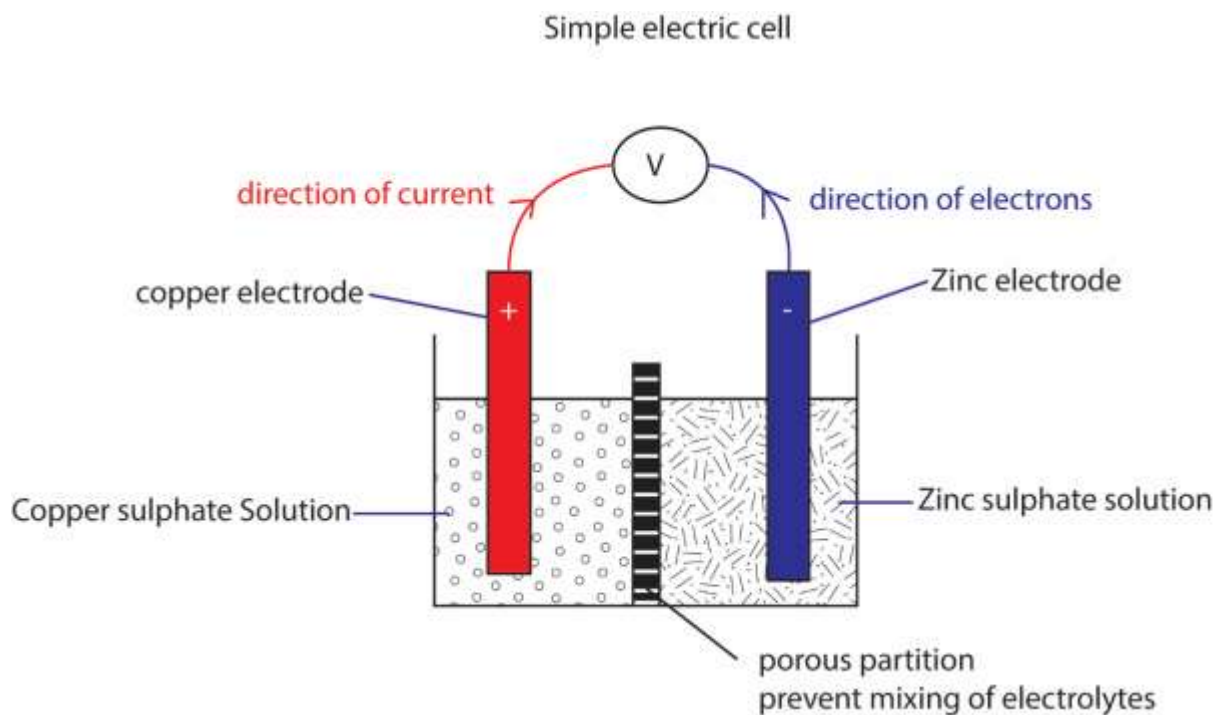
The cell's EMF is balanced against a known potential difference using a potentiometer circuit.

No current flows through the cell during measurement, so the true EMF is obtained without internal resistance effects.

Units of EMF

Unit: Volt (V)

Definition of 1 Volt: EMF is 1 volt if 1 joule of work is done to move 1 coulomb of charge.



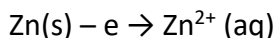
Components of simple cell

- (i) **Positive electrode (Copper):** Less reactive metal.
- (ii) **Negative electrode (Zinc):** More reactive metal.
- (iii) **Electrolyte:** A conducting liquid (e.g., dilute sulfuric acid) that allows ions to move.

Working Process

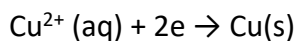
- (i) **Chemical reaction at electrodes:**

Zinc reacts with the electrolyte, releasing electrons.



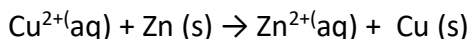
These electrons accumulate on the zinc electrode, making it negatively charged.

Copper ions in solution capture electrons from copper electrode



Positive ions accumulate on copper electrode making it positive

Overall reaction



(ii) Electron flow:

When the circuit is connected, electrons flow from the **zinc (negative)** electrode to the **copper (positive)** electrode through the external wire.

This flow of electrons constitutes an **electric current**.

(iii) Ion movement in electrolyte:

Positive ions move toward the copper electrode, and negative ions move toward the zinc electrode, completing the circuit internally.

(iv) Energy conversion:

Chemical energy from the reaction is converted into electrical energy that powers devices.

Summary Table

Component	Role
Zinc electrode	Releases electrons (negative terminal)
Copper electrode	Receives electrons (positive terminal)
Electrolyte	Allows ion movement
External circuit	Path for electron flow

Limitations of a Simple Cell

(i) Polarization

Hydrogen gas forms on the copper electrode, creating a layer that resists electron flow.

This reduces the efficiency of the cell.

(ii) Local Action

Impurities in the zinc electrode cause small currents to form within the electrode itself.

This wastes energy and corrodes the zinc.

(iii) **Low Voltage and Current Output**

A single simple cell produces only about **1.1 volts**, which is insufficient for many applications.

(iv) **Short Lifespan**

The zinc electrode wears out quickly due to continuous chemical reaction.

(v) **Not Portable or Practical**

Requires liquid electrolyte (like dilute sulfuric acid), which can spill and is unsafe for everyday use.

Improvements

(i) **Reducing Polarization**

Add a **depolarizer** (e.g., manganese dioxide in dry cells) to prevent hydrogen buildup.

(ii) **Preventing Local Action**

Use **pure zinc electrodes** or coat zinc with mercury (amalgamation) to reduce impurities.

(iii) **Increasing Voltage**

Connect several cells in **series** to form a battery, giving higher voltage.

(iv) **Improving Safety and Portability**

Replace liquid electrolyte with a **paste** (as in dry cells).

This makes the cell safer and more practical for portable devices.

(v) **Durability**

Use better electrode materials and controlled chemical reactions (as in modern alkaline and lithium cells).

Summary Table

Limitation	Improvement
Polarization	Use depolarizers (MnO_2)
Local action	Pure zinc or amalgamation
Low voltage	Connect cells in series
Short lifespan	Improved electrode materials
Unsafe electrolyte	Use paste (dry cell)

Primary Cells

Definition: Cells that produce electricity through chemical reactions but **cannot be recharged** once the chemicals are used up.

Examples: Dry cell, Leclanché cell, alkaline cell.

Features:

- Non-rechargeable.
- Provide a steady voltage for a limited time.
- Cheaper and lighter.

Applications:

- Used in torches, radios, clocks, remote controls, calculators.

Secondary Cells

Definition: Cells that can be **recharged** after use by passing current in the opposite direction to restore chemical energy.

Examples: Lead-acid battery, nickel-cadmium battery, lithium-ion battery.

Features:

- Rechargeable.
- Provide higher current and longer lifespan.
- More expensive but economical in the long run.

Applications:

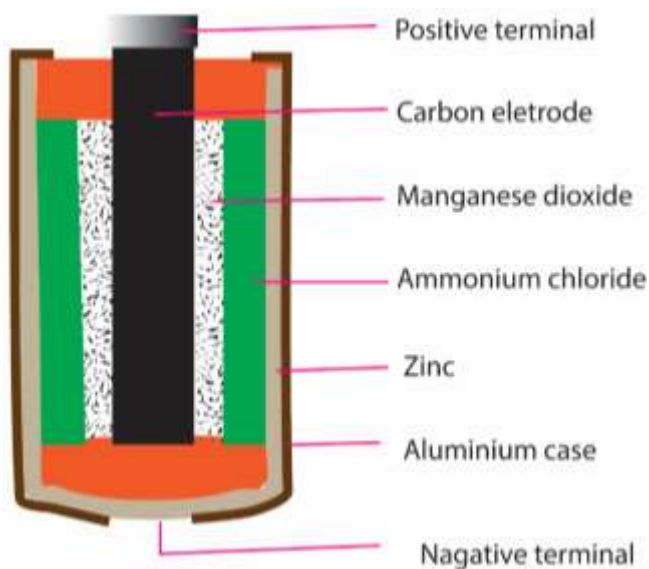
- Used in cars, laptops, mobile phones, UPS systems, power banks.

Comparison Table

Aspect	Primary Cells	Secondary Cells
Rechargeability	Not rechargeable	Rechargeable
Lifespan	Short, single use	Long, multiple cycles
Cost	Cheaper initially	More expensive initially
Voltage/current	Lower output	Higher output
Examples	Dry cell, alkaline cell	Lead-acid, lithium-ion
Applications	Radios, torches, remotes	Cars, laptops, phones

Dry Cell (Primary Cell)

Structure of dry cell



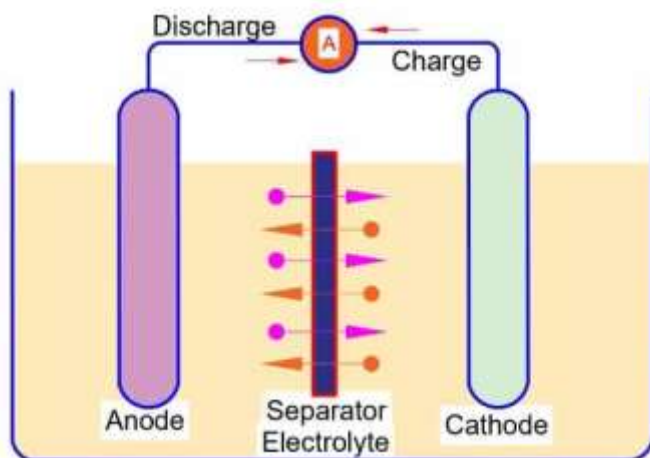
- (i) **Outer zinc container** → acts as the negative electrode (anode).
- (ii) **Carbon rod in the center** → positive electrode (cathode).
- (iii) **Electrolyte paste** → ammonium chloride and zinc chloride paste.
- (iv) **Depolarizer** → manganese dioxide surrounding the carbon rod to prevent polarization.
- (v) **Casing** → paper and pitch to keep the cell intact.

Action

- (i) Zinc undergoes oxidation → releases electrons.
- (ii) Electrons flow through the external circuit to the carbon rod.
- (iii) Manganese dioxide reacts with hydrogen ions to prevent buildup of hydrogen gas.
- (iv) Provides about **1.5 V**.
- (v) **Non-rechargeable** → once chemicals are used up, the cell is discarded.

Accumulator (Secondary Cell, e.g., Lead-Acid Battery)

Structure of secondary cell



- (i) **Plates:** Lead dioxide (PbO_2 , positive plate) and spongy lead (Pb , negative plate).
- (ii) **Electrolyte:** Dilute sulfuric acid (H_2SO_4).
- (iii) **Container:** Hard rubber or plastic casing holding the plates and electrolyte.

Action

Discharge:

PbO_2 and Pb react with $\text{H}_2\text{SO}_4 \rightarrow$ both plates gradually form lead sulfate (PbSO_4).

Electrons flow from negative plate to positive plate through the circuit.

Recharge:

External current reverses the reaction.

PbSO_4 converts back to PbO_2 (positive plate) and Pb (negative plate).

Electrolyte concentration of H_2SO_4 is restored.

Provides about **2 V per cell**; multiple cells are connected in series for higher voltages (e.g., 12 V car battery).

Rechargeable $\rightarrow$ can be used repeatedly.

Comparison Table

Feature	Dry Cell (Primary)	Accumulator (Secondary)
Electrodes	Zinc & Carbon	Lead dioxide & Spongy lead
Electrolyte	Ammonium chloride paste	Dilute sulfuric acid
Voltage per cell	~1.5 V	~2 V
Rechargeable?	No	Yes
Common uses	Torches, radios, clocks	Cars, UPS, solar systems
Lifespan	Short, disposable	Long, rechargeable

Process of charging an accumulator and proper handling methods

Charging an accumulator (secondary cell, e.g., lead-acid battery) requires a controlled process to restore its chemical energy safely

(i) Prepare the Charging Area

Ensure the environment is safe before connecting the battery.

- Place the accumulator in a **well-ventilated area**
- Keep away from **open flames** and sparks
- Wear **gloves and goggles** for protection

(ii) Check Battery Condition

Examine the battery before charging.

- Inspect terminals for **corrosion or damage**
- Ensure electrolyte levels are **adequate**
- Confirm the battery is not **swollen or leaking**

(iii) Connect Charger Correctly

Proper connection prevents accidents and ensures effective charging.

- Connect **positive (+) charger lead** to positive terminal
- Connect **negative (-) charger lead** to negative terminal
- Ensure connections are **tight and secure**

(iv) Set Charging Parameters

Adjust charger settings to match battery specifications.

- Select correct **voltage** (e.g., 12V for car battery)
- Set appropriate **current** (usually 10% of battery capacity)
- Use **slow charging** to prolong battery life

(v) Monitor Charging Process

Keep watch during charging to avoid overcharging.

- Observe **charging indicator** or ammeter
- Check battery temperature regularly
- Stop charging when battery is **fully charged**

(vi) Disconnect Safely

Remove charger connections in the correct order.

- Switch off charger before disconnecting
- Remove **negative lead first**, then positive
- Store battery properly after charging

Proper Handling Methods:

- (i) Always keep accumulators upright to prevent electrolyte spillage.
- (ii) Avoid short-circuiting the terminals.
- (iii) Regularly clean terminals and apply petroleum jelly to prevent corrosion.
- (iv) Do not overcharge or discharge completely, as this reduces lifespan.
- (v) Store in a cool, dry place when not in use.

Main Sources of Electricity in Uganda

(i) Hydropower (Dominant Source)

Major plants: Nalubaale & Kiira (Jinja), Bujagali (250 MW), Isimba (183 MW), Karuma (600 MW).

Contribution: ~82% of Uganda's installed capacity.

Reason: The Nile River provides abundant water flow, making hydropower the backbone of Uganda's grid.

(ii) Biomass (Bagasse from Sugarcane)

Contribution: ~9% of generation.

Use: Sugar factories burn bagasse (fibrous residue after extracting juice) to produce electricity.

Benefit: Renewable and supports agro-industrial sustainability.

(iii) **Solar Power**

Contribution: ~4% of generation.

Projects: Grid-connected solar farms (e.g., Soroti Solar Plant).

Potential: Uganda's sunny climate offers high expansion opportunities.

(iv) **Thermal Power (Backup Only)**

Diesel and heavy fuel oil plants provide emergency or backup supply during shortages.

Not a major contributor due to high costs and pollution.

(v) **Oil and Gas (Emerging)**

Albertine Graben reserves are being developed for electricity generation and export.

Expected to play a bigger role in Uganda's energy mix in the coming decade.

(vi) **Future Prospects**

Nuclear energy: Uganda has long-term plans to build nuclear plants to stabilize supply.

Geothermal energy: Potential sites in western Uganda (near volcanic regions).

Wind energy: Still under study, limited current use.

Summary Table

Source	Current Role	Examples/Projects	Future Potential
Hydropower	82% of capacity	Nalubaale, Kiira, Bujagali, Isimba, Karuma	Remains dominant backbone
Biomass (Bagasse)	9%	Sugar factories	Moderate expansion possible
Solar	4%	Soroti Solar Plant	High potential due to climate
Thermal (Diesel/HFO)	Backup only	Small thermal plants	Limited, costly, polluting
Oil & Gas	Emerging	Albertine Graben	Significant role in future
Nuclear	Planned	Government proposals	Long-term diversification
Geothermal/Wind	Minimal	Western Uganda sites	Under exploration

Key Takeaway

Uganda's electricity supply is **clean and renewable-heavy**, but **overdependent on hydropower**, which makes it vulnerable to droughts and climate change. Diversifying into **solar, biomass, oil, nuclear, and geothermal** is essential for reliable, affordable, and sustainable energy access.

Current

Electric current is the flow of electric charges (usually electrons) through a conductor such as a wire.

It represents how much charge passes a point in the circuit per unit time.

Mathematically:

$$I = \frac{Q}{t}$$

Where:

I = current (amperes)

Q = charge (coulombs)

t = time (seconds)

Measurement of current



Ameter

Instrument: Ammeter (connected in series in the circuit).

Units: Ampere (A), named after André-Marie Ampère.

1 ampere = 1 coulomb of charge passing a point per second.

What Causes Current

- (i) **Potential difference (voltage):** Current flows when there is a difference in electric potential between two points.
- (ii) **Source:** A cell, battery, or generator provides the electromotive force (EMF) that pushes charges.
- (iii) **Conductive path:** Wires or other conductors allow charges to move.
- (iv) **Closed circuit:** Current only flows when the circuit is complete.

Effects of Current

- (i) **Heating effect:** Current causes conductors to heat up (basis of electric heaters, bulbs).
- (ii) **Magnetic effect:** Current produces a magnetic field around the conductor (used in electromagnets, motors).
- (iii) **Chemical effect:** Current can cause chemical reactions (electrolysis in plating, charging batteries).
- (iv) **Physiological effect:** Can shock or harm living organisms if uncontrolled.

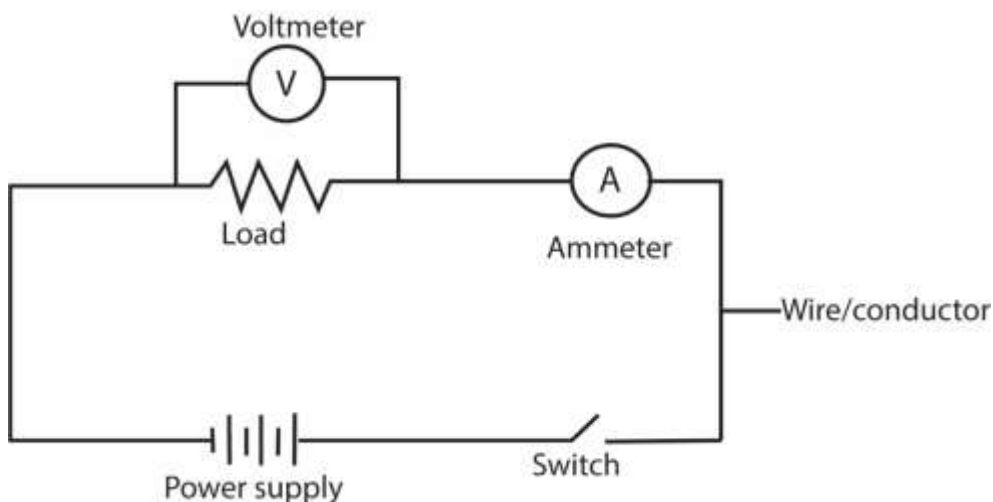
Summary Table

Aspect	Explanation
What is current	Flow of electric charges
Measurement	Ammeter, in amperes (A)
Formula	$I = Q/t$
Cause	Voltage difference, closed circuit
Effects	Heating, magnetic, chemical, physiological

Electric circuit

An **electric circuit** is a closed path through which electric current flows. It connects a source of electricity to devices (loads) using conductors, and may include control and protective components.

Components of an Electric Circuit



(i) **Source of EMF (Power Supply)**

Provides the energy to move charges.

Examples: Battery, cell, generator.

(ii) **Conductors (Wires)**

Metallic paths (usually copper or aluminum) that allow current to flow.

(iii) **Load (Appliance/Device)**

Converts electrical energy into another form (light, heat, motion).

Examples: Bulb, heater, motor.

(iv) **Switch/Key**

Opens or closes the circuit to control current flow.

(v) **Protective Devices**

Fuse or circuit breaker prevents damage from excess current.

(vi) **Measuring Instruments**

Ammeter: Measures current (connected in series).

Voltmeter: Measures voltage (connected in parallel).

Summary Table

Component	Function	Example
Source of EMF	Provides energy	Battery, generator
Conductors	Path for current	Copper wires
Load	Uses energy	Bulb, motor
Switch	Controls circuit	Toggle switch
Protective device	Prevents damage	Fuse, breaker
Instruments	Measurement	Ammeter, voltmeter

Conductors, semiconductors and Insulators

Conductors

Definition: Materials that allow electric current to flow easily due to free electrons.

Examples: Copper, aluminum, silver, gold.

Applications:

- Electrical wiring (copper, aluminum).
- Transmission lines (aluminum).
- Electronic components (gold plating for corrosion resistance).
- Household appliances and circuits.

Semiconductors

Definition: Materials whose conductivity lies between conductors and insulators; can be controlled by adding impurities (doping).

Examples: Silicon, germanium.

Applications:

- Diodes (rectifiers in power supplies).
- Transistors (switching and amplification in circuits).
- Integrated circuits (ICs in computers, phones).
- Solar cells (convert sunlight into electricity).

Insulators

Definition: Materials that do not allow current to flow easily; electrons are tightly bound.

Examples: Rubber, glass, plastic, ceramics, wood.

Applications:

- Covering wires (plastic insulation).
- Supporting electrical equipment (ceramic insulators on pylons).
- Safety devices (rubber gloves for electricians).
- Preventing leakage of current in appliances.

Summary Table

Type	Examples	Properties	Applications
Conductors	Copper, aluminum	High conductivity	Wiring, transmission lines
Semiconductors	Silicon, germanium	Moderate, controllable conductivity	Diodes, transistors, ICs, solar cells
Insulators	Rubber, glass, plastic	Very low conductivity	Wire covering, safety equipment, supports

a.c, d.c, rectifiers, inverters

AC (Alternating Current) and DC (Direct Current) are the two fundamental types of electricity. Rectifiers convert AC into DC, while inverters do the opposite—turning DC into AC. These devices are essential in everyday systems like phone chargers, solar panels, and power grids.

(i) **Direct Current (DC):**

Flows steadily in one direction.

Produced by **batteries, solar panels, and fuel cells.**

Used in electronics (phones, laptops, LEDs).

(ii) **Alternating Current (AC):**

Changes direction periodically (50 Hz in Uganda, 60 Hz in some countries).

Supplied by **power stations and wall sockets.**

Ideal for long-distance transmission because voltage can be easily stepped up or down using transformers.

(iii) **Rectifiers (AC → DC)**

Purpose: Convert AC from the grid into DC for devices.

How they work:

- Use **diodes** (one-way valves for current).
- **Half-wave rectifier**: passes only one half of the AC cycle.
- **Full-wave rectifier (bridge)**: flips negative half cycles, producing continuous one-direction flow.
- **Capacitors** smooth the output to reduce ripples.

Applications:

- Phone chargers
- Laptop adapters
- LED lighting systems

(iv) Inverters (DC → AC)

Purpose: Convert DC into AC.

How they work:

- Use **transistors** to rapidly switch DC on and off.
- Produce a waveform that mimics AC (sine wave or modified square wave).

Applications:

- Solar systems (DC from panels → AC for grid).
- Uninterruptible Power Supplies (UPS).
- Electric vehicles (battery DC → AC for motors).

Quick Comparison

Feature	AC	DC
Flow direction	Alternates periodically	Constant, one direction
Source	Generators, wall sockets	Batteries, solar panels
Transmission	Efficient long-distance	Short-distance only
Conversion device	Rectifier (AC → DC)	Inverter (DC → AC)
Common uses	Home appliances, motors	Electronics, storage cells

Ugandan Context

- **Grid electricity** is supplied as AC (from hydropower plants on the Nile).

- **Solar systems** in rural areas use inverters to feed DC panel output into AC household wiring.
- **Battery-powered devices** rely on rectifiers in chargers to convert AC from sockets into DC for charging.

Scenario Question

A rural health center in Uganda has installed **solar panels** to provide electricity. The panels generate **direct current (DC)**, but most of the medical equipment in the center requires **alternating current (AC)**.

1. Explain why the solar panels produce DC instead of AC.
2. Identify the device used to convert DC from the solar panels into AC for the equipment.
3. The health center also uses a **battery backup system**. Describe how rectifiers are involved when charging these batteries from the national grid.
4. Discuss one advantage of using AC for transmission in the national grid compared to DC.

Suggested Answers

- (i) Solar panels produce DC because they generate electricity directly from the movement of electrons in one direction when sunlight excites them.
- (ii) An **inverter** is used to convert DC into AC.
- (iii) A **rectifier** converts AC from the grid into DC, which is required to charge the batteries.
- (iv) AC is advantageous for transmission because its voltage can be easily stepped up or down using transformers, making long-distance transmission more efficient and reducing power loss.

Appliances Using AC (Alternating Current)

These are connected directly to the mains supply (wall sockets):

- (i) **Refrigerators** – compressors run on AC motors.
- (ii) **Washing machines** – powered by AC induction motors.
- (iii) **Microwave ovens** – magnetrons require AC supply.
- (iv) **Electric irons** – heating elements use AC.
- (v) **Fans** – most ceiling and pedestal fans use AC motors.

- (vi) **Televisions** – though internally converted to DC, they are powered by AC input.

Appliances Using DC (Direct Current)

These rely on batteries or adapters that convert AC to DC:

- (i) **Mobile phones** – batteries store DC.
- (ii) **Laptops** – powered by DC from chargers.
- (iii) **Flashlights/torches** – battery-operated DC.
- (iv) **Radios (portable)** – use DC batteries.
- (v) **Solar lamps** – powered by DC from solar-charged batteries.
- (vi) **Electric vehicles (EVs)** – batteries supply DC to motors (sometimes converted to AC depending on design).

Mixed Use (AC input, DC inside)

Many modern appliances **take AC from the wall but convert it to DC internally**:

- (i) **Computers** – power supply units (PSUs) rectify AC into DC for components.
- (ii) **LED bulbs** – require DC, so they have built-in rectifiers.
- (iii) **Smart TVs and routers** – adapters convert AC to DC.

Teaching Tip

You can frame this as a **classification exercise** for students:

“List five appliances in your home that use AC directly, five that use DC directly, and five that use AC but internally convert to DC.”

This helps them connect theory to everyday life.

Scenario Question

A Ugandan household has the following appliances: a refrigerator, a mobile phone, a laptop, a ceiling fan, and a solar lamp.

- (i) Classify each appliance as using **AC**, **DC**, or **AC input but internally converted to DC**.

- (ii) Explain why the refrigerator and ceiling fan are designed to run on AC instead of DC.
- (iii) Describe how rectifiers are involved when charging the mobile phone and laptop.
- (iv) Discuss one advantage of using DC in portable devices compared to AC.

Suggested Answers

- (i)
 - Refrigerator → AC
 - Mobile phone → DC
 - Laptop → DC (charger converts AC to DC)
 - Ceiling fan → AC
 - Solar lamp → DC
- (ii) AC is used because it is supplied directly from the mains and is efficient for running induction motors in refrigerators and fans.
- (iii) Rectifiers in chargers convert AC from the wall socket into DC, which is required to charge the batteries of phones and laptops.
- (iv) DC is safer and more suitable for portable devices because it can be stored in batteries, allowing mobility and independence from the grid.

Main Components of Domestic Wiring

(i) Main Switch

Function: Controls the entire supply of electricity to the house.

Importance: Allows safe disconnection during maintenance or emergencies.

(ii) Fuse / Circuit Breaker

Function: Protects the wiring and appliances from excess current (overload or short circuit).

Importance: Prevents fire hazards and damage to appliances.

(iii) Meter

Function: Measures the amount of electricity consumed.

Importance: Helps in billing and monitoring energy usage.

(iv) Distribution Board

Function: Distributes electricity to different circuits (lighting, sockets, heavy appliances).

Importance: Ensures organized and safe supply to various parts of the house.

(v) Cables and Wires

Function: Carry current from the supply to appliances.

Importance: Insulated to prevent shocks; different thicknesses used depending on load.

(vi) Sockets and Plugs

Function: Provide connection points for appliances.

Importance: Allow safe and convenient use of electrical devices.

(vii) Switches

Function: Control the flow of current to appliances (on/off).

Importance: Provides safety and convenience in operation.

(viii) Earthing (Grounding)

Function: Provides a path for leakage current to flow safely into the ground.

Importance: Protects users from electric shocks.

Summary Table

Component	Function	Importance
Main switch	Controls supply	Safety during emergencies
Fuse/Circuit breaker	Protects against excess current	Prevents fire & damage
Meter	Measures consumption	Billing & monitoring
Distribution board	Divides supply into circuits	Organized, safe distribution
Cables/Wires	Carry current	Safe transmission
Sockets/Plugs	Connect appliances	Convenient usage
Switches	Control appliances	Safety & convenience
Earthing	Leakage current path	Shock protection

Scenario Question

A family in Kampala notices that their **electric iron** stopped working after a power surge.

1. Which domestic wiring component is most likely to have protected the house during the surge?
2. Explain why earthing is important for appliances with metallic bodies like irons.
3. Suggest two reasons why the distribution board is essential in a modern household.

Answers

1. **Which domestic wiring component is most likely to have protected the house during the surge?**
 - The **fuse or circuit breaker**.
 - It automatically disconnects the circuit when excess current flows, preventing damage to appliances and reducing fire risk.
2. **Explain why earthing is important for appliances with metallic bodies like irons.**
 - Earthing provides a safe path for leakage current to flow into the ground.
 - If the iron's metallic body becomes live due to a fault, earthing prevents electric shock to the user by diverting current away.
3. **Suggest two reasons why the distribution board is essential in a modern household.**
 - It **divides electricity into separate circuits** (lighting, sockets, heavy appliances), ensuring organized and safe supply.
 - It allows **individual circuit protection** with fuses or breakers, so a fault in one circuit does not cut power to the entire house.

Methods of saving electricity

Household Methods

- (i) **Switch off unused appliances** – lights, fans, TVs, and chargers should not be left running.
- (ii) **Use energy-efficient bulbs (LEDs)** – they consume far less power than incandescent bulbs.
- (iii) **Unplug devices** – even when off, many appliances draw “standby power.”
- (iv) **Proper insulation** – reduces the need for heating or cooling.
- (v) **Efficient cooking** – use pressure cookers, cover pots, and avoid unnecessary reheating.

Industrial/Institutional Methods

- (i) **Energy audits** – identify areas of waste and recommend improvements.
- (ii) **Efficient machinery** – replace old motors with modern, energy-saving ones.
- (iii) **Shift work schedules** – run heavy machines during off-peak hours.
- (iv) **Recycling and reusing materials** – reduces energy needed for production.

Community/National Methods

- (i) **Promote renewable energy** – solar, wind, and hydropower reduce reliance on fossil fuels.
- (ii) **Public awareness campaigns** – educate people on responsible energy use.
- (iii) **Government policies** – enforce efficiency standards and provide incentives for clean energy.
- (iv) **Smart grids** – balance supply and demand more effectively.

Summary Table

Level	Method	Importance
Household	Switch off unused appliances	Cuts bills, prevents waste
Household	Use LED bulbs	Saves up to 80% energy
Industrial	Energy audits	Identifies inefficiencies
Industrial	Efficient machinery	Reduces long-term costs
National	Renewable energy adoption	Sustainable and eco-friendly
National	Awareness campaigns	Encourages responsible behavior

Scenario Question

A school in Kampala notices its electricity bills are very high. The administration wants to reduce costs without affecting learning.

1. Suggest two methods the school can use to save electricity in classrooms.
2. Explain how energy audits could help the school identify waste.
3. Discuss one long-term benefit of switching to solar power for the school.

Answers

1. **Suggest two methods the school can use to save electricity in classrooms.**
 - Replace traditional bulbs with **energy-efficient LED lights**.
 - Encourage teachers and students to **switch off lights, fans, and projectors** when not in use.
2. **Explain how energy audits could help the school identify waste.**
 - An energy audit systematically checks how electricity is consumed.
 - It can reveal **inefficient appliances**, unnecessary usage, or areas where power is wasted (e.g., lights left on during daylight).
 - This helps the school take targeted actions to reduce consumption.
3. **Discuss one long-term benefit of switching to solar power for the school.**
 - Solar power reduces dependence on the national grid, lowering electricity bills.
 - It provides a **sustainable and reliable energy source**, especially during power outages, ensuring uninterrupted learning.

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