PHYSICS NOTES

A Simplified and Comprehensive Guide to Physics

Unlock the World of Physics with Clarity and Confidence.

These notes provide a simplified and comprehensive guide to Physics, carefully written to cover all essential topics in the syllabus. They are designed to:

- Make difficult concepts easy to understand
- Provide clear definitions, formulas, and examples
- Serve as both a classroom companion and a revision handbook
- Prepare readers effectively for school exams, WAEC, NECO, JAMB/UTME, and other external exams

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CHAPTER 1

SCALAR AND VECTOR QUANTITIES

DEFINITION OF SCALAR QUANTITY

Scalar quantities are quantities that have only magnitude (size) and no direction. Examples of scalar quantity includes:

1. Area
2. Length
3. Mass
4. Volume
5. Density
6. Time
7. Pressure
8. Temperature
9. Energy
10. Work
11. Power
12. Speed
13. Current

DEFINITION OF VECTOR QUANTITY

Vector quantities are quantities that have both magnitude(size) and direction. Examples of vector quantity include:

1. Acceleration
2. Displacement
3. Tension
4. Velocity
5. Force
6. Moment
7. Momentum
8. Torque
9. Impulse
10. Magnetic flux
11. Weight
12. Stress

VECTOR REPRESENTATION

A vector can be represented by a line with an arrow pointing towards its direction.

NB: Vectors are often denoted by bold letters with arrow on top (e.g A)

VECTOR ADDITION

Vector addition is a method used to combine two or more vectors to have a single vector called resultant vector.

Let us consider two forces on magnitude P= 30N and Q= 40N acting in:

a. Same direction

b. Opposite direction

1. Acting in opposite direction

R = Q – P

R = 40 – 30 = 10N

2. Acting in same direction

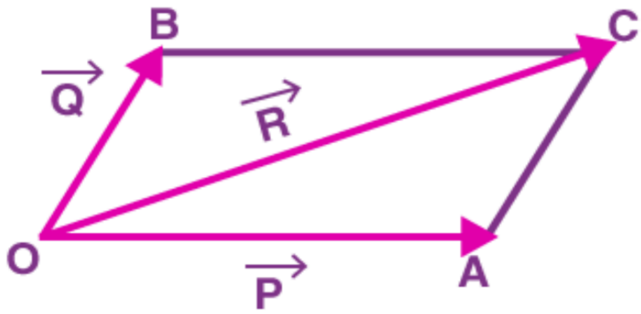
R = Q + P

R = 40 + 30 = 70N

TWO MAIN LAWS OF VECTOR ADDITION

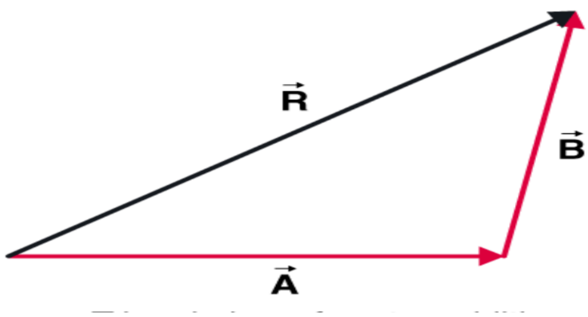
1. **Parallelogram law of vector:** This states that if two vectors are represented as adjacent sides of a parallelogram, the diagonal of the parallelogram gives the resultant vector.

Parallelogram law of vector addition is used when the vectors start from the state point and for an angle.



2. **Triangle law of vector addition:** This states that when two vectors are placed head to tail, the third side of the triangle gives the resultant vector or single vector.

Triangle law of vector addition is used when vectors are added one after the other in sequence.



Resultant Vector: Resultant vector is a single vector obtained from two or more vectors acting or combined together at a point.

RESOLUTION VECTOR

Resolution vector means splitting or breaking one or single or resultant vector into 2 parts (Horizontal and Vertical Components)

1. Horizontal (x)

   $F_x = F\cos\theta$

2. Vertical (y)

   $F_y = F\sin\theta$

CHAPTER 2

WORK, ENERGY AND POWER

DEFINITION OF WORK

Work is done when a force is applied on something and it moves in the direction of the force. The S.I unit for work is joule (J).

Work = Force × Distance

$W = F \times S$ or $F \times d$

$W = F \times S\cos\theta$ or $F \times d\cos\theta$

CONDITIONS FOR WORK TO BE DONE

1. A force must be applied
2. The object must move
3. The movement must be in same direction of the force

WORK DONE AGAINST GRAVITY

Work done against gravity

When you lift something upward, you are doing work against gravity because gravity tries to pull it down.

Work done against gravity = Weight × Height

$= w \times h$

$= (mg) \times h$

NB: g is always constant= $9.8m/s^2$ or $10m/s^2$

Work done against friction

When you push or pull an object on a surface or ground, friction tries to stop it. So, you must do extra work to overcome friction.

Work done against friction = Frictional force×Distance

$= (\mu \times R) \times d$

Where: μ = Coefficient of friction

Normal force (R) = Weight of object

DEFINITION OF ENERGY

Energy is the ability or capability to do work. The S.i unit for energy is also joule(J).

FORMS OF ENERGY

1. Kinetic Energy- Energy of a moving object
2. Potential Energy- Stored Energy
3. Heat Energy
4. Light Energy
5. Mechanical Energy
6. Chemical Energy
7. Sound Energy
8. Electrical Energy
9. Solar Energy, etc.

ENERGY TRANSFORMATION (CONVERSION)

This is the process of changing energy from one form to another.

	FROM	TO
1. Bulb	Electrical energy	Light energy
2. Speakers	Electrical energy	Sound energy
3. Car Engines	Chemical energy	Mechanical energy
4. Generator	Mechanical energy	Electrical energy
5. Solar panel	Solar energy	Electrical energy

CONSERVATION OF ENERGY

The principle of conservation of energy states that although energy can be changed from one form to another, the total energy of a given system remains the same. Therefore, Energy can neither be created nor destroyed during transformation.

WORK-ENERGY THEOREM

The work-energy theorem states that the work done on an object is equal to the change in its kinetic energy.

$$W = KE$$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

Where, W= work done (Joules, J)

M= Mass (kg)

U= Initial velocity (m/s)

V= Final velocity (m/s)

DEFINITION OF POWER

Power is the rate of doing work or using energy. It tells us how fast work is done. The S.I unit of power is watt(w).

$$\text{Power} = \frac{Work}{Time}$$

$$= \frac{F \times S}{T} = F \times V$$

Where, F = Force (N)

S = Distance (m)

V = Final velocity (m/s)

EFFICIENCY AND ITS FORMULAR

Efficiency means how well a machine or system uses energy.

$$\text{Efficiency} = \frac{Useful\ energy\ output}{Total\ energy\ input} \times 100$$

NOTE: No machine is 100% efficient, some energy is always lost.

COMMERCIAL UNIT OF ENERGY(kWh)

This is the unit used by electricity companies to charge for the energy use at home or offices. The unit is called Kilowatt-hour (kWh).

Relation of Kwh to joule:

1kWh = 1000W × 3600 = 3.6 × 10J

1kWh = 3.6 Million Joules

Example: If you use a 2kW electric heater for 3hours, what is the energy used?

Energy used = 2kW × 3h

= 6kWh

NOTE ON WHY USING KWH

1. Using joules would give large numbers (Too large to read)
2. Kwh is easier for billing and everyday calculations.

NB- Potential energy = mgh

Kinetic energy = $\frac{1}{2}$ mv²

CHAPTER 3

MOTION

Definition of motion: Motion can be defined as the change in position of an object with respect to time.

Terms used in motion

1. Displacement (s): This is the distance moved by an object in a specific direction.
2. Distance (d): This is the total path an object travelled (How far it travelled).
3. Speed (v): This is the rate at which an object covers distance.
4. Velocity (v): This is the rate of change of displacement.
5. Deceleration : This is the rate of change of decrease in velocity.
6. Acceleration (a): This is the rate of change of increase in velocity.

TYPES OF MOTION

1. Translational motion: This is also known as linear motion where objects move in a straight line.
   Example; A car moving from point A to point B.
2. Oscillatory Motion: This is the to and fro movement of an object.
   Example; A simple Pendulum Clock.
3. Random Motion: This is the irregular movement of an object.
   Example; Molecular movement in gas.
4. Rotational Motion: THis is the movement of an object around its fixed axis.
   Example; The blades of an electric fan.

EQUATION OF MOTION

1. $V = u + at$
2. $V^2 = u^2 + 2as$
3. $S = ut + \frac{1}{2} \times at^2$
4. $S = \left(\frac{u+v}{2}\right)t$

FREE FALL (MOTION UNDER GRAVITY)

These equations are used when an object is moving under the influence of gravity only (free fall), and there is no air resistance.

1. $V = u + gt$
2. $V^2 = u^2 + 2gh$
3. $h = ut + \frac{1}{2} gt^2$

Where: V = Final velocity, u = Initial velocity, a = Acceleration, s = Distance, t = Time, h = Height, g = Gravity (9.8 ms^{-2} or 10 ms^{-2}).

NEWTONS LAWS OF MOTION

Newton's First Law of Motion: State that an object continues in its state of rest or uniform motion unless it is acted upon by an external force.

Example**:** A book lying on a table will remain there until you push it.

Newton's Second Law of Motion: State that the acceleration of an object is directly proportional to the force acting upon it and inversely proportional to its mass.

Example**:** It is easier to push an empty wheelbarrow than a wheelbarrow full of sand. The heavier one (more mass) needs more force to produce the same acceleration.

$$F = M \times a$$

Under gravity:

Downward motion: $F = m(a + g)$ (e.g. a stone dropped from a building)

Upward motion: $F = m(a - g)$ (e.g. throwing a ball upward)

Impulse and Momentum

- Impulse (I) = $F \times t$
- Momentum (p) = $M \times V$

Relationship between momentum and impulse

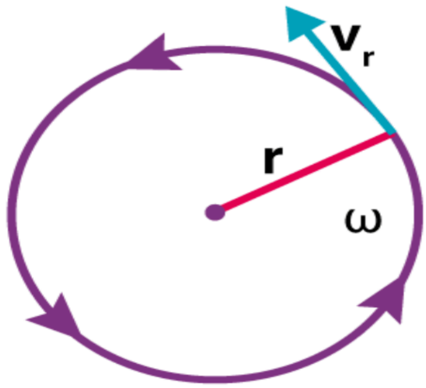
$$Ft = M(V - U)$$

Newton's Third Law of Motion: States that every action has an equal or opposite reaction.

Example: When you jump off a boat onto the shore, the boat moves backwards. Also, when a gun is fired, the bullet moves forward and the gun experiences a backward recoil.

CIRCULAR MOTION

Centripetal Force (Fc) is the force that keeps an object moving in a circular path directed towards the center of the circle.



Angular Velocity = $\dfrac{Angular\ displacement}{Time}$

$$\omega = \frac{\theta}{t}$$

Centripetal Acceleration:

$$a_c = \frac{V^2}{r} = \omega^2 r$$

Centripetal Force :

$$F_c = Ma_c$$

So: $F_c = \frac{MV^2}{r}$ or $F_c = M\omega^2 r$

PROJECTILE

Projectile occurs when an object is thrown into air or launched into space and moves freely under the influence of gravity.

TERMS USED IN PROJECTILE

1. Range (R) = $\frac{U^2 \, sin\theta}{g}$

2. Maximum height (H) = $\frac{U^2 \, sin\theta}{2g}$

3. Time of Flight (T)= $\frac{2Usin\theta}{g}$

SIMPLE HARMONIC MOTION

SHM is the oscillatory motion of a body in which the acceleration is proportional to its displacement and
directed towards its fixed axis or point.

TERMS IN SIMPLE HARMONIC MOTION

1. **Amplitude** (A): Is the maximum displacement of particles from mean position (Rest). It is measured in meters(m).
2. **Period** (T): is the time taken to complete one oscillation or cycle. It is measured in Second(s).

$$T = \frac{1}{F} \text{ or } \frac{n}{F} \text{ or } \frac{2\pi}{\omega}$$

3. **Frequency** (F): Is the number of oscillations or cycles completed in one second. It is measured in hertz (Hz).

$$F = \frac{1}{T} \text{ or } \frac{n}{T} \text{ or } \frac{\omega}{2\pi}$$

VELOCITY IN SIMPLE HARMONIC MOTION

$$V = \omega\sqrt{A^2 - X^2}$$

When X is 0 , V = Maximum

$$V = \omega\sqrt{A^2 - 0^2}$$

$$V = \omega\sqrt{A^2}$$

$$V_{max} = \omega A$$

ENERGY IN SIMPLE HARMONIC MOTION

Energy can be interchanged between Potential energy and Kinetic energy in simple harmonic motion.

Potential Energy (P.E) = $\frac{1}{2}KX^2$

Kinetic Energy (K.E) = $\frac{1}{2}K(A^2 - X^2)$

Total Energy in SHM:

Potential Energy + Kinetic Energy

$$\frac{1}{2}KX^2 + \frac{1}{2}K(A^2 - X^2)$$

$$\frac{1}{2}KX^2 + \left(\frac{1}{2}KA^2 - \frac{1}{2}KX^2\right)$$

P.E + K.E = $\frac{1}{2}KA^2$ or $\frac{1}{2}M\omega^2A^2$

CHAPTER 4

FRICTION

Definition of Friction: Friction is the force that opposes motion or tends to oppose motion between two surfaces in contact.

NOTE:

1. It acts in opposite direction to motion
2. Without friction walking, writing, holding objects would be impossible.

TYPES OF FRICTION

1. Static (Limiting) Friction: Static friction is the force that prevents an object at rest from starting to move even when a force is applied.
2. Dynamic (Kinetic/Sliding) Friction: Dynamic friction is the force that opposes motion when the object is already moving.

LAWS OF FRICTION

1. Friction is directly proportional to the normal reaction

$F \propto R$

$F = \mu R$

2. Friction is independent of the area of contact
3. Friction depends on the nature of the surface
4. Static friction is greater than dynamic friction

CAUSES OF FRICTION

1. Roughages
2. Nature of the material
3. Force of adhesion
4. Surface bumps

REDUCTION OF FRICTION

1. Applying lubricant
2. Smoothening surface
3. Streamlining
4. Using rollers or wheels

COEFFICIENT OF FRICTION

Co-efficient of friction is the ratio of frictional force to normal force.

$$\mu = \frac{F}{R} \longrightarrow \frac{Mg\sin\theta}{Mg\cos\theta}$$

FRICTIONAL FORCE

Frictional force is the force that slows down or stops movement between two surfaces that are in contact.

$F = \mu R$

Where F - Frictional force

μ - Coefficient friction

R - Normal force

ADVANTAGES OF FRICTION

1. Makes walking possible
2. Allows brake system to work
3. Make screwing possible

DISADVANTAGES OF FRICTION

1. Generates heats
2. Causes wear and tear
3. Makes machine less efficient

CHAPTER 5

MACHINE

Definition of Machine: A machine is a device that makes work easier and allows work to be done conveniently.

Mechanical Advantage (M.A): Mechanical advantage is the ratio of load to the effort. Mechanical advantage is also known as Force Ratio.

$$M.A = \frac{Load}{Effort} = \frac{L}{e}$$

Velocity Ratio(V.R): Velocity ratio is the ratio of distance moved by the effort to the distance moved by the load.

$$V.R = \frac{Distance\ moved\ by\ effort}{Distance\ moved\ by\ load} = \frac{x}{y}$$

Efficiency (E): Efficiency is the ratio of useful work done by a machine (work-output) to the total work put in the machine (work-input). It is usually expressed as a percentage.

$$E = \frac{Work\ Output}{Work\ Input} \times 100$$

$$= \frac{M.A}{V.R} \times 100$$

NOTE: Efficiency is always less than 100% due to energy loss (Frictional force)

TYPES OF MACHINE

1. **Lever**: Lever is a rigid bar that turns (pivot) about a fixed point called fulcrum.

M.A = V.R

$$\frac{Load}{Effort} = \frac{Effort\ Arm}{Load\ Arm}$$

Classes of lever

I. First class: Fulcrum is between load and effort.
II. Second class: Load is between fulcrum and effort.
III. Third class: Effort s between fulcrum and load.

2. **Pulley**: Pulley is a machine made of wheel with rope that helps lift a load.

M.A = V.R

$$\frac{Load}{Effort} = \text{Number of pulley (Number of supporting ropes)}$$

Load/Effort = Number of pulley (Number of supporting ropes)

3. **Inclined Plane**: Inclined plane is a sloped surface used to raise a load with less effort.

M.A = V.R

$$\frac{Load}{Effort} = \frac{L}{h} \text{ or } \frac{1}{\sin\theta}$$

4. **Wheel and Axle**: This is a machine with a large wheel attached to a small axle.

M.A = V.R

$$\frac{Load}{Effort} = \frac{Rw(Radius\ of\ wheel)}{Ra(Radius\ of\ axle)}$$

5. **Hydraulic Press**: This uses a liquid pressure to multiply force

M.A = V.R

$$\frac{Load}{Effort} = \frac{Area\ of\ big\ piston}{Area\ of\ small\ piston}$$

CHAPTER 6

ELASTICITY

Definition of Elasticity: Elasticity is the ability of a material to regain its original shape and size after the force is removed. E.g Rubber-band.

HOOKE'S LAW

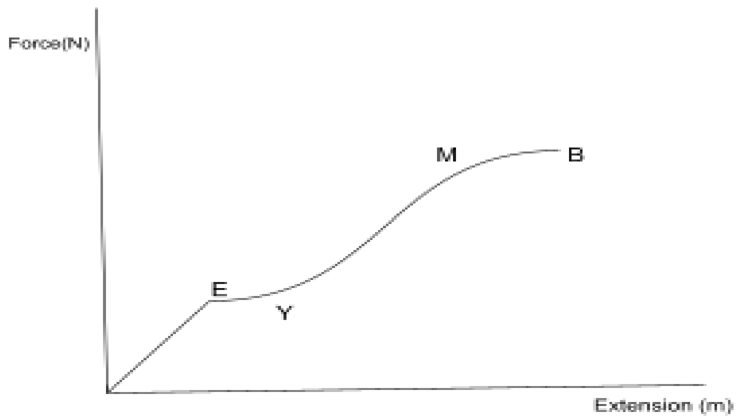
Hooke's law states that , provided that the elastic limit is not exceeded, the extension of an elastic material is proportional to the applied force.

Mathematically, $F \propto e$

$$F = Ke$$

Where: F = Force or Load (N) , e = Extension (m) and K = Force constant(Nm^{-1})

TERMS USED IN ELASTICITY



1. **Elastic Limit (E)**: This is the maximum force a material can withstand losing its elasticity, after the applied force is removed.
2. **Yield Point (Y)**: This is the point at which a material begins to stretch or deform permanently.
3. **Maximum Load (M):** This is the highest amount of force a material can support before it starts to weaken.
4. **Breaking Point (B)**: This is the point where material starts to break or fractures.

STRESS: Stress is the force acting on a cross-section area of the material.

$$\text{Stress} = \frac{Force\ (F)}{Area\ (A)}$$

STRAIN: Strain is the ratio of extension to original length.

$$\text{Strain} = \frac{Extension\ (E)}{Length\ (L)}$$

YOUNG MODULUS: Young modulus is the ratio of stress to strain within the elastic region.

Young modulus= $\frac{Stress}{Strain}$

$$\frac{F}{A} \div \frac{e}{L} = \frac{FL}{Ae}$$

WORKDONE ON A SPRING OR STRING

1 . W = $\frac{1}{2}$Fe 2. W = $\frac{1}{2}$Ke² 3. W = $\frac{F^2}{2K}$

CHAPTER 7

GRAVITATIONAL FIELD

A gravitational field is a region of space surrounding a mass in which another mass experiences a force of attraction.

NEWTON'S UNIVERSAL LAW OF GRAVITATION

Newton's universal law of gravitation states that the force of attraction between two objects is directly proportional to the product of their mass and inversely proportional to the square of their distance apart.

$$F = \frac{GM_1 M_2}{R^2}$$

Where: F - Force (N) , M - Mass (kg), R - Distance apart (m) and G - Gravitational constant (6.674×10^{-11} $N \cdot m^2/kg^2$)

ACCELERATION DUE TO GRAVITY

The weight of a body is equal to the gravitational force of the body.

$$W = F$$

$$Mg = \frac{GM_1 M_2}{R^2}$$

$$g = \frac{GM}{R^2}$$

Where: g - gravity (9.8 or 10 m/s^2)

GRAVITATIONAL POTENTIAL

The work done per unit mass in bringing a body from infinity to a point in a gravitational field.

$$V = \frac{-GM}{R}$$

Where: V - gravitational potential (J/kg)

ESCAPE VELOCITY

This is the minimum velocity required for an object to escape or leave the gravitational influence of the earth.

$$Ve = \sqrt{2gR}$$

$$Ve = \sqrt{\frac{2GM}{R}}$$

Where: Ve - Escape velocity

ORBITAL VELOCITY

This is the minimum velocity required to place or maintain a satellite in a given orbit. The centripetal force is required for a satellite to revolve in the orbit.

$$Vo = \sqrt{gR}$$

PARKING ORBIT

This occurs when a satellite’s **orbital period = Earth's rotation (24 hrs)**, causing the satellite to appear fixed over one point on Earth.

NOTE: Must orbit above the equator.

Used in telecommunications and weather satellites.

WEIGHTLESSNESS

This is a condition in which a body has no apparent weight because there is no reaction force acting on it. In space (or inside an orbiting satellite), astronauts experience weightlessness because they and the satellite are both falling freely around the Earth under gravity. Since everything is falling together, there is no contact force, so they feel no weight.

CHAPTER 8

FLUID MECHANICS

PRESSURE

Pressure is the force acting on a unit area of a surface. It tells us how much force is concentrated on a surface.

$$P = \frac{F}{A}$$

Where: P = Pressure (Nm^{-2}), F = Force (N) and A = Area (m^2)

The smaller the area, the greater the pressure when the same force is applied.

Atmospheric Pressure: This is the pressure caused by the weight of air in the atmosphere pressing down on the earth's surface. Atmospheric pressure starts to decrease as soon as you go *above sea level*, because the higher you go, there is less air above you and therefore less weight of air pressing down.

Solid Pressure: This is the pressure caused by a solid object when a force is applied over its surface area.
Example: A person standing on the ground.

Fluid Pressure: The pressure exerted by liquid can be observed to have the following;

1. Pressure increases with depth (i.e Pressure is greater at the bottom of a liquid container)

   $$P = \rho g h$$

   (P = Pressure, ρ = density, g = gravity, h = depth)
2. Pressure in liquid acts equally in directions
3. At the same level, pressure is equal at all points in the liquid.

Pascal's Principle: When pressure is applied to a fluid in a closed container, the pressure is transmitted equally in all directions throughout the fluid.

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Where: F_1 = Small force applied, F_2 = Large force applied, A_1 = Small area, A_2 = Large area

MEASUREMENT OF PRESSURE

1. Manometer: It is also known as U-Tube, used to measure gas pressure.
2. Barometer: It is used to measure atmospheric pressure. Barometer consists of; Simple, Fortin and Aneroid Barometer.

DENSITY

Density is defined as the mass per unit volume of a substance.

$$\text{Density} = \frac{Mass}{Volume}, \rho = \frac{m}{v}$$

Where ρ = density (kgm^{-3}), m= mass (kg), Volume (m^3)
Density of mixture is given by,

$$\rho_{mixture} = \frac{Sum\ of\ Masses}{Sum\ of\ Volumes} = \frac{M_1 + M_2}{V_1 + V_2}$$

Relative Density (R.D): Relative density is the ratio of density of substance to that of a reference substance. R.D is also known as Specific Density.

$$R.D = \frac{Density\ of\ substance}{Density\ of\ water} = \frac{Mass\ of\ substance}{Volume\ of\ substance}$$

Upthrust (U): Upthrust or buoyancy is an upward force exerted by a fluid that opposes the weight of an immersed object. It is the force that pushes objects up. The unit for upthrust is newton (N).

Archimedes' Principle: This states that when a body is fully or partly immersed in a fluid, it experiences upthrust which is equal to the weight of fluid displaced.

- Using – weight in air and weight in liquid

  $U = W_o - W_l$

  Where: W_o = Weight of object in air, W_l = Weight of object in liquid, U = Upthrust
- Using – density of fluid and volume displace

  $U = \rho g V$

  Where: ρ = Density of fluid, g = Gravity, V = Volume of fluid displaced

Law of Flotation: States that an object will float in a fluid if the weight of the object is equal to the upthrust acting on it.

SURFACE TENSION

Surface tension is the force per unit length acting along the surface of a liquid, causing it to minimize its surface area. The unit of surface tension is newton per meter.

$$\text{Surface Tension} = \frac{Force}{Length},\ T = \frac{F}{L}$$

Effect of Surface Tension

1. Water form droplet (Form spherical shape)
2. Insect can walk on water surface
3. Small objects (e.g Needle) can float on water

Methods of Reducing Surface Tension

1. By increasing temperature
2. Add soap or detergent
3. Mix with alcohol

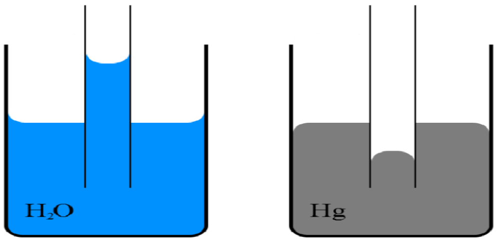
Capillarity: This is the tendency of a liquid to rise or fall in a narrow tube.

Adhesion: This is the force of attraction between different kinds of molecules. Examples: Water to glass, Mercury to glass.
Cohesion: This is the force of attraction between the same molecules. Examples: Water molecules, mercury molecules.

Angle of Contact: This is the angle between molecules of liquid and the wall of the container at the meniscus.

NOTE:

1. Meniscus is the curve seen at the top of a liquid container caused by surface tension. It can be concave or convex.
2. Angle of contact depends on the neatness of the capillary tube
3. Water wet glass and rises in capillary tube because of adhesion
4. Mercury does not wet glass and falls in capillary tube because of cohesion



CHAPTER 9

HEAT ENERGY AND TEMPERATURE

DIFFERENCE BETWEEN HEAT AND TEMPERATURE

HEAT	TEMPERATURE
Heat is a form of energy due to temperature gradient	Temperature is the measure of the degree of hotness or coldness of the body
Heat is measured by calorimeter	Temperature is measured by thermometer
Heat S.I unit is joule (j)	Temperature S.I unit is kelvin (K) or celsius (°C)

THERMOMETER: A thermometer is a device used to measure temperature.

Types of Thermometers

1. Mercury Thermometer – Used for measuring high temperatures. Mercury expands uniformly with temperature.
2. Alcohol Thermometer – Used for measuring low temperatures. Alcohol is colored for easy reading.
3. Digital Thermometer – Measures temperature electronically and shows readings on a display.

TEMPERATURE SCALE

Common temperature scales used are:

1. Celsius Scale (°C): Water freezes at **0°C** and boils at **100°C**.
2. Kelvin Scale (K): Water freezes at **273 K** and boils at **373 K**.
3. Fahenreit Scale (°F): Water freezes at **32°F** and boils at **212°F**.

TEMPERATURE CONVERSION

Unit	To Celsius (°C)	To Fahrenheit (°F)
Celsius (°C)	—	$\frac{9C}{5} + 32$
Kelvin (K)	K – 273	$\frac{9}{5}(K - 273)$
Fahrenheit (°F)	$\frac{5}{9}(F - 32)$	—

EFFECT OF HEAT ON A SUBSTANCE

1. Change in Volume
2. Change in Temperature
3. Change in Pressure
4. Change in Colour
5. Change in state
6. Expansion
7. Thermionic Emission

THERMAL EXPANSIVITY

Thermal Expansivity is the increase in size of an object or material when heated.

Linear Expansivity (α) — LENGTH

$$\alpha = \frac{L_2 - L_1}{L_1 \theta}$$

$L_2 - L_1 = L_1 \alpha\theta$

$L_2 = L_1 + L_1 \alpha\theta$

$L_2 = L_1 (1 + \alpha\theta)$

Where: L_1 = Initial length (m)

L_2 = New length (m)

$\theta = \theta_2 - \theta_1$ Temperature gradient (°C or K)

Superficial Expansivity (β) – AREA

$$B = \frac{A_2 - A_1}{A_1 \theta}$$

$A_2 - A_1 = A_1 \beta\theta$

$A_2 = A_1 + A_1 \beta\theta$

$A_2 = A_1 (1 + \beta\theta)$

NOTE: $\beta = 2\alpha$

Where: A_1 = Initial area (m^2)

A_2 = New area (m^2)

$\theta = \theta_2 - \theta_1$ Temperature change (°C or K)

Cubic Expansivity (γ) – VOLUME

$$\gamma = \frac{V_2 - V_1}{V_1 \theta}$$

$V_2 - V_1 = V_1 \gamma\theta$

$V_2 = V_1 + V_1 \gamma\theta$

$V_2 = V_1 (1 + \gamma\theta)$

NOTE: $\gamma = 3\alpha$

Where: V_1 = Initial volume (m^3)

V_2 = New volume (m^3)

$\theta = \theta_2 - \theta_1$ Temperature change (°C or K)

Apparent Cubic Expansivity — γ_a

Real Cubic Expansivity — γ_r

$\gamma_r = \gamma_a + \gamma_a$

$\gamma_r = \gamma_a + 3\alpha$

Advantages of Thermal Expansion

1. Used in thermometers
2. Used in bimetallic strips and thermostats
3. Expansion joints are added in bridges to allow expansion
4. Used in fire alarms and automatic electric switches

Disadvantages of Thermal Expansion

1. Metal rails and bridges can buckle in hot weather

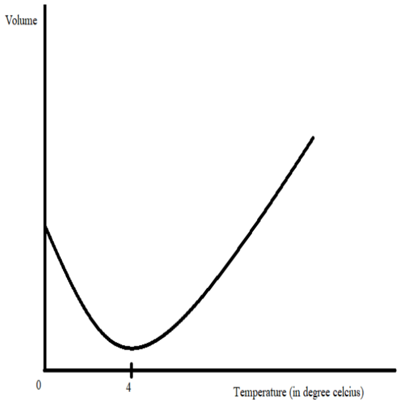
2. Overhead power lines may sag

3. Sudden heating can crack glass

4. Water pipes may burst when water expands

ANOMALOUS EXPANSION OF WATER

Anomalous expansion of water is also known as irregular expansion. It ranges between 0°C to 4°C. Water expands instead of contracting. The Maximum density and minimum volume of water is 4°C .



HEAT TRANSFER

1. Radiation: This is the transfer of heat through electromagnetic waves. It does not require a material medium.

2. Convection: This is the transfer of heat through fluid (Liquid or gas). It requires a material medium.

3. Conduction: This is the transfer of heat through direct contact between two objects. It requires a material medium.

Thermal Conductivity (K): Thermal conductivity is the ability of material to conduct heat.

$$Q = \frac{KA\,(\theta_2 - \theta_1)}{L}$$

Heat Flux (q): Heat flux is the rate of heat transfer per unit area.

$$q = \frac{Q}{A}$$

$$q = \frac{KA\,(\theta_2 - \theta_1)}{A \times L}$$

$$q = \frac{K\,(\theta_2 - \theta_1)}{L}$$

Where: K – Thermal conductivity ($Wm^{-1}K^{-1}$)

A – Area (m^2)

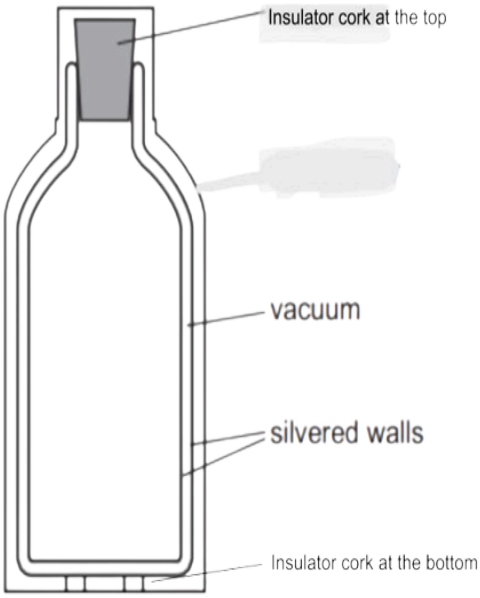
$\theta = \theta_2 - \theta_1$ – Temperature change (K)

L – Length (m),

q – Heat flux (js^{-1})

THERMOFLASK

Thermoflask keeps the temperature of water constant. It consists of insulator cork at the top and bottom, silvered wall and vacuum.



1. The insulator cork at the top prevents heat loss from conduction.
2. Vacuum prevents heat loss from conduction and convection.
3. Silvered walls prevent heat loss from radiation.
4. The insulator cork at the bottom prevents heat loss from conduction.

DIFFERENCE BETWEEN LAND AND SEA BREEZE

Land	Sea
Occurs at night	Occurs in day time
Land is cooler	Sea is warmer
Air moves from land → sea	Air moves from sea → land

QUANTITY OF HEAT

Heat (Q) is the form of energy in motion that transfers energy from one point to another as a result of temperature gradient.

$$Q = mc\theta$$

Specific Heat Capacity: Specific heat capacity is the heat required to raise a 1kg of a body by 1°C or 1k.

$$c = \frac{Q}{m\theta}$$

Heat Capacity: Heat capacity is the heat required to raise a whole body by 1kg of a body by 1°C or 1k.

$$H = mc$$

Where: Q = Heat supplied (joule, J), m = Mass (kilogram, kg), c = Specific heat capacity ($J\ kg^{-1}\ K^{-1}$), θ = Change in temperature (°C or K), H = Heat capacity ($J\ K^{-1}$)

CHANGE OF STATE IN HEAT

Latent Heat: Latent heat is the heat released or absorbed during the change of state of a substance at a constant temperature.

$$L = \frac{Q}{M}$$

Latent Heat of Fusion: Latent heat of fusion is the heat required to change a substance from solid to liquid at a constant temperature.

$$L_f = \frac{Q}{M}$$

Latent Heat of vaporization: Latent heat of vapourization is the heat required to change a substance from liquid to gas at a constant temperature.

$$L_v = \frac{Q}{M}$$

EVIDENCE OF MOLECULAR MOTION

Brownian Motion: This is the random and continuous zig-zag movement of tiny particles suspended in a fluid. It is caused by constant collision with fast-moving molecules of the fluid.

Diffusion: Diffusion is the spreading of particles from a region of high concentration to a region of low concentration. E.g The smell of perfume spreading in a room.

Factors Affecting Diffusion

1. Temperature
2. Pressure
3. Density
4. Particle size.

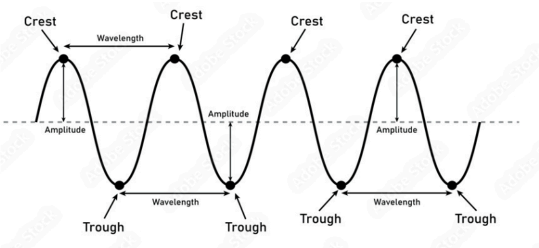
CHAPTER 10

WAVES

A wave is a disturbance which travels through a material medium and transfers energy from one place to another without permanent displacement of its medium itself.

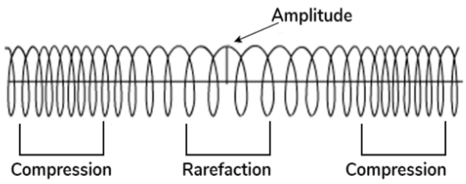
TYPES OF WAVE

1. Mechanical waves: Are waves that require material medium for their propagation.
   Examples: Sound waves, water waves, spring or string waves.
2. Electromagnetic waves: Are waves that do not need material medium for their propagation.
   Examples: Light rays, x-ray, ultraviolet rays, radio waves, gamma rays etc.
3. Transverse Waves: The particles of the medium move perpendicular to the direction of wave travel.
   Examples: Light wave, water wave.



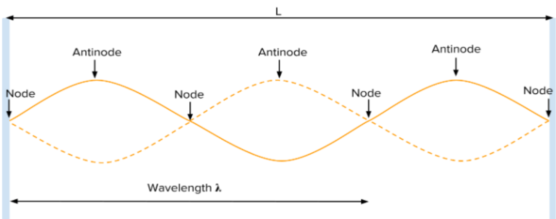
Crest: Highest displacement from rest.
Trough: Lowest displacement from rest.

4. Longitudinal Waves: The particles of the medium move parallel to the direction of wave travel.
   Example: Sound wave.



Compression: A point with high pressure.
Rare Faction: A point with low pressure.

5. Progressive waves: Are waves that spread continuously outwards from its source.
6. Stationary Waves: Are waves formed by the interference of two identical waves moving in opposite directions.



A - Antinode: Is a point where there is maximum movement of particles.
N - Node: Is a point where there is no movement of particles.

PROPERTIES USED IN WAVES

1. Amplitude (A): It is the maximum displacement of particles from mean position (Rest). It is measured in meters (m).
2. Period (T): It is the time taken to complete one cycle or oscillation. It is measured in seconds (S).

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

3. Frequency (f): it is the number of oscillations or cycles completed in one second. It is measured in hertz (hz).

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

4. wavelength (λ): It is the distance between two successful crests or troughs. It is measured in meters (m).

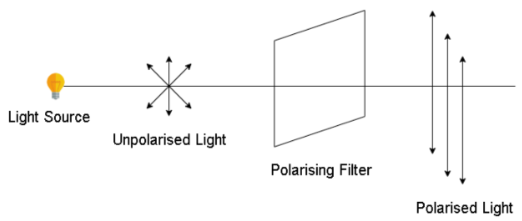
$$\lambda = \frac{v}{f}$$

5. Wave Speed (V): It is the distance traveled by wave in one second. It is measured in meters per second (ms-1).

$$v = f\lambda$$

WAVE BEHAVIOUR

1. Reflection: It is the bouncing back of a wave after hitting a barrier or encounter an obstacle.
2. Refraction: It is the bending of waves due to change in medium.
3. Diffraction: It is the spreading of waves around an obstacle.
4. Interference: It is the overlapping of two or more waves leading to constructive or destructive effect.
   (i). Constructive interference (waves add up)
   (ii). Destructive interference (waves cancel out)
5. Polarization: Restriction of wave vibrations to only one direction. Only transverse waves (like light) can be polarized.



SOUND WAVES

TRANSMISSION (PROPAGATION) OF SOUND WAVE

Sound is a mechanical and longitudinal wave produced by vibrating objects and requires a material medium for its propagation.

SPEED OF SOUND

It is the rate at which sound travels through a medium (Solid, Liquid or Air).

Solid → Liquid → Air

- Sound travels fastest in Solids
- Sound travels slower in Liquids
- Sound travels slowest in Gases (Air)

Formula: $V = f\lambda$

Material	**Speed of Sound** (m/s)
Iron	5000
Water	1500
Air	331(0°C) - 340 (20°C)
Mercury	1450
Steel	6000

FACTORS AFFECTING SPEED OF SOUND

Speed of sound is affected by temperature and pressure.

$$\frac{v_1}{\sqrt{T_1}} = \frac{v_2}{\sqrt{T_2}}$$

Where: v - Velocity
T - Temperature

REFLECTION OF SOUND

1. Echo: This is the reflection of sound heard after it encounters an obstacle and bounces back.

$$v = \frac{2d}{t}$$

2. Reverberation: This is a continuous sound heard after the source has been removed. This is also known as multiple echoes.

CHARACTERISTICS OF SOUND WAVES

Noise: Unpleasant, irregular sound (e.g., traffic, shouting).
Musical Note: Pleasant, regular sound (e.g., piano, violin).
1. Pitch: How high or low a sound is. It depends on frequency.
2. Loudness (Intensity): Strength of sound. It depends on amplitude.
3. Quality (Timbre): Differentiate between musical instruments. It depends on overtone or harmonic.

DOPPLER EFFECT

The Doppler Effect is the change in frequency or pitch of a sound as a result of the relative motion between the source of the sound and the observer.

$$f' = \frac{f(v \pm v_o)}{v \mp v_s}$$

Where: f' = Observed frequency
f = Actual frequency from the source
v = Speed of sound in air
v_o = Speed of observer
v_s = Speed of source

NOTE: Use '+' when observer moves toward the source
Use '–' when source moves away from observer

Resonance: Resonance is the phenomenon where one object vibrating at a certain frequency causes another object to vibrate at the same frequency, resulting in an increase of amplitude.

Examples:

1. A tuning fork vibrating near another tuning fork of the same frequency makes the second one vibrate — even without touching.
2. When you blow air across the mouth of an empty bottle, it produces a sound at a certain pitch , the air inside resonates.

Overtones: Overtones are sounds with frequencies higher than the fundamental frequency.

When a body vibrates, it produces:

- The fundamental frequency (lowest natural frequency)
- One or more overtones (higher frequencies)

Overtones give a sound its quality or timbre (what makes a piano sound different from a even if playing the same note).

Harmonics: Harmonics are whole number multiples of the fundamental frequency.

If the fundamental frequency is f, then the harmonics are:

Harmonic Name	Frequency
1st Harmonic (Fundamental Frequency)	f
2nd Harmonic	$2f$
3rd Harmonic	$3f$
4th Harmonic	$4f$

Note: All harmonics are overtones, but not all overtones are harmonics.

OPEN AND CLOSED PIPE

Open Pipe (open at both ends): The air vibrates at both ends.

Fundamental frequency: $\lambda=2L$

Produces all harmonics (1st, 2nd, 3rd, ...)

$$f, 2f, 3f, 4f, \dots$$

Closed Pipe (closed at one end): The air vibrates at one end only.

Fundamental frequency: $\lambda=4L$

Produces only odd harmonics (1st, 3rd, 5th, ...).

$$f, 3f, 5f, 7f, \dots$$

L = length of the pipe

λ = wavelength

f = 1st Harmonic or Fundamental frequency

LIGHT ENERGY

Light is a visible form of energy radiating outward from a source.

SOURCES OF LIGHT

1. Luminous Sources: are sources that produce light themselves. Examples: Sun,Bulb,Candle,Fireflies,Glow worm,torch,star,etc
2. Non Luminous Sources: are sources that reflect light that falls on them. Examples: Earth,Moon,etc

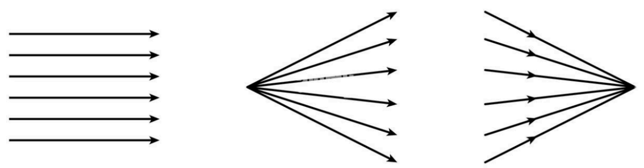
RAY AND BEAM OF LIGHT

Ray of Light: Is the direction or path through which light energy travels.

Beam of Light: Is the collection of ray of light

Types of beam of light

1. Parallel beams: are rays of light produced in a straight line e.g Laser.
2. Diverging beams: are rays of light produced from a small source and are scattered into different directions. e.g light from torch
3. Convergence beams: are rays of light produced from a large source and meet at a point to Form a convergent beam.



Parallel beam Divergent beam Convergent beam

RECTILINEAR PROPAGATION OF LIGHT

This is a phenomenon where light travels in a straight line.

Application of rectilinear propagation of light

1. Shadow: Image formed when light path is blocked by a non luminous object (opaque).Shadow consist of 2 types

(i) Umbra

(ii) Penumbra

2. Eclipse: Eclipse consist of

(i) Eclipse of the sun (Solar Eclipse): when the moon is between the sun and the earth.

(ii) Eclipse of the moon (Lunar Eclipse): when the earth is between the sun and the moon.

(iii) Annular Eclipse: Is the same as Solar Eclipse but the moon is further away from the earth.

SPEED OF LIGHT

Light travels at a constant speed in a vacuum

$$v = \frac{c}{n}$$

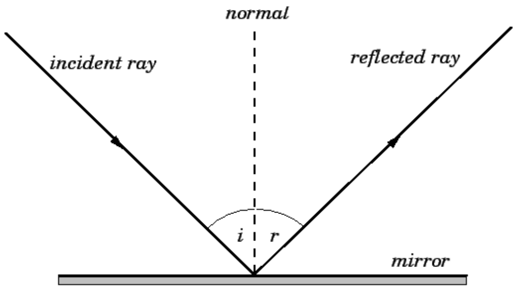
Where: v = speed of light in the medium

c = speed of light in vacuum (3.0×10 8m/s)

n = refractive index

REFLECTION OF LIGHT THROUGH PLANE AND CURVED SURFACE

Reflection is the bouncing back of a wave after encountering an obstacle.



LAWS OF REFLECTION

1. The incident ray, the reflected ray, and the normal all lie in same plane
2. The angle of incidence is equal to the angle of reflection (i = r)

IMAGES FORMED BY PLANE MIRROR

1. Virtual
2. Erect (Upright)
3. Literally inverted
4. Same size as the object
5. Same distance

APPLICATION OF PLANE MIRROR

1. Periscope
2. Kaleidoscope
3. Sextant

Number of images formed by an inclined mirror: n = 360 / θ - 1

where n = number of images

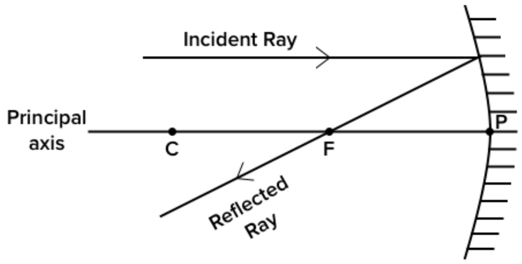
θ = angle between the mirror

Mirror Rotation: 2θ

IMAGES FORMED BY CURVED MIRROR

Terms used in curved mirrors:

1. Pole (P): The center of the mirror surface.
2. Principal Axis: A straight line passing through the pole and center of curvature.
3. Centre of Curvature (C): The center of the sphere from which the mirror is a part.
4. Radius of Curvature (R): The distance between C and P.
5. Principal Focus (F): The point where rays parallel to the principal axis converge after reflection.
6. Focal Length (f): The distance between the pole and the principal focus ($f=R/2$).



Reflection of light by curved surface can be classified into 2 (Concave and Convex).

Concave Mirror: Concave mirror can produce real or virtual images depending on object position.

1. Object beyond C: Produce real, inverted, and diminished image
2. Object at C: Produce real image, inverted and same size
3. Object at F: Produce image at infinity
4. Object between C and F: Produce real image, inverted and magnified
5. Object at infinity: Produce image at F
6. Object between F and P: Produce virtual image, erect and magnified

Where: C = Centre of curvature, F = Principal Focus and P = Pole

Convex Mirror: Convex mirror always forms virtual, upright, and diminished images.

Mirror Formula (Lens Formula)

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

1/f =1/u + 1/v

Where: f = focal length

u = object distance

v = image distance

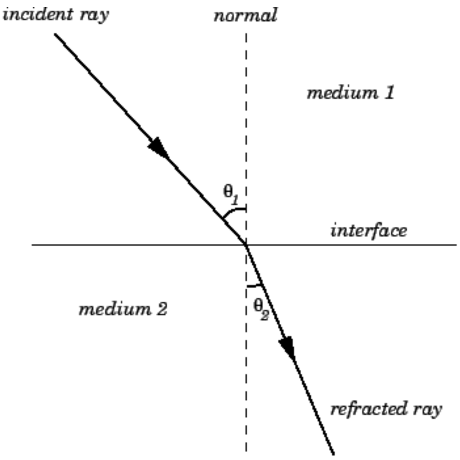
LINEAR MAGNIFICATION

$$M = \frac{Image\ Height}{Object\ Height} = \frac{Image\ distance}{Object\ distance}$$

$$M = \frac{v}{u}$$

REFRACTION OF LIGHT THROUGH PLANE AND CURVED SURFACE

Refraction is the change of direction (bending) of light when it moves from one medium to another.



LAWS OF REFRACTION

1. The incident ray, refracted ray, and normal all lie in the same plane.
2. Snell's Law: The ratio of the sine of the angle of incidence (i) to the sine of the angle of refraction (r) is constant

$$n = \frac{Sin\ i}{sin\ r}$$

where: n = refractive index

REAL AND APPARENT DEPTH

n = $\frac{R\ (Real\ Depth)}{A\ (Apparent\ Depth)}$

:. R = A + d (Lateral displacement)

TOTAL INTERNAL REFLECTION (TIR)

Conditions of TIR

1. Light travels from a denser to a less dense medium.
2. The angle of incidence is greater than the critical angle.

Applications of TIR

1. Mirage
2. Diamond
3. Optical fibre

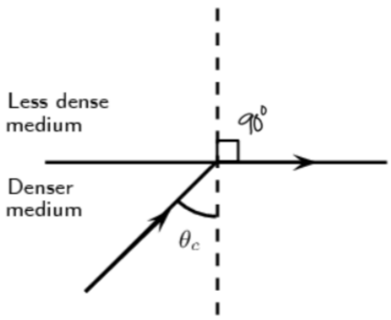
CRITICAL ANGLE

The critical angle is the angle of incidence in the denser medium that gives 90° angle of refraction in the less dense medium.

n = $\frac{1}{Sin\ C}$

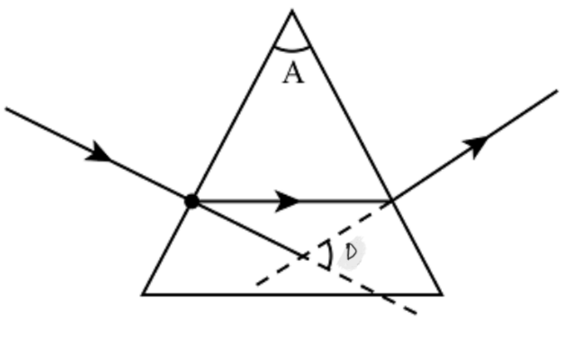
Where: C = critical angle

n = refractive index



DETERMINATION OF REFRACTIVE INDEX USING A GLASS PRISM

A triangular prism is used to determine the refractive index of a glass material.



Where: A = Angle of Prism

D = Angle of Deviation

i = $\frac{A + D}{2}$

r = $\frac{A}{2}$

From: n = $\frac{Sin\ i}{Sin\ r}$

:. n = $\frac{Sin\ (\frac{A+D}{2})}{Sin\ (\frac{A}{2})}$

DISPERSION OF LIGHT AND COLOURS

Dispersion of light is when white light passes through a triangular prism and separates into seven different colours called Visible Spectrum (ROYGBIV).

ROYGBIV → Red, Orange, Yellow, Green, Blue, Indigo and Violet.

Pure Spectrum: Occurs when colours do not overlap.

Impure Spectrum: Occurs when different colours overlap.

TYPES OF COLOUR (In Light)

1. Primary Colours of Light: These are the three basic colours of light that cannot be formed by mixing other colours.
    - Red
    - Green
    - Blue
2. Secondary Colours of Light: These are formed when two primary colours are mixed.
    - Red + Green = Yellow
    - Green + Blue = Cyan
    - Blue + Red = Magenta

So: Yellow, Cyan, and Magenta are the secondary colours of light.

3. Complementary Colours of Light: These are obtained by mixing two colours together to produce white light.
    - Red + Cyan = White
    - Green + Magenta = White
    - Blue + Yellow = White

RULES OF COLOUR APPEARANCE

1. An Object have colour because of the light it reflects
2. If an object absorbs all the colours, it appears black
3. If an object reflects all colours, it appears white

OPTICAL INSTRUMENT

Simple Microscope: A simple microscope is a single convex lens used to produce a magnified image of a small object placed close to it. The image formed is virtual, erect and magnified (VEM).

$$M = 1 + \frac{D}{F}$$

Where D = least distance of distinct vision (25 cm) and f = focal length of the lens.

Slide Projector: A slide projector consists of a single convex lens. The object is placed beyond the principal focus. The image formed is real, inverted and magnified (RIM).

Compound Microscope: A compound microscope uses two convex lenses (objective and eyepiece) to produce a highly magnified image of a very small object.

- The objective lens forms a real and inverted image.
- The eyepiece then magnifies this image further to give a final magnified virtual image.

Magnifying Power:

$$M = \frac{L}{Fo}\left(1 + \frac{D}{Fe}\right)$$

Where L = length of the microscope tube, f_o = focal length of objective, and f_e = focal length of eyepiece.

Telescope: A telescope is used for viewing distant objects. It consists of an objective lens with long focal length and an eyepiece with a short focal length. The image formed is virtual, inverted and magnified (VIM).

$$M = \frac{Fo}{Fe}$$

Telescope consist of two types: Astronomical and Terrestrial Telescope

Power of a Lens

The power of a lens is the ability of a lens to converge or diverge light.

$$P = \frac{1}{f}$$

Where P = power (dioptre, D) and f = focal length (meters, m)

Camera: A camera uses a convex lens to form the real and inverted image of an object on a photographic film or sensor (screen). The image is diminished and real.

Working Principle:

- Light from object → Lens → Screen
- Focusing is done by changing the distance between the lens and the screen.

Human Eye: The human eye works like a camera. A convex lens forms a real, inverted image on the retina.

Important Parts:

- **Cornea and lens** – focus the light
- **Iris** – controls the amount of light that enters
- **Retina** – receives the image
- **Optic nerve** – sends signals to the brain

Sight defect and their correction

1**. Myopia (Short-sightedness):** Can see near, not far. Image forms in front of the retina. Corrected with concave lens.

2. **Hypermetropia (Long-sightedness):** Can see far, not near. Image forms behind the retina. Corrected with convex lens.

3. **Presbyopia:** Old-age defect — loss of accommodation. Use a bifocal lens.

4. **Astigmatism:** Irregular curvature of eye surface → blurred vision. Use a cylindrical lens.

5. **Accommodation:** The ability of the eye to adjust its focal length so it can focus on both near and distant objects clearly.

CHAPTER 12

ELECTROSTATICS

Electrostatics is the branch of physics that deals with electric charges at rest and the forces, fields and potentials associated with them.

EXISTENCE OF POSITIVE AND NEGATIVE CHARGE

Electrons → Negative charge

Protons → Positive charge

If an object loses electrons, it becomes positively charged.

If an object gains electrons, it becomes negatively charged.

Normally objects are **neutral** (equal electrons and protons), but when this balance changes, positive or negative charge appears.

Laws of Electrostatic: This state that like charges repel, unlike charges attract.

METHOD OF CHARGING A BODY

1. **By Friction** – It occurs when two insulating objects are rubbed together, electrons move from one object to another. One becomes positively charged and the other becomes negatively charged.
2. **By Contact** – It occurs when a charged object touches a neutral object and transfers some of its electrons. Both objects end up with the same type of charge.
3. **By Induction** – It occurs when a charged object is brought close to a neutral object (without touching). Both of them become oppositely charged.

CONDUCTORS AND INSULATOR

Conductors – Materials that allow electric charges (electrons) to flow through them easily.

Examples: copper, aluminum, iron, salt water.

Insulators – Materials that do not allow electric charges to flow easily. They block the movement of electrons.

Examples: plastic, rubber, dry wood, glass.

IN SUMMARY: Conductors = allow current to pass

Insulators = prevent current from passing

LINES OF FORCE (Electric Field Lines)

Electric lines of force are imaginary lines that represent the direction and strength of an electric field.

Characteristics

1. Lines start from positive charge and end at negative charge.
2. They never intersect.
3. The closer the lines, the stronger the electric field

CHAPTER 13

ELECTRIC FIELD

An electric field is the region around an electric charged body where electric force can be experienced.

COULOMB'S LAW

Coulomb's law states that the electric force of attraction or repulsion between two charged bodies is directly proportional to their product and inversely proportional to the square of their distance apart.

$$F = \frac{KQq}{R^2}$$

$$\therefore K = \frac{1}{4\pi Eo} \quad (9 \times 10^9 \ Nm^2/C^2)$$

Where: ε_0 - Permittivity of free space (8.85 × 10-12)

F - Force (N)

Q, q - Charges (Coulombs)

R - Distance between charges (m)

ELECTRIC FIELD INTENSITY

Electric field intensity is the force per unit charge of a body. This is also known as the strength of an electric field.

$$E = \frac{F}{Q}$$

$$E = \frac{q}{4\pi\varepsilon_0 R^2} \text{ or } E = \frac{Kq}{R^2}$$

ELECTRIC FIELD POTENTIAL

Electric field potential is the work done per unit charge to move a body from infinity to the point of an electric field.

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

$$V = \frac{q}{4\pi\varepsilon_0 R}$$

LIGHTING CONDUCTOR

A lightning conductor is a metal rod fixed to the top of a building and connected to the ground with a wire. During a thunderstorm, it provides an easy path for lightning to flow safely into the ground, preventing damage to the building.

DISTRIBUTION OF A CHARGE ON A BODY

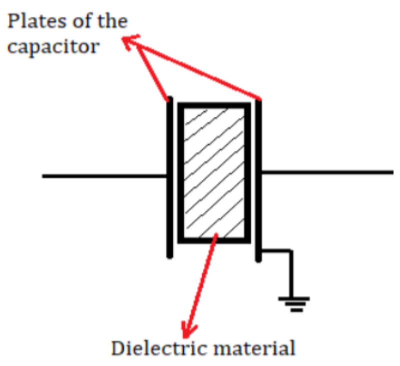
When a body is charged, the electric charge spreads over its outer surface.

For a sphere, the charge spreads uniformly. For irregular shapes, more charge gathers at sharp points or edges — these parts have higher charge density.

CAPACITOR

Capacitor is a device used for storing energy and charges. It consists of two metal plates separated by an insulator called di-electric.

Some examples include: Ceramic capacitor, mica capacitor, variable capacitor.



Capacitance: Capacitance is the ability of a capacitor to store charges.

$$\text{Capacitance} = \frac{Charge}{Potential\ difference\ (Voltage)}$$

$$C = \frac{Q}{V}$$

Where: C = Capacitance (Farad, F)

Q = Charge (Coulomb, C)

V = Voltage or Potential difference (Volts, V)

FACTORS AFFECTING CAPACITANCE OF A CAPACITOR

1. Area of the plate
2. Distance between the plate
3. Nature of the insulator

$$C = \frac{\varepsilon A}{d}$$

Where: C = Capacitance (Farad (f))

ε = permittivity of material

A = Area (m^2)

d = Distance (m)

Relative Permittivity

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_o}$$

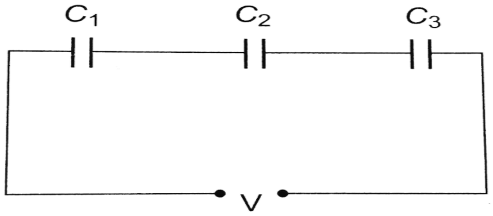
Where: ε_r = Relative permittivity

ε = Permittivity of material ()

ε_o = Permittivity of free space ($8.85 \times 10^{-12}\ Fm^{-1}$)

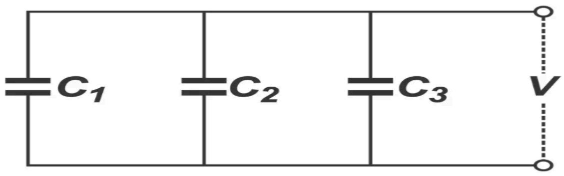
CAPACITANCE IN SERIES AND PARALLEL

Capacitance in Series: These are series connected end to end with the same current flowing through them.



$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Capacitance in Parallel: These are series connected side by side with same voltage or potential difference (P.d) across them.



$$C = C_1 + C_2 + C_3$$

ENERGY STORED IN A CAPACITOR

1. $\frac{Q^2}{2C}$

2. $\frac{CV^2}{2}$

2. $\frac{QV}{2}$

USES OF A CAPACITOR

1. Capacitor is used to store charges
2. Capacitor is used to cancel out electric spark
3. Timing circuits in electronics

CHAPTER 15

CURRENT ELECTRICITY

Electricity is the motion of electric charge through a conductor (wire).

Electric Current (I): Electric current is the rate of flow of electric charge around a circuit.

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

Where: I = Current (Ampere, A)

Q = Charge (Coulomb, C)

T = Time (Seconds, S)

Potential Difference (p.d): Potential difference is the work done in moving a unit charge between two points in a closed circuit (when current is flowing.

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

Where: V = P.d or Voltage (Volts, V)

W = Workdone (Joules, J)

q = charge (Coulomb, C)

Electro-motive Force (e.m.f): Electro-motive force is the work done in moving a unit charge round a circuit in an open circuit. It is the total energy supplied per unit charge by a source such as a cell or battery.

NOTE: Open Circuit: There is no flow of current

Closed Circuit: There is flow of current

Ohm's Law (Ω)

Ohm's law states that the current passing through a metallic conductor is directly proportional to the potential difference across its end.

$V \propto I$

$V = IR$

Where: R = Resistance (Ohms,Ω)

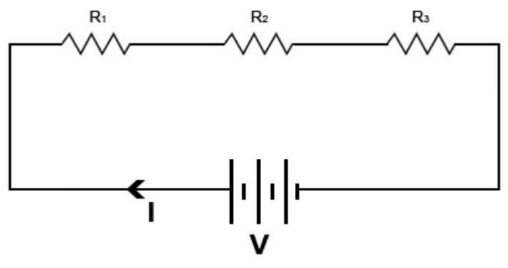
V = Voltage or P.d (Volts, V)

I = Current (Ampere, A)

Resistance (R): Resistance is the opposition to the flow of current in a circuit. It is also known as external resistance.

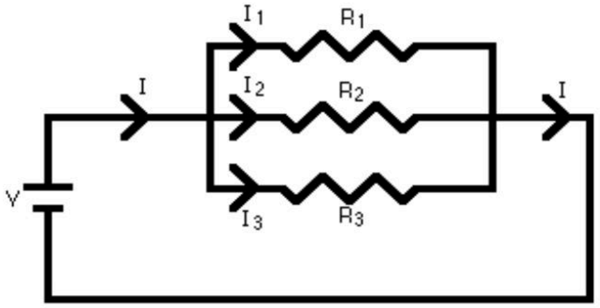
RESISTORS IN SERIES AND PARALLEL

Resistance in Series: Arrangement in continuous manner with same flow of current passing through them.



$$R = R_1 + R_2 + R_3$$

Resistance in Parallel: Arrangement with branching current. The same p.d across them.



$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Resistivity: Resistivity is the resistance of a material per unit length and cross sectional area.

$$\rho = \frac{RA}{L}$$

Where: ρ = Resistivity (Ohm-metre, Ωm)

R = Resistance (Ohms, Ω)

A = Cross Sectional Area (Square metre, m^2)

L = Length (Meter, m)

Internal Resistance of a cell (r): Internal resistance of a cell is the opposition to the flow of current in an electrolyte.

$$I = \frac{E}{R + r}$$

$$E = I(R + r)$$

$$E = IR + Ir$$

$$E = V + Ir$$

Where: E = e.m.f

R = Resistance

I = Current

r = Internal resistance of a cell

V = Voltage or P.d

Efficiency of a Cell

$$\text{Efficiency} = \frac{R}{R + r} \times 100$$

ELECTRIC ENERGY AND POWER

Electric Energy, E

$E = QV$

$E = IVt$

$E = I(IR)t$

$E = I^2Rt$

Electric Power

$$\text{Power} = \frac{Electric\ energy}{Time}$$

$$= \frac{I^2Rt}{t} \quad -> \quad I^2R \ or \ IV$$

CHAPTER 16

MAGNETS AND MAGNETIC FIELD

Definition of Magnets: Magnets are substances that attract magnetic materials. Examples of magnetic materials are: Nickel, iron, steel, cobalt, alloys, etc.

Types of Magnets

1. Natural Magnet: This Is a piece of naturally occurring iron ore known as loadstone or black iron or magnetite (Fe_3O_4).
2. Artificial Magnet: This is a magnet made from steel or alnico.

Magnetic Properties

1. Every magnets has two poles: North and South
2. Like poles repel, unlike poles attract
3. Magnet attract magnetic materials

Soft Iron: This is the type of iron that can be easily magnetized and demagnetized. It is used for making electric bell, electromagnet, transformer core, etc.

Magnetic Keeper: This is a small piece of soft iron used to protect bar magnet from self demagnetization.

Method of Making Magnet

1. Stroking Method: A piece of steel or iron is stroked several times in one direction with a strong permanent magnet.
2. Electrical Method: A steel bar is put in a solenoid and current is applied for a few minutes.
3. Hammering Method: By hammering a steel in the earth's magnetic field.

Method of Demagnetization

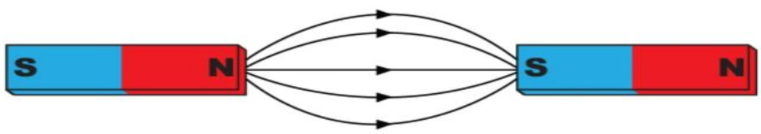
1. Heating Method: Heating a magnet to a very high temperature while lying in East-West direction, making it lose its magnetism.
2. Hammering Method: Hammering a magnet strongly while lying in the East-West direction reduces or destroys its magnetism.

CONCEPT OF MAGNETIC FIELD

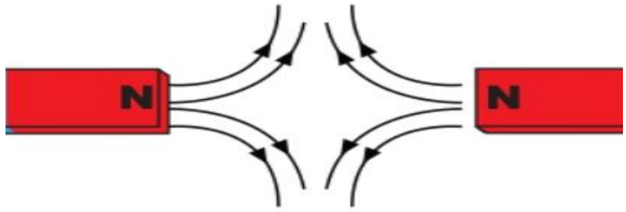
A magnetic field is a region around a magnet where magnetic force can be experienced. The direction of the magnetic field at a point can be obtained by using a compass needle.

Magnetic Field Pattern of Magnet

1. Unlike Pole Attract



2. Like Pole Repel



MAGNETIC LINE OF FORCE

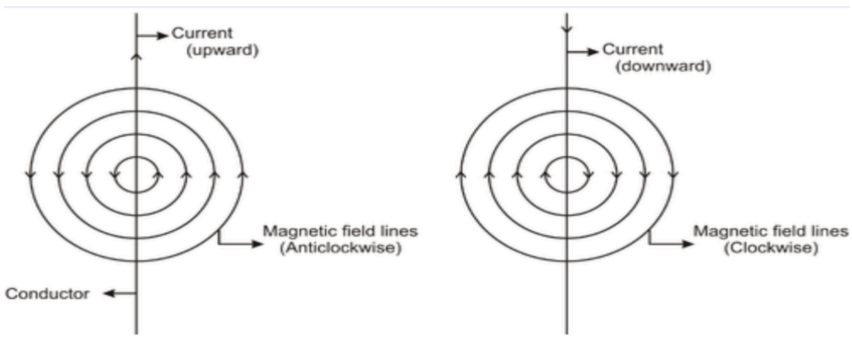
Magnetic lines of force are imaginary lines that represent the direction and strength of a magnetic field.

Properties of Magnetic Line of Force

1. They are originated from North Pole and ends at South Pole
2. They never intersect with each other.
3. They are continuous and do not have breaks.

Magnetic Field around a circular wire: A current in a circular wire produces a magnetic field of concentric circles. At the center, the fields combine to give a strong straight field.

The direction is given by the Right-Hand Rule, and the field strength increases with current and number of turns.



$$F = BIL \sin\theta$$

Where: F = Force (N)

B = Magnetic flux density (Tesla, T)

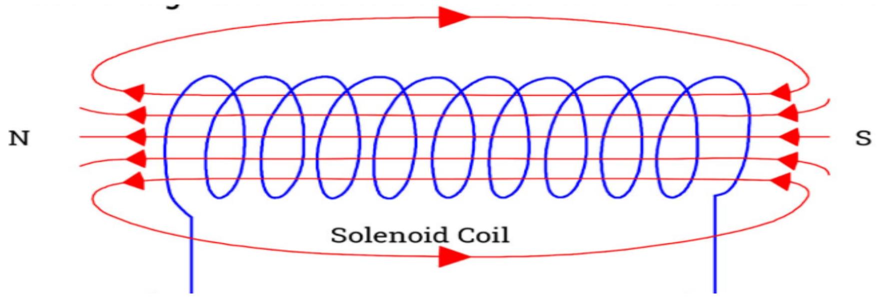
I = Current (A)

L = Length (m)

θ = Angle

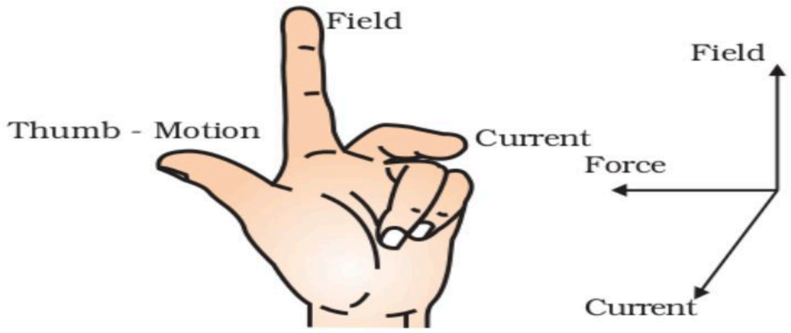
Magnetic Field around a Solenoid: A solenoid is a coil of many circular turns of wire. When current flows, it produces a strong, uniform magnetic field inside and a weak field outside, similar to a bar magnet.

One end acts as the North pole and the other as the South pole, with direction given by the Right-Hand Grip R



Fleming's Left Hand Rule

Fleming's Left-Hand Rule states that if the thumb, forefinger, and middle finger of the left hand are held at right angles, the forefinger shows the magnetic field, the middle finger shows the current, and the thumb shows the motion of the conductor.



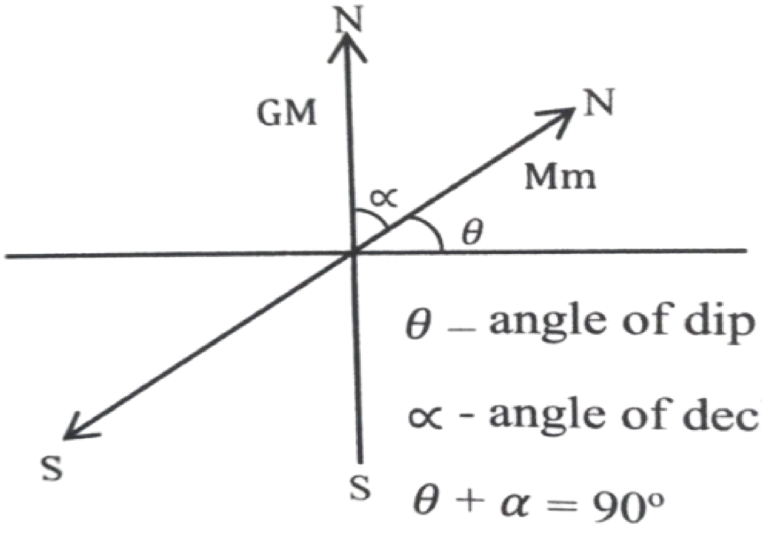
EARTH'S MAGNETIC FIELD

The Earth itself acts like a giant bar magnet with a magnetic field around it. This field is believed to be caused by movements of molten iron and nickel in the Earth's core.

Terms of Earth's Magnetic Field

1. Geographic Meridian (GM): The vertical plane passing through a place and the **g**eographic north and geographic south poles.
2. Magnetic Meridian (MM): The vertical plane passing through a place and the magnetic north–south poles.
3. Angle of Dip (θ): This is also known as Inclination. The angle between the geographic meridian and the magnetic meridian.

4. Angle of Declination (α): This is also known as Variation. The angle made by the Earth's magnetic field with the horizontal at a place.



θ – angle of dip

$\propto$ - angle of declined

$\theta + \alpha = 90^o$

Magnetic Flux:This is the total number of magnetic field lines passing through a surface.

$$\Phi = BA\cos\theta$$

Where: Φ = Magnetic flux (Weber, Wb)

B = Magnetic flux density (Tesla, T)

A = Area (Square meter, m^2)

Magnetic Flux Density: Magnetic flux density is the flux per unit area placed perpendicular to the magnetic field.

$$B = \frac{\Phi}{A}$$

CHAPTER 17

ELECTROMAGNETIC INDUCTION

Electromagnetic induction of the production of electric current by using a magnet in the absence of a battery. It was discovered by Michael Faraday in 1832.

Faraday’s Law of Electromagnetic Induction

This states that the induced e.m.f in a circuit is directly proportional to the rate of change of magnetic flux linking the coil.

$$E \propto \frac{d\Phi}{dt}$$

$$E = \frac{-Nd\Phi}{dt}$$

Where: Φ = BA

$$\therefore \quad E = \frac{-Nd\Phi}{dt}$$

Factors Affecting Induced e.m.f

1. The strength of the magnet (B)
2. The speed at which the magnet moves (w)
3. The number of turns (N)

The induced e.m.f is given by; $E = wBAN \sin\theta$

Lenz’s Law: This states that the induced current flows in such a direction as to oppose the charge producing it.

Example; If a magnet is pushed into a coil, the coil produces a current that sets up magnetic field opposing the motion of the magnet.

A.C AND D.C GENERATOR

A.C Generator: This is a device that converts mechanical energy to electrical energy in the form of alternating current. Current flows in different directions because it uses a slip ring.

D.C Generator: This is a device that converts mechanical energy to electrical energy in the form of direct current. Current flows in one direction because it uses a split ring commutator.

TRANSFORMER

A transformer is an electric device used for changing the size of an A.C (To increase or decrease the e.m.f of an alternating current).

A Transformer has two coils — Primary coil and Secondary coil.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad \text{or} \quad \frac{E_s}{E_p} = \frac{N_s}{N_p}$$

Where V_s or E_s = Voltage in secondary coil

V_p = Voltage in primary coil

N_s or E_s = Number of turns in secondary coil

N_p = Number of turns in primary coil

Types of Transformer

1. **Step Up Transformer**: This is a type of transformer where the voltage and number of turns in the secondary coil are greater than the primary coil .
2. **Step Down Transformer**: This is a type of transformer where the voltage and number of turns in the primary coil are greater than the secondary coil.

Induction Coil: This is a device that uses electromagnetic induction to produce high voltage from a low voltage direct current source.

Inductance: This is the ability of a coil to oppose change in current flowing through it due to induced e.m.f.

$$\text{Inductance} = \frac{Magnetic\ Flux}{Current}$$

$$L = \frac{\Phi}{t}$$

Where: L = Inductance (Henry, H)

Eddy Current: This is the current produced in a conductor when it is placed in a changing magnetic field.

Reduction of Eddy Current

1. By laminating soft iron core
2. By creating holes in metal plates
3. Using materials with high resistance

Applications of Eddy Current

1. Used in train brakes
2. Used in induction furnace
3. Used in electric powers meters

SIMPLE A.C CIRCUIT

Alternating current is a current that periodically reverses direction and changes magnitude continuously with respect to time. Alternating current (A.C) is produced by Alternating voltage (A.V).

Alternating Current $\Rightarrow$ $I = I_o \sin \omega t$

$= I_o \sin 2\pi ft$

Alternating Voltage $\Rightarrow$ $V = V_o \sin \omega t$

$= V_o \sin 2\pi ft$

Where: I_o = VPeak Current, V_o = Peak Voltage

f = Frequency

$\omega = 2\pi f$ = Angular frequency

Resistance (R)

Resistance is the opposition to the flow of current in a circuit.

From Ohm's Law:

$$V = IR$$

$$R = \frac{V}{I} \Rightarrow \frac{V_o \sin 2\pi f t}{I_o \sin 2\pi f t}$$

Root Mean Square

Root mean square is the steady or direct contact produced from the same heating effect per seconds in a resistor.

In A.C $\Rightarrow$ $I_{r.m.s} = \frac{I_o}{\sqrt{2}}$

$$I_o = I_{r.m.s}\sqrt{2}$$

In A.V $\Rightarrow$ $V_{r.m.s} = \frac{I_o}{\sqrt{2}}$

$$V_o = V_{r.m.s}\sqrt{2}$$

Reactance (X)

Reactance is the opposition to the flow of A.C in a circuit, produced by inductor and capacitor.

a. Inductance Reactance (X_L) = ωL

$= 2\pi fL$

b. Capacitance Reactance (X_c) = $\frac{1}{\omega C}$

$= \frac{1}{2\pi f C}$

Impedance (Z)

Impedance is the total opposition of alternating current by the combination of R - L - C (Resistance, Inductor, and Capacitor).

$$Z = \sqrt{R^2 + X_c^{\,2}}$$

$$Z = \sqrt{R^2 + X_L^{\,2}}$$

$$Z = \sqrt{R^2 + (X_L - X_c)^2}$$

Resonance Frequency (Fo)

Resonance frequency occurs when inductive reactance equals capacitance reactance.

$$X_L = X_c$$

$$2\pi fL = \frac{1}{2\pi fC}$$

$$2\pi fL\,(2\pi fC) = 1$$

$$4\pi^2 f^2 LC = 1$$

$$f^2 = \frac{1}{4\pi^2 LC}$$

$$f_o = \sqrt{\frac{1}{4\pi^2 LC}}$$

$$f_o = \frac{1}{2\pi LC}$$

CHAPTER 19

INTRODUCTORY ELECTRONICS

Electronics is the branch of physics and engineering in which the flow and control of electrons and matter is studied.

Conductors: These are materials that can easily conduct electricity. Examples of conductors include, zinc, iron, copper, aluminium.

Insulators: These are materials that do conduct electricity. Examples of insulators include rubber, glass, wood, plastic.

Semiconductors: These are materials that can sometimes conduct electricity and sometimes do not. Examples of semiconductors include, silicon, germanium, arsenic, gallium.

Band Theory

The electronic conduction in conductors, insulators and semiconductors depends on the space between the energy and the number of electrons in those gaps.

The gap between these bands is also known as the forbidden gap or band gap.

Types of Energy Bands

1. Valence Band (V.B): The band formed by grouping all the energy levels of the valence electrons.
2. Conductor Band (C.B): The band formed by grouping all the energy levels of free electrons.
3. Forbidden Gap (F.G): The gap between Valence band (V.B) and Conductor band (C.B), where no electrons are allowed. This is also known as Band Gap.

Intrinsic Semi conductors

These are pure semiconductors found in group 4 of the periodic table (E.g. Silicon, Germanium). Pure semiconductors cannot conduct electricity because the number of electrons in the conduction band (C.B) is equal to the number of holes in the valence band (V.B).

Extrinsic Semi conductors

These are impure semiconductors obtained by adding impurity to a pure semi conductor (Intrinsic semi conductor) in a process called doping.

Extrinsic semi conductor can be classified into 2 types: N – type and P – type

P – type Semi conductor: This is obtained by adding trivalent elements (group 3 elements) such as gallium, aluminium, thallium, indium, to a pure semiconductor.

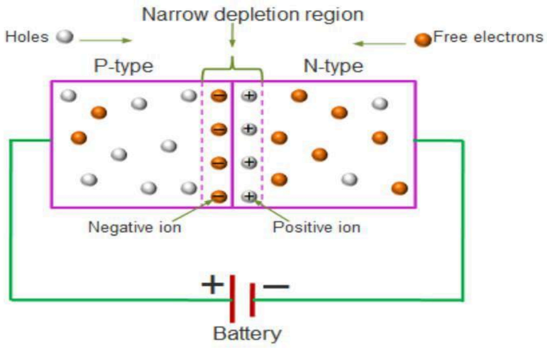
N - type Semi conductor: This is obtained by adding pentavalent elements (Group 5 elements) such as phosphorus, antinomy, arsenic, to a pure semi conductor.

NOTE: In P – type the charge carrier is holes
In N – type the charge carrier is electrons

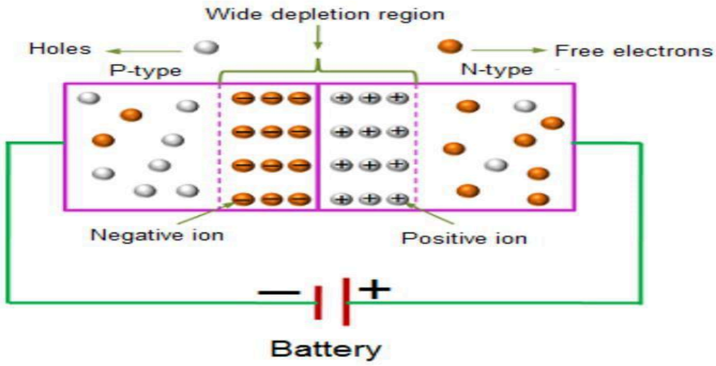
P-n Junction: This is the point at which p – type and n – type semiconductors are joined together creating a depletion region.

Diodes: Is an electronic component made from p-n junction. It allows current flow in only one direction (forward) and blocks other direction (reverse).

Forward Biased Diode: This is when P – type is connected to the positive terminal of the battery and N – type to the negative terminal. The depletion layer becomes thin for easy flow of current.



Reversed Biased Diode: This is when P – type is connected to the negative terminal of the battery and N – type to the positive terminal. The depletion layer becomes wider to partially block the flow of current.

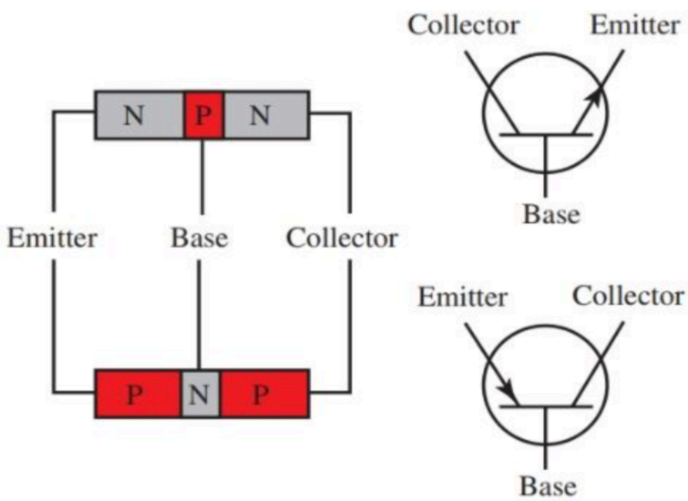


Uses of Diode

1. Used as a rectifier — To convert A.C to D.C
2. USed as a voltage regulator

Transistor: This is a semiconductor device used to amplify signal and switch electronic circuits. It has three terminals; collector, emitter and base.

Transistor can be classified it 2 types — PNP and NPN



CHAPTER 20

MODERN PHYSICS

Energy of Photon

Light travels as particles called photons, each carrying energy. The energy of a photon depends on its frequency.

$$E = hf$$

$$E = \frac{hc}{\lambda}$$

Where: E = Energy of Photon (Joules, J)

h = Planck's Constant (6.6×10^{-34} Js)

C = Speed of light (3.0×10^{8} ms^{-1})

f = Frequency of Photon (Hertz, Hz)

λ = Wavelength of the Photon (Meter, m)

Photoelectric Effect and Thermionic Emission

Photoelectric Effect: The photoelectric effect occurs when light shines on a metal surface and electrons are ejected or removed.

The surface electrons removed from the metal surface are called photoelectrons. Only light with a frequency above a certain minimum can eject these electrons.

Thermionic Emission: Thermionic emission is the release of electrons from a metal surface when it is heated to a high temperature.

Application of Thermionic Emission

1. It is used in burglar alarms
2. It is used in automatic doors
3. It is used in television cameras
4. It is used in automatic digital counter

Einstein's Photoelectric Equation

Einstein explained that photons carry energy which can be transferred to electrons. The maximum kinetic energy of the ejected or removed electron is:

$$K.E_{max} = E - W_o$$

$$K.E_{max} = hf - W_o$$

Where: $K.E_{max}$ = Maximum Kinetic energy

W_o = Work Function

E = hf = Energy of Photon

Stopping Potential (V_s)

The stopping potential is the minimum voltage required to stop the photoelectrons from moving.

$$K.E_{max} = eV_s$$

$$\frac{1}{2}MV^2 = eV_s$$

$$\frac{MV^2}{2} = eV\square$$

$$MV^2 = 2eV\square$$

$$V^2 = \frac{2eV\square}{M}$$

$$\therefore V = \sqrt{\frac{2eV\square}{M}}$$

Where: e = Charge of electrons (1.6×10^{-19} C)

V☐ = Stopping Potential (Volts, V)

M = Mass of electron (9.1×10^{-31} Kg)

V = Speed of Photon electrons (ms^{-1})

ATOMIC MODELS AND LIMITATION

1. **Dalton's Model**

Dalton proposed that the atom is a solid, indivisible particle (like a tiny billiard ball).

Limitations:

A. Cannot explain the existence of subatomic particles (electrons, protons, neutrons).

B. Cannot explain chemical reactions in terms of electron arrangements.

2. **Thomson's (Plump Pudding) Model**

The atom is a positive "pudding" with electrons embedded like "plums".

Limitations:

A. Cannot explain the stability of the atom.

B. Cannot explain atomic spectra (lines of light emitted by atoms).

3. **Rutherford's (Planetary) Model**

The atom has a small, dense nucleus with electrons moving around it.

Limitations:

A. Electrons would spiral into the nucleus and collapse the atom.

B. Cannot explain the discrete spectral lines of atoms.

4. **Neil Bohr's (Energy Quantization) Model**

Electrons move in fixed orbits with specific energies.

Limitations:

A. Works only for hydrogen; fails for multi-electron atoms.

B. Cannot explain why electrons in some orbits do not radiate energy continuously.

Radioactivity: Is the spontaneous disintegration of unstable nuclei by the emission of radiation and release of energy.

Types of Radiation and their Properties

Alpha (α) Particles:

1. They have low penetration
2. They can be stopped by paper or skin.
3. They carry a positive charge.
4. They have a relatively large mass.
5. Strongly ionizing.

Beta (β) Rays:

1. They have medium penetration
2. They can be stopped by aluminum sheets.
3. They carry a negative charge.
4. They have a very small mass.
5. Moderately ionizing.

Gamma (γ) Rays:

1. They have very high penetration
2. They can be stopped by thick lead or concrete.
3. They have no charge.
4. They do not have mass.
5. Weakly ionizing.

Nuclear Fusion: This is a process in which two or more light atomic nuclei combine to form a heavy nucleus with release of energy and radiation.

Example:

$$^{2}H + H^{3} \longrightarrow {}^{4}He + n + \text{energy}$$

Hence; Deuterium and Tritium combine to form Helium, a neutron, and energy.

Nuclear Fission: Nuclear fission is the splitting of a heavy atomic nucleus into two or more lighter nuclei, releasing energy and neutrons.

Example:

$$^{235}U + n \longrightarrow {}^{141}Ba + {}^{92}Kr + {}^{3}n + \text{energy}$$

Hence; Uranium-235 absorbs a neutron, becomes unstable, splits into Barium-141 and Krypton-92, releases 3 neutrons and energy.

Half Life: The half-life of a radioactive substance is the time taken for half of the radioactive atom to decay.

$$N = N_o \left(\frac{1}{2}\right)^{\frac{t}{T}}$$

Where: N = number of undecayed nuclei at time ttt

N_0 = initial number of nuclei

t = time elapsed

T = half-life of the substance

Mass Defect: The difference between the sum of the masses of protons and neutrons and the actual mass of the nucleus.

$$\Delta m = Zm_p + Nm_n - M$$

Binding Energy: The energy equivalent of the mass defect that holds the nucleus together.

$$\Delta b = \Delta mc^2$$

Where: Z = number of protons

N = number of neutrons

m_p,m_n = masses of proton and neutron

M = actual nuclear mass

X-rays: X-rays are high-energy electromagnetic waves produced when high-speed electrons are suddenly decelerated or strike a metal target.

Production of X-rays:

1. Electrons are emitted from a heated cathode (thermionic emission).
2. They are accelerated towards a metal target (anode) by high voltage.
3. When they hit the target, they lose energy, which is emitted as **X-rays**.

Properties of X-rays:

1. Travel in straight lines at the speed of light.
2. Highly penetrating (can pass through many materials).
3. Can ionize gases.
4. Affect photographic plates and produce fluorescence.
5. Can be harmful in large doses.

Uses of X-rays:

1. Medical: Imaging bones and tissues, treatment of cancer.
2. Industry: Detecting cracks in metals, checking luggage at airports.
3. Research: Studying crystal structures (X-ray crystallography).