Electric Current and Circuit

Flow of electrons

Charge contained by 6×10^{18} e−

$I = \frac{Q}{T}$ — Q → Coulomb, T → Sec

Coulomb/sec: Ampere

To measure Current:

Ammeter: measures only magnitude of current (→ large magnitude)

Galvanometer: measures magnitude of current and direction of current (→ small magnitude)

Electric Potential and Potential Difference

$V = \frac{\text{Work Done}}{q}$

Work Done → required for movement of e−

→ Work done to move a unit charge from one point to another

Unit: Volt

Measured using: Voltmeter

Ohm's Law

Georg Simon Ohm gave Ohm's law in 1827

$V \propto I$

$V = IR$

R → Resistance → Ω

Conductor: low resistance

Insulators: high resistance

Rheostat: is a variable resistor that controls the flow of electric current by increasing or decreasing its resistance

Factors on which Resistance of a Conduxtor depends

1. Length
2. Area of cross section
3. Nature of material

Nature of material → Silver has highest conduction and low resistance

$R \propto l$

$R \propto \frac{1}{A}$

$R = \rho \frac{l}{A}$

$\Omega = \rho \frac{m}{m^2}$

ρ → Specific resistance/ Resistivity → Ωm

A wire of given material having length l and area of cross-section A has a resistance of 4 Ω. What would be the resistance of another wire of the same material having length l/2 and area of cross-section 2A?

$R = \rho \frac{l}{A}$,

$R' = \rho \frac{\frac{l}{2}}{2A}$,

$R' = \rho \frac{l}{4A}$,

$R' = 1\Omega$

$R' = \frac{R}{4}$

Resistance of a System of Resistance

1. Connected in Series → Current in every resister is same

$R_{eq} = R_1 + R_2 + R_3 + \ldots\ldots\ldots$

2. Connected in Parallel → Potential difference is same

$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots$

Example:

Parallel resistance given = $1\Omega, 2\Omega, 3\Omega$

$I = 1A$

$V = ?$

$\frac{1}{R_{eq}} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3}$

$= \frac{6+3+2}{6} = \frac{11}{6}$

$R_{eq} = \frac{6}{11}$

$V = IR$

$V = 1 \times \frac{6}{11}$ V

Heating Effect of Electric Current

- Discovery by: James Joule
- Amount of heat produced (H) = V I t

Applications:

1. In rod, kettle, Iron
2. In bulb when heated → filament → Tungsten (W) → Ar/N_2 gas used; Tungsten (W) → high melting point

3. Fuse works in this concept
   → Made with a material that has low melting point and high resistance

Short circuit → Excessive current flow

Electric Power

$P = VI$

$V = IR$

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

$P = VI$

$P = I^2R$

$P = \frac{V^2}{R}$

Energy = Power x Time

Commercial unit of energy → kWh → Kilo Watt hour

An electric bulb is connected to a 220 V generator. The current is 0.50 A. What is the power of the bulb?

$P = VI$

$\frac{220}{2} = 110$ W

Appliance power supply = 20 W

30 days in 30 mins/day

$$E = kWh = 0.02 \times \frac{\cancel{30}^{15} \times 30}{\cancel{60}_{\cancel{2}}}$$

$= E = 0.30$ unit

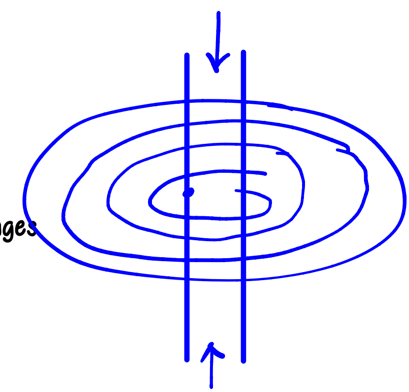
Magnetic Effect of Electric Current

Given by Hans Christian Orsted

Properties of Magnetic Field Lines

1. Closed curve
2. Never intersect each other
3. Density ⟶ Strength of magnetic field ↳ represented as "B"
4. Is a Vector quantity

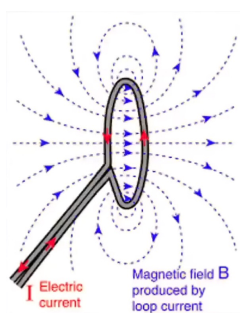
Magnetic Field due to a Current Carrying Conductor



- It is circular in nature
- Increase in distance ∝ Magnetic field strength decreases
- Direction of current if reversed ⟶ Magnetic field changes accordingly

Magnitude of current ∝ Magnitude of M.F strength

Magnetic Field due to a Circular Loop

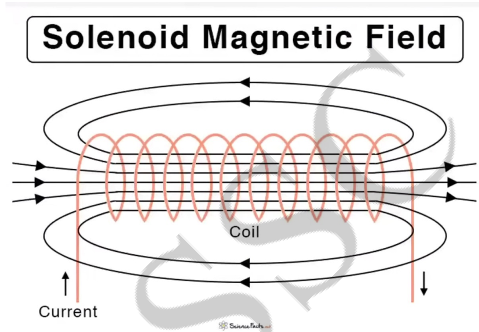


Current↑ ∝ M.F strength↑

No. of turns↑ ∝ M.F strength↑

Magnetic Field due to a Current Carrying Solenoid

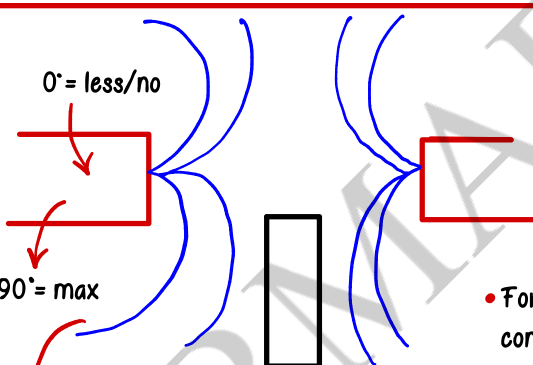
- Inside a solenoid → Magnetic field lines are straight, uniform, and constant
- Maximum field strength is seen → unit: Tesla



Electromagnet

- When in Solenoid, a soft Iron rod is inserted ↓ Behaves like a magnet → Shows magnetic properties

Force on a Current Carrying Conductor in a Magnetic Field

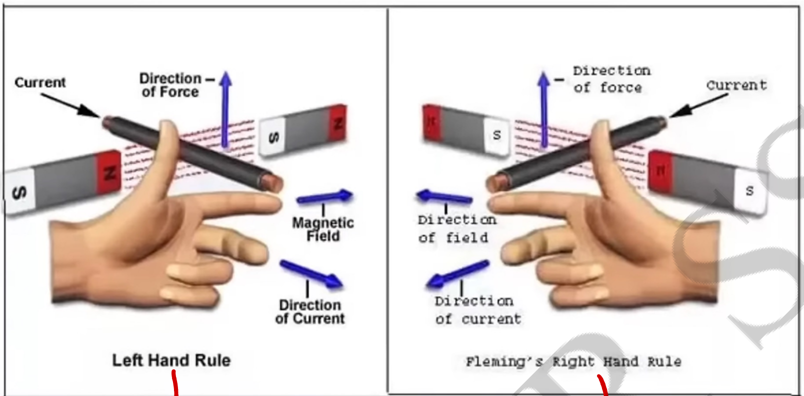


- Force will be maximum when conductor is perpendicular to the direction of magnetic field

Electric Motor: converts Electric Energy to Mechanical Energy

- Electromagnetic Induction
- Discovered by Michael Faraday, 1831
- A conductor when introduced in a changing magnetic field → Current is induced
- Magnetic Flux Unit: Weber

Electric Generator: Mechanical Energy converted to Electrical Energy



Force

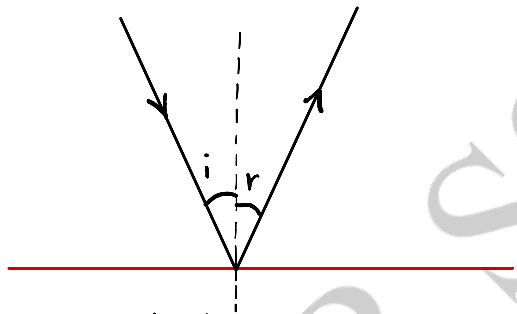
Induced current

Right hand thumb rule: is used to find direction of magnetic field in a straight current carrying conductor

Light-Reflection and Refraction

Reflection of Light

- The angle of incidence is equal to the angle of reflection
- The incident ray, the reflected ray, and the normal to the surface of all lie in the same plane



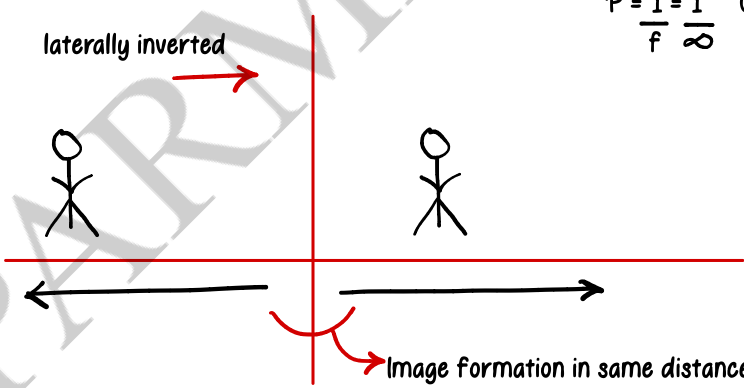
$\angle i = \angle r$

Reflection of Light in a Plane mirror

→ Focal length = ∞

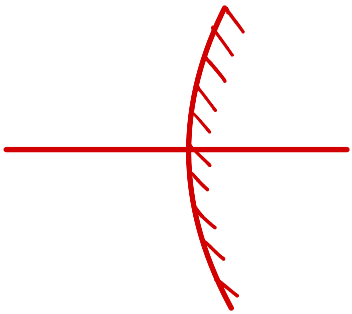
$P = \frac{1}{f} = \frac{1}{\infty}$ 0

laterally inverted



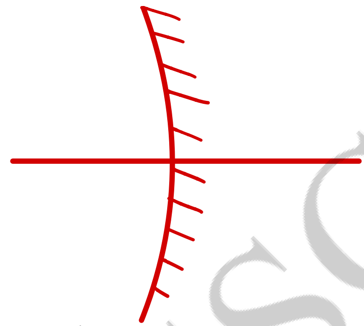
→ Image formation in same distance, formed behind the mirror

- Image is erect and virtual



Convex Mirror

→ Reflecting surface curved outwards



Concave Mirror

Spherical Mirrors

- It is a mirror that is shaped like a piece cut out of a spherical surface
- Usually made from glass
- The curved surface has a silver coating on one side and a polished surface on other where reflection of light takes place

- Real image → Inverted
- Virtual image → Erect

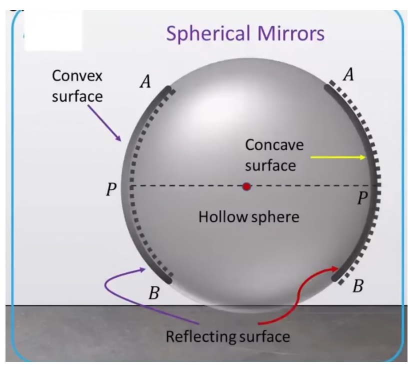
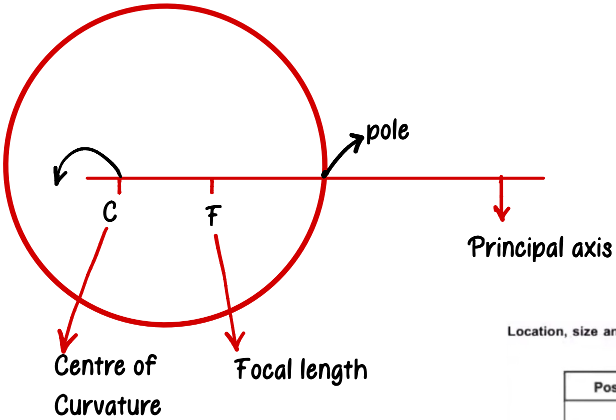


Image formation: Concave Mirror



Location, size and nature of image formed by Spherical Mirrors

Concave Mirror

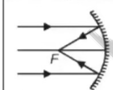
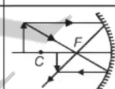
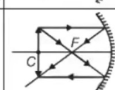
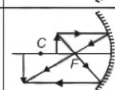
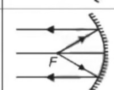
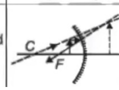
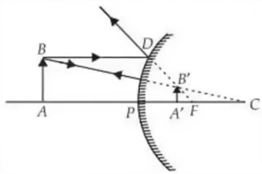
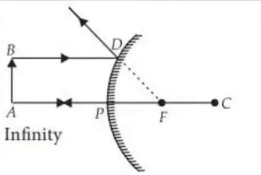
Position of object	Figure	Position of image	Nature of image
1. At infinity		At the principal focus or in the focal plane	Real, inverted, extremely diminished in size
2. Beyond the centre of curvature		Between the principal focus and centre of curvature	Real, inverted and diminished
3. At the centre of curvature		At the centre of curvature	Real, inverted and equal to object
4. Between focus and centre of curvature		Beyond centre of curvature	Real, inverted and bigger than object.
5. At the principal focus		At infinity	Extremely magnified
6. Between the pole and principal focus		Behind the mirror	Virtual, erect and magnified

Image Formation: Convex Mirror

Always forms

	Convex mirror			
Ray diagram		Object position	Image position	Nature of image
(a)		Between infinity and the pole	Behind the mirror between the focus and the pole	Virtual, smaller and erect
(b)		At infinity	Behind the mirror at the focus *F*	Virtual, point-sized and erect

Uses of Concave Mirror

- To magnify things
- Dentist uses this mirror
- Used as a shaving mirror

Uses of Convex Mirror

- To view images in small size
- In ATM, road turns, Railways
- In rear view mirror in vehicles

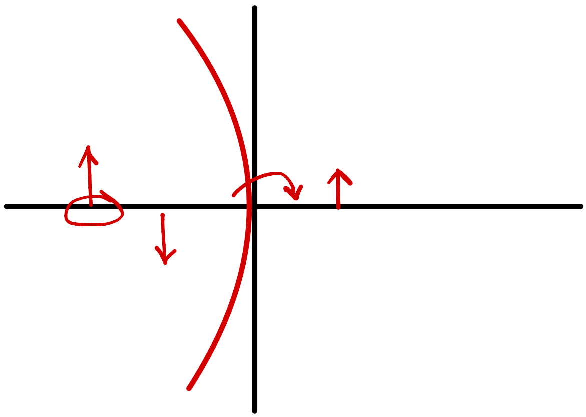
Mirror Formula and Magnification

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

$$M = \frac{h_i}{h_o} = -\frac{v}{u}$$

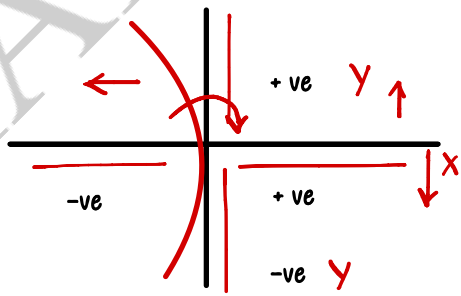
u: object distance
v: image distance
f: focal length → convex → +ve
f: focal length → concave → -ve

Cartesian System



- Object in front of mirror: u → −ve
- Image virtual, behind the mirror: v → +ve
  ↓
  Erect

M = −ve
↳ inverted



A convex mirror used for rear-view on an automobile has a radius of curvature of 3.00 m. If a bus is located at 5.00 m from this mirror, find the position, nature and size of the image.

$R = 3m = 2f \; ; \; f = 1.5$

$u = -5m$

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

$\frac{1}{v} + \frac{1}{(-5)} = \frac{2}{3}$

$\frac{1}{v} - \frac{1}{5} = \frac{2}{3}$

$\frac{1}{v} = \frac{2}{3} + \frac{1}{5}$

$\frac{1}{v} = \frac{10 + 3}{15}$

$v = +\frac{15}{13} m$ → virtual and erect image

$M = -\frac{15}{13} / (-5)$

$M = \frac{15}{13} \times \frac{1}{5}$

$M = \frac{3}{13}$

Refraction of Light

- The incident ray, refracted ray, and normal to the interface at the point of incidence all lie in the same plane
- The ratio of the sine of the angle of incidence (i) and the the sine of the angle of refraction (r) is constant

Apparent position of the object → Changes

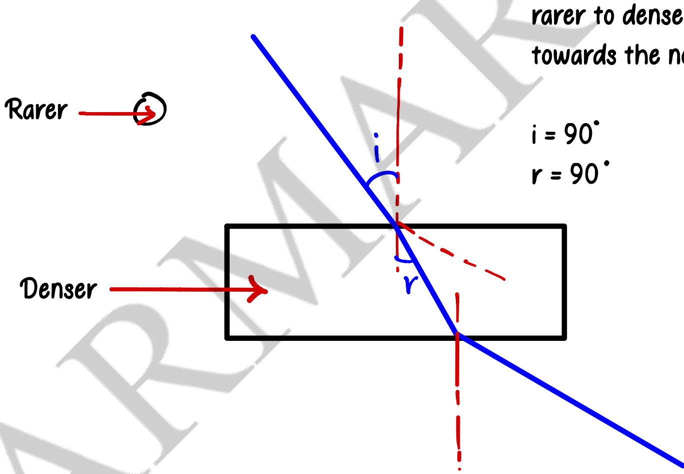
Snells Law

$$\frac{\sin i}{\sin r} = \text{constant} = \text{Refractive Index}$$

Refraction through a Rectangular Slab

- When ray of light passes from rarer to denser medium, it bends towards the normal

i = 90˚
r = 90˚



Refractive Index

→ denser ↑ n ↑

- It is a measure of how much a light ray bends when it passes from one medium to another
- It is calculated by dividing the speed of light in a vacuum by the speed of light in a substance.

→ 3×10^8 m/s

- The formula is n = c/v

↓ μ

Air, n = 1
Water, n = 1.33
Diamond, n = 2.4

- $n_{21} = \frac{V_1}{V_2}$

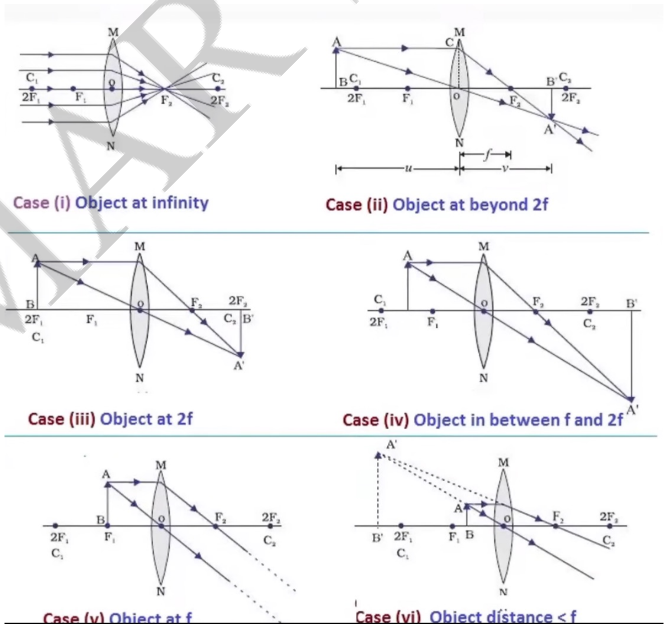
Refraction by Spherical Lenses

Convex lens = concave mirror

Concave lens = convex mirror

Image formed by Convex Lens

2f = c



Case (i) Object at infinity

Case (ii) Object at beyond 2f

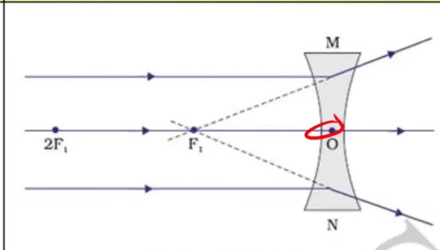
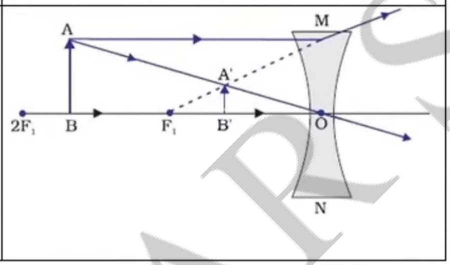
Case (iii) Object at 2f

Case (iv) Object in between f and 2f

Case (v) Object at f

Case (vi) Object distance < f

Image formation by Concave Lens

Position of the object	Ray Diagram
Infinity Point sized image formed	
Between infinity and optical center O of the lens Diminished image formed	

Power of a Lens

$$P = \frac{1}{\text{Focal length}} \rightarrow \frac{1}{m} \; m^{-1}$$

m^{-1} → Dioptre

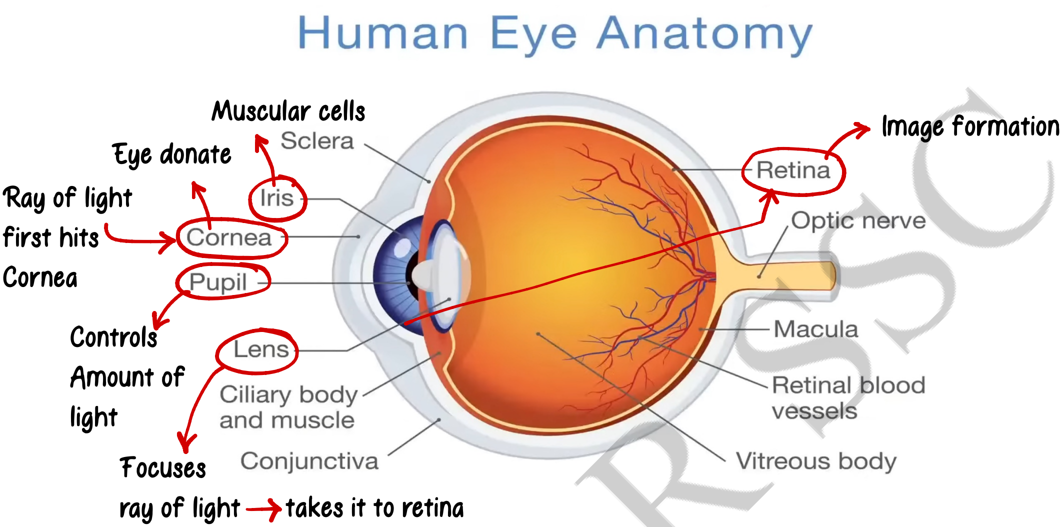
Focal length:
- +ve → Convex
- −ve → Concave

Lens Formula

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

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

The Human Eye and the Colourful World



Power of Accommodation

- The ability of the eye lens to focus on near and far objects clearly on the retina. The eye lens varies it's focusing distance by changing its shape

- Least distance of distant vision: 25 cm

Defects of Eye

Myopia
- Image formed before retina
- Near sightedness
  ↓
- Near ✓
- Far ✗
- Concave lens used

Hypermetropia
- Image formed beyond retina
- Far sightedness
- Convex lens used

- presbyopia: bifocal lens
  ↓
  Near and far sightedness

Dispersion of white lite by a Prism

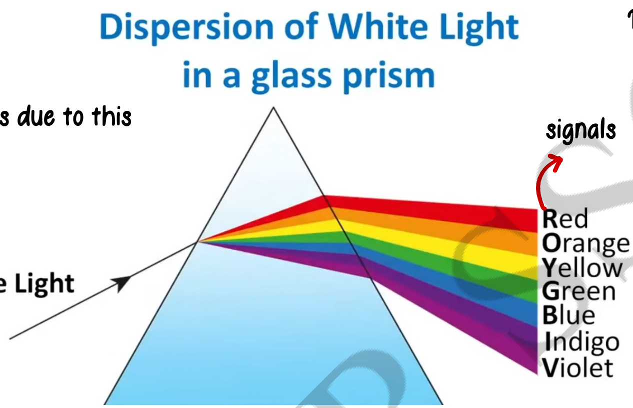
Newton did experiment with Prism

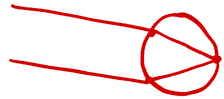
Occurs in rainbow

TIR → Mirage forms due to this

Diamond sparkles due to this

Optical fibre





Droplet of rainbow

2: refraction

1: TIR

signals

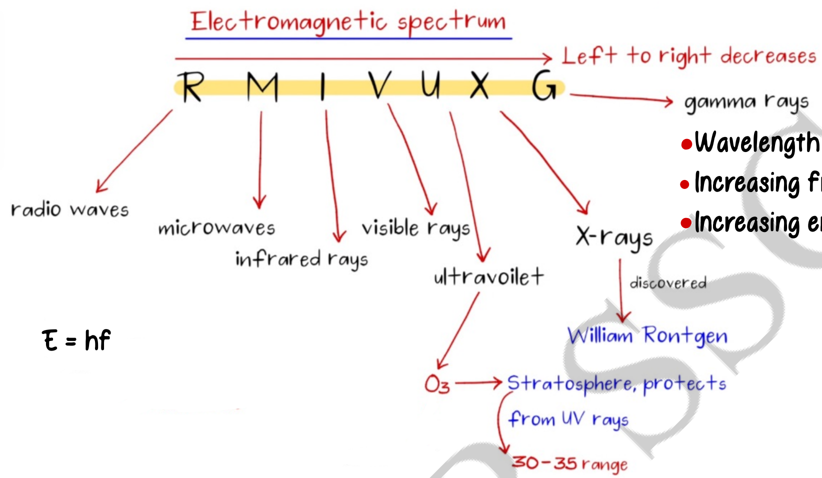
R O Y G B I V

increase wavelength ↑

Light that has less wavelength spreads quickly

- Twinkling of Stars due to refraction
- Advance sunrise and delayed sunset due to refraction
- Blue Colour of sky due to scattering
- Sky is seen black if no atmosphere
- Red colour of Sun during sunrise and sunset due to scattering

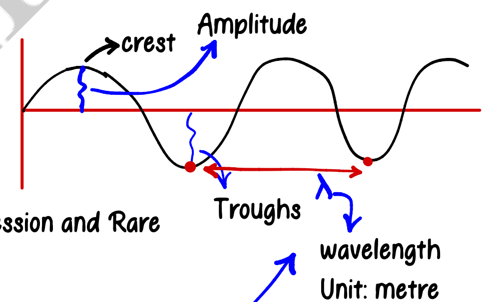
Electromagnetic Spectrum



- Wavelength decreases
- Increasing frequency
- Increasing energy

$E = hf$

Sound



- How is sound is produced: by a vibrating object
- What kind of waves are they: longitudinal waves
  - Creates Compression and Rare
- Can it travel in vacuum: No
  - Cannot be polarised
- What is wavelength:
- What is frequency: no. of vibrations/sec
  - unit: Hertz (s^{-1}) $\frac{1}{t}$
- Audible frequency range: 20 Hz-20 kHz
  - Ultrasonic
  - Infrasonic

- Reflection of Sound: Echo → Clear echo: 17 m (distance b/w sound producer and sound reflector)

- Repeated reflection of sound: reverberation

- Amount of sound energy passing each second is called: intensity

- Loudness of sound depends on: Amplitude
  Loud sound → Loud amplitude

- Pitch of sound depends on: Frequency

- Resonance: when the matching vibrations of another object increase the amplitude of an object's oscillations

Force and Laws of Motion

Uniform and Non-uniform Motion

Same distance covered in equal interval of time → Uniform motion

Speed → Magnitude

Speed → Scalar → Magnitude

Rate of Change of Velocity

Speed + Direction

Distance Vs Displacement

Distance → scalar

Displacement → vector

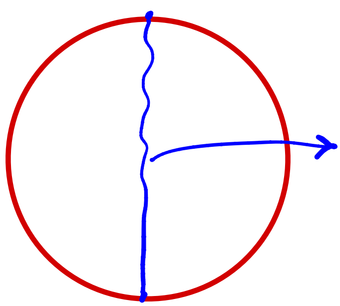
Displacement → initial and final point shortest distance

1 turn = 30 sec

After 105 sec where the person will be?

r = 10 m

Displacement = ?



Displacement= 20 m

r = 10 m

Diameter = 20 m

Uniform Circular Motion

Speed is constant (m/s)

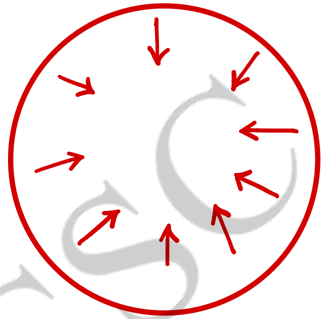
Changing velocity → Acceleration develops

Centripetal acceleration $a = \frac{v^2}{r}$

$a_c = \frac{\text{Change in velocity}}{\Delta t}$

m/s^2

Centripetal force $= \frac{mv^2}{r}$



Force

Type:

Unit of Force: Newton

1. Balanced forces: are equal in magnitude but opposite in direction. They cancel each other out and do not charge the motion of an object
2. Unbalanced forces: are not equal in magnitude and may or may not be directed in the same direction. They do not cancel each other out and cause an object to move in the direction of the greater force
3. Contact forces: occur when two objects are in direct physical contact.

eg: friction, tension, air resistance

4. Non-contact forces: when two objects are attracted or repelled but do not make direct physical contact.

eg: gravitational forces, magnetic force, electrostatic force

- Laws of Motion by: Newton

1st Law of Motion

Every object which is in a state of rest/motion will remain in same state if no external force applied → Law of Inertia

Eg: when brakes applied

2nd Law of Motion

$F \propto a$

$F = m \times a$

↑

Kg m/s² → Newton

↓

$[MLT^{-2}]$

3rd Law of Motion

Every action has equal and opposite reaction

eg: Rowing, swimming, walking, bullet firing, rocket expulsion

Conservation of Momentum

$P = m \times v$ → Kg m/s (scalar)

The law states that the total momentum of two or more bodies acting upon each other remains constant unless an external force is applied. This means that momentum can neither be created nor destroyed

$$m_1v_1 + m_1v_2 = (m_1 + m_2)v$$

Laws of Motion

1. $v = u + at$
2. $v = u^2 + 2as$
3. $s = ut + \frac{1}{2}at^2$

u: initial velocity

v: final velocity

s: distance

t: time

a: acceleration

Acceleration due to gravity

1. $v = u \pm gt$
2. $v^2 = u^2 \pm 2gh$
3. $s = ut \pm \frac{1}{2}gt^2$

free falling object: $u = 0$

Work and Energy

Unit: Joule

→ 1 J = erg

F x S

Nm

$Kg\ m^2/s^2$

- What is work: Force → Displacement
- Work done = F x S

$W = F.S$

$W = FS \cos \theta$

- When is zero work done:
  - → no displacement
  - → Force and displacement are perpendicular

→ Force and displacement are parallel → W.D → +ve

- When is negative work done: force and displacement anti parallel

Antiparallel → W.D → -ve

Different Forms of Energy

1. Kinetic Energy: when there is movement/ velocity in a body

$K.E = \frac{1}{2} m \times v^2 \rightarrow \frac{1}{2} \frac{mv^2 \times m}{m} = \frac{m^2v^2}{2m} = \frac{(mv)^2}{2m}$

$K.E = \frac{p^2}{2m}$ ↑

2. Potential Energy

→ mgh

In dynamo and motor

Mechanical energy → Electrical energy

←

Generator

K.E + P.E

$P = mv$

- Rate of doing work: Power

SI unit: Watt

1 HP = 746 W = 0.746 kW

Commercial Unit of Energy

- An electric bulb of 60 W is used for 6 h per day. Calculate the 'units' of energy consumed in one day by the bulb.

1 unit = kWh
= 0.06 x 6
= 0.36

Gravitational Force: it is a non-contact force

$$F \propto \frac{m_1 m_2}{r^2}$$

$$F = g\frac{m_1 m_2}{r}$$

g → given in 1798 in Henry Cavendish

Difference between Mass and Weight

Mass → Constant
Mass → Unit: kg

Weight → unit: Newton
Weight → Force applied by acceleration due to gravity
Weight → W = mg

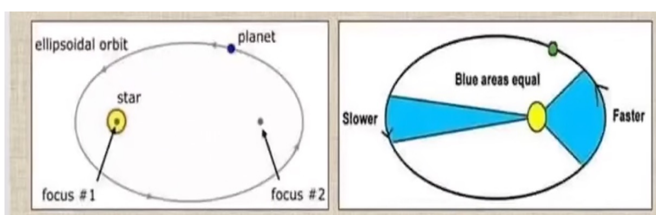
Gravity (g) = 9.8 m/s^2

Moon = $\frac{g}{6}$

Kepler's Planetary Laws

- 1st: Law of orbits

Every planets revolves around the sun in an elliptical orbit, as the sun is situated at one foci of the ellipse



- **2nd: Law of Area**
  The line joining the planets and the sun swept equal area in equal interval of time. i.e. The areal velocity of the planets around the sun is constant

- **3rd: Law of periods**
  The square of the time period of the planets revolve around the sun is directly proportional to the cube of the semi major axis of the elliptical orbit of the planet

$$T^2 \propto a^3$$

Thrust and Pressure → $P = \frac{\text{Force}}{\text{Area}}$ → Scalar

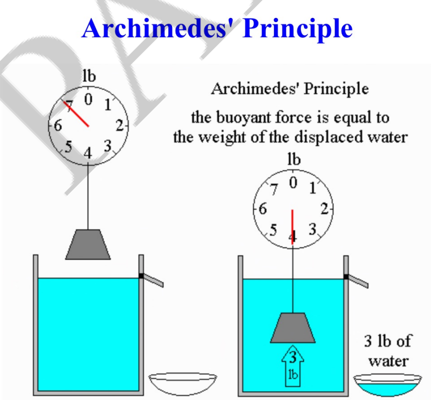
↓ Force applied perpendicular downwards

Pressure in fluids: Buoyancy

↳ upward force by a fluid

Archimedes' Principle

It states that the upward buoyant force on a body immersed in a fluid is equal to the weight of the fluid that the body displaces



- **Pascal's Law**: when an object is immersed in a fluid, it experiences equal pressure on the surfaces
  (hydraulic pressure system works on this principle)

  $F = PA$

  ↓ A: Cross-sectional area

- Relative Density = $\frac{\text{Density of one object}}{\text{Density of another object}}$

  ↓ No unit

$$d = \frac{m}{v}$$

- Surface Tension: tendency of liquid to shrink into minimum surface area possible

Boyle's Law (→ In 1662): Pressure $\propto \frac{1}{\text{volume}}$

PV = constant

$P_1 V_1 = P_2 V_2$

Charle's Law (→ 1782/1780): Volume of gas $\propto$ Absolute temperature

$$V \propto T$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Dalton's Law: Pressure applied to a gas = Sum of partial pressure applied by all the gases

$P = P_1 + P_2 + P_3 + \ldots\ldots$

Gay-Lussac Law: $V \propto T$

↓ 1809 ↓ At constant pressure