Work, Energy and Power

\[ W = \text{work} \]

Definition:

Product of force and displacement travelled in the direction of force is called work. Since the forces here are not parallel to each other, we will resolve them into their components.

\[ W = F \cdot s \cdot \cos \theta \]

- \( s \) - displacement
- \( F \) - force
- \( \theta \) - angle between force and displacement

- If \( \theta = 0 \), then \( W = F \cdot s \)
- If \( \theta \neq 0 \), then the formula will be

Units: Nm or Joule (J)

1 J = (1 N)(1 m)

P.S: Scalar

Dependancy:

- Force is not inclined \( \Rightarrow \theta = 0^\circ \)
- Force is either vertical or horizontal \( \Rightarrow \text{force} \parallel \text{to displacement} \)

i) Magnitude of force:
\[ W \times F \text{ for constant displacement (s)} \]

\[ \text{Gradient = displacement} \]

\[ \frac{W}{s} \]

\[ F/N \]

\[ \text{Case 1: Work done by a constant force} \]

\[ \text{Ex. 1:} \]

\[ \begin{align*}
F &= 20N \\
S &= 10m
\end{align*} \]

\[ W = Fs \cos \theta \\
= (20)(10)(1) \\
= 200J \]

\[ \text{(ii) Work done against resistive force} \]

\[ W = f(s) \cos 180^\circ \\
= (8)(10)(-1) \\
= (-8)(10) \\
= -80J \text{ or } 80J \]

\[ \text{(iii) Work done by a resultant force} \]

\[ W = (F-f)(s) \cos \theta \\
= (20-8)(10)(1) \\
= 120J \]
i) Work done against frictional force of 100 N

\[ W = F_5 \cdot s \] \[ s = 20 \text{ m} \]

\[ W = 100 \times 20 \]

\[ W = 2000 \text{ J} \]

\[ W = (100)(20)(-1) \]

\[ W = -2000 \text{ J} \]

*ii) Work done against gravitational pull of Earth

\[ W = (mg \sin 30) (s) \cos 180 \]

\[ m = 4 \times 9.81 \]

\[ W = 392.4 \text{ J} \]

\[ W = (4 \times 9.81)(20 \sin 30) \cdot 2 \]

\[ W = 392.4 \text{ J} \]

iii) Work done by an applied force

\[ W = F_5 \cdot s \]

\[ s = 8000 \times 20 \]

\[ W = 160000 \text{ J} \]

iv) Resultant work done by an applied force

\[ W = W_{\text{by friction}} - W_{\text{by applied force}} \]

\[ W = (8000 - 100)(20) \]

\[ W = 158000 \text{ J} \]
(a) A block of mass 20 kg is dropped so that it is moving with a terminal velocity of 80 m/s. Calculate

(i) Resultant work done
(ii) Work done per second by the Earth’s gravitational pull of mass

(i) 0, due to 0 resultant force

(ii) \[ \frac{W}{t} = \frac{mg}{t} \]

\[ P = mg \left( \frac{h}{t} \right) \]

\[ P = mg (V) \Rightarrow \begin{cases} \frac{b = Vt}{V = \frac{h}{t}} \\ V = (20 \times 9.81) (80) \end{cases} \]

\[ P = 800 \text{ W} \]

Case 2: Work done by a variable force

Ex-1: Elastic potential energy/strain energy
Since both force and displacement (extension) are values of a variable, so a graph is plotted between them which is a straight line as per Hooke’s law.

\[ W = \text{Area of } F/N \text{ graph along with extension axis} \]

\[ W = \frac{1}{2} F e \]

But \( F = ke \)

\[ W = \frac{1}{2} (ke)(e) \Rightarrow W = \frac{1}{2} ke^2 \]

Work will be done on the basis of extension i.e. work is dependent on extension if no work extension, no work, even if force is being applied \( \Rightarrow \) that's why work is taken with extension axis.

Ex.2: Work done by an expanding gas

\[ P_1 = P_0 \]

Frictionless piston
In equilibrium state,
\[ P_1 = P_a = P_2 \]
\[ A = P_1 - P_2 = 0, \text{ i.e. no change in pressure} \]

Again, the force exerted by the gas particles varies, so a graph is plotted between pressure and volume. Work done is obtained by taking the area of the graph and along with volume axis.

\[ W = P(v_2 - v_1) \]
\[ W = P_A \Delta V \]

\[ W = F_s \]
\[ = (PA)(h_2 - h_1) \]
\[ = (PA)(Ah) \]
\[ = P(Ah) \]

\[ W = P_A \Delta V \]
Notes:
(i) If the volume of gas decreases, then the work is done on the gas, which therefore increases the internal energy of the gas particles.

(ii) Work done by the gas decreases the internal energy of the gas particles and is obtained when the volume of gas increases.

Q)

\[ V_{m^3} \]

\[ 20 \]

\[ 10 \]

\[ 5 \]

\[ 10 \]

\[ P/\text{kPa} \]

Calculate:

(i) Work done on the gas

(ii) Work done by the gas

(iii) Resultant work done on the gas

(iv) Why no work is done in AD and BC

(v) What happens to the temperature of gas particles as a result of work done on it.

(i) Area of CD along with volume axis

\[ = (10)(20-10) = 100 \text{J} \]
(ii) Area of AB along with volume axis
\[ = (5)(20 - 10) = 50 \text{ J} \]

(iii) \[ (10 - 5)(20 - 10) = 50 \text{ J} \]
\[ \frac{W}{V} = \frac{100 - 50}{50} = 50 \text{ J} \]

b) Volume of gas is constant and pressure varies

c) Increase because kinetic or internal energy of the particles increases

\[ \Rightarrow \text{Dependence of work on displacement} \]

\[ W \propto \text{for constant force and } \theta = 0 \]

\[ \frac{W}{F} \quad \text{Gradient} = \text{force} \]

\[ \frac{W}{J} \quad \text{} \rightarrow \text{m} \]

Note:
- Work done is 0, due to 0 displacement if:
  a) force is applied on an immovable object (e.g., wall)
  b) the object return to its original position.
Energy - one form of energy can't be converted into another form unless work is done on it.

Definition: Ability or capacity of an object to do work is called energy.

Symbol: $E$, $A$, $U$

P.S.: Scales

Unit: Joule (J)

Types

1) Mechanical energy: It is the sum of kinetic and potential energy of a body.

\[ E = E_k + E_p \]

(i) Kinetic energy: The energy due to motion of a body is called kinetic energy.

Symbol: $E_k$

Formula: \[ E_k = \frac{1}{2}mv^2 \]
Proof: Suppose a body moves with an initial velocity \( u \). After time \( t \), its velocity becomes \( v \) and it travel a displacement \( s \) in the direction of force \( F \).

\[
\text{Work done} = (F)(s) \\
= (mx)(\frac{v^2 - u^2}{2a}) \\
= \frac{1}{2} m(v^2 - u^2)
\]

This work done becomes the change in \( E_k \) so,

\[ \Delta E_k = \frac{1}{2} m(v^2 - u^2) \]

If the object starts from rest \( (u = 0) \)

\[ E_k = \frac{1}{2} m(v^2 - 0^2) \]

\[ E_k = \frac{1}{2} m v^2 \]

\[ \rightarrow \text{Potential energy} \]

\[ \text{def} - \text{The ability of an object to do work due to change of its position is called potential energy.} \]

a) Gravitational

The ability of an object to do work due to change of its position i.e. height from
The surface of the Earth is called gravitational potential energy.

Symbol: \( E_p \) or \( G \cdot E_p \)

Formula: \( E_p = mgh \)

Proof:
Suppose an object of mass 'm' is raised to a height 'h' from the surface of the Earth against its pull.

Work done \( = (F)(s) \)
\[
W = (mg)(h)
\]

This work is done against gravitational pull becomes the \( G \cdot E_p \) by Work-energy principle.

\[
G \cdot E_p = mg \cdot h
\]

b) Elastic potential energy (only in solids)

The ability of a solid to do work due to change of its position when it is stretched or compressed from its initial position is called elastic potential energy.

Formula: \( E_p = \text{Area of } F/N - e/m \) graph along with extension axis
1) Electric potential energy is energy due to charge of particle to do work due to change of its position (i.e. distance) from another charged particle is called electric potential energy.

Note:
1) $\text{EF}_p \uparrow$ if $r \downarrow$

2) $\text{EF}_p \uparrow$ if $r \uparrow$

$\Rightarrow \text{Internal energy}$

Def: It is the microscopic sum of random kinetic energy and electric potential energy of particles of matter is called internal energy.

Symbol: $U$

$\Rightarrow \text{Formula:}$

(i) Solids: $U = \text{vibrational } E_k + \text{Electric } E_p$ due
(ii) Fluids: 1) Random/Translational E_k + Electric E_p due to binding

Dependence:
"In internal energy we consider the microscopic movement of molecules and not the bulk/macroscopic movement or overall movement of the body \( \rightarrow \) difference between internal energy and mechanical energy.

(i) Heat is provided to matter to increase its temp \( (+\theta) \)

(ii) Work is done on matter \( (+W) \) i.e. hammering/compress/elongate a solid, shake/stir a liquid or compress a gas.

b) \( \Delta E_p \uparrow \) and \( \Delta E_k = 0 \), so \( \Delta U \uparrow \) if,

(i) State of matter changes from solid to liquid to gas due to breaking of bonds and increase in the separation of opposite charges.

Note:
In internal energy we do not consider the bulk/macroscopic movement of the object, but the actual movement of the particles as per kinetic theory model is considered.
Principle of Conservation of Energy

Statement:
Energy can neither be created nor be destroyed, but can change its forms and the total energy of the system remain conserved.

Power

Definition:
Work done or energy transfer per unit time is called power.

Symbol: P

Formula:
(i) \[ P = \frac{W}{t} \]

(ii) \[ P = \frac{E}{t} \Rightarrow P = Fv \]

(iii) \[ P = \frac{1}{2}mv^2 \]

(iv) \[ P = \frac{mg\Delta h}{t} \]

Unit: Watt (W)
1W = 1J
Efficiency:

Ratio of useful energy out or power out to total energy input or power input is called efficiency.

\[ \text{Efficiency} = \frac{E_{\text{out}}}{E_{\text{in}}} \times 100 \]

\[ \text{Efficiency} = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100 \]
Statics

Study of properties of unaccelerated particles at rest is called Statics.

⇒ Moment of a force

Definition:
The product of force and perpendicular distance from the point of application of force to the axis of rotation (pivot) is called moment of a force.

Symbol: \( \tau \) (Tau) → not in syllabus

Formula:
(i) \( \tau = (F)(d) \)

(ii) \( \tau = (\text{component of force perpendicular to } d)(d) \)

\[ = (F \sin \theta)(d) \]

For this case use \( \tau = (F)(d) \)
Units: Nm
Force: vector
Direction: clockwise or anticlockwise
Dependence:
\[ T = F \sin \theta \]
\[ T \uparrow \text{ if} \]
(i) \( F \uparrow \)
(ii) \( d \uparrow \)
(iii) \( \theta \uparrow \)

\[ \Rightarrow \text{Equilibrium} \]

An object is said to be in equilibrium if its acceleration is 0
- acceleration 0, means no net resultant force = 0
- Also that object is either at rest or is moving with terminal velocity.

1) Resultant sum of all the forces acting on the object is 0.
\[ \Sigma F = 0 \]

2) Algebraic sum of clockwise moments must be equal to the algebraic sum of anticlockwise moments.
\[ \Sigma (C.W.M) = \Sigma (A.C.W.M) \]
Types:

a) Static equilibrium: Object is at rest.

b) Dynamic equilibrium: Object moves with uniform velocity (terminal velocity).

c) Weight:

\[ F_3 = 10 \text{ N} \]

calculate the magnitude of \( F_2 \) if the system is balanced.

\[ \sum (A \cdot C \cdot W \cdot M) = \sum (C \cdot W \cdot M) \]

\[ (F_2 \times 6) + (10 \times 6) = 40 \times 4 \]

\[ F_2 = \frac{16}{10 \times 6} \]

\[ 6F_2 + 60 = 160 \]

\[ F_2 = \frac{160 - 60}{6} \]

\[ F_2 = 16.67 \text{ N} \]

Calculate $F_1$ if the ladder is in equilibrium. 

- Turning effect is always greater on frictionless surfaces, hence it is to be taken at the pivot point.

**Hint:** Frictionless point is considered as pivot point at X.

Let $F_2$ be the pivot point.

\[
C \cdot W \cdot M = A \cdot C \cdot W \cdot M
\]

\[
100 \times 6 = (10 \times 20) + (F_1 \times 12)
\]

\[
600 = 200 + F_1 \times 12
\]

\[
600 - 200 = F_1 \times 12
\]

\[
400 = F_1 \times 12
\]

\[
F_1 = \frac{400}{12}
\]

\[
F_1 = 33.3 \text{ N}
\]
Calculate \( \frac{F_1}{F_2} \)

**Hint:** C.G be the pivot

\[
\text{C.W.M} = \text{A.C.W.M.}
\]

\[
(F_1) \left( \frac{L - \frac{L}{2}}{\frac{8}{2}} \right) = (F_2) \left( \frac{L - \frac{2L}{2}}{\frac{8}{2}} \right)
\]

\[
(F_1) \left( \frac{4L - L}{8} \right) = (F_2) \left( \frac{4L - 2L}{8} \right)
\]

\[
(F_1) \left( \frac{3L}{8} \right) = (F_2) \left( \frac{2L}{8} \right)
\]

\[
\frac{F_1}{F_2} = \frac{2}{3}
\]

\[
\Rightarrow \text{Centre of Gravity } = \text{ }
\]

The point inside or outside the object where its whole weight appears to act is called centre of gravity.

**Note:**

1) The centre of gravity of regular objects lie at their geometrical centre.
2) The centre of gravity of irregular objects is obtained by using freely suspension plum line method.

3) The moment about centre of gravity due to weight of object is always 0 due to perpendicular distance.

4) If pivot point is not given in question then centre of gravity is considered as pivot point.

\[ \Rightarrow \text{Couple} \]

**Definition:**

2 equal and opposite forces separated by a perpendicular distance form a couple.

**Examples**

(i) \[ F = 10 \text{N} \]

(ii) \[ F = 20 \text{N} \]

(iii) \[ W = 20 \text{N} \]

[Diagram showing forces and moments]
Whenever there is a turning effect, a couple is produced. A couple is associated with the turning effect.

Torque of couple

\[ \tau = F \cdot d \]

Total moment about pivot = \( (F_1) \cdot (d_1) + (F_2) \cdot (d_2) \)

\[ = (F) \cdot (d + d_0) \]

Torque of couple = \( F \cdot (d + d_0) \)

Torque of couple = \( \text{magnitude of any one of equal and opposite forces} \) \( \times \) \( \text{perpendicular separation} \)
Wave is basically disturbance in a medium. Not all waves transfer energy.

Definition: Disturbance in a medium is called wave.

Classification of waves:

a) On the basis of a state of matter:
   (i) Electromagnetic waves
   (ii) Material/matter waves

b) On the basis of vibration of a particle:
   (i) Transverse wave
   (ii) Longitudinal wave

   ![Diagram of Transverse and Longitudinal Waves]

   direction of wave
   direction of vibration of particle

   direction of wave

   direction of vibration of particle

c) On the basis of energy energy transfer:
   (i) Progressive wave (energy is transferred along the wave profile)
   (ii) Stationary/standing waves (no energy is transferred)
Important Terms

1) Time Period
   The time taken to complete one wave is called time period.
   - Symbol: $T$
   - Unit: $s$
   - SI: $s$

2) Frequency
   - Definition: No. of complete waves generated by a source per unit time is called frequency.
   - Symbol: $f$
   - Formula: $f = \frac{n}{t}$
     - Where $n$ has an integral value i.e., it is an integer such as 1, 2, 3...
   - Unit: $s^{-1}$ or Hertz (Hz)

3) Relation between $f$, $T$, and $n$
   - Since $f = \frac{n}{t}$
   - For one wave, $n = 1$ and $t = T$, so $f = \frac{1}{T}$
1) **Displacement**

**def:** Straight directed distance of a particle on a wave from its equilibrium position.

![Diagram of a wave with labeled points A to E, showing displacement]

2) **Amplitude**

**def:** It is the maximum displacement of a particle on a wave from its equilibrium position.

3) **Intensity**

**def:** Energy incident provided by a wave per unit time per unit perpendicular area is called intensity.

**Symbol:** \( I \)

**Formula:** \( I = \frac{E}{A} \)

\( (E \neq 0) \)

\( I = \frac{E}{\pi A} \) or \( I = \frac{P}{A} \)

**Unit:**
\[ E = \frac{1}{2} m v^2 \]

\[ E = \frac{1}{2} m (2\pi F)^2 \frac{v}{v_0}^2 \]

\[ E = 2 \pi^2 m F^2 \frac{v}{v_0}^2 \]

\[ E = (\text{constant}) F^2 \frac{v}{v_0}^2 \]

\[ T = \frac{\phi}{A} \]

\[ T = \frac{P}{4\pi \lambda^2} \]

\[ I = \frac{(P)}{(4\pi \lambda^2) \pi^2} \]

\[ I = (\text{constant}) \frac{1}{A^2} \]
Monochromatic light source

Source which emit light of single frequency (colour) is called monochromatic light source such as sodium light lamp.

Frequency doesn't alter and is dependant on source, that's why it is written in def and not wavelength, as different colours also have different wavelengths.

Phase angle

Supplied: $\phi$

Concept:

$360 = 2\pi \text{ rad}$

So, a way also represent $360^\circ \text{ or } 2\pi \text{ rad}$

Let 'B' be the pivot, move 'A' and join it to 'C' to form a circle.
Online Classes: Megalecture@gmail.com
www.youtube.com/megalecture
www.megalecture.com

Formula analysis

1. \[ \phi = \left(\frac{t}{T}\right) 360^\circ \]
\[ \phi = \left(\frac{t}{T}\right) 2\pi \text{ radian} \]

2. \[ \phi = \left(\frac{x}{\lambda}\right) 360^\circ \]
\[ \phi = \left(\frac{x}{\lambda}\right) 2\pi \text{ radian} \]
\[ \phi_{AB} = 90 \left( \frac{\pi}{2} \text{ rad} \right) \]

\[ \phi_{AC} = 180 \left( \pi \text{ rad} \right) \]

\[ \phi_{AD} = 270 \left( \frac{3\pi}{2} \text{ rad} \right) \]

\[ \phi_{AE} = 90 \left( \frac{\pi}{2} \text{ rad} \right) \]

\[ \phi_{BD} = 180 \left( \pi \text{ rad} \right) \]

\[ \phi_{ED} = 90 \left( \frac{\pi}{2} \text{ rad} \right) \]

\[ \phi = \left( \frac{k}{T} \right) 360^\circ \]

(i) \[ \phi_{AB} = \left( \frac{0.6}{1.0} \right) 360^\circ = 216^\circ \]

(ii) \[ \phi_{AC} = \left( \frac{14}{10} \right) 360 = 504^\circ \]

\[ \phi_{AC} = 360 - 504 = 144^\circ \]

(iii) \[ \phi \]
(a) \( \angle AD = \left( \frac{2 \cdot 0}{10} \right) 360^\circ = 720^\circ \)

\( \angle CD = 720 - 360 = 360^\circ \)

(b) \( \angle AC \) =

(c) \( \angle BD \) =

(d) \( \angle CD \) =

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**Leading and Lagging Concept**

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**Hint:**

Disturbance level/source of a wave is considered as an enemy. The particle on wave which is closest to this enemy is leading while the other behind this is lagging.

* Direction of motion of wave will always be given to us in this concept.

A leads B by 90°

A " C " 270°

A " D " 180°
Instantaneous motion of a particle of wave.

Hints:
- Always study the motion of Baba G against the motion of a wave. The instantaneous motion of Baba G defines the motion of a particle on a wave.
- A particle will be at rest where when we plot a tangent to the wave, it becomes parallel to the equilibrium position.

⇒ Inphase particle

Note:
1) Particles having 0° phase angle in between them
2) Displacement and instantaneous motion of inphase particles are same.
\[ \text{Wavelength} \]

Definition: Distance between 2 successive in-phase particles is called wavelength.

Symbol: \( \lambda \)

P.S.: Scalar

Unit: metre (m)

\[ \Rightarrow \text{Speed of a wave} \]

Definition: Distance travelled by a wave per unit time is called speed.

Formula: \( V = \frac{\lambda}{T} \)

For one wave, distance = wavelength(*), time taken = time period(**)

\( V = \frac{\lambda}{T} \)

But \( \frac{1}{T} = f \) \( \Rightarrow V = f \lambda \)
Difference b/w displacement-time graph and displacement-distance graph

Results:
- Instantaneous displacement $\rightarrow y$-axis
- Time period $\rightarrow x$-axis
- Amplitude $\rightarrow y$-axis
- Frequency $\rightarrow f = \frac{1}{T}$

$\ast$ Velocity of a particle on wave (Baba Ji's velocity) $\rightarrow$ gradient of graph

Note:
Velocity/speed of a wave is obtained from both graphs.
\[ \Rightarrow \text{i.e. we have to use both graphs.} \]
Coherent Sources

Sources which emit waves having constant phase angle in box them are called coherent sources.

Notes:

Coherent sources are derived from a single source and emit waves having constant time period, frequency and res wavelength, but amplitude varies due to their position from the main source/parent source.

Decrease in amplitude will be there due to loss of energy.

Distance of $s_1$ and $s_2$ from main source is not equal, so amplitude is also is not same.
$S_1$ and $S_2$ emit phase coherent waves with same amplitudes due to same distance from 'S' screen (main source)

$\Rightarrow$ Wavefront

plane wavefront
Imaginary parallel lines which are passing through inphase particles of multiple waves.

Principle of Superposition

Statement 2: When 2 or more waves meet at a point, the resultant wave has displacement which is equal to the vector sum of their individual displacements.

\[ A_1 + A_2 = A \]

\[ \text{Vector addition} \]

\[ \text{Resultant} \]

\[ \text{Individual waves} \]
Polarisation

def: The process to confine a wave to pass through in one plane is called polarisation.

Vertical plane polarised wave

Not a horizontal plane polarised wave

* The blocking of wave is not to polarisation
* Longitudinal waves can't be polarised
* Polarisation is of transverse waves
* A wave produced moves in all planes and is confined to move in one particular plane by a slit

The blocking of the waves in other planes is not polarisation
motion of light waves in multiple plane

vertical plane of light pass through the vertical slit and block other planes to reduce the intensity of light incident at an eye.

* Same principle/concept is used in windscreen of car to reduce the intensity of light

Note:

= Only transverse waves can be polarised because one cannot polarise the longitudinal waves

Differences

Transverse

1) def: Waves in which displacement of particle is

Longitudinal

1) def: Waves in which
the direction of motion of wave
the direction of motion of wave

2) Composition -
Compressions (high pressure/density region)
Rarefactions (low pressure/density region)

3) Polarization -
Can be polarized

4) E.g.: All electromagnetic waves, water waves, sound waves along a string, etc.

5) Geographical representation

Interference of Waves

Definition: Two or more waves meet at a point and superpose each other at one point. The effect of each other at another point is called interference.
Principle -

Principle of Superposition

Conditions for Interference:

1) Waves must be from coherent sources i.e. they have a phase coherence.
2) Waves must meet at a point.
3) Waves must be of the same type.
4) If transverse, then they must be polarised in the same plane.

* 2 crest or 2 trough meet forming a bigger resultant crest or trough respectively.
   → this is actually supporting one crest and one trough meet, canceling out each others effect.

Types of Interference:

a) Constructive Interference
b) Destructive II

Constructive Interference:

Definition: Superposition of waves which support each other to produce a resultant wave with greater displacements is called constructive interference.
i) Path difference:

Def: \( \Delta \) is the difference of distance travelled by both waves from their sources to their meeting region.

Note:
Path difference is represented in terms of wavelength.

(ii) Phase difference:

\[ \phi = \left( \frac{\text{Path difference}}{\text{wavelength}} \right) \times 2\pi \]

\[ \text{Path diff} = S_2P - S_1P \]
\[ = 1.5\lambda - 1.5\lambda \]
\[ = 0 \lambda \]

\[ \text{Phase diff} = \left( \frac{0\lambda}{\lambda} \right) \times 2\pi \]
\[ = 0 \]

\[ \text{Path diff} = S_2P - S_1P \]
\[ = 2.5\lambda - 1.5\lambda \]
\[ = 1\lambda \]
\[ \phi = \left( \frac{1\lambda}{\lambda} \right) \times 2\pi \]
\[ = 2\pi \]
Path diff: \[
\Delta s_1 - \Delta s_2 = \lambda \frac{n}{2}
\]

Phase diff: \[
\varphi = \left( \frac{2\lambda}{\lambda} \right) 2\pi
\]

\[
= 4\pi
\]

In general for constructive interference:

- Path diff: \(0\lambda, 1\lambda, 2\lambda, 3\lambda\ldots n\lambda\)
  \(\text{(i.e integral multiple of wavelength)}\)

- Phase diff: \(0\pi, 2\pi, 4\pi\ldots 2n\pi\)
  \(\text{(i.e. even multiple of } \pi)\)

\[\text{where } n = 0, 1, 2, 3, \ldots\]

b) Destructive Interference

- Superposition of waves which cancel out each other’s effect to provide a resultant wave with minimum displacement, is called destructive interference.
Conditions:

Path diff. \[ s_2 \rho - s_1 \rho \]
\[ = 2\lambda - 1.5\lambda \]
\[ = 0.5\lambda \]

\[ = \frac{1}{2} \lambda \]

Phase diff. \[ \phi = \left( \frac{\lambda}{\lambda} \right) 2\pi \]
\[ = 0 \]

Path diff. \[ s_2 \rho - s_1 \rho \]
\[ = 3\lambda - 1.5\lambda \]
\[ = 1.5\lambda \]
\[ = \frac{3\lambda}{2} \]

Phase diff. \[ \phi' = \left( \frac{3\lambda}{2} \right) 2\pi \]
\[ = 3\pi \]
\[ \phi = \left( \frac{5 \lambda}{2} \right) \ \text{2}\pi \]

Therefore, in general, in a destructive interference:

\[ \text{Path diff} = \frac{1\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, \frac{7\lambda}{2}, \ldots \]

\( (2n+1)\frac{\lambda}{2} \)

i.e. odd multiple of half wavelength.

\[ \text{Phase diff} = \pi, 3\pi, 5\pi, (2n+1)\pi \]

i.e. odd multiple of \( \pi \)

where \( n = 0, 1, 2, 3, \ldots \)

\( * \) for 2 constructive interference, 1 destructive interference is necessary and vice versa for destructive interference.

\( \text{Interference of Water waves} \)

\( * \) where phase diff = 0, these may constructive interference.
Interference of light waves (Young's double slit experiment)

Significance:
This experiment is used to measure the wavelength of monochromatic light source.

A slit means opening spreading of waves

For diffraction double slit

Single slit

Monochromatic light source

Max constructive
Since path phase difference is 0

Interference pattern in terms of fringes

Observation:
Alternate light and dark bands, also known as interference fringes are observed at the outer screen due to
light waves from different sources \( S_1 \) and \( S_2 \). 

* B/w every 2 constructive interferences, there is a destructive interference and vice versa for destructive interference.

**Fringe spacing/separation**

def: It is the distance b/w 2 successive bright or 2 successive dark fringes.

Symbol: \( \Delta x \)

**Formula**: \( \Delta x = \frac{\lambda D}{a} \)

where, \( \lambda \rightarrow \) wavelength of monochromatic light source

\( D \rightarrow \) perpendicular separation b/w double slit and screen

\( a \rightarrow \) separation b/w 2 slit

**Dependence**

\( \Delta x \) \( \propto \) \( \lambda \) \( \lambda \rightarrow \) if,

(i) \( \lambda \uparrow \Delta x \) \( \uparrow \)

(ii) \( D \rightarrow \Delta x \) \( \rightarrow \)

www.youtube.com/megalecture

www.megalecture.com
Notes:

1) The brightness of bright fringe increases with no change in dark fringe which therefore increases the contrast b/w them if:

a) Increase the intensity of source by increasing its power rating.

b) Decrease the distance, 'D' b/w the double slits and screen.

c) Decrease the distance b/w the source and the slits.

d) Replace the light source with one having lesser wavelength ⇒ Reason:

Energy of e.m waves = $E = hf$

But $c = f\lambda \Rightarrow f = \frac{c}{\lambda}$

$E = \frac{hc}{\lambda}$, where $h$ = planck’s constant ($6.63 	imes 10^{-34}$ Js)

$E = \text{constant} \frac{c}{\lambda}$ ⇒ speed of light ($3.0 \times 10^{8}$ ms$^{-1}$)
1. Size of double slit is increased without varying the separation, d, between slits.

2. The darkness of brightness of bright fringe decreases and the darkness of dark fringe also decreases, if the intensity of light incident on one slit of double slit is decreased.

3. Range of separation \( \frac{2}{w} \) double slit is \( 0.3 \text{ to } 3 \text{ mm} \) i.e.

\[ 3 \text{ mm} \geq a > 0.3 \text{ mm} \]

Interference of microwaves

<table>
<thead>
<tr>
<th>Microwave transmitters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium slits</td>
</tr>
</tbody>
</table>

Microwave detector connected to galvanometer
Observation:

The microwaves which are incident at the aluminium slits are not reflected back due to strong absorption of aluminium. The microwaves from 2 slits of aluminium meet at the screen to exhibit interference. The microwave detector is moved along the line XY which shows regions of maximum and minimum due to constructive and destructive interference of microwaves.

Diffraction

def: Spreading of light or waves after passing through a small gap or round an obstacle is called diffraction.

Notes:
1) There is no change in the wavelength, frequency or speed of incident and diffracted wave, but the amplitude or intensity decreases while passing through a medium.

2) The order of diffraction depends upon the wavelength of incident wave and the size of gap/aperture, i.e., greater is the diffraction if the wavelength of wave is greater than the size of aperture.
(iii) Diffraction decreases if the wavelength of wave is less than the size of aperture/gap.

(iv) Shadow formation is also due to diffraction of waves around an obstacle.

**Diffraction pattern:**

- **a) Diffraction through a narrow gap:***

*Incident wavefronts*  
*Slit*  
*λ₁ = λ₂ = λ₃*

- Greater is the diffraction and diffracted waves are circular.
$\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4$

b) Diffraction through a wide gap:

$\lambda_1 = \lambda_2 = \lambda_3$

This is diffraction (diffracted wavefronts are straight from the middle and curved from edges)
(c) Diffraction round an obstacle:

\[ \lambda_1 = \lambda_2 = \lambda_3 \]

Diffraction round an obstacle causes
short shadow region.

Diffraction of microwaves/radio waves round
a hill.

No reception of
signal due to
position of antenna
at the shadow.
**Diffraction Grating**

**Def:** A wafer made of glass, plastic or metal having 5000-6000 lines per inch ruled on it. Each line behaves like a slit and diffracts the incident waves which further meet to provide a pattern on a screen known as diffraction pattern.

\[ Nd = \frac{L}{d} \]

\[ d = \frac{L}{N} \]

i.e. slit separation = \( \frac{\text{length of grating Wafer}}{\text{no. of lines on it}} \)
Diffracting through diffraction grating

Monochromatic light is diffracted at different angles through a grating. Waves and further meet on a screen to provide a pattern known as diffraction pattern with different orders of diffraction.

\[ n \lambda = d \sin \theta \]

where:

- \( n \) = order of diffraction
- \( \lambda \) = wavelength of monochromatic light
- \( d \) = distance between two successive lines on grating

\[ N = \frac{1}{N} \left( \text{length of grating wave} \right) \]

(for, \( N \) of lines on it)

\( \theta \) = angle of diffraction

with zero orders \( n = 0 \).
Maximum order of diffraction

Diffraction is maximum if $\theta = 90^\circ$

$n\lambda = d \sin \theta$

$n\lambda = d$

$n = \frac{d}{\lambda}$ where $d = \frac{1}{N}$

Note:

The formula $n\lambda = d \sin \theta$ is only applicable when there is no path difference between different wave trains incident on the grating.
Since white light is composed of 7 component wavelengths and the size of slit on grating is constant, so each colour of white light is diffracted at different angles for the same order of slit diffraction.

Hence, one get a white band for 0 order and a visible spectrum for all other orders of diffraction.

The angle of diffraction of red colour is greatest and of violet is least for the same order.
Electromagnetic Spectrum

A sequence of all transverse waves which do not need a state of matter to travel are called electromagnetic spectrum.

Relative orders:

\[ V = f \lambda \]

For e.m. waves, \( V = c = 3.0 \times 10^8 \text{ m/s} \)

\[ f = \frac{3.0 \times 10^8}{\lambda} \]

\( f \propto \frac{1}{\lambda} \) (as \( 3.0 \times 10^8 = \text{constant} \))

<table>
<thead>
<tr>
<th>Order</th>
<th>Gamma</th>
<th>X-rays</th>
<th>Ultraviolet</th>
<th>Visible</th>
<th>Infrared</th>
<th>radio</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f/Hz )</td>
<td>( 10^{20} )</td>
<td>( 10^{18} )</td>
<td>( 10^{16} )</td>
<td>( 10^{14} )</td>
<td>( 10^{12} )</td>
<td>( 10^{10} )</td>
</tr>
<tr>
<td>( \lambda/m )</td>
<td>( 10^{-12} )</td>
<td>( 10^{-10} )</td>
<td>( 10^{-8} )</td>
<td>( 10^{-6} )</td>
<td>( 10^{-4} )</td>
<td>( 10^{-2} )</td>
</tr>
</tbody>
</table>

\[ V \quad I \quad B \quad G \quad Y \quad O \quad R \]

400 450 500 550 600 650 700

\( \lambda/m \)
Common properties of e.m. waves

1) All e.m. waves are transverse waves and therefore can be polarised.

2) All e.m. waves are progressive waves i.e. they transfer energy from one point to another.

3) All e.m. waves do not carry any charge (they do not deflect show any deflection in a & electric or magnetic field).

4) All e.m. waves move with the same speed of \(3\times10^3\) ms\(^{-1}\) in air or vacuum.

5) All e.m. waves exhibit interference and diffraction properties.

Stationary Waves

Definition: When 2 incident and reflected waves having same speed and frequency, but travelling in opposite direction are superposed, stationary waves are formed.
Note:

1) The particles in stationary waves, whose displacement remain 0 are called nodes.

2) The particles in stationary waves whose displacement is maximum and called anti-nodes.

3) The distance between 2 successive nodes or anti-nodes is equal to half of wavelength ($\frac{\lambda}{2}$).

4) The distance between a node and its successive anti-node is equal to quarter of wavelength as $\frac{\lambda}{4}$.

5) The speed of stationary wave is same as that of superposing progressive waves.

6) No energy is transferred along the wave profile due to static position of nodes.
7) The particles l/w 2 adjacent nodes always move in 1 direction and are in phase with each other.

8) The particles on either side of node are 180° out of phase with each other due to their opposite direction of motion.

Stationary waves along a short stretched string or a stretched spring (guitar/viscous spring).

Length of string l/w 2 fixed points = L

Fundamental node =

The simplest and slowest frequency is called fundamental frequency.
Displace the string sideways and release it to produce stationary waves with nodes at the ends and an antinode in the middle as shown.

Length of string in terms of wavelength = \( L = \frac{\lambda_0}{2} \)

Fundamental frequency is:

\[ f_0 = \frac{V}{\lambda_0} \]

First overtone frequency:

Fix the string from the middle to make a node and disturb it to produce first harmonic node as shown.

1st harmonic frequency is:

\[ f_1 = \frac{V}{\lambda_1} \]
2nd overtone frequency:

Fix the string from two points to make one node more node as shown.

\[ L = \lambda_2 + \frac{\lambda_2}{2} \]

\[ L = \frac{3\lambda_2}{2} \]

\[ \lambda_2 = \frac{2L}{3} \]

Second overtone frequency is,

\[ f_2 = \frac{V}{\lambda_2} \]

\[ f_2 = \frac{V}{2\sqrt{3}} \]

\[ f_2 = 3 \left( \frac{V}{2L} \right) \]
Therefore, in general, along a stretched string, stationary waves of frequency $f_0$, $2f_0$, $3f_0$, $4f_0$, ..., $nf_0$ are produced where, $n=1,2,3,4,...$ and represent the no. of loops along the wave. wave and

\[ f_0 = \frac{V}{2L} \]

* overtone \( \rightarrow \) is always the multiple of fundamental frequency

Speed of stationary wave along a string

\[ V \propto \sqrt{\frac{T}{\mu}} \]

where \( T \rightarrow \) tension in the string

\( \mu \rightarrow \) Mass per unit length of string

But \( V = \lambda f \) \( \Rightarrow f = \frac{V}{\lambda} \)

So,

\[ f \propto \frac{1}{\sqrt{\frac{T}{\mu}}} \]

Result:

(i) \( T \uparrow \)

(ii) \( \mu \downarrow \)
Stationary waves in a closed pipe

Mouth organ

Notes:

1) A pipe which is exposed to external atmosphere from one end and closed from the other end is called open a closed pipe. (def)

2) Stationary longitudinal waves are produced along the pipe when air is blown at or side of open end.

3) We always get a node at the closed end and an antinode at the open end.

4) Maximum loud sound is heard at the open end due to position of antinode there.

Analysis:

\[ \text{length of closed pipe} = \frac{L}{2} \]
Fundamental mode

Keep our calabash at its side of open end to get a node and at an antinode as shown.

Length of pipe and wavelength are related as,

\[ l = \frac{\lambda_0}{4} \]

\[ \lambda_0 = 4l \]

First fundamental frequency

\[ f_0 = \frac{V}{\lambda_0} \]

\[ f_0 = \frac{V}{4l} \]

1st overtone frequency:

Blow air forcefully to produce first overtone frequency as shown.
\[ L = \frac{\lambda_1}{2} + \frac{\lambda_1}{4} \]
\[ L = \frac{2\lambda_1}{4} + \lambda_1 \]
\[ L = \frac{3\lambda_1}{4} \]
\[ \lambda_i = \frac{11L}{3} \]

But \( f_i = \frac{V}{\lambda_i} \)

\[ f_i = \frac{V}{\text{in} \frac{1}{3}} \]

\[ f_i = 3 \left( \frac{V}{4L} \right) \]

\[ f_i = 3f_0 \]

2nd overtone frequency:

Now blow air more forcefully.
\[ \lambda_2 = \frac{4L}{5} \]

But \[ f_2 = \frac{V}{\lambda_2} \]

\[ f_2 = \frac{V}{4L/5} \]

\[ f_2 = 5 \left( \frac{V}{4L} \right) \]

\[ f_2 = 5f_0. \]

Therefore, in a closed pipe, stationary longitudinal waves of frequency \( f_0, 3f_0, 5f_0, \ldots, (2n+1)f_0 \) are produced, where,

\[ f_0 = \frac{V}{4L} \]

and \( n = 0, 1, 2, 3, 4, \ldots \)

and represent the no. of nodes.

Stationary waves in an open pipe (flute).

Note:

1) The pipe which is exposed to external atmosphere from both ends is called open pipe.

2) When air is blown at or side of one end, stationary longitudinal waves are produced along the pipe.
3) We always get an antinode at the open end and a node by 2 successive antinodes.

4) Maximum loud sound is available at the open end due to position of antinode there.

Analysis

Length of pipe = L

Fundamental node:

Blow air calmly at one side of open and end to produce first overtone frequency as shown.

Length of pipe and wavelength are related
\[ L = \frac{\lambda_0}{2} \]
\[ \lambda_0 = 2L \]

Now \[ v = f_0 \lambda_0 \]
\[ f_0 = \frac{v}{\lambda_0} \]
\[ f_0 = \frac{v}{2L} \] \hfill (i)

Let overtone frequency:

Blow air forcefully now.

\[ L = 2L \]
\[ f_1 = \frac{v}{\lambda_1} \]
\[ f_1 = \frac{v}{L} \]

\[ f_1 = 2f_0 \] \hfill from (i)
2nd overtone frequency in now slow air more forcefully

\[ l = \lambda_2 + \frac{\lambda_2}{2} \]

\[ l = 3\lambda_2 \]

\[ t = \lambda_2 = \frac{2L}{3} \]

Now,

\[ f_2 = \frac{V}{N_2} \]

\[ f_2 = \frac{V}{2\sqrt{3}} \]

\[ f_2 = 3 \left( \frac{V}{2L} \right) \]

\[ f_2 = 3f_0 \] -- from (i)

Therefore, in several general, in an open pipe, stationary longitudinal waves of frequency \( f_0 \), \( 2f_0 \), \( 3f_0 \), \( \ldots \) \( n \) \( f_0 \) are produced, where,

\[ n = 1, 2, 3, 4 \] and represent the
the no. of nodes in l/m open ends and

\[ f_0 = \frac{v}{2l} \]

Measurement of speed of sound by stationary waves

(Nov 2011 - P22)

Moves the microphone in the region between the speaker and reflector and let the two successive antinodes are obtained at distance \( x_1 \) and \( x_2 \) respectively from reflectors.

Distance between two successive antinodes = \( \frac{\lambda}{2} \)

\[ (x_2 - x_1) = \frac{\lambda}{2} \]

\[ \lambda = 2(x_2 - x_1) \]

But \( V = f \lambda \)

\[ V = \left( \text{frequency from signal generator} \right) \left( 2(x_2 - x_1) \right) \]
**Electrostatics**

- **Study of Study of properties of charged particles at rest**

  - This is a way how to identify whether a particle is charged or not, i.e., \( q \neq 0 \)

- **Charge**
  - The product of current and time is called charge.
  - **Symbol**: \( Q \) or \( q \)
  - **Formula**: \( Q = It \)
  - P.S. Scaler
  - **Nature**: +ive or -ive
  - Identification/property:
    1. Behavior of a charged particle in a electric field
      - direction: from electric field (from high to low potential) i.e. from +ive to -ive
      - \( E = \frac{q}{\varepsilon_0} \)

- If a particle shows deviation (from its original path) in a electric and magnetic field, then it must be a charged particle.

- If a particle doesn't show any deviation, then it doesn't possess any charge.
A moving charged particle always deviates from its original path in a magnetic field.

(iii) Behavior of a charged and a neutral particle in a magnetic field.

\[ \mathbf{B} \rightarrow \text{is directed into the plane of page} \]

\[ \alpha = 0 \]

Notes:

1) Charge cannot be created nor be destroyed, but can be transferred from one object to another by contact or by induction. This means either friction or conduction. No physical contact.

2) Protons being a massive particle cannot move in solids, but both the protons and electrons can move in fluids (liquids and gases) such as electrolysis in a solution and ionisation of air. Only electrons can move in solids and not protons.

3) Maximum charge is deposited at sharp edges such as in lightning conductors.

4) Charge is uniformly deposited at regular surface such as in sphere. This charge experiences an equal repulsive force from each other.
4) In static electric field only sphere is the region.
Surface, since it is not a conductor, cannot hold free electron.
Rectangle is not a conductor, it usually electron does not get deposited at sharp edges, so charge separation is not uniform.

5) An object can possess a charge, but is at O potential if it is connected to earth and another charged body is to brought near it.

* description on next page !!!!

6) Charge can only be deposited at the slites, surface and there is no charge even inside a hollow metallic sphere.

That’s why most of the electric wires are only laminated with Cu (i.e. their outer surface is of Cu but their core is of some other metal, mostly Al) for Electric field

* rest on next page

Electric field Strength

Electric force per unit positive charge is called electric field strength.

Symbol: \( E \)

Formula: \( E = \frac{F}{q} \)

Unit: \( NC^{-1} \) or \( Vm^{-1} \)

\( F \) is the force exerted by charged particle (whether +ive or -ive) on a unit +ive charge (i.e. +1C) as shown by the arrow.

\( q = +1C \) is the charged particle possessing +1 charge (as per definition) which experiences the force \( F \)
Direction:
From high to low potential, i.e. towards the motion of unit +ive charge in the field of another charge.

\[ \text{(i) } \begin{array}{c} + \ \stackrel{E}{\longrightarrow} \ - \ \stackrel{E}{\longrightarrow} \ (ii) \ + \ \stackrel{E}{\longrightarrow} \ + \end{array} \]

\[ +12V \quad +6V \]

\[ \text{(iii) } \begin{array}{c} - \ \stackrel{E}{\longleftarrow} \ - \ \stackrel{E}{\longleftarrow} \end{array} \]

\[ -12V \quad -6V \]

\[ \text{(iv) } \begin{array}{c} - \ \stackrel{E}{\longleftarrow} \ - \ \stackrel{E}{\longleftarrow} \end{array} \]

A high and low potential can be between similar charges, i.e. such as 2 +ive charges and 2 -ive charges, as shown in e.g. (ii) and (iii).

\[ \text{(v) } \begin{array}{c} + \ \stackrel{E}{\longrightarrow} \end{array} \]

In this case, the body which has 1 voltage/volt/p.d. will be at a higher potential than the other charged body which will be at a lower potential. In case of similar charges, their +/-/ive matter doesn't matter, but actually their p.d/volt matter. In case of +ive and -ive charges, it is understood that +ive will be at + potential and -ive at - potential.

5). The body which is connected to earth will always be at 0 potential whether it possess any charge or not, since earth is at 0 potential, e.g. at the surface of earth, we are at 0 potential, but as we move up from earth's surface, our potential increases as \( E \) is directed at 0 potential.
6) If we take a piece of wood and cover it surface with water (not pure water), and then connect it to the +ive and -ive terminal of the battery, then it will conduct, since charge are deposited at the outer surface and outer surface is tap water (and not pure water since pure water is an insulator).

- The concept of electric field strength is similar to that of gravitational field strength.

- In gravity field strong it is the strength of the earth which pulls everything on it, towards it. Earth exerts the force on a body irrespective of its mass i.e. it will exert the same on a truck and on a cycle (its force is not dependant on mass, but it exerts equal force on all masses).

- Electric field strength is the strength of to a charged body (whether +ive or -ive) with which it can attract or repel a charged body having +1 charge.

- The force (whether attractive or repulsive) is exerted by the charged on the unit +ive charge (i.e. the body having +1 charge).

5) Any body connected to earth will be at 0 potential. And if a charged body is brought near it, then the body will be oppositely charged by induction, but will remain at 0 potential.
Field Patterns

- Field lines represent the motion of unit +ive charge

Isolated +ive charge

Metallic sphere
and due to negative charge, the particle experiences an attractive force.

As it enters the field from the plate, it tries towards the right, making a curved path as the charged particle experiences an attractive force only from this side.

Note:

1) Each field line originate and terminate at 90° to the surface of object, i.e., at the potential.

2) If the separation between field lines vary, then this indicate a non-uniform field.

3) Uniform field is represented by equidistant parallel lines such as between 2 parallel plates.

Uniform electric field strength

\[
W = \text{Work done } = Fe \quad V_{OC} = Fe \quad \frac{F}{V} = \frac{d}{d} \\
E = \frac{V}{d} \quad \text{p.d. between parallel plates}
\]
the units: V/m (electric field)

Speed of a particle in a magnetic field

Since a charged particle initially at rest more along the field line due to electric force. So

Gain in $E_k$ = Loss of Electric $E_p$

\[
\frac{1}{2}mv^2 = VQ
\]

\[
v^2 = \frac{2VQ}{m}
\]

\[
v = \sqrt{\frac{2VQ}{m}}
\]

$v \Rightarrow$ speed
$V \Rightarrow$ p.d.
$q \Rightarrow$ charge of particle
$m \Rightarrow$ mass of particle

Force on a charged particle in an electric field

Since $E = \frac{F}{q}$ \hspace{1cm} (i)

Also $E = \frac{V}{d}$ \hspace{1cm} (ii)

From (i) and (ii):

\[
\frac{F}{q} = \frac{V}{d}
\]
\[ F = \frac{Vq}{d} \]

Magnitude of force \( \Rightarrow F = \frac{Vq}{d} \)

Direction of force \( \Rightarrow \) parallel to field lines

Path of a charged particle in a uniform electric field

**Case 1:** \( \theta = 0^\circ \)

- Straight line path with uniform acceleration (increasing velocity)
- Straight line path with a uniform deceleration (decreasing velocity)

**Case 2:** \( \theta = 90^\circ \)

*Arrows indicate motion of unit +ve charge (in direction of \( E \)) which is towards -ve plate*
both trace a curved path and move towards the oppositely charged plates

Case 3: $\Theta = 180^\circ$

+\(q\) move in a straight line path with a uniform acceleration

-\(-q\) moves in a straight line path with a uniform acceleration

Case 4: $\Theta = 270^\circ$

Both charged particles accelerate and move towards oppositely charged plates
Graphs

1) Electric field strength against distance between parallel plates

\[ E \propto \frac{1}{d} \]

Since \[ E = \frac{V}{d} \]

\[ E \propto \frac{1}{d} \]

\[ d_1 < d_2 < d_3 \Rightarrow \varepsilon_1 > \varepsilon_2 > \varepsilon_3 \]

Online Classes: Megalecture@gmail.com
www.youtube.com/megalecture
www.megalecture.com
b) Electric field strength against distance of a charged particle for any 1 plate

Since separation l/w parallel plates is constant and electric force/field strength is independent of position of charge particle l/w two plates. So electric field strength remain constant. A same concept as that of g (due to gravity) in earth’s field, no matter where the body is, the value of g will remain 9.81 m/s²

c) Speed against distance travelled by a charged particle in a uniform electric field

\[ u = 0 \]
\[2a_s = v^2 - u^2\]
\[2 \left(\frac{F}{m}\right)s = v^2 - (0)^2\]
\[v^2 = \left(\frac{2F}{m}\right)s\]
\[v^2 = \text{(constant)} s\]
\[v \propto \sqrt{s}\]
\[v \propto \sqrt{d}\]

<table>
<thead>
<tr>
<th>s/m</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>v/(m/s)</td>
<td>0</td>
<td>1</td>
<td>1.41</td>
<td>1.73</td>
<td>2</td>
</tr>
</tbody>
</table>

\[v/(m/s)\]

\[s/m\]
Electric Currents (Base Unit)

Definition:
Flow of charged particles (e) i.e. e² per unit time is called current.

Symbol: I

Formula:
(i) \( I = \frac{Q}{t} \)

(ii) If \( n \) charged particles each of charge \( e \) flows through a cross-section in time \( t \), then Total charge = \( Q = ne \)

Current = \( I = \frac{Q}{t} \)

Unit: Ampere (A)

PS: Vector

Direction: From high to low potential

Types:
- Alternating current (AC)
- Direct current (DC)

1) Definition:
The current whose magnitude and direction changes many times in one direction.

2) Definition:
The current which flows in one direction is called DC.
2) **Waveform**: a pattern in which magnitude changes regularly as well as direction as graph.

(i) is in 2 quadrants for pure sine wave AC.

(ii) is in 1 quadrant for square wave AC.

(iii) can be constant, like in (i).

(i) Here magnitude is 1st constant then direction.

(ii) Here magnitude is 1st constant then direction changes.

(iii) Here magnitude increases uniformly and then direction changes, then it decreases uniformly until reaches 0, then again.

3) **Sources**: AC generator, cell, battery, thermocouple, DC generator, etc.

4) **Colour code of wires**: -
   - Live wire (High potential wire) → Brown
   - Neutral wire (Low potential wire) → Blue
   - Earth wire (Zero/earth potential) → Green or
Note:
The area under the current against time graph defines the amount of charge flow.

Q2) The current in a wire changes uniformly from 200 mA to 180 mA over a period of 8 s. Calculate the charge which flows in this time.

1st method:

\[
\text{Area} = \frac{1}{2} \times (200 + 180) \times 8 \times 10^{-3}
\]

= \text{C}

2nd method:

\[
\text{Avg. current} = \frac{\text{total charge}}{\text{total time}}
\]

\[
\frac{200 + 180}{8} = \frac{\text{C}}{2}
\]

\[
\text{C} = 380 \text{ C}
\]

Resistance

def. Potential difference per unit current is called resistance.

Symbol: \( R \Rightarrow \) for external resistance

\( r \Rightarrow \) internal
Formulas:

\[ V = \frac{p \cdot d}{A} \quad \text{Ohm's Law} \]

P.S. - Scalar

unit = ohm (Ω)

\[ 1 \Omega = \frac{1 \text{ volt}}{1 \text{ Ampere}} \]

Dependance:

1) Length of conductor:

\[ R \propto \frac{L}{A} \]

2) Cross-sectional area:

\[ R \propto \frac{1}{A} \]

3) Nature of material:

Combining 1 and 2:

\[ R = \frac{L}{A} \]

where \( \rho \) is the constant of proportionality and is called resistivity of conductor and depends upon nature of material.
**Note:**

- $F \approx 10^{-8}$ N for conductor (Cu, Brass, Al, etc.)
- $F \approx 10^{-6}$ N for semiconductor (e.g., Si)
- $F \approx 10^{-4}$ N for insulator (e.g., plastic)

(a) The tensile force is acting on a copper wire of length `L` and cross-sectional area `A` which extend it to a length of `2L`, but no change in volume occur. Calculate the ratio of final resistance to initial resistance of wire.

\[
\frac{R_f}{R_i} = \frac{V}{\frac{V}{2A}}
\]

\[
R_f = \frac{(2L)}{(L)} \left( \frac{A_i}{A_i} \right) = \frac{2}{1} \times \frac{A_i}{A_i}
\]

\[
= 4:1
\]

\[\text{volume remains explanation: volume remains equal to the volume of } R_i, \text{ which is } A \times L.\]

\[\text{volume volume same, area } (i.e. A) \text{ must be divided by 2.} \]

\[\text{volume } Vol = (A)(2L) \implies Vol = A \times L \text{ hence.}\]
Panel A is a same material with same dimensions. Calculate the ratio $\frac{R_p}{R_o}$ of opposite shaded regions of material.

$R_p = \frac{X_1 L_p}{A_p}$  
$R_o = \frac{X_2 L_o}{A_o}$

$\frac{R_p}{R_o} = \frac{\frac{X_1 L_p}{A_p}}{\frac{X_2 L_o}{A_o}}$

$= \left( \frac{L_p}{A_p} \right) \left( \frac{A_o}{L_o} \right)$

$= \left( \frac{7.0}{4.0} \right) \left( \frac{3.0 \cdot 2.0}{4.0} \right)$

$= \frac{4.0}{1}$

*flow of $e^-$ is from low to high potential i.e. from $-i.e.$ to $+i.e.$

*flow of current is from high to low potential i.e. from $+i.e.$ to $-i.e.$
Difference between e.m.f. and p.d. (Voltage)

1. metallic wire contains a lot of free electrons
   - e.m.f. is always EMF of a source

2. def. EMF converted to electrical energy = e.m.f.
   Any form of energy converted to electrical energy per unit charge is called e.m.f.

3. def. Electrical energy converted into any other form = p.d.
   - Energy can’t be transformed from one form to another

4. 12V = 12J i.e.
   - Energy carried/occupied by 1 C of charge

5. def. It is the amount of energy dissipated to move a unit charge in a complete circuit it or external component of appliance
   - It is the energy dissipated by the source
The viscosity (or resistance/opposition) of liquid is more as compared to metallic wire → 10^6 times, when moving in the fluid, in the battery/cell experiences opposition or resistance which is represented by small ‘r’ and has to do work against it (and this chemical energy is converted to electrical, e.g. for us, even walking/running in water is difficult).

3) emf is always a source such as cell, battery, thermocouple, generator, etc.

\[ E = I(R+r) \]

3) pd or potential difference is always across a component, appliance or external circuit.

4) A voltmeter connected across a source measures anywhere in the circuit. If no current circuit measures the flow through the p.d. of component or circuit → if switch is closed then all the voltmeters connected across source → only then emf will be recorded by the voltmeter.

When S is open:
\[ V_1 = 12 \text{ V and measure emf} \]
\[ \Rightarrow V_1 = V_2 = V_3 = V_4 = 12 \text{ V and all} \]
\[ \text{and no pd measured on all the voltmeter} \]
**OHM's Law**

- This law only applies to conductors and not to semi conductors or insulators.

**Statement:**
- The pd across the ends of a conductor is directly proportional to current, provided physical conditions remain constant.

**Mathematical Form:**
- \[ V = I \times R \]
- \[ V = R \times I \]

Where 'R' is the constant of proportionality and is called resistance of a conductor.

**Graph:**
- \( V \) against \( I \)
- \( R = \text{gradient of } V \) against \( I/A \) graph
- \( R = \text{reciprocal of gradient of } I/A \) against \( V \) graph
1) Ohm’s Law is only applicable to conductors, not to semi-conductors, insulators or gas discharge tube.

2) The physical conditions of the conductor such as its temperature, pressure, length, cross-sectional area or stress must remain constant.

Ohmic and Non-ohmic conductors

a) Ohmic Conductors:
Conductors which obey Ohm’s law and provide a straight line graph from origin between voltage and current.

b) Non-Ohmic Conductors:
Conductors which provide a curved graph between voltage and current due to change of resistance are non-ohmic conductors i.e. diode (PN junction), thermistor, LDR, filament lamp, etc.

i) Filament Lamp
Characteristic:
- Temperature leads to expansion which leads to an increase in the value of $R$ in $R = \frac{\rho L}{A}$, hence $R$ increases. So, due to the above reason, resistance will increase in filament lamp, also $R_{metal} \uparrow$ if $(temp) \uparrow$ or vice versa.
Online Classes: Megalecture@gmail.com
www.youtube.com/Megalecture
www.megalecture.com

Note: For curved graphs between \( y \) and \( \frac{I}{A} \), draw straight lines from instantaneous points on graph to origin (i.e. 0) and get their gradient.

Relative order of gradient:
- Relative order of gradient: 
  \[ A < B < C \]
- Relative order of resistance:
  \[ R_A < R_B < R_C \]

(ii) Thermistor
- Characteristic: A temperature sensor whose resistance decreases with the increase of temperature, or vice versa.
Symbols:

Non-ohmic graph:

\[ V/I \]

Relative order of gradient:

\[ A > B > C \]

Relative order of resistance:

\[ R_A > R_B > R_C \]

(iii) Light dependant resistor (LDR)

Characteristics:

\[ R_{LDR} \propto \text{(intensity of light)} \]

Symbol:

Non-ohmic graph: Same as the previous graph.

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www.megalecture.com
(iv) **Semi-conductor Diode**

Symbols

- **N-type**
- **P-type**
- **N-type (i.e. negative type)**
- **P-type (i.e. positive type)**

Non-ohmic graphs

- **Forward biasing**
- **Reverse biasing**

*Here, a microammeter is used instead of milliammeter (mA), as due to biasing, current is already very less and in reverse biasing, diode doesn’t conduct, so (mA) is showing 1x10⁻⁶ (as shown in graph), and mA will show nothing at all.*

*Which option provides the greatest resistance?*
Identify the correct graph for filament lamp and ohmic conductor.

- Metal at high temp
- LDR
- Metal at low temp

(A) $S$  $T$  $U$
(B) $U$  $S$  $T$
(C) $S$  $U$  $S$
(D) $T$  $T$  $U$

(Q) $R = \frac{V}{I}$

$= \frac{9}{3}$

$= 3\ \Omega$
\( R = \frac{U}{I} \)

\( E = 10 \text{V} \)

\[ E = I(R + r) \\
10 = 2(4 + r) \\
r = 1 \Omega \]

**Electrical power**

**Definition:** Electrical energy transferred per unit time is called electrical power.

**Symbol:** \( P \) (capital P)

**Formulas:**

\[ P = \frac{W}{t} \]

But \( W = VI \)

\[ P = V(\frac{\delta}{t}) \]

\[ P = VI \]

\[ P = (IR)(I) \]

\[ P = I^2R \]

\[ P = \frac{V^2}{R} \]
Electrical energy

Since \( E = PE \)

\[
E = \sqrt{VI} = I^2RT = \frac{V^2t}{R}
\]
DC Circuits

KIRCHHOFF'S FIRST LAW / KIRCHHOFF'S CURRENT LAW

**Statement:**
The algebraic sum of all the currents entering a junction must be equal to the algebraic sum of currents leaving a junction.

**Mathematical Form:**

\[ I_1 + I_5 = I_1 + I_3 + I_4 \]

Note:
1) Kirchhoff's first law is based upon the principle of conservation of charge, since current is the flow of charged particles.
2) The effective resistance of resistors in series is proved by using this law.
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www.youtube.com/megalecture
www.megalecture.com

**Statement:**

The algebraic sum of emfs of the sources must be equal to the potential drop or pd or voltage across components in a closed loop or circuit.

**Mathematical Form:**

\[ \varepsilon_1 + \varepsilon_2 = I(R_1 + R_2 + R_3) \]
\[ \varepsilon_1 + \varepsilon_2 = IR_1 + IR_2 + IR_3 \]
\[ \varepsilon_1 + \varepsilon_2 = V_1 + V_2 + V_3 \]
\[ \leq E = V \leq \varepsilon \]

**Note:**

1) Kirchhoff's 2nd law is based upon the principle of conservation of energy.
2) The effective resistance of resistors in parallel is proved by using this law.
Loop Analysis

Notes:
1) emfs of the sources are added if they draw current in the direction of assumed loop and subtracted if the current drawn by them is opposite to the loop.

2) We put +ve sign with current if it is along the loop and -ve sign if it is against the assumed loop.

a) Single loop analysis

\[ E_1 - E_2 = I(R_1 + R_2 + R_3 + r_2 + r_4) \quad \text{(1)} \]

b) Loop abcda

\[ -E_1 + E_2 = -I(R_1 + R_1 + R_2 + R_3 + r_2 + r_4) \quad \text{(2)} \]

I have multiplied whole eq. (2) with \(-1\).
b) Multiple loop analysis:

\[ E_1 - E_2 = I_1 R_6 + I_1 R_1 + I_1 R_2 - I_2 R_2 - I_2 R_5 \]

Consider only this loop for and leave the rest of the circuit (i.e., consider only abefa circuit)

\[ E_1 - E_2 = I_1 R_6 + I_1 R_1 + I_1 R_2 - I_2 R_2 - I_2 R_5 \]

Now consider only cbdedc loop

\[ -E_3 - E_2 = -I_2 R_2 - I_3 R_5 - I_3 R_2 - I_3 R_3 - I_3 R_4 - I_3 R_3 \]

Now consider the whole circuit and only leave out the central be for branch

\[ E_1 + E_3 = I_1 R_1 + I_1 R_4 + I_2 R_3 + I_3 R_4 + I_3 R_3 + I_3 R_6 \]
a) Mark the directions of current at junction b and c.

b) Write down the voltage eq. for loop:
   (i) abcba
   (ii) bcdecb
   (iii) abcdedfa

b) i) \[ -E_1 + E_2 = -I_1 R_2 - I_2 R_4 - I_1 R_6 + I_2 R_3 \]
   (ii) \[ E_2 - E_3 = I_3 R_4 + I_3 R_5 - I_2 R_3 \]
   (iii) \[ E_1 - E_3 = I_1 R_1 + I_2 R_2 + I_3 R_4 + I_3 R_5 + I_1 R_6 \]

Q)

a) Mark the directions of current at junction c and d.

b) Use K\'s 1st law to write current eq.

(i) loop abcdefga
(ii) loop dcdefed
(iii) loop agfedcba
junction \( f \Rightarrow I_3 = I_1 + I_2 \)

(i) \( \varepsilon_1 - \varepsilon_2 = I_1R_1 + I_1R_2 - I_2R_3 \)

(ii) \( -\varepsilon_2 - \varepsilon_3 = -I_3R_4 - I_3R_5 - I_2R_3 \)

(iii) \( -\varepsilon_1 - \varepsilon_3 = -I_3R_5 - I_3R_4 - I_2R_2 - I_1R_1 \)

(i) \( \varepsilon_1 \)

(ii) \( I_1 \)

(iii) \( I_2 \)

(iv) \( I_3 \)

(v) \( R \)

(vi) \( \varepsilon_2 \)

(vii) \( \varepsilon_3 \)

(i) Relate \( I_1, I_2 \) and \( I_3 \)

(ii) Write voltage eq. for loop

1) \( BCXYB \)

2) \( ABCXYZA \)

(i) \( I_1 + I_2 = I_3 \)

(ii) \( -\varepsilon_2 = -I_2R - I_3R \)

(iii) \( \varepsilon_1 = I_1R = I_1R - I_2R \)

(iv) \( 2I_1R - I_2R \)
a) Relate $I_1$, $I_2$, $I_3$ and $I_4$

b) Write eq. for loop

1) NKLMN
2) NKO N

a) $I_1 + I_3 = I_2 + I_4$

b) $\varepsilon_2 = -I_3R - I_4R - I_4R$

2) $\varepsilon_2 = I_3R + 2I_1R$

Not given in $\Omega$

1) $\varepsilon = T - 20.1$

Calculate current in circuit by using +
\[ \varepsilon_0 - \varepsilon_A = I (r_1 + r_2 + R_0) \]

\[ 12 - 3.0 = I (0.10 + 0.20 + 3.3) \]

\[ I = \frac{2.5}{A} \]

BF is a uniform wire of resistance \( R_2 \). The junction J is half way of BF

a) Relate \( I_1 \), \( I_2 \) and \( I_3 \)

b) Use K2nd law to write loop eq for loop

1) \( HBJFGH \)

2) \( HBODJFGH \)

a) \( I_1 + I_3 = I_2 \)

b) \( \varepsilon_1 = I_1 r_1 + I_1 R_1 + I_2 R_2 \)

\[ \varepsilon_1 = I_2 \frac{r_1}{2} + I_1 \frac{R_1}{2} + I_1 R_1 + I_1 r_1 \]

2) \( \varepsilon_1 - \varepsilon_2 = I_1 r_1 + I_1 R_1 - I_3 R_2 + I_2 R_2 - I_2 \frac{1}{2} R_2 \)
Combination of Resistors

Resistance in series:

A combination in which current gets single path for its flow is called series combination.

Properties:

1) Current: Same amount of current flows through each resistor and is equal to the current which flows through the emf source.

\[ I = I_1 = I_2 = I_3 \]

(ii) P.d/voltage:

The p.d across each resistor is different as per its resistance but the sum of potential drops/p.d is equal to the emf of source by Kirchoff’s 1st law.

\[ V = V_1 + V_2 + V_3 \]

(iii) Effective resistance:

Since \( V = V_1 + V_2 + V_3 \)

\[ IR = I_1R_1 + I_2R_2 + I_3R_3 \]

But in series, \( I_1 = I_2 = I_3 \)

\[ IR = I(R_1 + R_2 + R_3) \]
b) Resistances in Parallel

Definition: The combination in which current gets several paths for its flow is called parallel combination.

Properties

1) Currents: Different amount of current flows through each resistor as per its resistance, but the sum of current through each resistor is equal to the current which flows through the emf source by Kirchoff’s 1st/current law.

\[ I = I_1 + I_2 + I_3 \]

2) pd/voltage: The pd across each resistor is same and is equal to the emf of source as per Kirchoff’s 2nd law.

\[ V = V_1 = V_2 = V_3 \]

3) Effective resistance: Since \( I = I_1 + I_2 + I_3 \)

\[ \frac{V}{R} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \]

\[ \frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \]

or

\[ \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \]
Therefore, the effective resistance of resistors  in parallel is always less than the least resistance of a resistor connected in the combination.

Notes: 1) Effective resistance of n-similar resistors resistances in parallel:

\[ R_n = \frac{R}{n} \]

where, \( R \rightarrow \) resistances of single resistors
\( n \rightarrow \) no. of identical resistors

2) Effective resistance of two resistors in parallel:

\[ \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \]

\[ \frac{1}{R} = \frac{R_2 + R_1}{R_1 R_2} \]

\[ R = \frac{R_1 R_2}{R_1 + R_2} \]

\[ \text{i.e. Effective resistance} = \frac{\text{Product of resistances}}{\text{Sum of resistances}} \]

(a) No. of resistors each having a resistance of 100Ω are available. Show their connection in a combination so as to get an effective resistance of:

a) 400Ω

b) 40Ω \( \Rightarrow R_n = \frac{R}{n} = 100 = 20 \)
Calculate the effective resistance between:

(i) AB
(ii) BC
(iii) CA

Hint: Always assume that an emf source is connected across the junctions between which the effective resistance is to be calculated.

(i) $R_{AB} = R_1 \parallel (R_2 + R_3)$
   \[= \frac{6 \times 8}{6 + 8} = \frac{48}{14} = 3.43 \, \Omega\]

(ii) $R_{BC} = R_3 \parallel (R_1 + R_2)$
   \[= \frac{4 \times 10}{4 + 10} = \frac{40}{14} = 2.86 \, \Omega\]

(iii) $R_{CA}$
If the current $I_2$ is zero, calculate the emf $E_2$ of the source

$$E_1 = 15I_1 + 10I_1 - (1)$$

$$E_1 - E_2 = 0 + 15I_1$$

Loop 1:

$$E_1 = I_1R_3 + I_1R_1$$

$$5 = (I_1 + I_2)R_3 + I_1R_1$$

$$5 = 10I_1 + 10I_2 + 15I_1$$

$$5 = 25I_1 + 10I_2$$

$$1 = 5I_1 + 2I_2 - (1)$$

Loop 2:

$$E_1 - E_2 = -I_2R_2 + I_1R_1$$

$$5 - E_2 = -5I_2 + 15I_1 - (2)$$

Apply condition i.e. $I_2 = 0$ on (1) and (2)

$$I_1 = 1.5 \text{ A}$$

$$5 - E_2 = 15I_1$$

$$5 - E_2 = 15 \left( \frac{I_1}{5} \right)$$
Calculate effective resistance across:

(i) $R_{AB}$

(ii) $R_{BD}$

(iii) $R_{CD}$

(iv) $R_{AC}$

(i) $R_{AB} = R_1 = 2 \Omega$

(ii) $R_{BD} = \frac{R_2}{4} \parallel \frac{R_3}{8}$

\[
= \frac{4 \times 8}{4 + 8} = \frac{32}{12} = 2.7 \Omega
\]

(iii) $R_{CD} = \frac{R_2}{4} \parallel \frac{R_3}{8} = 2.7 \Omega$

(iv) $R_{AC} = R_1 = 2 \Omega$

(v) $R_{AF} = R_1 + \left(\frac{R_2}{4} \parallel \frac{R_3}{8}\right)$

\[
= 2 + \frac{32}{12}
\]

\[
= 2 + 2.7 = 4.7 \Omega
\]
If \( R_1 = R_2 = R_3 = R_4 = R_5 = \text{constant} \), calculate the effective resistance.

(i) \( AC \)

\[
\frac{1}{AC} = \frac{1}{5} + \frac{1}{10} + \frac{1}{10}
\]

\[
\frac{1}{AC} = \frac{2 + 1 + 1}{10}
\]

\[
\frac{1}{AC} = \frac{4}{10}
\]

\[
AC = \frac{5}{2}
\]

(ii) \( AD \)

\[ AD \Rightarrow \]

(iii) \( BD \Rightarrow \) parallel across \( R_5 = 0 \), so no current flows through \( BD \) if it is not taken.
Calculate $R_{AB}$

\[ \Rightarrow R_{AB} = R_1 \parallel R_3 \]

\[ = \frac{(5)(50)}{5 + 50} \]

\[ = \frac{250}{55} \]

\[ = 4.54 \, \text{\(\Omega\)} \times \]

\[ \frac{1}{R} = \frac{1}{5} + \frac{1}{10} + \frac{1}{50} \]

\[ = \frac{10 + 5 + 1}{50} \]

\[ = \frac{16}{50} \]

\[ = \frac{50}{16} \]

\[ = 3.13 \, \text{\(\Omega\)} \]
Step 1: Effective resistance of circuit
\[ R = R_1 + R_2 \]

Step 2: Current in the circuit by Kirchhoff's 2nd law
\[ E = I(R_1 + R_2) \]
\[ I = \frac{E}{R_1 + R_2} \]

Step 3: Same amount of current flows through each resistor
\[ I_1 = I_2 = I = \frac{E}{R_1 + R_2} \]

Step 4: p.d. across \( R_1 \)
\[ V_1 = I_1 R_1 = \left( \frac{E}{R_1 + R_2} \right) R_1 \]

p.d. across \( R_2 \)
\[ V_2 = I_2 R_2 = \left( \frac{E}{R_1 + R_2} \right) R_2 \]
\[ p.i.l = \left( \frac{\text{given resistance}}{\text{sum of resistances in series}} \right) \text{input emf} \]

Practise Q.2

1. \[ V = \frac{10}{2+10+20} \cdot 12 \]
   \[ = 3.75 \text{ V} \]

2. \[ R_1 = 2 \Omega \]
   \[ R_2 = R_3 = 20 \Omega \]
   \[ R_4 = R_5 = R_6 = 60 \Omega \]
   \[ V_1 = \frac{20}{2+2} \cdot 12 \]
   \[ = \left( \frac{10}{32} \right) \cdot 12 \]
   \[ = 3.75 \text{ V} \]
\[ V_2 = \frac{20}{R_{10} + R_{22} + R_{33}} \]
\[ = \frac{20}{3} \]
\[ = 7.5 \text{V} \]

\[ \text{Effective} \ R = 10 + \left( \frac{22}{3} \right) \]
\[ \frac{10 + 22}{3} = \frac{32}{3} \]

\[ V = \frac{R_{22}}{R_{10}} \]
4) \[ R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = 10\, \Omega \]

Potential is taken with reference to earth or 'i.e.',

\[ V = V_A - V_B \]

\[ = \left( \frac{R_2}{R_1 + R_2 + R_3} \right) E - \left( \frac{R_6}{R_4 + R_5 + R_6} \right) E \]

\[ = \left( \frac{20}{10 + 10 + 10} \right) (12) - \left( \frac{10}{10 + 10 + 10} \right) (12) \]

\[ = 4\, V \]
Calculate
(i) \( V_{CD} \)
(ii) \( V_{BD} \)
(iii) \( V_{AC} \)

\[
(i) \quad V_{CD} = \left( \frac{R_3}{R_4 + R_3} \right) E = 20 \]  \\
= \left( \frac{20}{12 + 20} \right) (12) \quad (\#)  \\
= 7.5 \text{ V}
\]
Calculate

(i) \( V_{AB} \)

\( V_{AB} = \left( \frac{R_1}{R_1 + R_2} \right) E \)
\( = \left( \frac{2}{2 + 4} \right) \quad (12) \)
\( = 4 \, V \)

(ii) \( V_{EO} \)

\( V_{EO} = \left( \frac{R_4}{R_5 + R_4 + R_3} \right) E \)
\( = \left( \frac{16}{32 + 16 + 8} \right) \quad (12) \)
\( = 3.43 \, V \)

(iii) \( V_{BE} = V_{BC} - V_{EC} \)

\( V_{BE} = \left( \frac{R_2}{R_1 + R_2} \right) E - \left( \frac{R_{43}}{R_5 + R_4 + R_3} \right) E \)
\( = \left( \frac{4}{2 + 4} \right) \quad (12) - \left( \frac{24}{32 + 16 + 8} \right) \quad (12) \)
\( = 2.86 \, V \)
a) Calculate
(i) $V_{AB}$
(ii) $V_{BC}$
(iii) $V_{CD}$

b) Draw the graph of P.D against position A, B, C and D of above figure.

(i) $V_{AB} = \left( \frac{L_1}{L_1 + L_2 + L_3 + L_4} \right) (12) = 3.4 \text{ V}$

(ii) $V_{BC} = \left( \frac{8}{L_1 + L_2 + L_3 + L_4} \right) (12) = 6.8 \text{ V}$

(iii) $V_{CD} = \left( \frac{2}{L_1 + L_2 + L_3 + L_4} \right) (12) = 1.7 \text{ V}$
Sliding wire potentiometers

\[ V_{\text{out}} = \left( \frac{E}{R_1 + R_2} \right) R \]

Output voltage = (constant current) (Resistance)

\[ V_{\text{out}} \propto R \]

But, \[ R = \frac{L}{A} \Rightarrow R \propto L \]

\[ \Rightarrow V_{\text{out}} \propto L \]

So, \[ V_{\text{out}} \propto L \]

i.e. output voltage \( \propto \) length of conductor

Relative speed of motor:

\[ V_A > V_B > V_C > V_D > V_E \]

Reason:

- length of conductor across (in parallel to) motor

\[ L_A > L_B > L_C > L_D > L_E \]
So, resistance of conductor across motor \((R_{A-L})^2\) is less than each other;

\[R_A > R_b > R_c > R_d > R_e\]

Therefore, potential across motor:

\[V_A > V_b > V_c > V_d > V_e\]

Use of thermister as potentiometers in fire alarm circuit:

<table>
<thead>
<tr>
<th>At low temp:</th>
</tr>
</thead>
<tbody>
<tr>
<td>* (R_v) ↑ but (R_f) remain fixed</td>
</tr>
<tr>
<td>* By comparison ((R_v &gt; R_f))</td>
</tr>
<tr>
<td>* By potentiometer principle, (V_{max} R_v) ((\text{pd across } R_v)) &gt; ((\text{pd across } R_f))</td>
</tr>
<tr>
<td>* This lesser pd across (R_f) is even lesser than the operating voltage of bell, so it will not switch on</td>
</tr>
</tbody>
</table>
At high temp:

* $R_v \downarrow$, but $R_f$ remain fixed
* By comparison ($R_v < R_f$)
* By potentiometer principle, $(V_{out} < R) - (p.d. across R_v) \leq (p.d. across R_f)$
* This greater p.d. it across $R_f$ is equal to the operating voltage of LED, so it will ring.

Use of LDR as potentiometer in LED circuit:

```
  \[ \begin{array}{c}
    \text{LDR} \\
    R_v \\
    R_f \\
    \text{to other LEDs in parallel}
  \end{array} \]
```

Day time (sunlight):

* $R_v \downarrow$, but $R_f$ remain constant
* By comparison, $(R_v < R_f)$
* By potentiometer principle $(V_{out} < R) - (p.d. across R_v) \leq (p.d. across R_f)$
* This will lesser p.d. across $R_v$ is even lesser than the operating voltage of LEDs, so they will not emit light.
Night time (Moon light) -

* \( R_V \uparrow \) but \( R_P \) remain fixed
* By comparison \( (R_V > R_P) \)
* By potentiometer principle
* (p.d across \( R_V \)) \( > \) (p.d across \( R_P \))
* This greater p.d across \( R_P \) is equal to the operating voltage of LEDs, so they all emit light with equal brightness.

(Balance method) \( \Rightarrow \) in which current becomes 0

Comparison of end sources of by Null method

\[ E (\text{Driver/source cell}) \]

\[ L_1 = 0 \]

\[ L_2 = R_2 \]

\[ E_2 = ? \]

Move the sliding contact 'B' along the wire AC until the galvanometer shows zero deflection. So potential difference across \( AB = \text{p.d across XY} \)

i.e. potential at A = potential at X

and " " B = " " Y

So,

\[ V_{AB} = E_{XY} = \left( \frac{L_{AB}}{L_{XY}} \right) E \]
\[ E_2 = \left( \frac{L_{AB}}{L_{AC}} \right) E_1 \]

\[ \frac{E_2}{E_1} = \frac{L_1}{L_2} \]

**Terminal p.d. (def)**:

It is the potential p.d. across the terminals of the cell if it is

\[ E = I(r + R) \]
\[ E = Ir + IR \]
\[ E = Ir + V \]

If the source does not provide current to an external circuit i.e. \( V = 0 \)

\[ E = Ir + V \]
\[ V_{AB} = E = Ir \]

i.e.

Terminal p.d. = emf of source if it does not provide current to an external circuit.
\[ E = (\text{voltage loss in the source}) + V \]
\[ V = E - (\text{voltage loss}) \]

i.e.
the terminal p.d. across the cell is always the same as the potential p.d. across the internal resistance if the internal resistance has negligible value.

**Notes:**
The terminal p.d. of the power supply decreases if the current supplied by it increases due to short circuiting.

* Short circuiting \( \Rightarrow \) high current will pass, as
  \[ E = \frac{V}{R} \Rightarrow \text{heating effect produced} \]
  \[ R = 0 \]
  \[ \text{loss of voltage} \]

\[ \text{Diagram} \]
\[ \text{Current} \]
\[ \text{Resistance} \]
\[ \text{Voltage} \]
**Matter**

- Avg. separation of solids and liquids is same (i.e., the molecules in cluster form in liquid have same separation as the solid.)

Liquid

Solid

- ΔQ (fusion/melting) + ΔQ (sublimation/sublimation) + ΔQ (evaporation)

ΔQ = 0

i.e., no change in temp

- ΔQ (condensation)

Note: particles greater than original, then ΔP > 0, and if lesser, then ΔP < 0

1. If ΔQ = +ive, then ΔU ↑ because

ΔU = ΔE_k + ΔE_p

ΔE_k = 0, due to constant temp

ΔE_p = ↑ due to breaking of bond and/or increase in separation b/w particles

2. If ΔQ = -ive, then ΔU ↓ because

ΔE_k = 0, due to constant temp

ΔE_p = ↓ due to decrease in the separation b/w particles

3. Therefore, (ll) ice < (ll) water < (ll) steam

* ll of ice is lesser than water at same temp (i.e., as its ΔP ↑ due to separation b/w particles, hence it cools, peeps quickly, then cold water at same temp.)

* Bys of steam < than water at 100°C, as ll of steam.

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Relation between volume and average separation between particles/molecules.

Assumption: particles are as small spheres.

Separation between particles = diameter of sphere

\[ V = \frac{4}{3} \pi r^3 \]
\[ V = \frac{4}{3} \pi \left(\frac{d}{2}\right)^3 \]
\[ V = \frac{4 \pi}{24} d^3 \]

\[ V \propto d^3 \] (constant)

or \[ d \propto (V)^{1/3} \]

i.e., separation = cube root of volume

Assumption: particles/molecules.

Atoms as small cubes.

Separation = length of cube

\[ V = l^3 \]
\[ l = (V)^{1/3} \]
Relation b/w density and average separation

\[ \rho = \frac{m}{V} \]

\[ \rho = \frac{m}{d^3} \]

\[ \rho \propto \frac{1}{d^3} \]

Density \( \propto \) (cube of separation)\(^{-1} \)

separation = inverse cube root of density

i.e. \( d = \left( \frac{1}{\rho} \right)^{\frac{1}{3}} \)

Note:

<table>
<thead>
<tr>
<th>Solid</th>
<th>Liquid</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>separation</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Density</td>
<td>1000</td>
<td>1000</td>
</tr>
</tbody>
</table>

* ratio of spacing b/w solids and liquids is same

\( \rho_1 = 5.07 \) g cm\(^{-3} \)

\( \rho_{H_2O} = 1.0 \) g cm\(^{-3} \)

Water vapour = \( \frac{1}{6000} \) g cm\(^{-3} \)

Determine the ratio of:

1. Volume of water vapour
2. Temperature

\[ \frac{1}{6000} : \frac{1}{1600} \]
(ii) Mean separation of molecules in water vapour is liquid water.

(ii) Density of a metal = 4.5g cm\(^{-3}\)

A cube of water metal of mass 48g contains

\[
\frac{V_w}{V_m} = \frac{1}{\frac{1}{V}} = \frac{f_e}{f_v} = 1.0 = 100:1
\]

\[
\frac{dv}{de} = \left(\frac{1}{V}\right)^{\frac{1}{3}} = \left(\frac{f_e}{f_v}\right)^{\frac{1}{3}} = \left(\frac{1.0}{1600}\right)^{\frac{1}{3}} = \left(1600\right)^{\frac{1}{3}} = (1.7)
\]

(i) Calculate the volume of cube

\[
v = \frac{m}{\rho} = \frac{48g}{4.5g cm^{-3}} = 10.7 cm^3
\]
(i) Estimate

1) volume occupied by one atom in a cube

Total volume = (no. of atoms in a cube) \times (volume of each atom)

\[ 10.7 = (6.0 \times 10^{23}) (V) \]

\[ V = 1.78 \times 10^{-23} \text{ cm}^3 \]

2) the separation of the atoms in the cube

\[ d = (V)^{\frac{1}{3}} \]

\[ d = (1.78 \times 10^{23})^{\frac{1}{3}} \]

Melting point:

The max temp at which a solid changes to liquid state.

* temp has a constant value

Note:

1) The addition of impurity and pressure exerted on a solid decreases its melting point.

Boiling point:

The max temp at which the internal vapour pressure becomes equal to external pressure and liquid changes to gaseous state.

\[ \text{Condition} \]

\[ \text{P}_{\text{atm}} \]

\[ \text{P}_{\text{vapour}} = \text{P}_{\text{atm}} + \text{P}_{\text{liquid}} \]

then \( \sigma = \text{constant} \)
Boiling will start quickly in B, as pressure due to liquid column is less in B due to less depth. Hence the condition of internal vapour pressure to external pressure will be satisfied quickly.

Note:
1) The addition of impurity and pressure exerted on a liquid increases its boiling point.

**Difference b/w boiling and evaporation**

**Boiling**
1) Occurs throughout the liquid
2) The temperature of liquid during boiling remain constant
3) Bubbles are formed
4) Occurs at a constant temperature

**Evaporation**
1) Occurs at the surface of liquid
2) The temperature of liquid during evaporation decreases
3) No bubbles are formed
4) Occurs at any temperature i.e. below or even at boiling

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5) Condition of internal vapour pressure to external pressure must be satisfied.

4) No condition of evaporation.

Similarities b/w boiling and evaporation:

1) In both these processes, a liquid changes to vapour state.
2) Thermal energy need to be supplied to increase the rate of evaporation and boiling.

Pressure:

- Force at 90° (i.e., perpendicular force)

- Definition: Normal force per unit area is called pressure.

- Symbol: P

- Formula: \( P = \frac{F}{A} \)

- Unit: \( \text{Nm}^2 \) or \( \text{Pa} \) (Pascal)

Fluid Pressure:

- The force exerted by the fluid particles due to their random collisions per unit area is called fluid pressure.
Formula: \[ P = h \cdot \rho \cdot g \]

where:
- \( h \) = depth of liquid column
- \( \rho \) = density of fluid
- \( g \) = gravitational field strength

Proof of \( P = h \cdot \rho \cdot g \):

\[
P = \frac{F}{A} = \frac{W}{A} = \frac{mg}{A} = \frac{\rho \cdot V \cdot g}{A} = \frac{\rho \cdot (A \cdot h) \cdot g}{A} = \rho \cdot h \cdot g
\]

Upthrust:
The force exerted by the fluid on a submerged object in upward direction due to the difference in pressure is called upthrust.
**Symbol:** $U$

**Formula:**

$$U = F_2 - F_1$$

$$U = P_2A - P_1A$$

$$U = A(P_2 - P_1)$$

$U = \text{constant} \ (P_2 - P_1)$

$U \propto (P_2 - P_1)$

**In Air:**

$$F = W = 570\text{N}$$

$$W = F + ll$$

$$570 = 510 + ll$$

$$ll = 60\text{ N}$$

$$W = F + ll$$

$$570 = 490 + ll$$

$$ll = 80\text{ N}$$
Brownian Motion

def: The random motion of particles of fluid is called Brownian motion. i.e. direction

* Random \rightarrow \text{independent of space and time}
* \text{direction}

Figures:

* Straight lines of different lengths
* Abrupt (rapid) \rightarrow \text{change of path (shown by sharp corners)}
* At least one line must be cut

(If a pattern like this is also not acceptable) \rightarrow \text{there should be no pattern}

Smoke Cell experiment

[Diagram of smoke cell experiment]
Observation:
Small specs of light are observed due to reflection of light rays from the smoke particles. The rapid change of path of smoke particles is due to bombardment of invisible air particles with them. This signifies that air as well gas particles also move randomly.

Note:
Same observation is obtained when pollen grains suspended in water are viewed through a microscope, so this indicates us that all liquid particles move randomly throughout the available space.

Density + States of Matter → from handout
Stress

def. force per unit cross-sectional area is called Stress

* In case of pressure ⇒ 2 objects are involved

* In stress ⇒ the cross-sectional area of that object is taken on which force is applied (i.e. only one object involved, on which force is applied, and the area of which is taken as cross-sectional area).

⇒ Also in stress that object is deformed on which force is applied

* In pressure ⇒ object deformed, other than on which force is applied

Symbol = \( \sigma \) (sigma)

Formula = \( \sigma = \frac{F}{A} \)

Unit = Nm\(^2\) or Pascal (Pa)

PS = Scalar
Types:
(i) Tensile stress:
* extension is produced in the object due to tensile stress

(ii) Compressive stress:
* compression is caused from due to force/stress

Strain

def: change in length per unit original length is called strain.

Symbol: E (Epsilon)

Formula: \[ \frac{\Delta L}{L} \]

Unit: no units due to ratio of similar quantities

\( \sigma \) = Scalar

Types:

(i) Tensile strain:

Extention
original length
1) Compressive strain = \frac{\text{Compression}}{\text{original length}}

**Hooke's Law**

**Statement:** Within the elastic limit, the force applied is directly proportional to the extension produced.

**Mathematical Form:**

\[ F \propto e \]

\[ F = ke \]

where \( k \) is the constant of proportionality and is called spring or elastic limit constant. Its value depends upon the nature of the material.

**Graph:**

- \( F/N \) vs. \( e/m \)
- \( F/N \) vs. \( e/m \)
- \( \text{Lim} \) is the limit of proportionality (End pt. of straight line from origin)
- \( \text{OL} \) is the region where Hooke's Law holds.
* $E \Rightarrow$ Elastic limit (End pt. from where object returns to its original shape and size when applied force is removed from it)
* $OE \Rightarrow$ Elastic region
* Beyond $E \Rightarrow$ Plastic region (Region in which an object is permanently stretched)

- $K$ = Gradient of $F/N$ against $E/N$ graph
- $\frac{1}{K}$ = Reciprocal of gradient of $e/N$ against $F/N$ graph

**Combination of Springs**

(i) Springs in Series:

\[
\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} \rightarrow F
\]

Resultant spring constant $(K_R)$

\[
K_R = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3}
\]

- Identical springs in series

\[
K_n = \frac{K}{n}, \quad K \Rightarrow \text{spring constant of single spring}
\]

$n \Rightarrow$ no. of identical springs

(ii) Springs in Parallel:

* diagram on next page.
\[ K_R = K_1 + K_2 + K_3 \]

### Table

<table>
<thead>
<tr>
<th>Combination</th>
<th>Resultant ( K )</th>
<th>Resultant Extension in terms of ( e )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N=0 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( K )</td>
<td>( K_R = \frac{K}{2} )</td>
<td>( e_{R} = \frac{F}{K_R} )</td>
</tr>
<tr>
<td>( K )</td>
<td>( K_R = K + K )</td>
<td>( e_{R} = \left( \frac{F}{K} \right) \left( \frac{K}{K} \right) )</td>
</tr>
<tr>
<td>( F )</td>
<td>( K_R = \frac{K}{2} )</td>
<td>( e_{R} = \frac{K}{K_R} ) ( \Rightarrow e_{R} = \frac{2}{e} )</td>
</tr>
</tbody>
</table>

\[
K_R = K_1 + K_2 \quad K_R = K + K \quad K_R = 2K
\]

\[
\begin{align*}
K_R &= (2K + K) \\
\frac{e_R}{e} &= \frac{K}{3K} \\
\Rightarrow e_R &= \frac{3K}{2K} \\
\end{align*}
\]

\[
\begin{align*}
K_R &= \frac{2K}{3} \\
\frac{e_R}{e} &= \frac{2K}{3K} \\
\Rightarrow e_R &= \frac{2}{3} e
\end{align*}
\]
Elastic Potential Energy

Already done in work, energy, power.

\[ F_p = \frac{1}{2} \cdot F \cdot x \]

But \( F \cdot x = Ke \)

\[ F_p = \frac{1}{2} (Ke) (x) \Rightarrow F_p = \frac{1}{2} Ke^2 \]

Young Modulus

- **def:** Stress per unit strain is called young modulus.

- **Symbol:** \( E \)

- **Formula:** Stress \( \sigma \) \( \propto \) strain \( \varepsilon \)

\[ \sigma = E \varepsilon \quad \text{This proportionality constant is} \quad E \quad \text{called Young modulus} \]
\[ F = \frac{F_1}{A} = \frac{F_2}{A} \]

Units: Nm^2 or Pascal (Pa)

P.S.: Scalar

Dependence:
Nature of solid material i.e. its crystal structure (arrangement of atoms)

Note:-
(i) Young Modulus is only for solid because one cannot perform deformation fluids, fluids (liquids and gasses) in one direction.
(ii) Its value for metal \( > 10^6 \) Pa.

Example: Experimental determination of Young Modulus of a metallic wire

Significance of apparatus

Main scale \(<\) Vernier scale
is fixed in its position

Vernier scale

Main scale

Vernier scale

Will slide as the wire is when masses are added.
Significance of Apparatus:

(i) A and B are two metallic wires of same material for fair comparison.
(ii) Mass are attached to the lower ends to wire to keep them taut so that there must be no kinks in the wires and accurate length can be determined.
(iii) The lengths of wires should lie long so that lesser is the % percentage uncertainty for greater degree of accuracy (\( \frac{\Delta L}{L} \times 100 \)).
(iv) Measure diameter of wire ‘B’ at different positions along its length and get its mean value.
(v) Main scale is fixed to wire A and a sliding vernier scale to wire B to measure the increase in length.

Procedure:

(i) Add standard masses to the lower end of wire of B and keep the mass of wire constant.
(ii) Measure the corresponding increase in tension of wire B using vernier scale.
(iii) Also remove masses from wire B after loading it one by one to check that wire does not exceed its elastic limit.
Analysis:
Plot the graph of Force/N against extension/m which should be a straight line from origin and finally get its gradient.

\[ \text{Gradient} = \frac{F}{e} \]

Calculation:
\[ E = \left( \frac{E}{e} \right) \left( \frac{L}{A} \right) \Rightarrow E = \left( \text{gradient} \right) \left( \frac{L}{A} \right) \]
\[ \Rightarrow E = \left( \text{gradient} \right) \left( \frac{L}{A} \right) = \frac{\pi d^2}{4} \]

Behavior of a metal wire under stress/tension
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- $L = E \Rightarrow \text{ ultimate }$
- $Y = \text{ peak of curve}$

* $L \Rightarrow \text{ limit of proportionality (end pt. of straight line from origin)}$
* $OE \Rightarrow \text{ region where Hooke's law is valid/applicable}$
* $E \Rightarrow \text{ elastic limit (end point from where the object returns to its original shape and size when applied force is removed from it)}$
* $OE \Rightarrow \text{ Elastic region / Elastic deformation region}$
* Beyond $E \Rightarrow \text{ Plastic region in which an object undergoes permanent deformation and never returns to its original shape/size, where}$
* $Y \Rightarrow \text{ yield point (region from ductile to wire)}$
  - Ductile region starts in which a lesser increase in force causes greater extension in necking is the property of this region

$F \leq 0 \rightarrow F \rightarrow \text{ Neeking}$

$\sigma \Rightarrow \text{ Ultimate tensile stress/Strength pt. of wire}$
Types of Solids

a) Crystalline Solids
   - A definite and uniform pattern throughout structure
   - Definite structure
   - Solids in which atoms are arranged in a definite geometric pattern throughout the lattice structure are called crystalline solids.

Examples:
   - All metals and diamond

Graph:

Area under OAB = energy required to stretch a crystalline solid
Area under BC = energy recovered from a stretch crystalline solid
Area of loop $OABC = \frac{1}{2}$ Energy which cannot be recovered and become the internal energy of solid.

b) (i) Polymers

- Def: *particles arranged in tangled format*
- in a chain, arrangement of atoms regular, same throughout.
- Solid in which atoms are arranged in a regular pattern in a long chain, but the arrangement of atoms in the neighbouring chains is random.

Examples: nylon, rubber (latex), protein, cellulose, plastic, PVC, polythene

Figure:

Regular arrangement of atoms in tangled chains of a polymer, but different chains (neighbouring chains) have different patterns (arrangement) of atoms.
Graph:

\[ F/N \quad \text{loading} \quad \text{unloading} \quad \epsilon/m \]

*Area under OAB \rightarrow Energy required to stretch a polymer
*Area under BCO \rightarrow Energy recovered from a stretched polymer
*Area of loop OABC \rightarrow Energy which cannot be recovered and becomes the internal energy of solid.

b)(i) Amorphous solids

*arrangement of atoms \rightarrow small / short chain format

def: \text{Solids in which atoms are arranged in to a tangled manner over short ranges are called amorphous solids.}

Examples:

Talc, Dust particles, flour

(Anything in ground form)
c) Brittle solids → immediately break when their elastic limit exceeds.
   def. * a very strong compression solids, which break immediately or its elastic limit is exceeded.
   e.g. glass, ceramic, tile, thigh bone, brick.

Notes:
1) The elastic limit, limit of proportionality or breaking point are nearly at the same point.
2) Brittle solids are very strong under compression, but break immediately as their elastic limit is exceeded due to small impulsive force.
Alpha particle scattering experiment

Significance:
To study the smaller size and and greater mass of nucleus.
\[ V \uparrow \text{ and } m \uparrow, \text{ so } x = \frac{m}{V} \]

i.e. dense there is a dense nuclear atom (i.e. dense nucleus is present inside an atom)

Apparatus:
- Zinc sulfide for fluorescence
- Flo
- Travelling microscope
- Gold foil
- Evacuated chamber
- Transparent chamber
- Alpha particle source
- Ra
- 226
Significance of apparatus

(i) α-particles:
- Alpha particle is a massive particle and does not show any deflection due to orbiting e⁻ and come closer to gold nucleus (beta particles show deflection due to orbiting e⁻) and also
- Alpha particles have a constant energy, unlike beta particles. ⇒ p has range of Ex
- Gamma rays ⇒ have no charge, so simply pass through

(ii) Gold foil is used due to its negligible thickness so that alpha particle can pass through

Read black is used so that a collimated beam of alpha particle is directed to the gold foil and absorb randomly emission of particles

Evacuated chambers:
- An evacuated chamber is taken so that alpha particles do not transfer their energy or collision with the gas particles and reach the gold foil with same kinetic energy
Fluorescent wall of Chamber:

Fluorescence (a small spot of light) occurs when alpha particles hit or it whose deflection from the gold foil is studied by the angles marked in degrees.

Observation

Most pass with very little deflection.
Most of the alpha particles pass through the foil with very little deflection and very few of them are deflected at large angles.
One out of 8000 is deflected at at an angle greater than 90°.

Microscopic View

1
2
3
4
5

Reason: Reason of deflection is due to similar charges on a nucleus and α-particles.
Angle of deflection of α-particles depends on the distance of α-particles from gold nucleus \( \left( F \alpha \frac{1}{r^2} \right) \).

Path 1:
- Resultant force = 0 due to same distance from the nuclei of neighbouring atoms.

Path 2, 3, 4:
- Greater deflection as \( F \alpha \frac{1}{r^2} \) is applied.

Path 5:
- α-particle does not carry sufficient energy to overcome the electric potential energy and is bounced back.

Result:
- Smaller size of nucleus.

* Size of nucleus small → hence α-particle deviates otherwise, it would bounce back.

Most of the α-particles pass through the foil with very little deviation, indicating that size of nucleus is very small as compared to an atom.

⇒ Massive nucleus is:
- The concept of light body colliding with massive body.

The bouncing back of α-particle indicates that...
Charge no.:
It is the no. of protons in the nucleus of an atom.

Symbol: Z

Mass no. / Nucleon no.:
It is the no. of protons and neutrons in the nucleus of an atom.

Symbol: A

Formula: A = Z + N where N = no. of neutrons

Isotope:
Nuclei having same charge no. but different mass no. is called isotope.
"only no. of neutrons are different \[\Rightarrow\] hence different mass no."
Nuclide
An element which is identified by its mass no. and charge no. is called nuclide.

Notation: mass no.  \[ {_{6}^{12}C} \]
Symbol: \( ^{12}C \)

Note:
1) Mass of alpha particle = 4.18
\[ = 4 \times (1.66 \times 10^{-27}) = 6.64 \times 10^{-27} \text{ kg} \]

2) Mass of beta particle = 9.11 \times 10^{-31} \text{ kg}

\( 1 \text{ Electron Volt (eV) is the unit of energy} \)
\[ 1 \text{eV} = 1.60 \times 10^{-19} J \]

1) There is no change in the mass no., charge no., mass and energy in any nuclear reaction i.e. all are conserved in a nuclear decay.
Nuclear Reaction

Alpha decay ($\alpha$, $^4_2$He):

$$ ^{A}_{Z}X \rightarrow ^{A-4}_{Z-2}Y + ^{4}_{2}$He $$

$^{226}_{88}$Ra $\rightarrow ^{222}_{86}$Rn + $^{4}_{2}$He

In alpha decay, the mass and charge no. of daughter nuclide is decreased by 4 and 2 respectively.

Beta decay ($^0\beta$ or $^1\bar{e}$):

$$ ^{A}_{Z}X \rightarrow ^{A}_{Z+1}Y + ^{0}_{-1}\beta $$

$^{90}_{38}$Sr $\rightarrow ^{90}_{39}$Y + $^0_{-1}\bar{e}$

In $\beta$-decay, the charge of daughter nuclide is increased by 1, but there is no change in its mass no.

Gamma decay ($\gamma$):

$$ ^{A}_{Z}X \rightarrow ^{A}_{Z}Y + \gamma $$

$^{60}_{30}$Co $\rightarrow ^{60}_{30}$Co + $\gamma$

+ neutrons excite $^0\gamma$ to emit $\gamma$-rays
In $\gamma$-decay, there is no change in the mass no. and charge no. of daughter nuclide.

Radioactivity

The spontaneous and random disintegration of charged particles and rays from the nucleus of unstable nuclide is called radioactive radioactivity. 

Explanation:

i) Spontaneous: Independent of any physical condition i.e. temperature, pressure, humidity factor, electric or magnetic field etc i.e. decay is independent of above factors.

(ii) Random: Constant probability of decay of a nucleus and is specified by the fluctuations in the decay graph.

(iii) Unstable nuclide: nuclide have lesser binding energy per nucleon are unstable.

(iv) Radioactive nuclide: Unstable nuclide which on emit $\alpha$, $\beta$ or $\gamma$ rays is called radioactive nuclide. $\alpha$, $\beta$ and $\gamma$ are not radioactive, the source which the emit these is radioactive.
At 25°C

At 95°C

Note:

If graph of different temperatures shows spontaneous nature,

Fluctuations in decay curve graph curve indicate random nature.
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Exp 1:

- Lead block to produce uniform electric field
- Collimator

Exp 2:

- Photographic plate as a detector
- Evacuated chamber
- Magnetic field directed into the plane of page

\[ x = 2 \]

\[ F \]

Horizontal plate to vertical mounted plate glass screen coated with zinc sulfide (ZnS) for fluorescence
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<table>
<thead>
<tr>
<th>Property</th>
<th>Nature</th>
<th>Helium nucleus</th>
<th>fast moving electron</th>
<th>e.m. ray of highest frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge</td>
<td>Positive</td>
<td>-ive</td>
<td>no charge</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>( \frac{1}{10} c )</td>
<td>( \frac{9}{10} c )</td>
<td>( c )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \frac{1}{10} (3.0 \times 10^7) \text{ms}^{-1} )</td>
<td>( \frac{9}{10} (3.0 \times 10^7) \text{ms}^{-1} )</td>
<td>( 3.0 \times 10^8 \text{ms}^{-1} )</td>
<td></td>
</tr>
<tr>
<td>Ionising ability</td>
<td>Greatest</td>
<td>Intermediate</td>
<td>Least</td>
<td></td>
</tr>
<tr>
<td>Penetration Power</td>
<td>least</td>
<td>Intermediate</td>
<td>Greatest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.0 cm in air</td>
<td>40.0 cm in blocked by air</td>
<td>blocked by 1 mm paper</td>
<td>blocked by 1 mm aluminium</td>
</tr>
</tbody>
</table>