1. Natural of physical world and measurement

1. Briefly explain the types of physical quantities.

Types of physical quantities :

1. Fundamental Quantity :

The quantity which can not be expressed in terms of other physical quantity is known as " fundamental or base quantity "

Example : mass , time , length

2. Derived Quantity :

The quantity that can be expressed in terms of fundamental quantities are called derived quantities.

Example : Area , volume , Force

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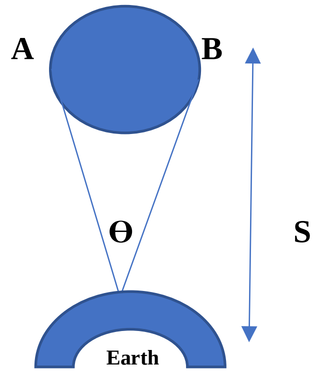
2. How will you measure the diameter of the moon using parallax method ?



* Let O be the observation point on earth.
* d is the diameter of the moon.
* s is the average distance between moon and earth.
* Θ is called angle of parallax.

$$d = S \times \Theta$$

* d can be calculated when S , Θ are measured.

4.What are the limitations of dimensional analysis?

1. It gives no information about dimensionless constant . 1,2 , … π , e (Euler number)

2. It cannot decide whether the given quantity is a vector or scalar.

3.It cannot apply to an equation involves more than three physical quantities.

4. This method is not suitable to derive relations involves trigonometry , exponential and logarithmic quantities.

5.It can only check on whether a physical relation is dimensionally correct but not the correctness of the relation.

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5. Define precision and accuracy . Explain with one example.

Accuracy :

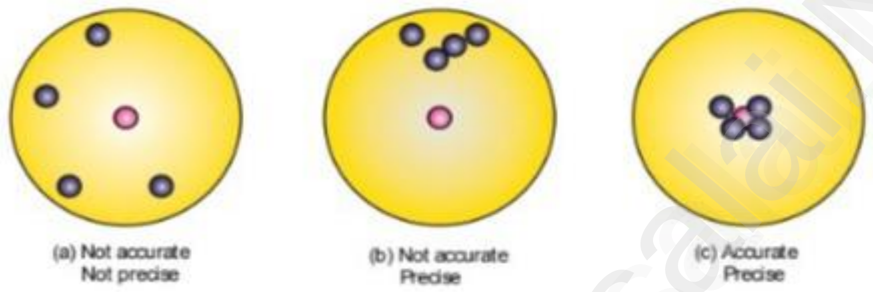
Accuracy refers to how far we are from true value.

Precision :

- **Precision refers to how well we measure.**
- **If a measurement is precise , it not be accurate.**

Example :

1. Not accurate Not precise **2. Not accurate but precise** **3. Accurate precise**



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3. Write the rules for determining significant figures.

Rules	Example	Significant Figure
1. All non zero digits	1342	Four
2. All zero between two non zero	2008	Four
3. All zero left of decimal point	30700.	Five
4. Number without decimal point	30700	Three
5. zeros are significant with measurement	30700 m	Five
6. All zero right decimal point	40.00	Four

---

6 . Define unit.

An arbitrarily chosen standard of measurement of quantity , which is accepted internationally is called unit of the quantity.

---

7. Define Rounding off.

* **Calculators are widely used now a days for calculations.**
* **Calculators has too many figures.**
* **Results have more significant figures.**
* **Numbers containing more than one uncertain number should be round off.**

8.Define dimensionless quantities.

<u>Dimensionless variable :</u>

Physical quantity which have no dimension but have variable.

Ex : Strain , Specific gravity

<u>Dimensionless constant :</u>

Physical quantity which have constant values but have no dimension.

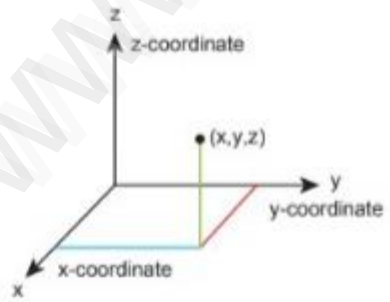
Ex : π , e (Euler's number)

---

2. Kinematics

1. What is meant by cartesian coordinate system ?

The frame of reference with respect to which the position of the object , is described in terms of position coordinates is called cartesian coordinate system.



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2. Define a scalar . Give examples .

It is a property which can be described only by magnitude.

Example : Distance , Mass , Speed

3. Define a vector . Give examples .

It is a quantity which can be described by both magnitude and direction.

Example : Force , Velocity , Displacement

---

4. Write a short note scalar product between two vectors.

The scalar product (dot product) of two vectors is defined as the product of the magnitude of both the vectors and the cosine of the angle between them.

$$\vec{A} \cdot \vec{B} = A B \cos \theta$$

---

5. Write a short note vector product between two vectors.

The vector product (Cross product) of two vectors is defined as another vector having magnitude equal to the product of the magnitudes of two vectors and the sine of the angle between them.

$$\vec{C} = \vec{A} \times \vec{B} = (A B \sin \theta) n$$

6.How do you deduce that two vectors are perpendicular ?

If two vectors A and B are perpendicular to each other then,

1. **Scalar product :** $\vec{A} \cdot \vec{B} = 0$
2. **Because** $\cos 90^0 = 0$
3. **They are mutually orthogonal..**

7.Define displacement and distance.

<u>Distance :</u>

- **Actual path travel by an object.**
- **Given interval of time during the motion.**
- **It is a positive scalar quantity.**

<u>Displacement :</u>

- **It is the difference between the final and initial position of the objects.**
- **Given interval of time during the motion.**
- **It is a vector quantity.**

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8. Define velocity and speed.

Velocity :

- Rate of change of position vector with respect to time.
- It is a vector quantity.
- $V = \lim_{\Delta t \to 0} \frac{\Delta r}{\Delta t} = \frac{d r}{dt}$

Speed :

- Distance travelled in unit time.
- It is positive scalar quantity.
- Magnitude of velocity v is called as speed.
- $v = \sqrt{v_x^2 + v_y^2 + v_z^2}$

---

9. Define acceleration.

- Rate of change of velocity.
- It is a vector quantity.
- SI unit : $m\,s^{-2}$
- Dimension : $M^0 L^1 T^{-2}$
- $a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{d v}{dt}$

---

10. What is the difference between velocity and average velocity ?

Velocity :

- Rate of change of position vector with respect to time.
- It is a vector quantity.
- $V = \lim_{\Delta t \to 0} \frac{\Delta r}{\Delta t} = \frac{d r}{dt}$

Average Velocity :

- Rate of change of displacement vector with respect to time.
- It is a vector quantity.
- $V_{avg} = \frac{\Delta r}{\Delta t}$

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11. Define radian.

Angle subtended at the center of a circle by an arc that is equal in length to the radius of the circle.

$$1 \text{ radian} = \frac{180}{\pi} \text{ degree} = 57.27^{0}$$

---

12. Define angular displacement and angular velocity.

Angular Displacement :

The angle described by the particle about the axis of rotation in a given time is called angular displacement.

$$\Theta = S / r \qquad \text{Unit : radian}$$

Angular Velocity :

- **The rate of change of angular displacement is called angular velocity.**
- **SI unit : rad s^{-1}**

$$\omega = \lim_{\Delta t \to 0} \frac{\Delta \Theta}{\Delta t} = \frac{d\Theta}{dt}$$

---

13. What is non uniform circular motion?

If the velocity changes in both speed and direction during the circular motion we get non uniform circular motion.

Ex : When the bob attached to a string moves in vertical circle , the speed of the bob is not same at all time.

14.Write down the kinematic equation for angular motion.

1. $\omega = \omega_0 + \alpha t$
2. $\omega^2 = \omega_0^2 + 2\alpha\Theta$
3. $\Theta = \omega_0 t + \frac{1}{2}\alpha t^2$
4. $\Theta = \frac{(\omega_0 + \omega)t}{2}$

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15. Write down the expression for angle made by resultant acceleration and radius vector in the non uniform circular motion.

$$\tan \theta = \frac{a_t}{(v^2 / r)}$$

a_t ---------→ Tangential acceleration
v ---------→ Velocity of object
r ---------→ Radius vector

3.Laws of motion

1.Explain the concept of inertia . Write two examples each for inertia of motion , inertia of rest and inertia of direction.

Concept of inertia :

- Inertia means resistance to change its state.
- The inability of an object to move on its own or change its state of motion.

Inertia of rest :

The inability of an object to change its state of rest.
Ex : 1. Passengers experience backward push in sudden start of bus.
2. Tightening of seat belts in a car when it stops quickly.

Inertia of motion :

The inability of an object to change its state of motion.
Ex : 1. Passengers experience forward push in sudden brake of bus.
2. Ripe fruits fall from the trees in the direction of wind.

Inertia of direction :

The inability of an object to change its state of direction.
Ex : 1. A stone moves tangential to circle.
2. When a car moves towards left , we turn to right.

---

2. State Newton's second law.

The force acting on an object is equal to rate of change of its momentum.

$$\vec{F} = \frac{d\vec{p}}{dt}$$

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3. Define one Newton.

One newton is defined as the force which acts on 1 kg of mass to give an acceleration 1 m s^{-2} in the direction of force.

---

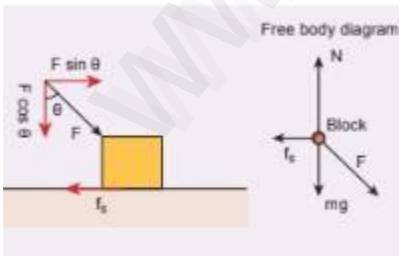
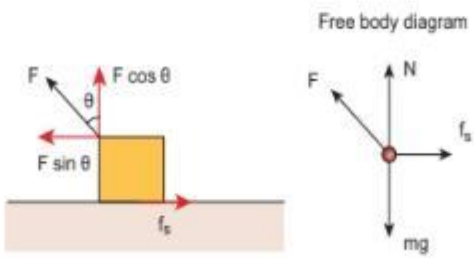
4. Show that impulse is the change of momentum,.

If a force F acts on the object in a very short interval of time Δt.

1. $F = \frac{dp}{dt}$
2. $dp = F\,dt$
3. $\int dp = F \int dt$
4. $p_f - p_i = F(t_f - t_i)$
5. $\Delta p = F\,\Delta t$
6. $J = \Delta p.$

---

4. Using free body diagram , show that it is easy to pull an object than to push it.

Push on object	Pull on object
$N_{PUSH} = mg + F\cos\theta$	$N_{PUSH} = mg + F\cos\theta$
$F\cos\theta$ → Perpendicular Component	$F\sin\theta$ → Parallel Component
	

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6. Explain various types of friction . Suggest a few methods to reduce friction.

Friction :

Friction is form of force . It always oppose the relative motion between an object and the surface where it is placed.

Types of friction :

1. Static friction
2. Kinetic friction

1. Static friction

- The force which opposes the initiation of motion of an object on the surface.
- It does not depend upon area of contact.
- Coefficient of static friction μ_s

$$0 \leq f_s \leq \mu_s N$$

2. Kinetic friction

- If the external force acting on the object is greater than maximum static friction , the objects begin to slide.
- When an object slides , the surface exerts frictional force called ' Kinetic friction'
- It is also called ' sliding friction ' or Dynamic friction'
- Coefficient of kinetic friction is μ_k

$$f_k = \mu_k N$$

Methods to reduce friction :

1. By polishing surface
2. By using lubricant
3. By using ball bearings

---

7. What is the meaning of " pseudo force " ?

- Centrifugal force arise whenever the motion is analysed from rotating frame.
- The inertial motion of the object appears as centrifugal force in the rotating frame.
- It is called as " Pseudo Force "
- It acts outwards the canter of circle
- $F_{cf} = m a_{cf} = \frac{m v^2}{r}$

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8.State the empirical laws of static and kinetic friction.

1. Empirical relation for magnitude of static frictional force.

$$0 \leq f_s \leq \mu_s N$$

2. The force of static friction can take any value from zero to $\mu_s N$.

3. If the object is at rest and no external force is applied on the object , the static friction on the object is zero. $f_s = 0$.

4. If there is an external force applied parallel to the surface , then force of static friction exactly equal to external force. $f_s = F_{ext}$.

---

9. State Newton's third law.

Newton's third law states that every action there is an equal and opposite reaction.

$$\vec{F}_{12} = - \vec{F}_{21}$$

10.What are inertial frames ?

- **Newton's first law is valid only in certain special reference frame called 'inertial frame '**
- **If an object experiences no force , it moves with constant velocity or remains at rest.**
- **If an object is free from all forces then it moves with constant velocity or remains at rest when seen from inertial frame.**

---

11. Under what condition will a car skid on a levelled circular road ?

If static friction is not able to provide enough centripetal force to turn , the vehicle will start to skid.

$$\frac{m v^2}{r} > \mu_s m g$$

$$\mu_s < \frac{v^2}{r}$$

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4. Work , Energy , Power

1. Explain how the definition of work in physics is different from general perception.

- The term work refers to both physical as well as mental work.
- Any activity can generally be called as work.
- Work is said to be done by force when the force when the force applied on a body displaces it.
- Work and energy are equivalents.
- Work done is scalar quantity.
- SI UNIT : N m (or) joule
- Dimension : $M L^2 T^{-2}$

$$W = \vec{F} \cdot \vec{dr}$$

2.Write the various types potential energy . Explain the formulae.

1. **Gravitational Potential Energy :**

The energy possessed by the body due to gravitational force.

$$U = m g h$$

m → mass g → gravity h → height

2. **Elastic Potential Energy :**

The energy due to spring force and other similar forces give rise to elastic potential energy.

$$U = \frac{1}{2} k x^2$$

k → Force constant x → Displacement

3. **Electrostatic Potential Energy :**

The energy possessed due to electrostatic force.

$$U = \frac{1}{4 \pi \epsilon_0} q_1 q_2$$

q_1 q_2 → Charges r → distance

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3. Write the differences between conservative and non conservative forces. Give two examples.

Conservative Force :

1. Work done is independent of path.
2. Work done in a round trip is zero.
3. Total energy remains constant.
4. Work done is completely recoverable.
5. Force is negative gradient of potential energy.
6. Example : Spring force , Magnetic force

Non conservative Force :

1. Work done is dependent of path.
2. Work done in a round trip is not zero.
3. Energy is dissipated as heat energy.
4. Work done is not completely recoverable.
5. No such relation exists.
6. Example : Frictional force , Viscous force

---

4. Explain the characteristics of elastic and inelastic collision.

Elastic Collision :

1. Total momentum is conserved.
2. Total kinetic energy is conserved .
3. Forces involved are conservative forces.
4. Mechanical energy is not dissipated.

Inelastic Collision :

1. Total momentum is conserved.
2. Total kinetic energy is not conserved .
3. Forces involved are non conservative forces.
4. Mechanical energy is dissipated into heat and light.

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5. Define coefficient of restitution .

$$e = \frac{\text{Velocity of separation after collision}}{\text{Velocity of approach before collision}}$$

$$e = \frac{V_2 - V_1}{u_2 - u_1}$$

6.Define power.

* Rate of work done or energy delivered is called as " power "
* It is a scalar quantity.
* S I unit : Watt ($1\ W = J\ s^{-1}$)
* Dimension : $M\ L^2\ T^{-3}$
* $P = W / t$

---

7. Define Law of conservation of energy.

- The law of conservation of energy states that energy can neither be created nor destroyed.
- It may be transformed from one form to another form.
- But total energy of an isolated system remains constant.

---

8. Define loss of kinetic energy in inelastic collision.

In perfectly inelastic collision , the loss in kinetic energy during collision is transformed to another form of energy like sound , thermal , heat , light etc.

K . E before collision : $K.E_i = \frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2$

K . E after collision : $K.E_f = \frac{1}{2} (m_1 + m_2) v^2$

Loss of K . E : $\Delta Q = K.E_i - K.E_f$

$$\Delta Q = \frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 - \frac{1}{2} (m_1 + m_2) v^2$$

$$\Delta Q = \frac{1}{2} \frac{m_1 m_2}{m_1 + m_2} (u_1 - u_2)^2$$

---

5. Motion of system of particles & Rigid bodies

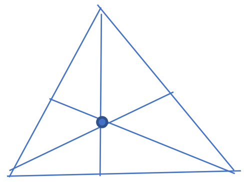
1.Define centre of mass.

- **The centre of mass of a body is defined as a point where the entire mass of the body appears to be concentrated.**
- **The centre mass is at the geometric centre of the body.**

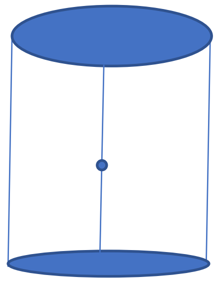
----

2. Find out of the centre of mass of the given geometrical structures.

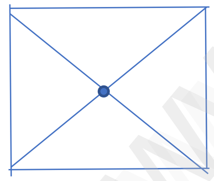
a) Equilateral triangle : centre of mass lies on centre



b) Cylinder : Centre mass lies on central axis



c) Square : Centre of mass lies in diagonal meet



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3. Define torque and mention its unit.

- **Torque is defined as the moment of external applied force about a point or axis of rotation.**
- **Torque is a vector quantity.**
- **It is called as pseudo vector.**
- **S I Unit : N m**

$$\vec{\tau} = \vec{r} \times \vec{F} = r\ F\ \sin\theta\ n$$

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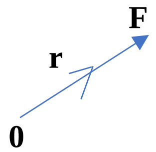
4. What are the conditions in which force can not produce torque ?

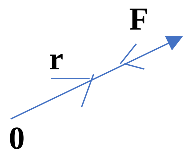
1. The torque is zero when r and F are parallel or antiparallel.

- If parallel , then $\Theta = 0^0$ and $\sin 0^0 = 0$



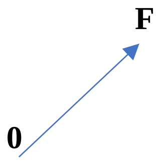
$\Theta = 0^0$; $\tau = 0$

- If anti parallel , then $\Theta = 180^0$ and $\sin 180^0 = 0$



$\Theta = 0^0$; $\tau = 0$

2. If torque is zero if the force acts at the reference point as r = 0 , $\tau = 0$



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5. Give any two examples of torque in day-to-day life

1. Turning of a nut using wrench fully.
2. Opening a bottle cap.
3. Opening and closing a door about the hinges.

---

6. What is the relation between torque and angular momentum?

An external torque on a ridge body fixed to an axis produces rate of change of angular momentum in the body about the axis.

$$\tau = I\alpha$$

$$\tau = I\frac{d\omega}{dt}$$

$$\tau = \frac{d(I\omega)}{dt}$$

$$\tau = \frac{dL}{dt}$$

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7. What is equilibrium ?

- When all the forces act upon the object are balanced, then the object is said to be an equilibrium.
- A rigid body is said to be in mechanical equilibrium when both its linear momentum and angular momentum remain constant.

---

8. How do you distinguish between stable and unstable equilibrium.

Stable equilibrium	Unstable equilibrium
1.Linear momentum and angular momentum are zero.	1.Linear momentum and angular momentum are zero.
2.The body tries to come back to equilibrium if slightly disturbed and released.	2.The body cannot come back to equilibrium if slightly disturbed and released.
3.The center of mass of the body shifts slightly higher if disturbed from equilibrium.	3.The center of mass of the body shifts slightly lower if disturbed from equilibrium.
4.Potential energy of the body is minimum and it increases if disturbed.	4.Potential energy of the body is not minimum and it decreases if disturbed.

---

9. Define couple. (or) Define moment of couple.

A pair of forces which are equal in magnitude but opposite in direction and separated by a perpendicular distance so that their lines od action do not coincide that causes a turning effect is called a couple.

---

10. State principle of moments.

Sum of the clockwise moments is equal to sum of the anti clock wise moments when a body is rotational equilibrium or algebraic sum of moments at any point is zero.

$$d_1 \; F_1 = d_2 \; F_2$$

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11. Define centre of gravity.

The centre of gravity of a body is the point at which the entire weight of the body acts irrespective of the position and orientation of the body.

---

12. Mention any two physical significance of moment of inertia.

1. **For rotational motion, moment if inertia is a measure of rotational inertia.**
2. **The moment of inertia of a body is not an invariable quantity. Its depends not only on the mass of the body, but also on the way the mass is distributed around the axis of rotation.**

---

13. What is radius of gyration?

The radius of gyration of an object is the perpendicular distance from the axis of rotation to an equivalent point mass, which would have the same mass as well as the same moment of inertia of the object.

- **Radius of gyration is a distance.**
- **Its unit is metre (m).**
- **Dimension is L.**
- $I = M K^2$
- **I → Moment of inertia**
- **M → Mass of the object**
- **K → Radius of gyration.**

---

14. State conservation of angular momentum.

When no external torque acts on the body, the net angular momentum of a rotating rigid body remains constant. This is known as law of conservation of angular momentum.

- **If** $\tau = 0$ **then** $L = \text{constant}$
- $I\omega = \text{Constant}$

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15. What are the rotational equivalents for the physical quantities, (1) mass and (2) force?

(1) For mass : Moment of inertia, $I = mr^2$
(2)For force : Torque $\tau = I\alpha$

---

16. What is the condition for pure rolling ?

- **Rolling is the combination of rotational and translational motions.**
- **V_{TRANS} and V_{ROT} are equal in magnitude and opposite in direction.**
- $V = V_{TRANS} - V_{ROT} = 0$
- $V_{TRANS} = V_{ROT}$
- $V_{TRANS} = V_{CM} = R\omega$
- $V_{CM} - R\omega = 0$
- **$V_{roll} = 0$ = translational velocity + tangential velocity due to rotation. $v - r\omega = 0$.**

---

17. What is the difference between sliding and slipping?

S.NO	Sliding	Slipping
1.	The translation is more than rotation.	The translation is more than rotation.
2.	Sliding also referred as forward slipping.	Sliding also referred as backward slipping.
3.	$V_{CM} > R\omega$	$V_{CM} < R\omega$
4.	$V_{TRANS} > V_{ROT}$	$V_{TRANS} < V_{ROT}$
5.	Ex : When sudden brake is applied in a moving vehicle.	Ex : When we suddenly start the vehicle from rest.

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1. Electrostatics

1. What is meant by quantisation of charge ?

The charge q on any object is equal to an integral multiple of fundamental unit of charge e. This is called quantisation of electric charge.

Charge of electron = -1.6×10^{-19} C.

$$\boxed{q = ne}$$

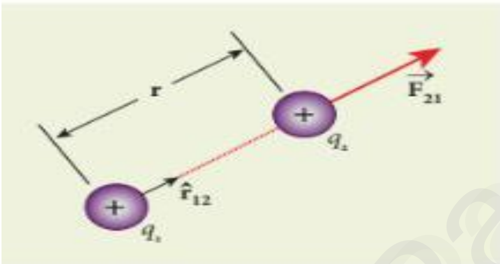
n is any integer ($0, \pm 1, \pm 2, \pm 3 \ldots$)

---

2. Write down the Coulomb's law in vector form and mention what each term represents.

Coulomb's law states that,

Electrostatic force is directly proportional to the product of the magnitude of the point charges and inversely proportional to the square of the distance between two point charges.



- The force on the point charge q_2 exerted by another point charge q_1 is

$$\boxed{\vec{F}_{21} = k \frac{q_1 q_2}{r^2} \hat{r}_{12}}$$

- $q_1, q_2 \longrightarrow$ Point Charges
- $\hat{r}_{12} \longrightarrow$ Unit Vector
- K $\longrightarrow$ Proportionality Constant $k = \dfrac{1}{4 \pi \epsilon_0}$

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3.What are the differences between Coulomb force and gravitational force?

S.No	Coulomb Force	Gravitational Force
1.	It may be attractive or repulsive.	It is always attractive in nature
2.	It depends upon medium.	It does not depend upon the medium.
3.	It is always greater in magnitude because of high value of K $K = 9 \times 10^{9}\ N\,m^{2}\ C^{-2}$	It is lesser than Coulomb force because value of G $G = 6.67 \times 10^{-11}\ N\,m^{2}\ kg^{-2}$
4.	The force between the charges will not be same during motion or rest.	It is always same whether the two masses are rest or motion.

---

4. Write short note on superposition principle.

When a number of charges are interacting the total force of a given charge is the vector sum of the individual forces exerted on the given charge by all the other charges.

$$\vec{F}_1^{\,tot} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \ldots\ldots + \vec{F}_{1n}$$

$$\vec{F}_1^{\,tot} = K\left\{ \frac{q_1 q_2}{r_{21}^2}\hat{r}_{21} + \frac{q_1 q_3}{r_{31}^2}\hat{r}_{31} + \ldots\ldots\ldots \frac{q_1 q_n}{r_{n1}^2}\hat{r}_{n1} \right\}$$

---

5. Define electric field .

The electric field at the point P at a distance r from the point charge q is the force experienced by a unit charge and is given by

$$\boxed{\vec{E} = \frac{\vec{F}}{q_0} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}}$$

S I unit : $N\,C^{-1}$

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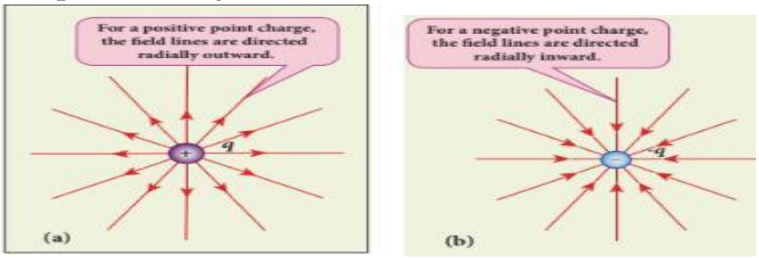
6. What is meant by " electric field lines " ?

- **Electric field vectors are visualized by the concept of electric field lines.**
- **They form a set of continuous lines which represent the electric field in some region of space visually.**



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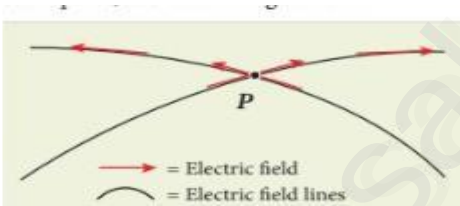
7. The electric field lines never intersect . Justify.

If some charge is placed in the intersection point , then it has to move in two different directions at the same time., which is physically impossible. Hence , electric field lines do not intersect.



---

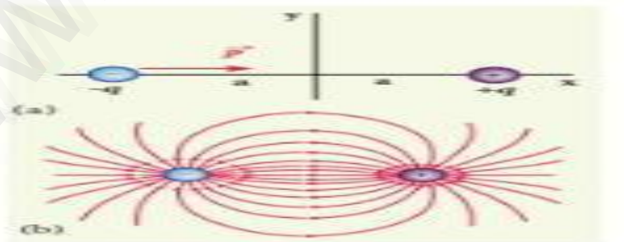
8. Define electric dipole . Give the expression for the magnitude of its electric dipole moment and the direction.

<u>Electric Dipole :</u>

Two equal and opposite charges separated by a small distance constitute electric dipole.

Example : C o , H Cl , Ammonia

$$\boxed{\vec{p} = 2qa\,\hat{i}}$$



<u>Magnitude of electric dipole moment :</u>

The product of magnitude of one of the charges and distance between them.

$$\boxed{|\vec{P}| = 2qa}$$

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9. Write the general definition of electric dipole moment for a collection of point charge.

The electric dipole moment for a collection of ' n ' point charges is given by

$$\vec{p} = \sum_{i=1}^{n} q_i \vec{r}_i$$

$r_i \longrightarrow$ Position vector of charge q_i

S I Unit : Coulomb meter (C m)

---

9. Define ' electrostatic potential ".

Electric potential at a point P is equal to the work done force to bring unit positive charge with constant velocity from infinity to the point P in the region of the external electric field.

$$V_P = -\int_{\infty}^{P} \vec{E}\cdot d\vec{r}$$

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

---

10. What is an equipotential surface ?

An equipotential surface is a surface on which all the points are at the same electric potential.

---

11. What are the properties of an equipotential surface ?

1. The work done to move a charge q between any two points A and B, $W = q(V_A - V_B)$.
2. If the points A and B lie on same equipotential surface, Work done is zero because $V_A = V_B$
3. The electric field is always normal to an equipotential surface.

---

13. Give the relation between electric field and electric potential.

- Consider a positive charge q kept fixed at the origin .
- To move a unit positive charge by a small distance dx towards q in electric field E.
- The work done is given by dW = - E dx.
- The minus sign implies that work done against the electric field.
- This work done is equal to electric potential difference.
- The electric field is negative gradient of electric potential.

1. $dW = dV$
2. $dV = -E\,dx$
3. $E = -\frac{dV}{dx}$

$$E = -\left(\frac{\partial V}{\partial x}\hat{i} + \frac{\partial V}{\partial y}\hat{j} + \frac{\partial V}{\partial z}\hat{k}\right)$$

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14. Define electrostatic potential energy.

Electric potential energy is defined as the work done in bringing the various charges to their respective positions from infinitely large mutual separation.

---

15. Define electric flux.

- **The number of electric field lines crossing given area kept normal to be electric field lines is called " electric flux "**
- **It is a scalar quantity. S I unit : N m^2 C^{-1}**

$$\boxed{\Phi_E = \vec{E} \cdot \vec{A} = E\ A\ \cos\theta}$$

---

16. What is meant by electrostatic energy density ?

The energy stored per unit volume of space is defined as energy density.

$$\boxed{u_E = \frac{U}{\text{Volume}} = \frac{1}{2}\varepsilon_0 E^2}$$

---

17. Write a short note on electrostatic shielding.

1. The phenomenon of protecting a region of space from any external electric field is called as " electrostatic shielding "

2. Consider a cavity inside the conductor whatever the charges at the surfaces and whatever the electrical disturbances outside , the electric field inside cavity is zero.

Ex : Faraday Cage

---

18. What is polarization ?

Polarization $\vec{p}$ is defined as the total dipole moment per unit volume of dielectric.

$$\boxed{\vec{P} = \chi_e\ \vec{E}_{ext}}$$

$\chi_e \longrightarrow$ **Electric Susceptibility**

19.What is dielectric strength ?

The maximum electric field the dielectric can withstand before it breakdown is called " dielectric strength ".

For example : Dielectric strength of air 3 X 10^6 V m^{-1}

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20. Define capacitance . Give its unit.

The capacitance of a capacitor is defined as the ratio of the magnitude of charge on either of the conductor plates to the potential differences existing between them.

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

- **SI unit : Coulomb per volt or farad (F)**

---

21. What is corona discharge ?

- **The total charge of the charged conductor near the sharp edge reduces.**
- **Leakage of charges from the sharp points to the charged conductor.**
- **Corona discharge also known as " action of points "**

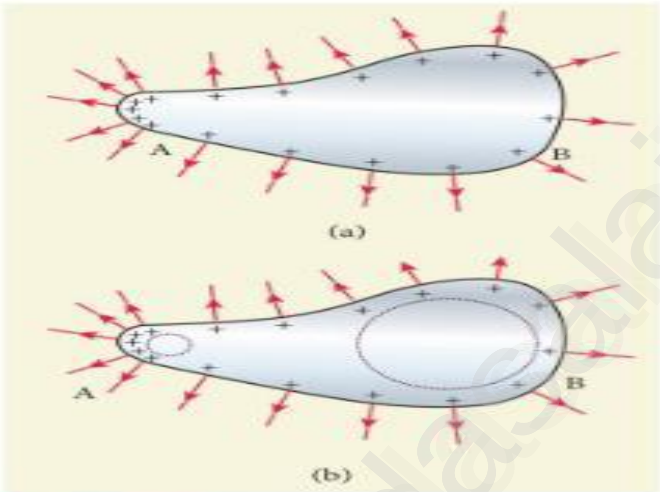

Figure 1.61 Action of points or corona discharge

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2. Current Electricity

1.Why current is a scalar ?

- **Current has both magnitude and direction.**
- **But the direction of current does not obey vector law of addition.**
- **In general , current is defined as the scalar product of the current density and area vector in which charges cross.**
- **Current (I) may be positive or negative.**

$$\boxed{I = \vec{J} \cdot \vec{A}}$$

- **Depends on unit vector normal to surface area A.**

2.Define current density.

The current per unit area of cross section of the conductor is called current density.

$$\boxed{J = \frac{I}{A}}$$

SI Unit : A m^{-2}

---

3. Distinguish between drift velocity and mobility.

S.NO	Drift Velocity	Mobility
1.	Average velocity acquired by electron inside the conductor when it is subjected to an electric field.	Magnitude of drift velocity per unit electric field.
2.	It is a vector quantity.	It is a scalar quantity.
3.	S I Unit : m s^{-1}	S I Unit : $m^2 V^{-1} s^{-1}$
4.	$\vec{V}_d = \vec{a}\,\tau = = -\mu\,\vec{E}$	$\mu = \dfrac{\lvert\vec{V}_d\rvert}{\lvert\vec{E}\rvert} = \dfrac{-e\,\tau}{m}$

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3. **State microscopic form of Ohm's law.**

Microscopic form of Ohm's law : $\boxed{\vec{J} = \sigma \vec{E}}$

J ⟶ Current Density

σ ⟶ Conductivity

E ⟶ Electric field

---

4. State macroscopic form of Ohm's law.

Macroscopic form of Ohm's law states that "the potential difference across a given conductor is directly proportional to the current passing through it when the temperature remains constant "

V ⟶ Potential Difference

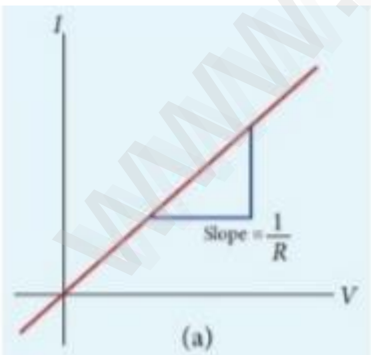
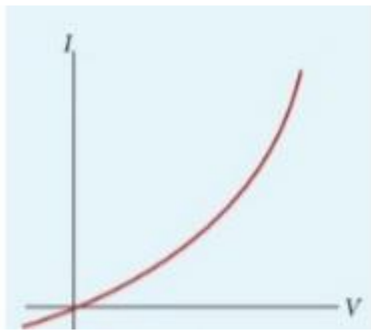
I ⟶ Current

R ⟶ Resistance

$\boxed{V = I\,R}$

---

5. What are ohmic and non ohmic device ?

S.NO	Ohmic Device	Non Ohmic Device
1.	Material or devices that obey Ohm's law.	Material of devices that do not obey Ohm's law.
2.	A graph of I against V is linear .(straight line)	A graph of I against V is non-linear
3.		

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6. Define electrical resistivity .

It is defined as resistance offered to current flow by a conductor of unit length having unit area of cross section. S I Unit : Ω m

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

8.Define temperature coefficient of resistance.

It is defined as the ratio of increase in resistivity per degree rise in temperature to its resistivity.

$$\boxed{\alpha = \frac{\rho_T - \rho_0}{\rho(T - T_0)} = \frac{\Delta\rho}{\rho\,\Delta T}}$$

9.Write a short note on super conductor.

The resistance of certain materials become zero below certain temperature T_C . This temperature is known as critical temperature or transition temperature . The materials which exhibit this property are known as super conductor.

Ex : Mercury exhibits super conductor at 4.2 K [R = 0]

10.What is electric power and electric energy?

<u>Electric Power :</u>

The rate at which the electrical potential energy is used. Unit : Watt

$$\boxed{P = \frac{W}{t} = V\ I}$$

<u>Electrical Energy :</u>

Electrical energy is the product of electric power and time.

Unit : Watt hour (1 K W h = 3.6 X 10^6 J)

---

11. Derive the expression for power P = V I in electrical circuit.

1. $P = \frac{dU}{dt}$ ($dU = V\,dQ$)

2. $P = V\frac{dQ}{dt} = V\ I$

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12. Write down the various forms of expressions for power in electrical circuits.

Power : $P = V I$

Ohm's Law : $V = I R$

1. $P = (I R) I = I^2 R$

2. $P = V \left(\frac{V}{R} \right)$

---

13. State Kirchoff's current rule.

Kirchhoff's First Rule:

- **Current rule or junction rule.**
- **It states that the algebraic sum of currents of any junction of a circuit is zero.**
- **Charge enter a junction must leave the junction.**
- **Current entering the junction as positive, current leaving the junction as negative.**
- **Law of conservation of electric charge.**
- $I_1 + I_2 - I_3 - I_4 - I_5 = 0$

$I_1 + I_2 = I_3 + I_4 + I_5$

Figure 2.23 Kirchhoff's current rule

---

14. State Kirchhoff's voltage rule.

Kirchhoff's Second Rule:

- **Voltage rule or loop rule.**
- **Law of conservation of energy.**
- **It states that in a closed circuit the algebraic sum of the products of the current**

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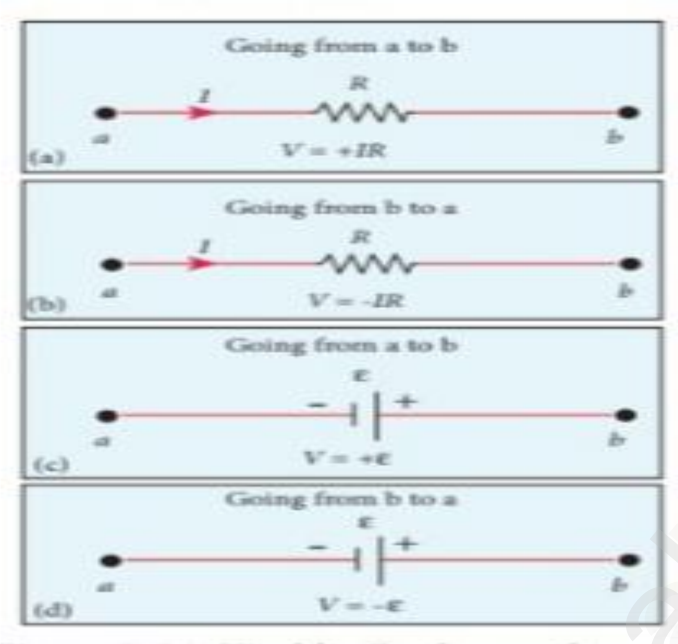
and resistance of each part of the circuit is equal to total emf included in the circuit.



- Product of current and resistance is taken as positive when the direction of current is followed. $V = + IR$
- Product of current and resistance is taken as negative if the direction of current is opposite. $V = - IR$

---

15. State the principle of potentiometer.

- The emf of the cell is directly proportional to the balancing length.

$$\boxed{\begin{array}{c} \varepsilon \propto l \\ \varepsilon = I r l \end{array}}$$

When constant current flows through a wire of uniform cross – sectional area , the potential drop across any length of the wire is directly proportional to that length.

16. What do you mean by internal resistance of a cell ?

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The battery is made of electrodes and electrolyte , there is resistance to the flow of charges with in the battery . This resistance is called " Internal resistance "

---

17. State Joule's law of heating.

It states that , Heat developed in an electrical circuit due to flow of current varies directly as,

1. Square of the current
2. Resistance of the circuit
3. Time of flow of current

$$\boxed{H = I^2 R t}$$

---

18. What is Seeback effect.

- Seeback discovered that in a closed circuit consisting of two dissimilar metals , when junctions are maintained at different temperatures an emf is developed.
- The current that flows due to the emf developed is called " thermoelectric current ".
- The two dissimilar metal connected to form two junctions is known as " Thermocouple "

---

19. What is Thomson effect ?

- If two points in a conductor are at different temperatures , the density of electrons at these points will be different.
- Due to difference in electron density , The potential difference is created between these Point.

---

20. What is Peltier effect ?

When current is passed through a thermocouple , heat is evolved at one junction and absorbed at other junction.

---

21. State the applications of Seeback effect.

1. Used in thermoelectric generators to convert waste heat into electricity.
2. Used in automobiles for increasing fuel efficiency.
3. Used in thermocouples to measure the temperature difference.

3. Magnetism & Magnetic effects of electric current

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1. What is meant by magnetic induction ?

The magnetic induction inside the specimen is equal to the sum of magnetic field produces in vacuum due to magnetizing field and the magnetic field due to induced magnetism of the substance.

$$\vec{B} = \vec{B_0} + \vec{B_M} = \mu \vec{H} + \mu \vec{M}$$

---

2. Define magnetic flux.

The number of magnetic field lines crossing per unit area is called magnetic flux Φ_B .

- **Scalar Quantity.**
- **SI unit : weber**
- **CGS unit : maxwell**
- **Dimension : $M\ L^2\ T^{-2}\ A^{-1}$**

$$\Phi_B = \vec{B} . \vec{A} = B\ A \cos\ \theta$$

$$1 \text{ weber} = 10^8 \text{ maxwell}$$

---

3. Define magnetic dipole moment.

- **Product of pole strength and magnetic length.**
- **It is a vector quantity.**

It is denoted by $\vec{P_m}$. SI Unit : $A\ m^2$

$$\vec{p_m} = q_m \vec{d} = 2\ q_m\ l$$

---

4. State Coulomb' s inverse law.

The force of attraction or repulsion between two magnetic poles is directly proportional to product of their pole strength and inversely proportional to square of the distance between them.

$$\vec{F} \propto \frac{q_{mA}\, q_{mB}}{r^2}\, \hat{r}$$

$$F = \frac{\mu_0}{4\pi} \frac{q_{mA}\, q_{mB}}{r^2}\, r$$

$$K = \frac{\mu_0}{4\pi} = 10^{-7}\ H\ m^{-1}$$

---

5. What is magnetic susceptibility ?

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It is defined as the ratio of the intensity of magnetisation ($\vec{M}$) induced in the material to the applied magnetising field $\vec{H}$. It is a dimensionless quantity.

$$\chi_m = \frac{|\vec{M}|}{|\vec{H}|}$$

---

6. State Biot – Savart's law .

Magnetic field due to current element is

- **Directly as strength of current I**
- **Directly as length of element dl**
- **Directly as sine of angle θ between dl and r**
- **Inversely as square as distance r**

$$dB \;\alpha\; \frac{I\ dl\ \sin\theta}{r^2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{I\ dl\ \sin\theta}{r^2}$$

---

7. What is magnetic permeability ?

- **Measure of ability of the material to allow the passage of magnetic field lines.**
- **Measure of capacitance of the substance to take magnetisation.**
- **Degree of penetration of magnetic field through the substance.**

---

8. State Ampere's circuital law.

The line integral of the magnetic field over a closed loop μ_0 times net current enclosed by loop .

$$\oint_C B\,.dl = \mu_0\ I_{\text{enclosed}}$$

9. Compare dia , para and ferro magnetism. (or)

18. Give the properties of dia / para / ferro materials.

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Properties	Dia Magnetism	Para Magnetism	Ferro Magnetism
1. Magnetic susceptibility	χ_m is negative	χ_m is positive & small	χ_m is positive & large
2.Susceptibility	Temperature independent	$\chi_m \propto \frac{1}{T}$	$\chi_m = \frac{C}{T - T_C}$
3. Relative Permeability	μ_r less than unity	μ_r greater than unity	μ_r is large
4. Magnetic field lines	Repelled or expelled when placed in magnetic field .	Attracted when placed in magnetic field.	Strongly attracted when placed in a magnetic field.
5. Examples	Bismuth , Copper , Water	Aluminium , Platinum , Chromium , Oxygen	Iron , Nickel , Cobalt

---

10. What is meant by hysteresis ?

The phenomenon of lagging of magnetic induction behind the magnetising field is called hysteresis.

---

11. Define magnetic declination and inclination.

Magnetic Declination :

Angle between magnetic meridian at a point and geographical meridian.

Magnetic Inclination :

Angle subtended by Earth's total magnetic field $\vec{B}$ with horizontal direction in the magnetic meridian.

---

12. What is resonance condition in cyclotron ?

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When the frequency ' f ' at which the positive ion circulates in the magnetic field becomes equal to the constant frequency of the electrical oscillator f_{osc}. This is called as " resonance condition".

$$\boxed{f_{osc} = \frac{q\,B}{2\,\pi\,m}}$$

---

12. Define one ampere.

One ampere is defined as that constant current which when passed through each of the two infinitely long parallel straight conductor kept side by side parallelly at a distance of one meter apart in air or vacuum causes each conductor to experience a force of 2×10^{-7} newton per meter length of conductor.

14.State Fleming's left hand rule.

Stretch out fore finger , the middle finger and the thumb of the left hand such that they are in three mutually perpendicular directions.

- **Fore finger points in the direction of magnetic field.**
- **Middle finger points in the direction of the electric current.**
- **Thumb points in the force experienced by the conductor.**

---

15. Is an ammeter connected in series or parallel in a circuit . why ?

The ammeter is connected in series in a circuit because it si a low resistance instrument. Such that it will not change the current passing through it.

---

16. Explain the concept of velocity selector.

By proper choice of electric field $\vec{E}$ and magnetic field $\vec{B}$ inside an arrangement

- **such as Bainbridge mass spectrometer.**
- **The particle with particular speed can be selected .**
- **This speed is independent of mass and charge.**
- **Such an arrangement of fields is called velocity selector**

$$\boxed{V = \frac{E}{B}}$$

---

17. Why is the path of a charged particle not a circle when its velocity is not perpendicular to the magnetic field ?

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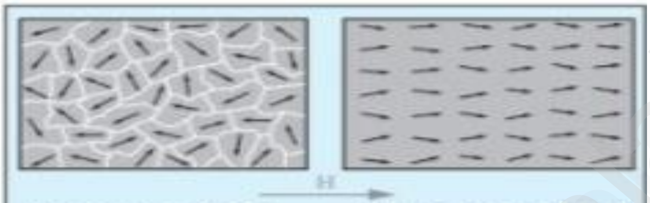
- If a charged particle moves in uniform magnetic field , then velocity of a particle is split up into two components :

1. One component parallel to the field which remains unchanged.
2. Other component perpendicular to the field keeps changing due to Lorentz force.
3. Hence , the path of particle is not a circle. It is a helical around field lines.

---

19. What happens to the domains in a ferromagnetic material in the presence of external magnetic field ?

1. The domains having magnetic moments parallel to the field grow bigger in size.
2. The other domains are rotated so that they are aligned with the field.



(a) Domains randomly aligned (b) Domains aligned with external field

---

20. How is a galvanometer converted into i) an ammeter ii) a voltmeter.

1. A galvanometer can be converted into an ammeter of given range by connecting a suitable low resistance S called shunt in parallel to the galvanometer.
2. A galvanometer can be converted into a voltmeter by connecting a suitable High resistance R called shunt in parallel to the galvanometer.

4.Electromagnetic induction & Alternating current

1. What is meant by electromagnetic induction ?

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Whenever the magnetic flux linked with a closed coil changes , an emf is induced and hence an electric current flows in the circuit .This phenomenon is known as " electromagnetic induction "-

---

2.State Faraday's laws of electromagnetic induction.

Faraday's first law :

Whenever magnetic flux linked with a closed circuit changes , an emf is induced in the circuit which lasts in the circuit as long as the magnetic flux is changing.

Faraday's second law :

The magnitude of induced emf in a closed circuit is equal to the time rate of change of magnetic flux linked with the circuit.

$$\boxed{\varepsilon = \frac{d\Phi_B}{dt} = \frac{d}{dt}(N\Phi_B)}$$

---

3. State Lenz's law.

- Len's law states that direction of the induced current is such that it always opposes the cause responsible for its production.

$$\boxed{\varepsilon = -\frac{d}{dt}(N\Phi_B)}$$

- Negative sign signifies that the direction of induced emf is such that it opposes the change in magnetic flux.

---

4. How is Eddy current produced ? How do they flow in a conductor ?

- Even for a conductor in the form of sheet or plate , an emf is induced when magnetic flux linked with it changes.
- There is no definite loop or path for induced current to flow away.
- The induced current flow in concentric circular path.
- The electric current resemble eddies of water.
- This is known as " Eddy current " or "Foucault current ".

---

6. Mention the ways of producing induced emf.

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1. By changing the magnetic field (B)
2. By changing the area of the coil (A)
3. By changing the relative orientation of the coil with magnetic field (θ)

$$\varepsilon = \frac{d\Phi_B}{dt} = \frac{d}{dt}(BA\cos\theta)$$

7.What for an inductor is used ? Give some examples.

Inductor is a device used to store energy in a magnetic field when an electric current flows through it.

EX : Coils , Solenoid , Toroid's

---

8. What do you mean by self – induction ?

If magnetic flux is changed by changing the current , an emf is induced in that same coil. This phenomenon is known as " self – induction ".

$$N\Phi_B \propto i$$
$$N\Phi_B = L i$$

---

9. What is meant by mutual induction ?

When an electric current passing through a coil changes with time , an emf is induced in the neighboring coil. This phenomenon is knowns mutual induction.

---

10. Give the principle of AC generator.

- Based on the principle of electromagnetic induction.
- Relative motion between conductor and magnetic field changes.
- Magnetic flux linked with the conductor induces an emf.
- Magnitude of emf given by Faraday law of electromagnetic induction.
- Direction by Fleming's right hand rule.

11.List out the advantages of stationary armature rotating field system of AC generator.

1. The current is drawn directly from fixed terminals on the stator without the use of brush contacts.

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2. The insulation of stationary armature winding is easier.
3. The number of sliding contact is reduced. The sliding contacts are used for low – voltage DC source.
4. Armature windings can be constructed more rigidly to prevent deformation due to any mechanical stress.

12.What are step- up and step- down transformer ?

Step – up transformer

If the transformer converts an alternating current with low voltage into an alternating current with high voltage , it is called as step – up transformer.

Step – down transformer

If the transformer converts an alternating current with high voltage into an alternating current with low voltage , it is called as step – down transformer.

---

13. Define average value of an alternating current.

The average (mean) value of alternating current is defined as the average of all values of current over a positive half – cycle or a negative half – cycle.

$$I_{av} = \frac{\text{Area of } +\text{ve } (-\text{ve}) \text{ half cycle}}{\text{Base length of half cycle}}$$

---

14. How will you define RMS value of an alternating current ?

The root mean square value of an alternating current is defined as square root of the square of all current over one cycle.

$$I_{RMS} = \sqrt{\frac{\text{Area of one cycle of squared wave}}{\text{Base length of one cycle}}}$$

15.What is phasors ?

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A sinusoidal alternating voltage or current represented by a vector which rotates about the origin in anti – clockwise direction at constant angular velocity ω. Such a rotating vector is called phasor.

16.Define electric resonance .

When the frequency of the applied alternating source (ω) is equal to the natural frequency $1 / \sqrt{LC}$ of the RLC circuit , the current in the circuit reaches it maximum value. Then the circuit is said to be electrical resonance.

---

17. What do you mean by resonant frequency ?

When the frequency of the applied alternating source (ω) is equal to the natural frequency $1 / \sqrt{LC}$ of the RLC circuit , the current in the circuit reaches it maximum value. Then the circuit is said to be electrical resonance. The frequency at which resonance takes place is called resonant frequency.

$$\boxed{f_r = \frac{1}{2 \pi \; L C}}$$

---

18. How will you define Q – factor ?

It is defined as the ratio of voltage across L or C to the applied voltage.

$$\text{Q – factor} = \frac{\text{Voltage across L or C}}{\text{Applied voltage}} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

19.What is meant by wattless current ?

The current in an AC circuit is said to be wattless current if the power consumed by it is zero.

This wattless current occurs in purely inductive or capacitive circuit.

---

20. Give any one definition of power factor.

1. **Power Factor = cos Φ**
2. **Power Factor = cosine angle of lead or lag**
3. **Power Factor** $= \dfrac{R}{Z} = \dfrac{\text{Resistance}}{\text{Impedance}}$

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4. **Power Factor** $= \dfrac{P_{av}}{V_{RMS}\, I_{RMS}} = \dfrac{\text{True Power}}{\text{Apparent Power}}$

---

21. What are Lc oscillations ?

1. **Whenever energy is given to a circuit containing pure inductor of inductance L and capacitor of capacitance C.**
2. **The energy oscillates back and forth between the magnetic field of inductor and electric field of capacitor.**
3. **The electrical oscillations of definite frequency are generated. These oscillations are called LC oscillations.**

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5.Electromagnetic waves

1. What is displacement current ?

The displacement current can be defined as the current which comes into play in the region in which electric field and electric flux is changing with time.

$$\boxed{i_d = \varepsilon_0 \frac{d\Phi_E}{dt}}$$

---

2. What are electromagnetic waves ?

- Electromagnetic waves is a transverse wave.
- Electromagnetic waves are non mechanical waves they do not require any medium for propagation.
- Electromagnetic waves is radiated by an accelerated charge which propagates through space as coupled electric and magnetic fields , oscillating perpendicular to each other and to the direction of propagation of the wave.

---

3. Write down the integral form of modified Ampere's circuital law.

Integral form of modified Ampere's circuital law,

$$\boxed{\oint_l \vec{B} \cdot \vec{dl} = \mu_0 i_c + \mu_0 \epsilon_0 \frac{d}{dt} \int_S \vec{E} \cdot \vec{dA}}$$

---

4. Write down the Gauss's law in magnetism.

$$\boxed{\oint \vec{B} \cdot \vec{dA} = 0}$$

* The surface integral of magnetic field over a closed surface is zero.
Where B is the magnetic field

1. Magnetic lines of force form continuous closed path.
2. No isolated magnetic monopole exists.

5.Give two uses each of i) I R radiation ii) Micro waves iii) U V radiation

i) I R Radiation :

1. Produce dehydrated fruits.
2. Keep plants warm in green house.
3. Heat therapy for muscular pain or sprain.
4. T V remote as a signal carrier.

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ii) Micro waves :

1. Used in radar system for air craft and navigation .
2. Used in microwave oven for cooking.
3. Used in speed of the vehicle.

iii) U V radiation :

1. Used to study atomic structure.
2. Used to detect invisible finger prints.
3. Used in burglar alarm.
4. Used to destroy bacteria in sterilize surgical instrument.

---

6. What are Fraunhofer lines ? How are they useful in the identification of elements present in the sun ?

- Dark lines seen in the solar spectrum are known as Fraunhofer lines.
- It is used to identify the elements present in the sun.

---

7. Write notes on Ampere – Maxwell law.

- This law relates the magnetic field around any closed path to the conduction current and displacement current through the path.

$$\oint_l \vec{B} \cdot \vec{dl} = \mu_0 \, i_c + \mu_0 \, \epsilon_0 \frac{d}{dt} \oint_S \vec{E} \cdot \vec{dA}$$

---

8. Why are em waves are non – mechanical ?

- Electromagnetic waves do not require any medium for propagation.
- So em waves are non – mechanical wave.

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Lesson 1

1. (i) Explain the use of screw gauge and vernier calliper in measuring smaller distances.

Screw Gauge :

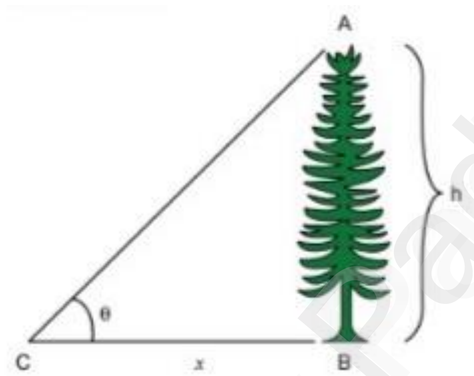
1. Used to measure object dimension about 50 mm.
2. Principle of instrument : i) Linear motion ii) Circular motion
3. Least count of screw gauge is 0.01 mm.

Vernier Calliper :

1. It is a versatile instrument.
2. Used to measure : i) Diameter of hole ii) Depth of hole
3. Least count of vernier is 0.01 cm.

(ii) Triangulation method to measure larger distance

Diagram :



Formula :

$$\boxed{h = x \tan \theta}$$

Theory :

1. Height of the tree AB = h .
2. Base distance BC = x
3. Point of observation is C.
4. Angle of elevation θ = < ACB .

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5. **From triangle ABC ,**

$$\tan \theta = \frac{AB}{BC}$$

6. $$\tan \theta = \frac{h}{x}$$

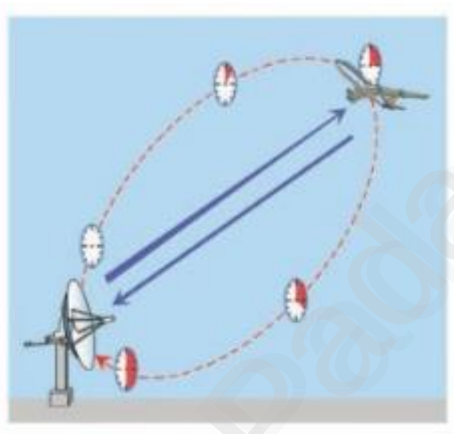
7. $$\frac{h}{x} = \tan \theta$$

8. $$h = x \tan \theta$$

9. By knowing the distance x , θ then h can be determined.

(iii) Radar method to measure larger distance :

Diagram :



Formula :

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

Theory :

1. Radar means " Radio detection and ranging " .
2. Used to measure large distance.
3. Radio waves send to transmitters .
4. Radio waves detect by receiver.
5. Distance : $d = \frac{v \times t}{2}$

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2. Explain in detail the various types of errors.

Error : Uncertainty in a measurement is called as error.

Types of error :

1. Random Error
2. Systematic Error
3. Gross Error

1. Systematic Error :

i) Reproducible Error
ii) Inaccuracy Error

Types of systematic error :

1. **Instrumental Error :**

- Error due to instrumental manufacture .
- Example : Meter scale whose end worn out.

2. **Imperfection Error :**

- Error due to experiment limitation .
- Example : Experiment with calorimeter.

3. **Personal Error :**

- Error due to personal and individual .
- Example : Carelessness of individual.

4. **External Cause Error:**

- Error due to external cause .
- Example : Humidity, Pressure .

5. **Least Count Error:**

- Smallest value measured by instrument .
- Example : L.C of screw gauge 0.01 mm.

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Random Error:

1. Error due to random condition.
2. Also known as "Chance Error"

Gross Error:

1. Recording wrong observation.
2. Wrong values in calculations.

---

3. What do you mean by propagation error? Explain the propagation errors in addition and multiplication.

The various possibilities of the propagation or combination of errors in maths operation.

1) **Error in sum of quantities:**

1. Two quantities ⟶ A , B
2. Error in quantities ⟶ ΔA , ΔB
3. Sum of quantities ⟶ $Z = A + B$
4. Error in sum ⟶ ΔZ
5. Measured value of A = $A \pm \Delta A$
6. Measured value of B = $B \pm \Delta B$

$$Z = A + B$$

$$Z \pm \Delta A = A \pm \Delta A + B \pm \Delta B$$

$$\boxed{\Delta Z = \Delta A + \Delta B}$$

" The maximum possible errors in the sum of the quantities is equal to the sum of the absolute errors in the individual quantities "

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2) **Error in multiplication of quantities:**

1. Two quantities $\longrightarrow$ A , B
2. Error in quantities $\longrightarrow$ ΔA , ΔB
3. Sum of quantities $\longrightarrow$ Z = A B
4. Error in sum $\longrightarrow$ ΔZ
5. Measured value of A = $A \pm \Delta A$
6. Measured value of B = $B \pm \Delta B$

$$Z = A B$$

$$Z \pm \Delta A = (A \pm \Delta A)(B \pm \Delta B)$$

$$Z \pm \Delta A = A B \pm A \Delta B \pm B \Delta A \pm B \Delta B$$

$$\boxed{\frac{\Delta Z}{Z} = \pm\left(\frac{\Delta A}{A} + \frac{\Delta B}{B}\right)}$$

" The maximum fractional error in the product of the quantities is equal to the sum of the fractional errors in the individual quantities "

4.Write a short notes on the following

a) Unit b) Rounding off c) Dimensionless quantities

a) **Unit**

An arbitrarily chosen standard of measurement of quantity , which is accepted internationally is called unit of the quantity.

b) **Rounding off**

* Calculators are widely used now a days for calculations.
* Calculators has too many figures.
* Results have more significant figures.
* Numbers containing more than one uncertain number should be round off.

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c) <u>Dimensionless quantities</u> :

<u>Dimensionless variable :</u>

Physical quantity which have no dimension but have variable.

Ex : Strain , Specific gravity

<u>Dimensionless constant :</u>

Physical quantity which have constant values but have no dimension.

Ex : π , e (Euler's number)

---

5. Explain the principle of homogeneity of dimension . What are its uses ? Give example.

<u>Principle of homogeneity of dimension :</u>

It states that the dimensions of all the terms in physical expression should be same.

<u>Applications / Uses of Principle of homogeneity of dimension :</u>

1. **Convert physical quantity from one system of units to another.**
2. **Check the dimensional correctness of a given physical equation.**
3. **Establish relations among various physical quantities.**

<u>1. Conversion of physical quantity :</u>

Convert the numerical value of physical quantity from one system of unit into other unit.

$$n_1 \, [\, M_1^a \;\; L_1^b \;\; T_1^c \,] \;=\; n_2 \, [\, M_2^a \;\; L_2^b \;\; T_2^c \,]$$

Quantity	Power	One System	Another System
Mass	a	M_1	M_2
Length	b	L_1	L_2
Time	c	T_1	T_2

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2. Check the dimensional correctness of physical quantity

$$V = u + a\,t$$

$$[LT^{-1}] = [LT^{-1}] + [LT^{-2}]\,[T]$$

$$[LT^{-1}] = [LT^{-1}] + [LT^{-1}]$$

- **Dimension of both sides are equal.**
- **This equation is dimensionally correct.**

3. Establish the relation among physical quantity

- **If the physical quantity Q depends on Q_1, Q_2, Q_3**
- **Q is proportional to Q_1, Q_2, Q_3**
- $Q \;\alpha\; Q_1^a\; Q_2^b\; Q_3^c$
- $Q = K\; Q_1^a\; Q_2^b\; Q_3^c$

K -------------------- Dimensionless Constant.

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Lesson 2

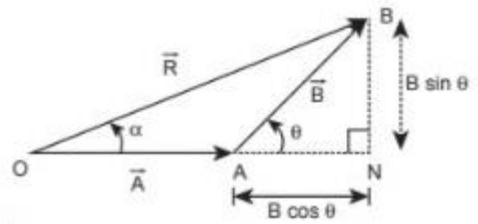
1. Explain in detail the triangle law of addition .

Triangle law of addition :

The vectors $\vec{A}$ and $\vec{B}$ two adjacent sides of triangle then resultant is given by the third side of the triangle.

$$\boxed{\vec{R} = \vec{A} + \vec{B}}$$

Diagram :



From Figure :

OA = A	AB = B	OB = R
AN = B cos Θ	BN = B sin Θ	

1. Magnitude of resultant vector

Triangle OBN

1. $OB^2 = ON^2 + BN^2$
2. $OB^2 = (OA + AN)^2 + BN^2$
3. $OB^2 = OA^2 + AN^2 + 2\ OA\ .\ AN + BN^2$
4. $R^2 = A^2 + B^2\ \cos^2\Theta + 2\ A\ B\cos\Theta + B^2\ \sin^2\Theta$
5. $R = \sqrt{A^2 + B^2 + 2\ A\ B\cos\Theta}$

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2. Direction of resultant vector

Triangle OBN

1. $\tan \alpha = \frac{BN}{ON}$

2. $\tan \alpha = \frac{BN}{OA + AN}$

3. $\tan \alpha = \frac{B \sin \theta}{A + B \cos \theta}$

---

2. Discuss the properties of scalar and vector product.

Scalar Product :

1. Product of the magnitudes of both the vectors and cosine of angle between them.

$$\vec{A} \cdot \vec{B} = A\,B\,\cos\theta$$

2. Scalar product is commutative $\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}$

3. Distributive law $\vec{A} \cdot (\vec{B} + \vec{C}) = \vec{A} \cdot \vec{B} + \vec{A} \cdot \vec{C}$

4. Unit Vector : $\hat{i} \cdot \hat{i} = \hat{j} \cdot \hat{j} = \hat{k} \cdot \hat{k} = 1$

5. Orthogonal : $\hat{i} \cdot \hat{j} = \hat{j} \cdot \hat{k} = \hat{k} \cdot \hat{i} = 0$

6. Scalar product is maximum when $\theta = 0^0$ then $\cos\theta = 1$

$$(\vec{A} \cdot \vec{B})_{max} = A\,B$$

7. Scalar product is minimum when $\theta = 180^0$ then $\cos\theta = -1$

$$(\vec{A} \cdot \vec{B})_{min} = -\,A\,B$$

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Vector Product :

1. Product of the magnitudes of both the vectors and sine of angle between them.

$$\vec{C} = \vec{A} \times \vec{B} = (A\ B \sin \Theta)\ \hat{n}$$

2. Vector product is not commutative $\vec{A} \times \vec{B} = \vec{B} \times \vec{A}$

3. Unit Vector : $\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0$

4. Orthogonal : $\hat{i} \times \hat{j} = \hat{K}$; $\hat{j} \times \hat{k} = \hat{i}$; $\hat{k} \times \hat{i} = \hat{j}$;

5. Vector product is maximum when $\Theta = 90^0$ then $\sin \Theta = 1$

$$(\vec{A} \times \vec{B})_{max} = A\,B$$

6. Vector product is minimum when $\Theta = 0^0$ then $\sin \Theta = 0$

$$(\vec{A} \times \vec{B})_{min} = 0$$

7. Self cross product is null vector.

$$\vec{A} \times \vec{B} = A\,A \sin 0^0\ \hat{n} = 0$$

---

3. Derive the kinematic equation of motion for constant acceleration.

1. Velocity - Time relation

- $a = \dfrac{dV}{dt}$
- $dV = a\ dt$

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- $\int_u^v dV = a \int_0^t dt$
- $[v]_u^v = a[t]_0^t$
- $v - u = at$
- $v = u + at$

2.Displacement - Time relation

- $v = \frac{ds}{dt}$
- $ds = v\, dt$
- $ds = (u + at)\, dt$
- $\int_0^s ds = \int_0^t (u + at)\, dt$
- $\int_0^s ds = \int_0^t u\, dt + a \int_0^t t\, dt$
- $\boxed{S = ut + \frac{1}{2} a t^2}$

3. Velocity - Displacement relation :

- $a = \frac{dv}{dt}$
- $a = \frac{dv}{dt} \frac{ds}{ds}$
- $a = \frac{dv}{ds} \frac{ds}{dt}$
- $a = \frac{dv}{ds} v$

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- $a \int_0^s ds = \int_u^v v\, dv$
- $a s = \frac{v^2 - u^2}{2}$
- $2 a s = v^2 - u^2$
- $v^2 = u^2 + 2 as$

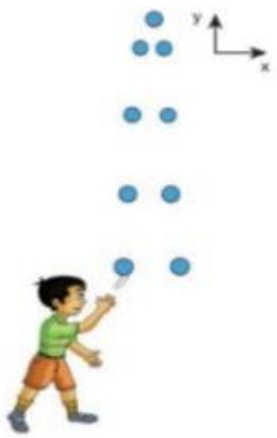
4. $S = ut + \frac{1}{2} a t^2$

- $at = v - u$
- $s = ut + \frac{1}{2} vt - \frac{1}{2} ut$
- $s = \frac{1}{2} ut + \frac{1}{2} vt$
- $S = \frac{(u + v)t}{2}$

4.Derive the equation of motion for a particle

a) Falling vertically b) Projected vertically.

a) Falling Vertically **b) Projected Vertically**



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a) **Falling vertically**

- **Consider an object of mass m falling from a height h.**
- **Let us choose downward direction as positive y – axis.**

Kinematics equation :

- $v = u + at$
- $v^2 = u^2 + 2as$
- $S = ut + \frac{1}{2} a t^2$

Body at rest u = 0

- $v = gt$
- $v^2 = 2gy$
- $y = \frac{1}{2} g t^2$

Particle reach ground t = T and y = h

$v^2 = 2gh \qquad v_{ground} = \sqrt{2gh}$

$h = \frac{1}{2} g t^2 \qquad T = \sqrt{\frac{2h}{g}}$

b) Projected vertically a = - g

- $V = u - gt$
- $V^2 = u^2 - 2gy$
- $S = ut - \frac{1}{2} g t^2$

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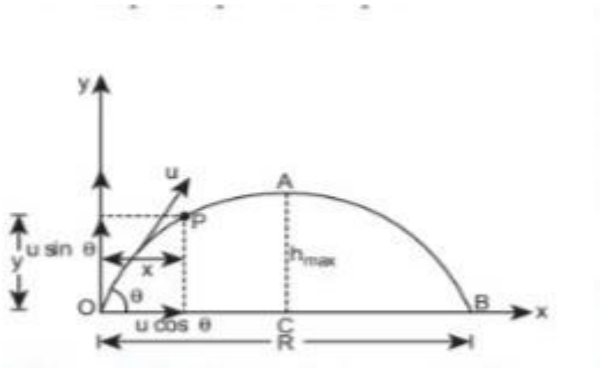
5. Derive the equation of motion , range and maximum height reached by the particle thrown at an oblique angle with respect to horizontal direction.

Diagram :



Maximum Height :

The maximum vertical distance travelled by the projectile during its journey.

Vertical part of motion :

- $V_y^2 = u_y^2 - 2\ a_y S$

$$\boxed{\begin{aligned} V_y &= 0 \\ u_y &= u \sin \Theta \\ a &= -g \\ S &= h_{max} \end{aligned}}$$

- $V_y^2 = u_y^2 - 2\ a_y S$
- $0^2 = (u \sin \Theta)^2 + 2(-g)\ h_{max}$
- $0 = u^2 \sin^2 \Theta - 2\ g\ h_{max}$
- $2\ g\ h_{max} = u^2 \sin^2 \Theta$
- $\boxed{h_{max} = \dfrac{u^2 \sin^2 \Theta}{2\ g}}$

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Horizontal Range :

The maximum horizontal distance between the point of projection and the point of on the horizontal plane where the projectile hits the ground.

Range = Horizontal component of velocity X Time of flight

$$R = u\cos\theta \times \frac{2u\cos\theta}{g}$$

$$R = \frac{2u^2\sin\theta\cos\theta}{g}$$

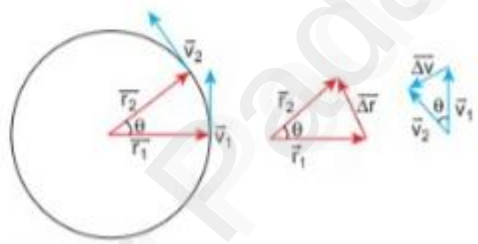
$$R = \frac{u^2\sin 2\theta}{g}$$

---

6. Derive the expression for centripetal acceleration.

The centripetal acceleration is derived from a simple geometrical relationship between position and velocity vector .

Diagram :



Formula

$$\boxed{a = -\frac{v^2}{r}}$$

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For uniform circular motion

1. Position Vector : $r = |\vec{r_1}| = |\vec{r_2}|$

2. Velocity Vector : $v = |\vec{v_1}| = |\vec{v_2}|$

3. Change in position : $\Delta r = \vec{r_2} - \vec{r_1}$

4. Change in velocity : $\Delta v = \vec{v_2} - \vec{v_1}$

5. Angle : $\theta = \frac{\Delta r}{r} = -\frac{\Delta v}{v}$

6. Negative sign implies that Δv points radially inward , towards centre of the circle.

7. $$-\frac{\Delta v}{v} = \frac{\Delta r}{r}$$

8. $$\Delta v = -\frac{v}{r}\,\Delta r$$

9. $$\frac{\Delta v}{\Delta t} = -\frac{v}{r}\,\frac{\Delta r}{\Delta t}$$

10. $$a = -\frac{v}{r}\,v$$

$$\boxed{a = -\frac{v^2}{r}}$$

11. Relation between linear and angular velocity

$$a = -\frac{r^2\ \omega^2}{r} = -\ \omega^2\ r$$

$$\boxed{a = -\ \omega^2\ r}$$

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7. Derive the expression for total acceleration in the non uniform circular motion.

Non Uniform Circular motion :

If the speed of the object in circular motion is not constant , then we have non – uniform circular motion.

For Example :

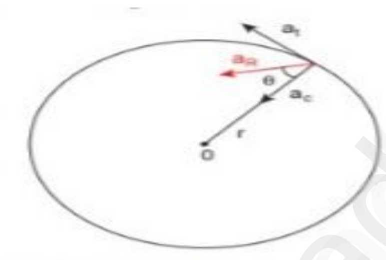
When the bob attached to a string moves in vertical circle , the speed of the bob is not same at all time.

Formula :

1. $a_R = \sqrt{a_t^{\,2} + \left(\frac{v^2}{r}\right)^2}$

2. $\tan\theta = \dfrac{a_t}{(v^2/r)}$

Diagram :



Acceleration :

1. Centripetal acceleration : $a_c = \dfrac{v^2}{r}$
2. Tangential acceleration : a_t
3. Resultant acceleration : a_R
4. $a_R^{\,2} = \sqrt{a_t^{\,2} + a_c^{\,2}}$
5. $a_R = a_t^{\,2} + a_c^{\,2}$
6. $a_R = \sqrt{a_t^{\,2} + \left(\frac{v^2}{r}\right)^2}$
7. Angle : $\tan\theta = \dfrac{a_t}{a_c}$

$\tan\theta = a_t \;/\; (v^2/r)$

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LESSON - 3

1. Prove the law of conservation of linear momentum . Use it to find the recoil velocity of a gun when bullet is fired from it.

Law Of Conservation of Linear Momentum :

- **If there are no external forces acting on the system , then the total linear momentum of the system ($\vec{p}_{tot}$) is always a constant vector.**
- **The total linear momentum of the system is conserved in time.**

Explanation :

When two particles interact with each other , they exert equal and opposite forces on each other.

Particle 1 exert force on particle 2 ⟶ $\vec{F}_{21}$

Particle 2 exert force on particle 1 ⟶ $\vec{F}_{12}$

By Newton's 3rd Law : $\vec{F}_{21} = -\vec{F}_{12}$

By Newton's 2nd Law :

$$\vec{F}_{21} = \frac{d\vec{p}_1}{dt}$$

$$\vec{F}_{12} = \frac{d\vec{p}_2}{dt}$$

$$\vec{F}_{21} = -\vec{F}_{12}$$

$$\frac{d\vec{p}_2}{dt} = -\frac{d\vec{p}_1}{dt}$$

$$\frac{d\vec{p}_1}{dt} + \frac{d\vec{p}_2}{dt} = 0$$

$$\frac{d}{dt}(\vec{p}_1 + \vec{p}_2) = 0$$

$$\vec{p}_{tot} = \vec{p}_1 + \vec{p}_2 = \text{Constant}$$

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Recoil momentum of gun :

- **Consider the firing of a gun.**
- **The system is Gun + Bullet**

Initially

- **Gun and bullet are at rest.**
- **Total linear momentum is zero.**

Before Firing

- **Momentum of the bullet is** $\vec{p_1}$
- **Momentum of the gun is** $\vec{p_2}$
- **Total linear momentum is Zero.**
- $\vec{p_1} + \vec{p_2} = 0$

After Firing

- **Momentum of the bullet is** $\vec{p_1}$ **to** $\vec{p_1'}$
- **Momentum of the gun is** $\vec{p_2}$ **to** $\vec{p_2'}$
- **Total linear momentum is Zero.**
- $\vec{p_1'} + \vec{p_2'} = 0$

Law of conservation of linear momentum

- **Total linear momentum has to be zero after the firing also.**
- **When the gun is fired , a force is exerted by the gun on the bullet in forward direction.**
- **The momentum of the gun is exactly equal , but in opposite direction to the momentum of the bullet.**
- **This is the reason after firing , the gun suddenly moves backward with the momentum** ($-\vec{p_2}$)
- **It is called as " recoil momentum ".**
- **This is an example of conservation of linear momentum.**

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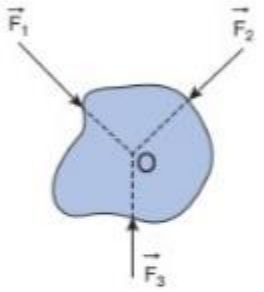
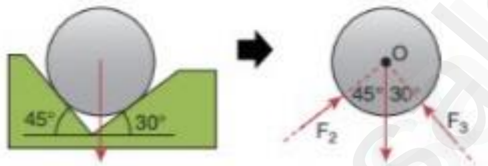
2. What are concurrent forces ? State Lami's theorem.

Concurrent Force :

- Collection of forces is said to be concurrent if the lines of forces act at a common point.
- Concurrent forces need not be in the same plane.
- If they are in same plane , they are concurrent as well as coplanar forces.



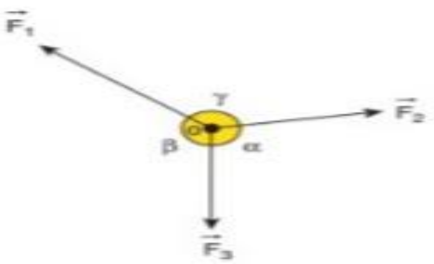


Concurrent forces

Lami's Theorem :

" If the system of three concurrent and coplanar forces is in equilibrium , then Lami's theorem states that the magnitude of each force of the system is proportional to the sine of the angle between the other two forces. The constant of proportionality is Same for all three forces ".

- Let us consider three coplanar and concurrent forces $\vec{F_1}$, $\vec{F_2}$, $\vec{F_3}$ which act at a common point O .
- If the point is in equilibrium , then according to Lami's theorem



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$$|\vec{F_1}| \propto \sin\alpha$$

$$|\vec{F_2}| \propto \sin\beta$$

$$|\vec{F_3}| \propto \sin\gamma$$

$$\frac{|F_1|}{\sin\alpha} = \frac{|F_2|}{\sin\beta} = \frac{|F_3|}{\sin\gamma}$$

- **Lami's theorem is useful to analyse the forces acting on object which are in static equilibrium.**

---

3. Explain the motion of blocks connected by a string in

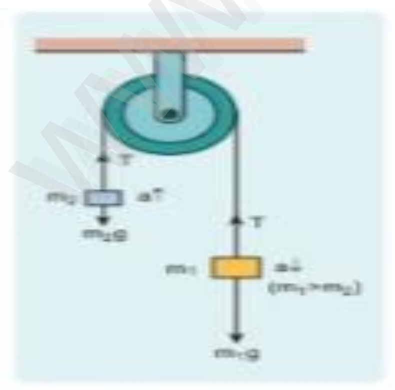
i) Vertical motion ii) Horizontal motion

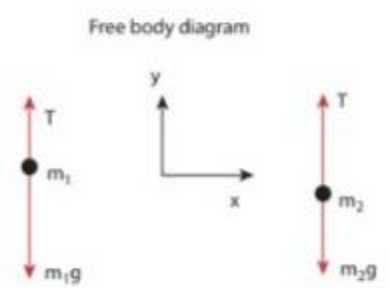
<u>Motion of connected bodies :</u>

- **When objects are connected by strings and a force F is applied either vertically or horizontally or along an inclined plane.**
- **It produces a tension T in the string , which affects the acceleration to an extent.**

<u>i) Vertical Motion :</u>

- **Consider two blocks of masses m_1 and m_2 ($m_1 > m_2$)**
- **They are connected by a light and inextensible string that passes over a pulley.**
- **When the system is released , both the blocks start moving .**
- **m_2 moves vertically upward and m_1 moves downward with same acceleration a .**





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Derivation :

1. Applying Newton's second law

For mass m_2

$$T\,j - m_2 g\,j = m_2 a\,j$$

$$T - m_2 g = m_2 a$$

For mass m_1

$$T\,j - m_1 g\,j = -\,m_1 a\,j$$

$$T - m_1 g\,j = -\,m_1 a$$

$$m_1 g - T = m_1 a\,j$$

2. Adding the above two equations

$$\cancel{T} - m_2 g + m_1 g - \cancel{T} = m_2 a + m_1 a$$

$$m_1 g - m_2 g = m_2 a + m_1 a$$

$$(m_1 - m_2)\,g = (m_2 + m_1)\,a$$

$$(m_2 + m_1)\,a = (m_1 - m_2)\,g$$

$$a = \frac{(m_1 - m_2)\,g}{(m_2 + m_1)}$$

3. Tension acting on the string

$$T - m_2 g = m_2 a$$

Substitute acceleration value in above equation

$$T - m_2 g = m_2 \left(\frac{m_1 - m_2}{m_2 + m_1}\right) g$$

$$T = m_2 g \left(\frac{m_1 - m_2}{m_2 + m_1}\right) + m_2 g$$

$$T = m_2 g \left(1 + \frac{m_1 - m_2}{m_2 + m_1}\right)$$

$$T = m_2 g \left(\frac{\cancel{m_2} + m_1 + m_1 - \cancel{m_2}}{m_2 + m_1}\right)$$

$$T = m_2 g \left(\frac{2 m_1}{m_2 + m_1}\right)$$

$$\boxed{T = \left(\frac{2 m_1 m_2}{m_1 + m_2}\right) g}$$

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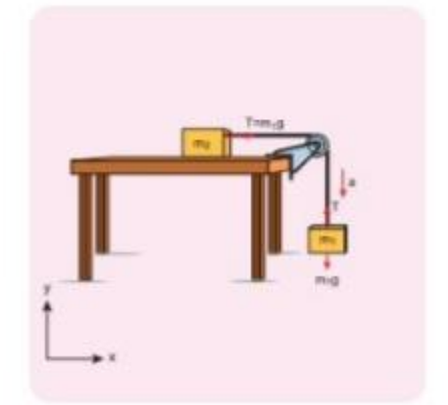
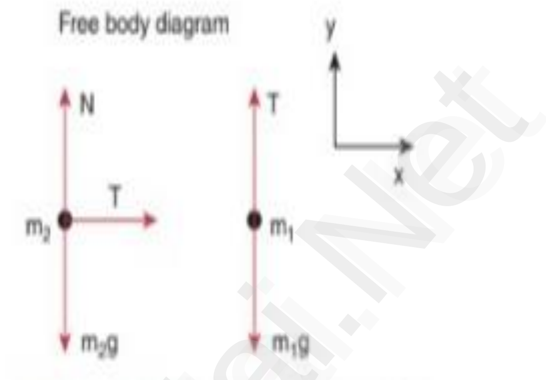
ii) Horizontal Motion :

- In this case mass m_2 is kept on a horizontal table and mass m_1 is hanging through a small pulley .

- If m_1 moves with an acceleration a downward then m_2 also moves with the same acceleration a horizontally.

Diagram :





Forces acting on mass m_2 :

1. Downward gravitational force ($m_2 g$)
2. Upward normal force exerted by the surface (N)
3. Horizontal tension exerted by the string (T)

Forces acting on mass m_1 :

1. Downward gravitational force ($m_1 g$)
2. Tension acting upwards (T)

Derivation :

1. Applying Newton's second law

For mass m_1	For mass m_2
$T\,\hat{j} - m_1 g\,\hat{j} = -m_1 a\,\hat{j}$	$T\,\hat{i} = m_2 a\,\hat{i}$
$T - m_1 g = -m_1 a$	$T = m_2 a$

2. $m_2 a - m_1 g = -m_1 a$

$$m_2 a + m_1 a = m_1 g$$

$$(m_2 + m_1)\,a = m_1 g$$

$$a = \frac{m_1 g}{(m_2 + m_1)}$$

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Tension in the string :

$$T = \left(\frac{m_1 \; m_2}{m_1 + m_2} \right) g$$

- **Tension in the string for horizontal motion is half of the tension for vertical motion for same set of masses and strings.**

Applications in industries :

- **The ropes used in conveyor belts (horizontal motion) work for longer duration than those of cranes and lifts (vertical motion)**

---

4. Briefly explain the origin of friction . Show that in an inclined plane , angle of friction is equal to angle of repose. (or)

9. Describe the method of measuring angle of repose .

Origin of friction :

- **The origin of friction is electromagnetic interaction between the atom of the surfaces which are touching each other .**
- **It is a very gentle force in the horizontal direction is given to an object at rest on the table , it does not move .**
- **It is because of the opposing force exerted by the surface on the object and the surface where its placed.**
- **This force is called the frictional force which always opposes the relative motion between an object and the surface where it is placed .**
- **If the force applied is increased , the object moves after a certain limit.**

Angle of friction equal to angle of repose :

- ✓ **Consider an object placed in an inclined plane. Let the angle θ makes with horizontal plane.**
- ✓ **For small angle of θ , the object may not slide down . As θ is increased for particular value the object begins to slide down . This value is called " Angle of repose "**

Formula :

$$\tan \theta = \mu_s$$

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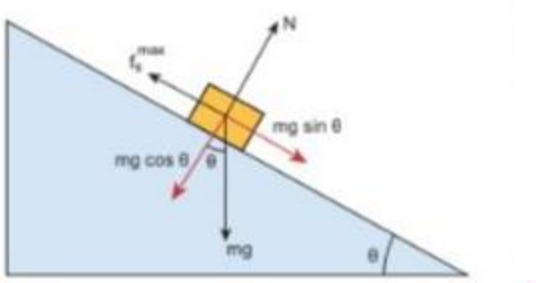
Diagram :



Gravitational Force :

Gravitational force mg resolved into two components.

i) Parallel component : mg sin θ

ii) Perpendicular component : mg cos θ

Normal Force :

The component of force perpendicular to inclined plane is balanced by the normal force.

$$N = mg \cos\theta \longrightarrow (1)$$

Static Friction :

The component of force parallel to the inclined plane tries to move the object down. When the object just begins to move , the static friction attain its maximum value.

$$f_s^{max} = \mu_s N \longrightarrow (2)$$

Sub eqn (1) in eqn (2)

$$f_s^{max} = \mu_s mg \cos\theta \longrightarrow (3)$$

From Free body diagram :

$$f_s^{max} = mg \sin\theta \longrightarrow (4)$$

Dividing eqn (4) by (3)

$$\frac{f_s^{max} = mg \sin\theta}{f_s^{max} = \mu_s mg \cos\theta}$$

$$1 = \frac{\tan\theta}{\mu_s} \qquad \boxed{\tan\theta = \mu_s}$$

$$\tan\theta = \mu_s$$

"Angle of repose is same as the angle of friction "

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5. State Newton's three laws and discuss their significance .

Newton's First Law :

Every object continues to be in the state of rest or of uniform motion unless there is external force acting on it.

Newton's Second Law :

The force acting on an object is equal to the rate of change of its momentum.

$$\boxed{\vec{F} = \frac{d\vec{p}}{dt} = m\vec{a}}$$

Newton's Second Law :

For every action there is an equal and opposite reaction.

$$\boxed{\vec{F}_{12} = -\vec{F}_{21}}$$

Discussion on Newton's Laws :

1. Newton's laws are vectors laws.

$$\vec{F} = m\vec{a}$$

$$F_x \hat{i} + F_y \hat{j} + F_z \hat{k} = m a_x \hat{i} + m_y \hat{j} + m a_z \hat{k}$$

- **The acceleration along the x direction depends only on the component of force acting along x – direction.** $F_x = m a_x$
- **The acceleration along the y direction depends only on the component of force acting along y – direction.** $F_y = m a_y$
- **The acceleration along the z direction depends only on the component of force acting along z – direction.** $F_z = m a_z$

2. The acceleration experienced by the body at time t depends on the force which acts on the body at that instant of time. It does not depend on the force which acted on the body before the time t.

$$\vec{F}(t) = m\vec{a}(t)$$

3. In general the direction of a force may be different from the direction of motion.

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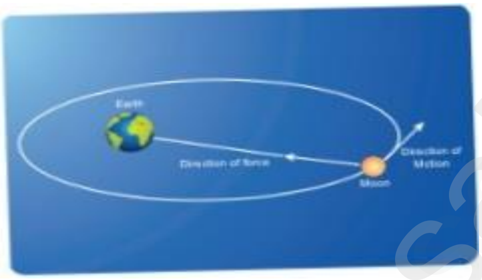
Case 1 : Force and motion in the same direction

When an apple falls towards the Earth , the direction of motion of the apple and that of force are in same direction.

Case 2 : Force and motion not in the same direction

The moon experiences a force towards the earth. But it actually moves in elliptical orbit. In this case , the direction of the force is different from the direction of motion.



Case 3 : Force and motion in opposite direction

If an object is thrown vertically upward the direction of motion is upward but gravitational force is downward.

Case 4 : Zero net force but there is motion

When raindrop gets detached from the cloud it experiences both downward gravitational force and upward air drag force . As it descends towards the earth , the upward air drag force increases and cancel downward gravity. Then raindrop moves at constant velocity till it touches the surface of the earth. Hence the raindrop comes with zero net force , with zero acceleration but with non zero terminal velocity.

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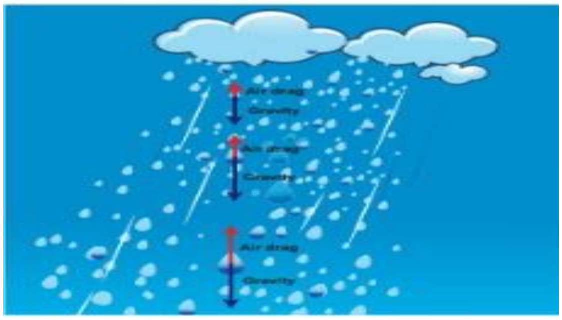
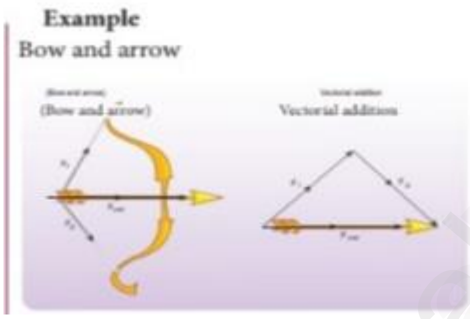


4. If multiple forces $\vec{F}_1$, $\vec{F}_2$, $\vec{F}_3$ ……. $\vec{F}_n$ act on the same body , the total force $\vec{F}_{net}$ is equivalent to the vectorial sum of the individual forces.

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots\ldots + \vec{F}_n = m\vec{a}$$



5. Newton's second law can also be written as

$$\vec{F} = m \frac{d^2\vec{r}}{dt^2}$$

The acceleration is the second derivative of position vector of the body.

---

7. Briefly explain centrifugal force with suitable examples.

<u>Centrifugal Force :</u>

- Centrifugal force is called as " pseudo force " .
- Pseudo force has no origin.
- It arises due to the non inertial nature of the frame considered.
- To use Newton's first and second laws in the rotational frame of reference , we include pseudo force.
- This centrifugal force appears to act on the object with respect to rotating frames.

<u>Example :</u>

- Consider the case of a whirling motion of a stone tied to a string.
- The stone has angular velocity ω in the inertial frame .

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- If the motion of the stone is observed from which is also rotating along with the stone with same angular velocity ω then , the stone appears to be at rest.
- Inward centripetal force - $m \omega^2 r$.
- There must be an equal and opposite force that acts on the stone.
- Outward centripetal force + $m \omega^2 r$.
- The total force acting on the stone in a rotating frame is equal to zero.
- $- m \omega^2 r + - m \omega^2 r = 0$
- This outward force $+ m \omega^2 r$ is called the centrifugal force.
- The word " centrifugal " means " flee from centre "
- The centrifugal force appears to act on the particle , only when we analyse the motion from a rotating frame.

---

8. Briefly explain " rolling friction "

- One of the important applications is suitcase with rolling on coasters.
- Rolling wheels makes it easier than carrying luggage .
- When an object moves on a surface , essentially it is sliding on it.
- But wheels move on the surface through rolling motion.
- In rolling motion when a wheel moves on a surface , the point of contact with surface is always at rest .
- Since the point of contact is at rest , there is no relative motion between the wheel and surface.
- Hence the frictional force is very less.
- At the same time if an object without a wheel , there is a relative motion between the object and the surface.
- As a result frictional force is larger. This makes it difficult to move the object.

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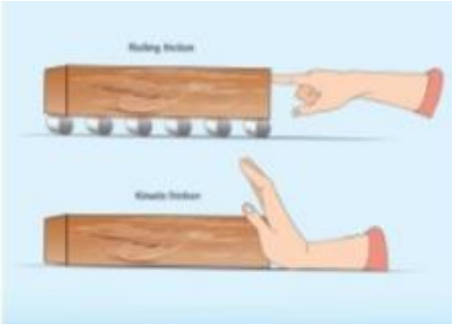

- **Ideally in pure rolling , motion of the point of contact with the surface should be at rest , but in practice it is not so.**
- **Due to the elastic nature of the surface at the point of contact there will be some deformation on the object at this point on the wheel or surface.**
- **Due to this deformation , there will be minimal friction between wheel and surface .**
- **It is called " rolling friction ". It is much smaller than kinetic friction.**

---

10. Explain the need for banking of tracks.

Banking of tracks :

- **In a levelled circular road , skidding mainly depends on the co efficient of static friction μ_s .**
- **The coefficient of static friction depends on the nature of the surface which has a maximum limiting value.**

Diagram :

To avoid the problem :

The outer edge of the road is slightly raised compared to inner edge is called " banking of roads or tracks " and the angle is called " banking angle ".

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Theory

- Let the surface of the road make angle θ with horizontal surface .
- Then the normal force makes the same angle θ with the vertical.
- When the car takes a turn , there are two forces acting on the car.

Forces acting on the car :

- Gravitational force acts downward (mg)
- Normal force perpendicular to surface (N)

Normal Force :

- Normal force resolved into two components.
- N cos θ balances the downward gravitational force mg
- N sin θ provides the necessary centripetal acceleration.

By using Newton's second law :

$$N \cos\theta = mg \longrightarrow (1)$$

$$N \sin\theta = \frac{m v^2}{r} \longrightarrow (2)$$

Eqn (2) % by (1)

$$\frac{N \sin\theta}{N \cos\theta} = \frac{m v^2}{r} \times \frac{1}{mg}$$

$$\tan\theta = \frac{v^2}{r g}$$

$$v^2 = r g \tan\theta$$

$$\boxed{v = \sqrt{r g \tan\theta}}$$

The banking angle θ and radius of curvature of the road or track determines the safe speed of the car at the turning.

If the speed of car exceeds safe speed

Then it starts to skid outward but frictional force comes into effect and provides additional centripetal force to prevent the outward skidding .

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If the speed of car lesser than safe speed

Then it starts to skid inward and frictional force comes into effect which reduces centripetal force to prevent the inward skidding .

If the speed of car greater than correct speed

Then the frictional force cannot stop the car from skidding.

---

6. Explain the similarities and differences of centripetal and centrifugal forces.

S. NO	Centripetal Force	Centrifugal force
1.	It is a real force .	It is a pseudo force or fictitious force.
2.	Real force and has real effects.	Pseudo force but has real effects.
3.	Acts in both inertial and non - inertial frames	Acts only in rotating / non – inertial frame.
4.	Origin of centripetal force is interaction between two objects.	Origin of centrifugal force is inertia. It does not arise from interaction.
5.	It is exerted on the body by the external agencies like gravitational force , tension in the String , normal force etc.	It cannot arise from gravitational force , tension in the String , normal force etc.
6.	It acts towards the axis of rotation or centre of the circle in circular motion.	It acts outwards from the axis of rotation or radially outwards from the centre of the circular motion.
7.	In inertial frames centripetal force has to be included when free body diagrams are drawn.	In inertial frames there is no centrifugal force. In rotating frames , both centripetal and centrifugal force have to be included when free body diagrams are drawn.
8.	$\lvert F_{CP} \rvert = m\omega^2 r = \frac{m v^2}{r}$	$\lvert F_{Cf} \rvert = m\omega^2 r = \frac{m v^2}{r}$

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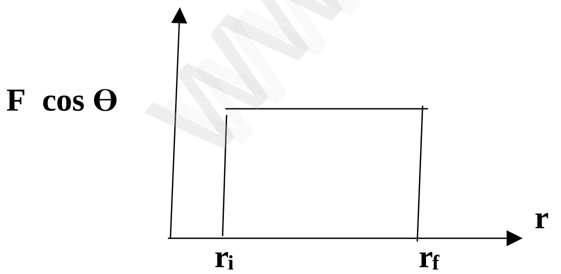
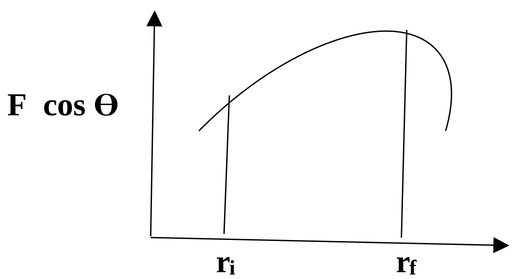
LESSON 4

1.Explain with graphs the difference between work done by a constant force and by a variable force.

Work done by a constant force	Work done by a variable force
1. Constant Force → F	1. Variable Force → F
2. Small work done → d W	2. Small work done → d W
3. Small displacement → d r	3. Small displacement → d r
4. Initial Position → r_i	4. Initial Position → r_i
5. Final Position → r_f	5. Final Position → r_f
6. Work done : $\int_{r_i}^{r_f} dW = F\cos\theta \int_{r_i}^{r_f} dr$	6. Work done : $\int_{r_i}^{r_f} dW = \int_{r_i}^{r_f} F\cos\theta \, dr$
7. $W = F\cos\theta\,(r_f - r_i)$	7. $W = \int_{r_i}^{r_f} F\cos\theta \, dr$
8. **Graph :** 	8. **Graph:** 

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2.State and explain work energy principle . Mention any three examples for it.

<u>Work Energy principle :</u>

Work done by the force on the body changes the kinetic energy of the body. This is called as work energy theorem.

- **Let us consider a body of mass at rest on frictionless horizontal surface.**

1. Work done : $W = F . s$

2. Constant Force : $F = m a$

3. Equation of motion : $v^2 = u^2 + 2 a s$

$$2 a s = v^2 - u^2$$

$$a = \frac{v^2 - u^2}{2 s}$$

4. $F = m \left(\frac{v^2 - u^2}{2 s} \right)$

5. $W = m \left(\frac{v^2 - u^2}{2 s} \right) s$

6. $W = m \left(\frac{v^2 - u^2}{2} \right)$

7. $W = \frac{1}{2} m v^2 - \frac{1}{2} m u^2$

8. $W = \Delta \ K.E$

Work done	Kinetic Energy
Positive	Increases
Negative	Decreases
No Work done	No Kinetic energy

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3. Arrive at an expression for power and velocity.

Work done by a force $\vec{F}$ for a displacement $\vec{dr}$ is $W = \int \vec{F} \cdot \vec{dr}$

L.H.S

$$W = \int dW = \int \frac{dW}{dt}\, dt$$

R.H.S

$$\int \vec{F} \cdot \vec{dr} = \int \left(\vec{F} \cdot \frac{\vec{dr}}{dt} \right) dt = \int \left(\vec{F} \cdot \vec{v} \right) dt$$

Derivation :

1. $\int \frac{dW}{dt} \cdot dt = \int \left(\vec{F} \cdot \vec{v} \right) dt$

2. $\int \left(\frac{dW}{dt} - \vec{F} \cdot \vec{V} \right) dt = 0$

3. $\int \frac{dW}{dt} - \vec{F} \cdot \vec{v} = 0$

4. $\frac{dW}{dt} = \vec{F} \cdot \vec{v} = P$

---

4. Arrive at an expression for elastic collision in one dimension and discuss various cases.

Diagram:

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Theory :

Consider two elastic bodies of masses m_1 and m_2 moving in a straight line on a frictionless horizontal surface.

Mass and Velocity

Mass	Initial Velocity	Final Velocity
m_1	u_1	v_1
m_2	u_2	v_2

Momentum

Collision	Mass m_1	Mass m_2	Total Momentum
Before Collision	$P_{i1} = m_1 u_1$	$P_{i2} = m_2 u_2$	$P_i = m_1 u_1 + m_2 u_2$
After Collision	$P_{f1} = m_1 v_1$	$P_{f2} = m_2 v_2$	$P_f = m_1 v_1 + m_2 v_2$

Kinetic Energy

Collision	Mass m_1	Mass m_2	Total Kinetic Energy
Before Collision	$K.E_{i1} = \frac{1}{2} m_1 u_1^2$	$K.E_{i2} = \frac{1}{2} m_2 u_2^2$	$K.E_i = \frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2$
After Collision	$K.E_{f1} = \frac{1}{2} m_1 v_1^2$	$K.E_{f2} = \frac{1}{2} m_2 v_2^2$	$K.E_f = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$

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Law Conservation of Momentum :

1. $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$

2. $m_1 u_1 - m_1 v_1 = m_2 v_2 - m_2 u_2$

3. $m_1 (u_1 - v_1) = m_2 (v_2 - u_2)$ -------------- (1)

For Elastic Collision :

1. $\frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$

2. $\frac{1}{2} m_1 u_1^2 - \frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_2 v_2^2 - \frac{1}{2} m_2 u_2^2$

3. $\frac{1}{2} m_1 (u_1^2 - v_1^2) = \frac{1}{2} m_2 (v_2^2 - u_2^2)$

4. $m_1 (u_1 + v_1) (u_1 - v_1) = m_2 (v_2 + u_2) (v_2 - u_2)$ ------- (2)

Equation (2) % (1)

5. $\frac{\cancel{m_1} (u_1 + v_1) \cancel{(u_1 - v_1)}}{\cancel{m_1} \cancel{(u_1 - v_1)}} = \frac{\cancel{m_2} (v_2 + u_2) \cancel{(v_2 - u_2)}}{\cancel{m_2} \cancel{(v_2 - u_2)}}$

6. $u_1 + v_1 = v_2 + u_2$

7. $v_2 = u_1 + v_1 - u_2$ ------------------- (3)

To find final velocity :

Sub equation (3) in (1)

8. $m_1 (u_1 - v_1) = m_2 (u_1 + v_1 - u_2 - u_2)$

9. $m_1 (u_1 - v_1) = m_2 (u_1 + v_1 - 2u_2)$

10. $m_1 u_1 - m_1 v_1 = m_2 u_1 + m_2 v_1 - 2 m_2 u_2$

11. $m_1 u_1 - m_2 u_1 + 2 m_2 u_2 = m_1 v_1 + m_2 v_1$

12. $(m_1 - m_2) u_1 + 2 m_2 u_2 = (m_1 + m_2) v_1$

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Formula :

1. $$v_1 = \frac{(m_1 - m_2)}{(m_1 + m_2)} u_1 + \frac{2 m_2}{(m_1 + m_2)} u_2$$

2. $$v_2 = \frac{2 m_1}{(m_1 + m_2)} u_1 + \frac{(m_2 - m_1)}{(m_1 + m_2)} u_2$$

Case 1 : **When bodies have same mass $m_1 = m_2$**

$$V_1 = u_2 \text{ and } v_2 = u_1$$

Case 2 : **When bodies have same mass $m_1 = m_2$ but second body is at rest**

$$V_1 = 0 \text{ and } v_2 = u_2$$

Case 3 : **First body lighter than second body $m_1 < m_2$: $m_1 / m_2 = 0$; $u_2 = 0$**

$$V_1 = -u_1 \text{ and } v_2 = 0$$

Case 4 : **Second body lighter than First body $m_2 < m_1$: $m_2 / m_1 = 0$; $u_2 = 0$**

$$V_1 = u_1 \text{ and } v_2 = 2 u_1$$

---

5. What is inelastic collision ? In which way it is different from elastic collision . Mention few examples.

Elastic Collision :

1. Total momentum is conserved.
2. Total kinetic energy is conserved .
3. Forces involved are conservative forces.
4. Mechanical energy is not dissipated.

Inelastic Collision :

1. Total momentum is conserved.
2. Total kinetic energy is not conserved .
3. Forces involved are non conservative forces.
4. Mechanical energy is dissipated into heat and light.

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Total Kinetic Energy

Before Collision = After Collision

K.E Before Collision - K.E After Collision = Loss in energy during collision = ΔQ

Example :

When a clay putty is thrown on moving vehicle , the clay putty sticks to moving vehicle and they move together with same velocity.

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UNIT - 5

1. Explain the types of equilibrium with suitable examples.

1. Translational Equilibrium :

- Linear momentum is constant.
- Net force is zero.

2. Rotational Equilibrium :

- Angular momentum is constant.
- Net torque is zero.

3. Static Equilibrium :

- Linear momentum and angular momentum are *zero*.
- Net force and torque are zero.

4. Dynamic Equilibrium :

- Linear momentum and angular momentum are *constant*.
- Net force and torque are zero.

5. Stable Equilibrium :

- Linear momentum and angular momentum are zero.
- The body tries to come back to equilibrium if slightly disturbed and released.
- The centre of mass of the body shifts slightly *higher* if disturbed from equilibrium.
- Potential energy of the body is minimum and it increases if disturbed.

6. Unstable Equilibrium :

- Linear momentum and angular momentum are zero.
- The body *cannot* come back to equilibrium if slightly disturbed and released.
- The centre of mass of the body shifts slightly *lower* if disturbed from equilibrium.
- Potential energy of the body is *not* minimum and it increases if disturbed.

7. Neutral Equilibrium :

- Linear momentum and angular momentum are zero.
- The body remains at the same equilibrium if slightly disturbed and released.
- The centre of mass of the body *does not* shifts slightly higher if disturbed from equilibrium.
- Potential energy of the body remains *same* even if disturbed.

---

2. Explain the method to find the centre of gravity of a irregularly shaped lamina.

Centre of gravity :

The point at which the entire weight of the body acts irrespective of the position and orientation of the body.

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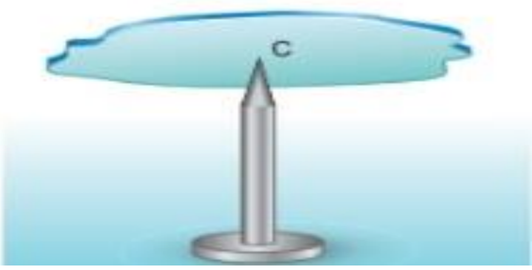
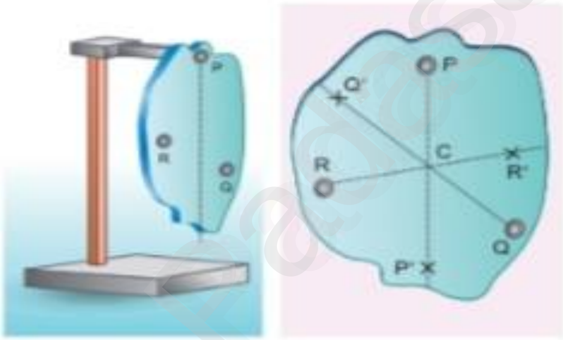
Method to find centre of gravity of a irregularly shaped lamina :

Method 1 :



- **The lamina remains horizontal when pivoted at the point where the net gravitational force acts , which is at the centre of gravity.**
- **When a body is supported at the centre of gravity , the sum of the torques acts on all point masses of the rigid body becomes zero.**
- **The weight is compensated by the normal reaction force exerted by the pivot.**
- **The body is in static equilibrium and hence it remains horizontal.**

Method 2 :



- **There is also another way to determine the centre of gravity of an irregular lamina.**
- **If we suspend the lamina from different points like P , Q , R .**
- **The vertical lines PP′ , QQ′ , RR′ all pass through the centre of gravity.**
- **Reaction force acting at the point of suspension and the gravitational force acts on the centre of gravity cancel each other.**
- **The torques caused by them also cancel each other.**

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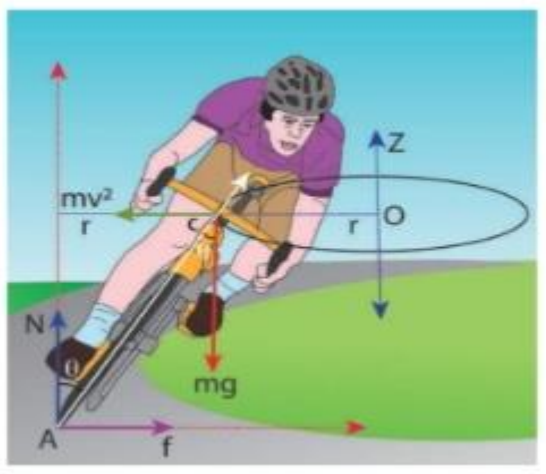
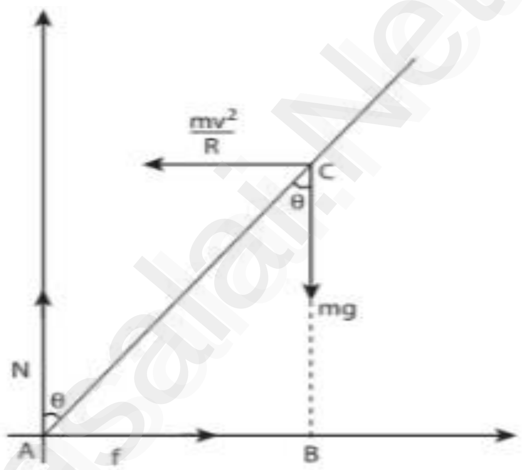
3. Explain why a cyclist bends while negotiating a curved road ? Arrive at the expression for angle of bending for a given velocity.

Bending of cyclist

- Let us consider a cyclist negotiating a circular level road of radius r with a speed v.
- The cycle and the cyclist are considered as one system with mass m.
- The centre gravity of the system is C and circle centre is O.

Diagram :





Theory :

- Let us choose the line OC as X – axis and the vertical line through O as Z – axis.
- The system as a frame is rotating about Z - axis.
- The system is at rest in this rotating frame.
- In rotating frame pseudo force acts on the system
- This force will act through the centre of gravity.

Forces acting on the system :

1. Gravitational force (mg)
2. Normal force (N)
3. Frictional force (f)
4. Centrifugal force ($m v^2 / r$)

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As the system is in equilibrium :

In the rotational frame of reference ,

Net external external force and net external torque must be zero.

- **Torque due to the gravitational force :**
  - **About the point A is mg AB**
  - **It causes clockwise turn.**
  - **And it is taken as negative.**

- **Torque due to the Centrifugal force :**
  - **About the point B is mg $\frac{mv^2}{r}$ BC**
  - **It causes anticlockwise turn.**
  - **And it is taken as positive.**

Derivation :

1. $- mg\, AB + \frac{mv^2}{r} BC = 0$

2. $mg\, AB = \frac{mv^2}{r} BC \longrightarrow (1)$

3. From Δ A B C

4. $\sin\theta = \frac{AB}{AC}$

5. $AB = AC \sin\theta \longrightarrow (2)$

6. $\cos\theta = \frac{BC}{AC}$

7. $BC = AC \cos\theta \longrightarrow (3)$

8. Sub eqn (2) and (3) in (1)

$$mg\, AB = \frac{mv^2}{r} BC$$

$$\cancel{m} g\, \cancel{AC} \sin\theta = \frac{\cancel{m} v^2}{r} \cancel{AC} \cos\theta$$

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9. $$\frac{\sin\theta}{\cos\theta} = \frac{v^2}{r g}$$

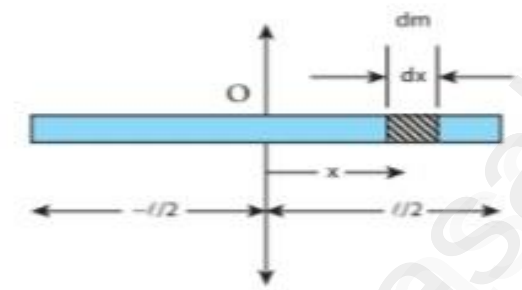
10. $$\tan\theta = \frac{v^2}{r g}$$

$$\boxed{\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)}$$

---

4. Derive the expression for moment of inertia of a rod about its centre and perpendicular to the rod.

<u>Diagram :</u>



<u>Theory :</u>

- Let us consider a uniform rod of mass (M) and length (l)
- The rod about an axis passes through centre of mass and perpendicular to the rod.
- The rod is along the x - axis and geometric center is O.
- Infinitesimal small mass (dm) at a distance (x) from the origin.

<u>Moment of inertia of a rod :</u>

1. $dI = (dm)\,x^2 \longrightarrow (1)$
2. Linear mass density = mass per unit length
3. For mass M : $\lambda = \frac{M}{l} \longrightarrow (2)$
4. For mass dm : $\lambda = \frac{dm}{dx}$
5. $dm = \lambda\, dx \longrightarrow (3)$

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6. Sub eqn (2) in (3)

$$dm = \frac{M}{\ell}\, dx \longrightarrow (4)$$

7. Sub eqn (4) in (1)

$$d\,I = \left(\frac{M}{\ell}\right) dx \quad x^2$$

8. $$\int d\,I = \int (d\,m)\, x^2$$

9. $$I = \int \frac{M}{\ell}\, dx \quad x^2$$

10. $$I = \frac{M}{\ell} \int x^2\, dx$$

11. As the mass is distributed on either side of the origin , the limits for integration are taken from $-\ell / 2$ to $\ell / 2$

12. $$I = \frac{M}{\ell} \int_{-\ell/2}^{\ell/2} x^2\, dx$$

13. $$I = \frac{M}{\ell} \left[\frac{x^3}{3}\right]_{-\ell/2}^{\ell/2}$$

14. $$I = \frac{M}{3\,\ell} \left(\frac{\ell^3}{2^3} - \left(\frac{-\ell^3}{2^3}\right)\right)$$

15. $$I = \frac{M}{3\,\ell} \left(\frac{\ell^3}{8} + \frac{\ell^3}{8}\right)$$

16. $$I = \frac{M}{3\,\ell} \left(\frac{2\,\ell^3}{8}\right)$$

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17. $I = \frac{1}{12} M l^2$

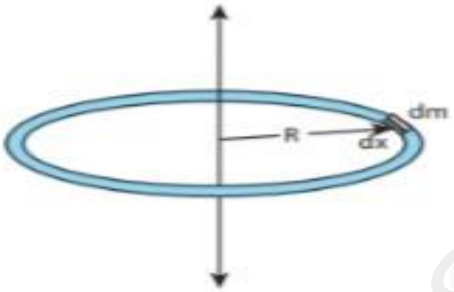
Moment of inertia of a uniform rod :

$$\boxed{I = \frac{1}{12} M l^2}$$

---

5. Derive the expression for moment of inertia of a ring about an axis passing through the centre and perpendicular to the plane.

Diagram :



Theory :

- Let us consider a uniform ring of mass (M) and radius (R)
- Moment of inertia of the ring about an axis passes through its centre and perpendicular to the plane.
- Infinitesimal small mass (dm) of length (dx) of the ring.
- This (dm) is located at a distance R , which is the radius of the ring from the axis.

Moment of inertia of a rod :

1. $dI = (dm) R^2 \longrightarrow (1)$

2. Linear mass density = mass per unit length

3. For mass M : $\lambda = \frac{M}{2\pi R} \longrightarrow (2)$

4. For mass dm : $\lambda = \frac{dm}{dx}$

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5. $dm = \lambda \; dx \longrightarrow (3)$

6. Sub eqn (2) in (3)

$$dm = \frac{M}{2\pi R} dx \longrightarrow (4)$$

7. Sub eqn (4) in (1)

$$\int dI = \int (dm) R^2$$

8. $$I = \frac{M}{2\pi R} \int (dx) R^2$$

9. $$I = \frac{MR}{2\pi} \int dx$$

10. To cover the entire length of the ring , the limits for integration from 0 to $2\pi R$

11. $$I = \frac{MR}{2\pi} \int_0^{2\pi R} dx$$

12. $$I = \frac{MR}{2\pi} \left(x \right)_0^{2\pi R}$$

13. $$I = \frac{MR}{2\pi} \left(2\pi R - 0 \right)$$

14. $$I = \frac{MR}{2\pi} \left(2\pi R \right)$$

15. $$I = M R^2$$

Moment of inertia of a uniform ring :

$$\boxed{I = MR^2}$$

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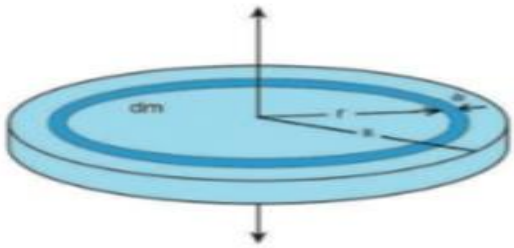
6. Derive the expression for moment of inertia of uniform disc about an axis passing through the center and perpendicular to the plane.

Diagram :



Theory :

- Let us consider a uniform disc of mass (M) and radius (R)
- This disc is made up of many infinitesimally small rings.
- Infinitesimal small mass (dm) and thickness (dr) and radius (r).

Moment of inertia of a rod :

1. $dI = (dm)\, r^2 \longrightarrow (1)$
2. Surface mass density = mass per unit area
3. For mass M : $\sigma = \dfrac{M}{\pi R^2} \longrightarrow (2)$
4. For mass dm : $\sigma = \dfrac{dm}{2\pi r\ dr}$
5. Area of the elemental ring = length x thickness = $2\pi r\, dr$
6. $dm = \sigma\, 2\pi r\, dr \longrightarrow (3)$
7. Sub eqn (2) in (3)

$$dm = \frac{M}{\pi R^2}\, 2\pi r\ dr$$

8. $dm = \dfrac{2M\ r\ dr}{R^2} \longrightarrow (4)$

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9. Sub eqn (4) in (1)

$$\int dI = \int (dm)\, r^2$$

10. $$I = \left(\frac{2M}{R^2}\right) \int (r\,dr)\, r^2$$

11. $$I = \frac{2M}{R^2} \int r^3\, dr$$

12. The limits for integration are taken from 0 to R

13. $$I = \frac{2M}{R^2} \int_0^R r^3\, dr$$

14. $$I = \frac{2M}{R^2} \left(\frac{r^4}{4}\right)_0^R$$

15. $$I = \frac{2M}{4R^2} \left(R^4 - 0\right)$$

16. $$I = 1\ M\ \frac{R^2}{2}$$

Moment of inertia of a uniform disc :

$$\boxed{I = \frac{1}{2} M R^2}$$

---

7. Discuss conservation of angular momentum with example .

Conservation of angular momentum :

When no external torque acts on the body , the net angular momentum of a rotating rigid body remains constant. This is known as law of conservation of angular momentum.

Derivation :

1. Angular momentum : $L = I\,\omega$

2. Torque : $\tau = \frac{dL}{dt}$

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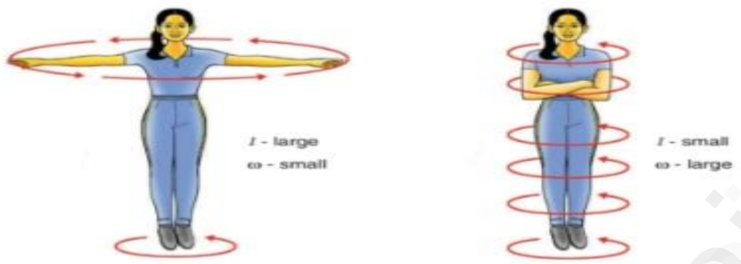
3. If $\tau = 0$ then , L = constant

4. Angular momentum kept as constant.

5. If I increases then ω will decreases and vice – versa.

$$I\omega = \text{constant}$$
$$I_i\,\omega_i = I_f\,\omega_f$$

Example :



1. An ice dancer spins slowly when the hands are stretched out and spins faster when the hands are brought close to the body.
2. Stretching of hands away from body resulting in slower spin
   - Increases moment of inertia
   - Decreases angular velocity
3. Stretching of hands brought close to the body resulting in faster spin
   - Decreases moment of inertia
   - Increases angular velocity

A diver while in air , curls the body close to decrease the moment of inertia , which in turn helps to increase the number of somersaults in air.

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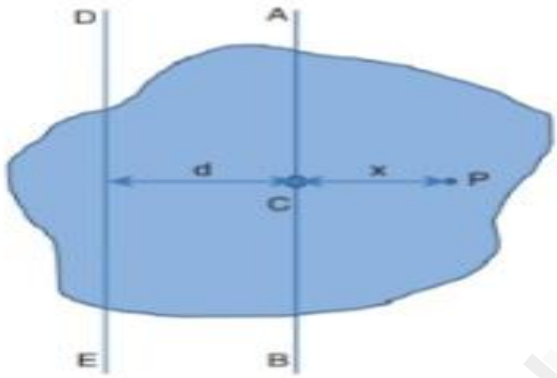
8. State and prove parallel axis theorem.

Parallel Axis Theorem :

The moment of inertia of a body about any axis is equal to sum of its moment of inertia about a parallel axis through its centre of mass and the product of the mass of the body and the square of the perpendicular distance between the two axes.

Diagram :



- **I_C is the moment of inertia of the body of mass M about an axis passing through the centre of mass.**
- **Moment of inertia I about a parallel axis at a distance d from it is given by the relation,**

$$\boxed{I = I_C + M d^2}$$

Theory :

1. **Let us consider a rigid body .**
2. **Moment of inertia about an axis AB passing through centre mass is I_C.**
3. **Moment of inertia about an axis DE passing through centre mass is I.**
4. **Consider a point mass m on the body at position x from its centre of mass.**
5. **Moment of inertia about a parallel axis at a distance d .**

Derivation :

1. $I = \Sigma\, m\, (x + d)^2$
2. $I = \Sigma\, m\, (x^2 + d^2 + 2\,x\,d)$
3. $I = \Sigma\, (m\, x^2 + m\, d^2 + 2\,m\,x\,d)$

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4. $I = \Sigma m x^2 + \Sigma m d^2 + 2 d \Sigma m x$

5. Moment of inertia of the body about centre of mass : $I_C = \Sigma m x^2$

6. Σm is the entire mass M of the object : $\Sigma m = M$

7. $\Sigma m x$ will be zero. $\Sigma m x = 0$ because x can take positive and negative values w.r.t the axis AB.

8. $I = I_C + M d^2$

9. Hence , the parallel axis theorem is proved.

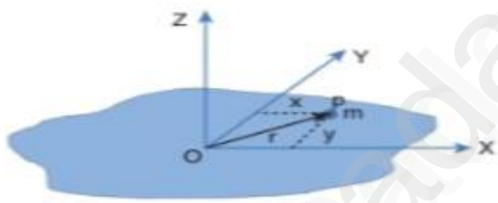
---

9. State and prove perpendicular axis theorem.

Perpendicular Axis Theorem :

The moment of inertia of a plane laminar body about an axis perpendicular to its plane is equal to sum of its moment of inertia about two perpendicular axes lying in the plane of the body such that all the three axes are mutually perpendicular and have a common point.

Diagram :



- Let the X and Y axes lie in the plane and Z – axis perpendicular to the plane of the laminar object.
- Moment of inertia about X and Y - axes are I_X and I_Y.
- Moment of inertia about Z - axis is I_Z .
- The perpendicular axis theorem could be expressed as , $\boxed{I_Z = I_X + I_Y}$

Theory :

1. Let us consider a plane laminar object of negligible thickness on which lies the origin (O).
2. The X and Y axes lie on the plane and Z - axis is perpendicular to it.
3. The lamina is considered to be made up of a large particles of mass m.

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4. Let us choose one such particle at a point P which has coordinates (x , y)
   At a distance r from O.
5. Moment of inertia of the particle about Z – axis is $m\ r^2$. ($r^2 = x^2 + y^2$)
6. Moment of inertia of the entire lamina about Z - axis as , $I_Z = \Sigma\ m\ r^2$

Derivation :

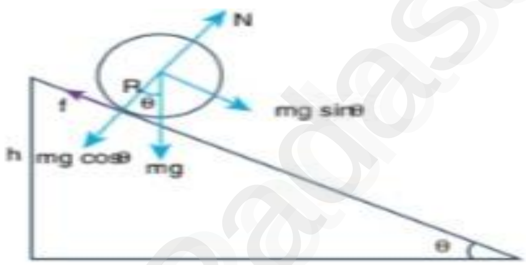
1. $I = \Sigma\ m\ r^2$
2. $I = \Sigma\ m\ (\ x^2 + y^2\ )$
3. $I = \Sigma\ m\ x^2 + \Sigma\ m\ y^2$
4. Moment of inertia about Y – axis : $I_Y = \Sigma\ m\ x^2$
5. Moment of inertia about X – axis : $I_X = \Sigma\ m\ y^2$
6. $I = I_X + I_Y$

Thus , the perpendicular axis theorem is proved.

---

10. Discuss rolling on inclined plane and arrive at the expression for the acceleration.

Diagram :



Theory :

- Let us assume a round object of mass m and radius R.
- Let it is rolling down an inclined plane without slipping.
- There are two forces acting on the object along the inclined plane.
- One is the component of gravitational force m g sin θ .
- Other is the static frictional force f .
- Other is the component of gravitational force m g cos θ .
- Other is the normal force N exerted by the plane .
- We can write the equation for motion from the free body diagram of the object.

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Derivation :

1. For translational motion ,

   - Supporting force $\longrightarrow$ $m\ g\ \sin\theta$
   - Opposing force $\longrightarrow$ f

2. $m\ g\ \sin\theta - f = ma \longrightarrow (1)$

3. For rotational motion ,

   - Frictional force $\longrightarrow$ f
   - Torque $\longrightarrow$ $\tau = R\ f$

4. Relation between torque and angular acceleration

$$\tau = I\ \alpha$$

$$I\ \alpha = R\ f \longrightarrow (2)$$

5. Moment of inertia : $I = m\ K^2$

   Angular acceleration : $a = r\ \alpha$

$$\alpha = a\ /\ R$$

6. $$R\ f = I\ \alpha$$

$$R\ f = m\ K^2 \left(\frac{a}{R} \right)$$

$$f = m\ K^2 \left(\frac{a}{R^2} \right) \longrightarrow (3)$$

7. Sub eqn (3) in eqn (1)

$$m\ g\ \sin\theta - f = m\,a$$

$$m\ g\ \sin\theta - m\ K^2 \left(\frac{a}{R^2} \right) = m\,a$$

$$m\ g\ \sin\theta - m\,a \left(\frac{K^2}{R^2} \right) = m\,a$$

$$m\ g\ \sin\theta = m\,a \left(\frac{K^2}{R^2} \right) + m\,a$$

$$\cancel{m}\ g\ \sin\theta = \cancel{m}\,a \left(\frac{K^2}{R^2} + 1 \right)$$

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$$a = \frac{g \sin \theta}{\left(1 + \frac{K^2}{R^2}\right)}$$

<u>Acceleration of rolling of round object in an inclined plane :</u>

$$\boxed{a = \frac{g \sin \theta}{\left(1 + \frac{K^2}{R^2}\right)}}$$

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1. Electrostatics

1. Discuss the basic properties of electric charges.

Properties of electric charge :

1. Electric charge 2. Conservation of charge 3. Quantisation of charge

1. Electric Charge :

- Objects in the universe are made up of atoms.
- Atoms are made up of protons , neutrons and electrons.
- These particles have mass , an inherent property of particles.
- Electric charge is another intrinsic and fundamental property of particles.
- S I Unit of electric charge is Coulomb.

2. Conservation of Charge :

- Total electric charge in the universe is constant.
- Charge can neither be created nor be destroyed.
- Net change in charge will always be zero.
- Objects are electrically neutral before rubbing process happen.
- After rubbing simply transfers charges from one object to the others.

Example :

1. When a glass rod rubbed with silk cloth then negative charge transferred from glass to silk.
2. As a result , glass rod is positively charged and silk cloth is negatively charged.

3. Quantisation of charge :

The charge q on any object is equal to an integral multiple of fundamental unit of charge e.

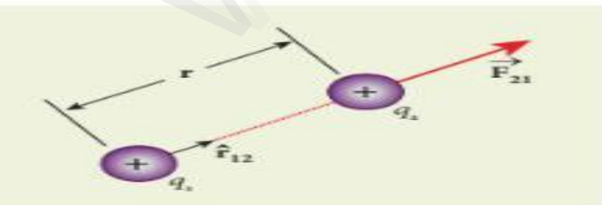
$\boxed{q = ne}$ n is any integer (0 , + 1 , $\pm$ 2) __

Charge of electron : -1.6×10^{-19} C

---

2. Explain in detail Coulomb's law and its various aspects .

1.Coulomb's law states that , electrostatic force is directly proportional to the product of the magnitude of the two point charges and inversely proportional to the square of the distance between the two point charges.



$$\vec{F}_{21} = K \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

2. Consider two point charges q_1 and q_2 at rest in vacuum , and separated by a distance r. r_{12} is a unit vector and K is the proportionality constant.

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3. Force on the charge q_2 exerted by the charge q_1

$$\boxed{\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12}}$$

4. Force on the charge q_1 exerted by the charge q_2

$$\boxed{\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{21}}$$

5. $$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} (- \hat{r}_{12})$$

$$\boxed{\vec{F}_{21} = - \vec{F}_{12}} \qquad \hat{r}_{21} = - \hat{r}_{12}$$

Therefore , the electrostatic force obeys Newton's third law.

6. **Value of proportionality constant K :**

$$K = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \ N\,m^2\,C^{-2}$$

$$\varepsilon_0 = \frac{1}{4\pi K} = 8.854 \times 10^{-12} \ C^2\,N^{-1}\,m^{-2}$$

7. **Permittivity :**

It is a physical constant that called as permittivity because of how much a given substance permits electric field lines to pass through them.

- Permittivity of free space or vacuum $\longrightarrow \varepsilon_0$
- Permittivity of a medium $\longrightarrow \varepsilon \ (\varepsilon > \varepsilon_0)$
- Relative permittivity of free space $\longrightarrow \varepsilon_r \ (\varepsilon_r = \varepsilon / \varepsilon_0)$
- For vacuum or air , $\varepsilon_r = 1$ and for other media $\varepsilon_r > 1$.
- Coulomb's law in vacuum : $\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12}$
- Coulomb's law in medium : $F_{21} = \frac{1}{4\pi\varepsilon} \frac{q_1 q_2}{r^2} \hat{r}_{12}$

8. The magnitude of the electrostatic force between two charges each of one coulomb and separated by a distance 1 m is calculated as follows :

$$|F| = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$$

Here , $q_1 = q_2 = 1\,C$ and $r = 1\ m$, $r = 1$

$$|F| = \frac{9 \times 10^9 \times 1 \times 1}{1^2} = 9 \times 10^9 \ N$$

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- This is the huge quantity , almost equivalent to weight of one million ton.

9. Similarity between Coulomb's law and Newton's gravitational law.

- Coulomb's law have same structure as Newton's law of gravitation.
- Both are inversely proportional to distance between the particles.
- Electrostatic force : Directly proportional to product of two point charges.
- Gravitational force : Directly proportional to product of two masses.

10. Difference between Coulomb's force and Gravitational force :

S.No	Coulomb Force	Gravitational Force
1.	It may be attractive or repulsive.	It is always attractive in nature
2.	It depends upon medium.	It does not depend upon the medium.
3.	It is always greater in magnitude $K = 9 \times 10^{9}\ N\,m^2\ C^{-2}$	It is lesser than Coulomb force $G = 6.67 \times 10^{-11}\ N\,m^2\ kg^{-2}$
4.	The force between the charges will not be same during motion or rest.	It is always same whether the two masses are rest or motion.

---

3. Define electric field and discuss its various aspects .

Electric Field :

Electric field at a point P , at a distance r from the point charge q is the force experienced by a unit point charge .

Formula :

$$\boxed{\vec{E} = \frac{\vec{F}}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}}$$

S I unit : $N\,C^{-1}$

Important aspects of Electric field :

1. * If q is positive , electric field points away from the source charge q.
   * If q is negative , electric field points towards the source charge q.

2. Force experienced by the test charge q_0 is $\vec{F} = q_0 \vec{E}$

3. Electric field is independent of test charge q_0 and depends only on source charge q.

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4. Test charge q_0 is small , not modify the electric field of source charge.

5. Electric field equation is only valid for point charges.

6. Electric field is a vector quantity which has unique direction and magnitude .

7. Electric field decreases when distance increases.

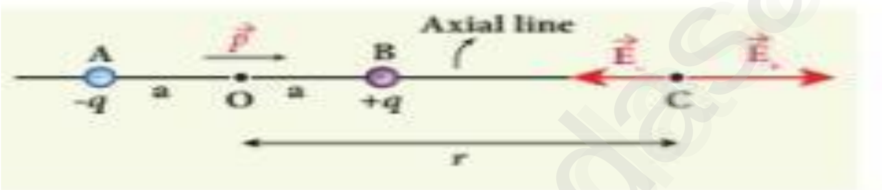
Uniform Electric field	Non uniform Electric field
It has same direction and constant magnitude at all points.	Different directions and different magnitudes or both at different points.

---

4. Calculate the electric field due to a dipole on its axial line and equatorial plane.

i) Electric field due to a electric dipole on its axial line:

Diagram :



Formula :

$$\vec{E}_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$$

Explanation :

Consider an electric dipole placed on the x - axis . A point C is located at a distance of r from the midpoint O of the dipole on the axial line. Electric dipole moment vector $\vec{p}$ is from -q to +q and is directed along BC.

Derivation :

1. Electric field due to + q : $\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p}$

2. Electric field due to _ q : $\vec{E}_- = \frac{-1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$

- Since +q is located closer to the point C than -q , $\vec{E}_+$ is stronger than $\vec{E}_-$.

  Therefore , Length of the $\vec{E}_+$ vector is larger than $\vec{E}_-$ vector.

3. Total Electric field by superposition principle : $\vec{E} = \vec{E}_+ + \vec{E}_-$

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4. $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$

5. $\vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{p}$

6. $\vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{(r+a)^2 - (r-a)^2}{(r-a)^2(r+a)^2}\right]\hat{p}$

7. $\vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{4\,a\,r}{(r^2 - a^2)^2}\right]\hat{p}$

If the point C is far away from the dipole $(r >> a)$ then $(r^2 - a^2)^2 = r^4$

8. $\vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{4\,a\,r}{r^4}\right]\hat{p}$

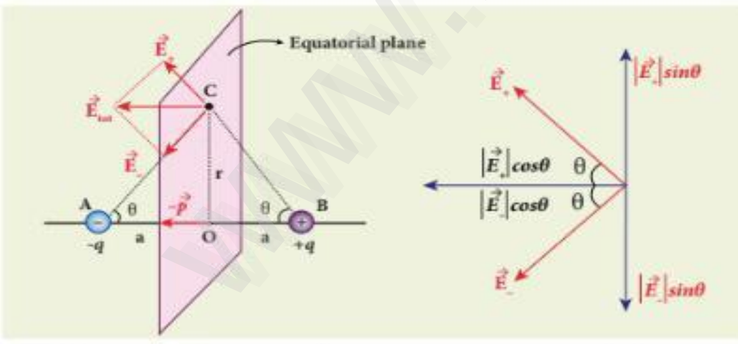
9. $\vec{E} = \frac{1}{4\pi\varepsilon_0}\left[\frac{2.\ 2qa}{r^3}\right]\hat{p}$

10. Since $2aq\hat{p} = \vec{p}$

$$\boxed{\vec{E}_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}}$$

ii) Electric field due to a electric dipole on its Equatorial plane:

Diagram :



Formula :

$$\boxed{\vec{E}_{equatorial} = \frac{-1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}}$$

Explanation :

- Let a point C at a distance r from the midpoint O of the dipole on equatorial plane.
- The point C is equi distant from + q and – q , the magnitude of the electric fields is same.
- The direction of $\vec{E}_+$ along BC and direction of $\vec{E}_-$ along CA.

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- $\vec{E}_+$ and $\vec{E}_-$ can be resolved into two components.
- One component parallel to the dipole axis and other perpendicular to it.
- Perpendicular components $|\vec{E}_+| \sin\theta$ and $|\vec{E}_-| \cos\theta$ are equal in magnitude and oppositely directed , they cancel each other.
- The magnitude of total electric field is the sum of the parallel component of $\vec{E}_+$ and $\vec{E}_-$ and its direction along p.

Total electric field :

1. $\vec{E}_{tot} = - |\vec{E}_+| \cos\theta \, \hat{p} - |\vec{E}_-| \cos\theta \, \hat{p}$

2. $|\vec{E}_+| = |\vec{E}_-| = \dfrac{1}{4\pi\varepsilon_0} \dfrac{q}{r^2 + a^2}$

3. $\vec{E}_{tot} = -2 |\vec{E}_+| \cos\theta \, \hat{p}$

4. $\vec{E}_{tot} = -2 \dfrac{1}{4\pi\varepsilon_0} \dfrac{q}{r^2 + a^2} \cos\theta \, \hat{p}$

5. $\vec{E}_{tot} = - \dfrac{2q}{4\pi\varepsilon_0 (r^2 + a^2)} \cos\theta \, \hat{p}$

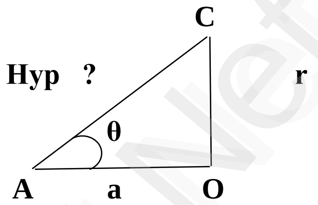
6. From triangle OAC , $\cos\theta = a / (r^2 + a^2)^{1/2}$

7. $\vec{E}_{tot} = - \dfrac{2q}{4\pi\varepsilon_0 (r^2 + a^2)} \dfrac{a}{(r^2 + a^2)^{1/2}} \hat{p}$

8. $\vec{E}_{tot} = - \dfrac{2qa}{4\pi\varepsilon_0 (r^2 + a^2)^{3/2}} \hat{p}$

9. At very large distance ($r >> a$) then $(r^2 + a^2)^{3/2} = r^3$ and $\vec{p} = 2qa \, \hat{p}$

10. $$\boxed{\vec{E}_{equatorial} = \frac{-1}{4\pi\varepsilon_0} \frac{\vec{p}}{r^3}}$$



$Hyp^2 = r^2 + a^2$

$Hyp = (r^2 + a^2)^{1/2}$

$\cos\theta = \dfrac{adj}{hyp} = \dfrac{a}{(r^2 + a^2)^{1/2}}$

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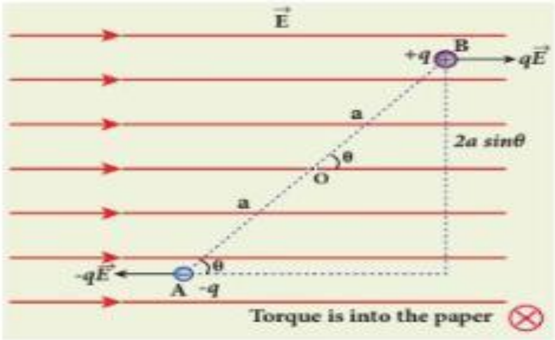
5. Derive an expression for the torque experienced by a dipole due to a uniform electric field.

Diagram :



Formula :

$$\boxed{\vec{\tau} = \vec{p} \times \vec{E} = p\,E \sin\theta}$$

Torque on dipole due to uniform electric field :

1. Consider an electric dipole moment $\vec{p}$ placed in a uniform electric field E .
2. Uniform electric field $\vec{E}$ whose field lines are equally spaced and point in the same direction.
3. Charge + q will experience a force q $\vec{E}$ in the direction of the field.
4. Charge - q will experience a force -q $\vec{E}$ in the direction opposite to the field.
5. The external field $\vec{E}$ is uniform , the total force acting on the dipole is zero.
6. These two forces acting at different points will constitute a couple.
7. The dipole experience a torque and the torque tends to rotate the dipole.

Derivation :

1. Total torque on the dipole : $\vec{\tau} = \vec{OA} \times (-q\vec{E}) + \vec{OB} \times q\vec{E}$
2. Using right – hand corkscrew rule , it is found that total torque is perpendicular to the plane of the paper and is directed into it.
3. Magnitude of total torque : $\tau = |\vec{OA}|\,|(-q\vec{E})| \sin\theta + |\vec{OB}|\,|q\vec{E}| \sin\theta$
4. $\tau = q\,E \,.\, 2a \sin\theta$
5. Where θ is the angle made by $\vec{p}$ with $\vec{E}$. Since p = 2 q a .
6. The torque is written in terms of the vector produce as $\vec{\tau} = \vec{p} \times \vec{E}$
7. Torque experienced by a dipole at uniform electric field $\vec{\tau} = \vec{p} \times \vec{E} = p\,E \sin\theta$
8. Magnitude of torque is $\tau = p\,E \sin\theta$ and is maximum when $\theta = 90^0$.
9. This tends to rotate the dipole and align it with the electric field E.
10. If $\vec{p}$ is aligned with $\vec{E}$, the total torque on the dipole becomes zero.

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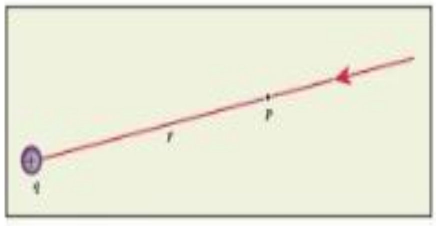
6. Derive an expression for electrostatic potential due to a point charge.

Diagram :



Formula :

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

Explanation :

- **Consider a positive charge q kept fixed at a origin .**
- **Let P be a point at distance r from charge q.**

Derivation :

1. Electric potential at the point P.

$$V = \int_{\infty}^{r} (-\vec{E}).\vec{dr} = -\int_{\infty}^{r} \vec{E}.\,\vec{dr}$$

2. Electric field due to positive point charge q is

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

3. $$V = \frac{-1}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{q}{r^2}\hat{r}\,\vec{dr}$$

4. $$V = \frac{-1}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{q}{r^2}\hat{r}\,dr\,\hat{r} \qquad (\vec{dr} = dr\,\hat{r})$$

5. $$V = \frac{-1}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{q}{r^2}\,dr\,\hat{r}.\hat{r} \qquad (\hat{r}.\hat{r} = 1)$$

6. $$V = \frac{-1}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{q}{r^2}\,dr$$

7. $$V = \frac{-1}{4\pi\varepsilon_0}\,q\left[\frac{-1}{r}\right]_{\infty}^{r}$$

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8. $V = \frac{-q}{4\pi\varepsilon_0}\left[\frac{-1}{r}\right]$

9. $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

10. Electric field due to a point charge :

$$\boxed{V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}}$$

Important Points :

S.NO	Charge	Potential Formula	Potential Value	Distance
1.	Positive	$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$	Decreases	Increases
2.	Negative	$V = \frac{-1}{4\pi\varepsilon_0}\frac{q}{r}$	Increases	Increases

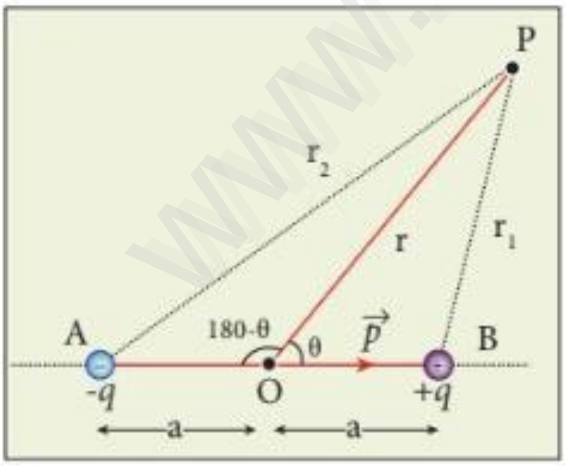
---

7. Derive an expression for electrostatic potential due to an electric dipole.

Explanation

- Consider two equal and opposite charges separated by a small distance 2 a.
- The point P is located at a distance r from the midpoint of the dipole.
- Let θ be the angle between the line OP and dipole axis AB.
- Let r_1 be the distance of point P from +q.
- Let r_2 be the distance of point P from -q.

Diagram :



Formula :

$$\boxed{\vec{V} = \frac{1}{4\pi\varepsilon_0}\frac{p\cdot r}{r^2}}$$

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Derivation :

1. Potential at P due to charge $+q$ $= \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r_1}$

2. Potential at P due to charge $-q$ $= \dfrac{-1}{4\pi\varepsilon_0}\dfrac{q}{r_2}$

3. Total potential at point P

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_1} - \frac{1}{4\pi\varepsilon_0}\frac{q}{r_2}$$

$$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right] \longrightarrow (1)$$

4. By the cosine law for triangle BOP

$$r_1^2 = r^2 + a^2 - 2\,a\,r\cos\theta$$

$$r_1^2 = r^2\left[1 + \frac{a^2}{r^2} - \frac{2\,a\,r\cos\theta}{r^2}\right]$$

$$r_1^2 = r^2\left[1 + \frac{a^2}{r^2} - \frac{2\,a\cos\theta}{r}\right]$$

5. Since the point P far from the dipole ($r >> a$). As a result term $\dfrac{a^2}{r^2}$ is very small and be neglected. Therefore,

$$r_1^2 = r^2\left[1 - \frac{2\,a\cos\theta}{r}\right]$$

$$r_1 = r\;\; 1 - \left[\frac{2\,a\cos\theta}{r}\right]^{1/2}$$

$$\frac{1}{r_1} = \frac{1}{r}\;\; 1 - \left[\frac{2\,a\cos\theta}{r}\right]^{-1/2}$$

6. Since $\dfrac{a}{r} << 1$, we can use binomial theorem and retain the term up to first order

$$\frac{1}{r_1} = \frac{1}{r}\left[1 + \frac{2\,a\cos\theta}{2\,r}\right]$$

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$$\frac{1}{r_1} = \frac{1}{r}\left[1 + \frac{a}{r}\cos\theta\right] \longrightarrow (2)$$

7. By the cosine law for triangle AOP

$$r_2^2 = r^2 + a^2 - 2ar\cos(180-\theta) \qquad \left[\cos(180-\theta) = -\cos\theta\right]$$

$$r_2^2 = r^2\left[1 + \frac{a^2}{r^2} + \frac{2a\cos\theta}{r}\right]$$

8. Since the point P far from the dipole (r >> a) . As a result term a^2 / r^2 is very small and be neglected.

$$r_2^2 = r^2\left[1 + \frac{2a\cos\theta}{r}\right]$$

$$r_2 = r\left[1 + \frac{2a\cos\theta}{r}\right]^{1/2}$$

$$\frac{1}{r_2} = \frac{1}{r}\left[1 + \frac{2a}{r}\cos\theta\right]^{-1/2}$$

9. Since $\frac{a}{r} << 1$, we can use binomial theorem and retain the term up to first order

$$\frac{1}{r_2} = \frac{1}{r}\left[1 - \frac{2a}{2r}\cos\theta\right]$$

$$\frac{1}{r_2} = \frac{1}{r}\left[1 - \frac{a}{r}\cos\theta\right] \longrightarrow (3)$$

10. <u>Sub (2) and (3) in eqn (1)</u>

$$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\left[1 + \frac{a}{r}\cos\theta - \left[1 - \frac{a}{r}\cos\theta\right]\right]\right]$$

$$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\left[\cancel{1} + \frac{a}{r}\cos\theta - \cancel{1} + \frac{a}{r}\cos\theta\right]\right]$$

$$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\left[\frac{a}{r}\cos\theta + \frac{a}{r}\cos\theta\right]\right]$$

$$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\left[\frac{2a}{r}\cos\theta\right]\right]$$

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$$V = \frac{1}{4\pi\varepsilon_0} \frac{2qa}{r^2}\cos\theta$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{p\cos\theta}{r^2} \quad (p = 2qa)$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{\vec{p}\cdot\hat{r}}{r^2} \quad (p\cos\theta = \vec{p}\cdot\hat{r})$$

Electrostatic potential due to an electric dipole :

$$\boxed{\vec{V} = \frac{1}{4\pi\varepsilon_0} \frac{\vec{p}\cdot\hat{r}}{r^2}}$$

Special Cases :

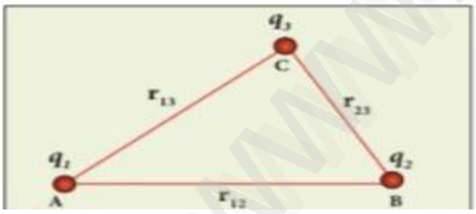
S. NO	Point P lies on the axial line of dipole	Value of θ	Electric Potential
1.	On the side of + q	$\theta = 0$	$V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$
2.	On the side of - q	$\theta = 180^0$	$V = \frac{-1}{4\pi\varepsilon_0}\frac{p}{r^2}$
3.	Point P lies on equatorial line of dipole	$\theta = 90^0$	$V = 0$

---

8. Obtain an expression for potential energy due to a collection of three point charges which are separated by finite distance.

- To calculate the total electrostatic potential energy bring all the charges one by one and arrange them according to the configuration.

Diagram :



Formula :

$$\boxed{U = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right)}$$

Explanation :

1. Bringing a charge q_1 from infinity to the point A requires no work , because there are no other charges already present in the vicinity of charge q_1.

2. To bring the second charge q_2 to the point B , work must be done against the electric field created by the charge q_1 . So the work done on the charge q_2 is $W = q_2 V_{1B}$. Here V_{1B} is the electrostatic potential due to charge q_1 at point B.

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$$U_I = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$$

3. Similarly to bring the charge q_3 to the point C , work must be done against the total electric field due to both charges q_1 and q_2 . So the work done to bring the charge q_3 is $W = q_3 \ (V_{1C} + V_{2C})$. Here V_{1C} is the electrostatic potential due to charge q_1 at point C and V_{2C} is the electrostatic potential due to charge q_2 at point C.

$$U_{II} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right]$$

4. Total electrostatic potential energy for the system of charges q_1, q_2 and q_3 is

$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right]$$

5. Electrostatic potential is independent of the configuration of charges since force is conservative one.

S.NO	Charges	Work done	Potential Energy
1.	Bring the charge q_1 from infinity to the point A	Requires no work	No other charges present in the vicinity of charge q_1
2.	Bring the charge q_2 to the point B	$W = q_2 \ V_{1B}$	$U_I = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$
3.	Bring the charge q_3 to the point C	$W = q_3 \ (V_{1C} + V_{2C})$	$U_{II} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right]$

---

9. Derive an expression for electrostatic potential energy of the dipole in a uniform electric field.

Explanation :

1. Consider a dipole placed in the uniform electric field $\vec{E}$.
2. A dipole experiences a torque when kept in an uniform electric field $\vec{E}$.
3. This torque rotates the dipole to align it with the direction of the electric field.
4. To rotate the dipole from its initial angle θ' to another angle θ against the torque exerted by the electric field.
5. An equal and opposite external torque must be applied on the dipole.

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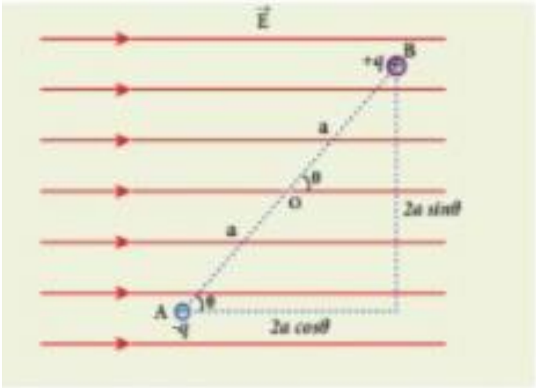
Diagram :



Formula :

$$U = -\vec{p} \cdot \vec{E} = -pE\cos\theta$$

Derivation :

1. Work done by the external torque to rotate the dipole from angle θ' to θ at constant velocity

$$W = \int_{\theta'}^{\theta} \tau \, d\theta \quad (\tau = \tau_{ext}) \longrightarrow (1)$$

2. Since , $\vec{\tau}_{ext}$ is equal and opposite to $\tau_E = \vec{p} \times \vec{E}$

3. $$|\vec{\tau}_{ext}| = |\vec{\tau}_E| = |\vec{p} \times \vec{E}| = pE\sin\theta \longrightarrow (2)$$

4. Sub eqn (2) in eqn (1)

$$W = \int_{\theta'}^{\theta} pE\sin\theta \, d\theta$$

5. After integrating we get ,

$$W = pE\int_{\theta'}^{\theta} \sin\theta \, d\theta$$

$$W = pE\left(-\cos\theta\right)_{\theta'}^{\theta}$$

$$W = pE\left(-\cos\theta - (-\cos\theta')\right)$$

$$W = pE\left(-\cos\theta + \cos\theta'\right)$$

$$W = -pE\cos\theta + pE\cos\theta'$$

6. This work done is equal to the potential energy difference between the angular positions θ and θ' .

$$U(\theta) - U(\theta') = \Delta U = -pE\cos\theta + pE\cos\theta'$$

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7. If the initial angle is $\theta' = 90^0$ and is taken as reference point , then

$$U(\theta') = p\ E\ '\ \cos 90^0 = 0$$

8. The potential energy stored in the system of dipole kept in uniform electric field is given by

$$U(\theta) = -\ p\ E\ \cos\theta = -\ \vec{p}\,.\,\vec{E}$$

9. The potential energy is maximum when the dipole is aligned anti – parallel ($\theta = \pi$) to the external electric field.

10 . The potential energy is minimum when the dipole is aligned parallel ($\theta = 0$) to the external electric field.

---

10. Obtain Gauss law from Coulomb's law.

Diagram :

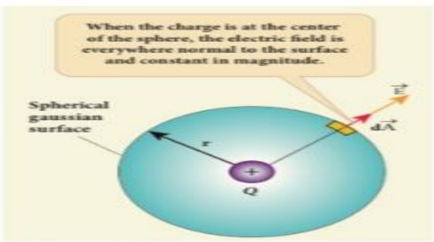

Figure 1.34 Total electric flux of point charge

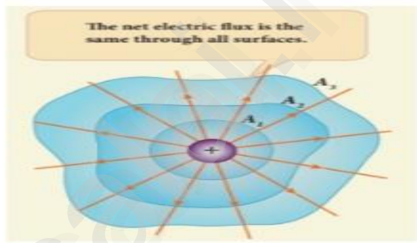

Figure 1.35 Gauss law for arbitrarily shaped surface

Formula :

$$\boxed{\Phi_E = \oint \vec{E}\,.\,d\vec{A} = \frac{Q_{encl}}{\varepsilon_0}}$$

Explanation :

1. A positive point charge Q is surrounded by an imaginary sphere of radius r.

2. Total electric flux through the closed surface of the sphere

$$\Phi_E = \oint \vec{E}\,.\,d\vec{A} = \oint E\ dA\cos\theta$$

3. The electric field of the point charge is directed radially outward at all points on the surface of the sphere.

4. The direction of the area element d A is along the electric field $\vec{E}$ and $\theta = 0^o$.

$$\Phi_E = \oint E\ dA\cos 0^0 = \oint E\ dA$$

5. E is uniform on the surface of the sphere $\Phi_E = E\oint dA$

6. $E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{r^2}$ $\oint dA = 4\pi r^2$

7. $\Phi_E = E\int dA = \dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{r^2}\ X\ 4\pi r^2$

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8. $\Phi_E = \frac{Q}{\varepsilon_0}$ This is called as Gauss's law.

9. Gauss law for arbitrarily shaped surface A_1, A_2, A_3t total electric flux is same for closed surface.

10. Gauss's law states that if a charge Q is enclosed by an arbitrary closed surface then the total electric flux Φ_E through the closed surface is

$$\boxed{\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0}}$$

Where Q_{encl} denotes the charges within the closed surface.

---

11. Obtain the expression for electric field due to an infinitely long charged wire.

Diagram :

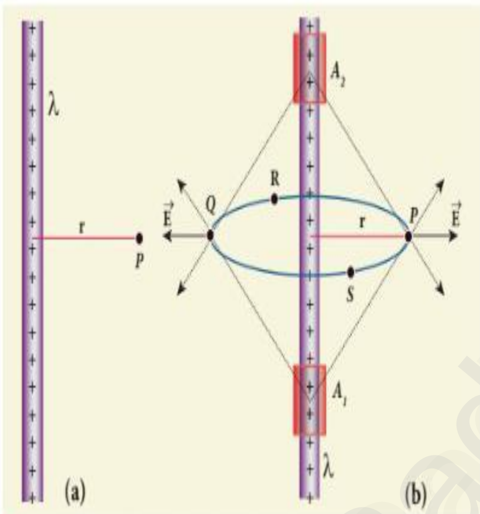

Figure 1.36 Electric field due to infinite long charged wire

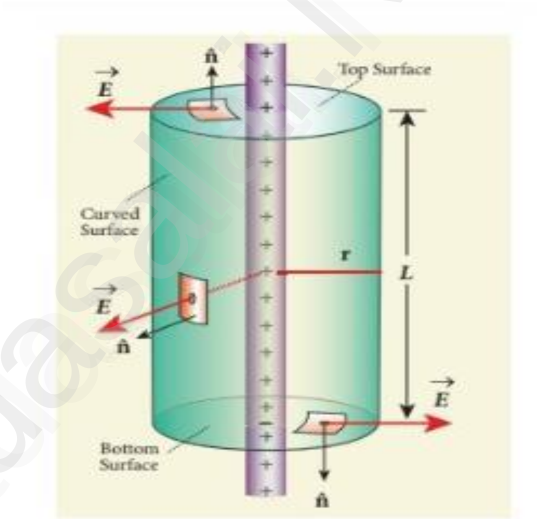

Figure 1.37 Cylindrical Gaussian surface

Formula :

$$\boxed{\vec{E} = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r}\hat{r}}$$

Explanation :

1. Consider an infinitely long straight wire having uniform linear charge density λ .

2. Let P be a point located at a perpendicular distance r from the wire.

3. The electric field at the point P can be found using Gauss law.

4. Two small charge elements A_1, A_2 on the wire which are at equal distances from point P.

5. Resultant electric field due to two charge elements points radially away from charged wire.

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6. The magnitude of electric field is same at all points on the circle of radius r.

7. The charged wire possesses a cylindrical symmetry , let us choose a cylindrical Gaussian surface of radius r and length L.

Derivation :

1. Total electric flux through the closed surface $\Phi_E = \oint \vec{E} \cdot d\vec{A}$

2. $\Phi_E = \int_{\substack{\text{Curved}\\\text{surface}}} \vec{E} \cdot d\vec{A} + \int_{\substack{\text{top}\\\text{surface}}} \vec{E} \cdot d\vec{A} + \int_{\substack{\text{bottom}\\\text{surface}}} \vec{E} \cdot d\vec{A}$

3. For the curved surface , $\vec{E}$ is parallel to $\vec{A}$ then , $\vec{E} \cdot d\vec{A} = E\, dA$.

4. For the top and bottom surface , E is perpendicular to A then , E . d A = 0.

5. Applying Gauss law to the cylindrical surface , $\Phi_E = \int_{\substack{\text{Curved}\\\text{surface}}} \vec{E} \cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0}$

6. $\Phi_E = E \int_{\substack{\text{Curved}\\\text{surface}}} dA = \frac{Q_{encl}}{\varepsilon_0}$

7. The magnitude of the electric field for the entire curved surface is constant , E is taken out of the integration.

8. Linear charge density (charge per unit length) : $\lambda = \frac{Q_{encl}}{L}$

9. Q_{encl} is given by $Q_{encl} = \lambda L$.

10. Total area of the curved surface : $\int_{\substack{\text{Curved}\\\text{surface}}} dA = 2\pi r L$

11. $\Phi_E = E \int_{\substack{\text{Curved}\\\text{surface}}} dA = \frac{Q_{encl}}{\varepsilon_0}$

$$E \cdot 2\pi r L = \frac{\lambda L}{\varepsilon_0}$$

12. Electric field due to infinite long charged wire , $E = \frac{1}{2\pi\varepsilon_0} \frac{\lambda}{r}$

In vector form , $\boxed{\vec{E} = \frac{1}{2\pi\varepsilon_0} \frac{\lambda}{r} \hat{r}}$

13. The electric field due to infinite charged wire depends on 1 / r rather than 1 / r^2 which is for a point charge.

14. If $\lambda > 0$ then $\vec{E}$ points perpendicularly outward ($\hat{r}$) from the wire.

15. If $\lambda < 0$ then $\vec{E}$ points perpendicularly inward ($-\hat{r}$) from the wire.

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12. Obtain the expression for electric field due to a charged infinite plane sheet.

Diagram :

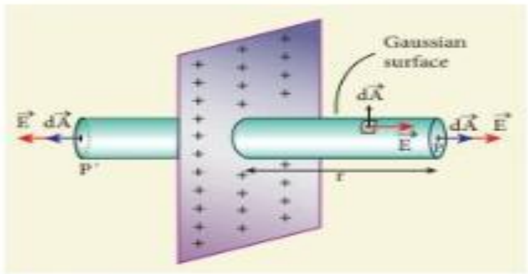

Figure 1.38 Electric field due to charged infinite planar sheet

Formula :

$$\vec{E} = \frac{\sigma}{2\,\varepsilon_0}\,\hat{n}$$

Explanation :

1. Consider an infinite plane sheet of charges with uniform surface charge density σ .

2. Let P be a point at a distance r from the sheet.

3. The plane sheet is infinitely large , the electric field should be same at all points equidistant from the plane and radially directed outward at all points.

4. A cylindrical Gaussian surface of length 2r and two flats surface each of area A is chosen.

5. The infinite plane sheet passes perpendicularly through the middle part of the Gaussian surface.

Derivation :

1. Total electric flux linked with the cylindrical surface $\Phi_E = \int \vec{E}\cdot d\vec{A}$

2. $\Phi_E = \int_{\text{Curved surface}} \vec{E}\cdot d\vec{A} + \int_{P} \vec{E}\cdot d\vec{A} + \int_{P'} \vec{E}\cdot d\vec{A}$

3. For curved surface : Electric field is perpendicular to the area element at all points.

$$\int_{\text{Curved surface}} \vec{E}\cdot d\vec{A} = 0$$

4. At P and P : Electric field is parallel to the area element at all points.

$$\Phi_E = \int_{P} E\, dA + \int_{P'} E\, dA$$

5. The magnitude of the electric field at these two equal flat surfaces is uniform.

$$\Phi_E = E\int_{P} dA + E\int_{P'} dA$$

$$\Phi_E = EA + EA = 2EA$$

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6. Surface charge density = charge present per unit area ($\sigma = Q / A$)

7. Total charge enclosed by the area $Q_{encl} = \sigma A$

8. By using Gauss law , $\Phi_E = \frac{Q_{encl}}{\varepsilon_0}$

$$2 E \cancel{A} = \frac{\sigma \cancel{A}}{\varepsilon_0}$$

$$2 E = \frac{\sigma}{\varepsilon_0}$$

$$E = \frac{\sigma}{2 \varepsilon_0}$$

9. In vector form , $\boxed{\vec{E} = \frac{\sigma}{2 \varepsilon_0} \hat{n}}$

10. If $\sigma > 0$ then $\vec{E}$ points perpendicularly outward to the plane ($\hat{n}$) .

11. If $\sigma < 0$ then $\vec{E}$ points perpendicularly inward to the plane ($-\hat{n}$) .

---

13. Obtain the expression for electric field due to a uniformly charged spherical shell.

1. Consider a uniformly charged spherical shell of radius R and total charge Q .

2. The electric field at points outside and inside the sphere can be found using Gauss law.

Diagram :

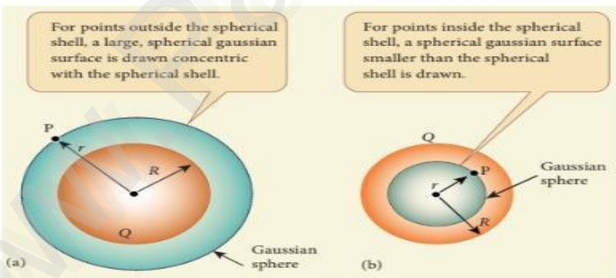

Figure 1.40 The electric field due to a charged spherical shell

Case i : At a point outside the shell (r > R)

For point outside the spherical shell , a large spherical Gaussian surface is drawn concentric with the spherical shell.

Explanation :

1. Let us choose a point P outside the shell at a distance r from the centre.

2. The charge is uniformly distributed on the surface of the sphere. (spherically symmetry)

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3. The electric field must point radially outward if $Q > 0$.

4. The electric field must point radially inward if $Q < 0$.

5. Spherical Gaussian surface of radius r is chosen.

Derivation :

1. Applying Gauss law :

$$\oint_{\text{Gaussian surface}} \vec{E} \cdot d\vec{A} = \frac{Q}{\varepsilon_0}$$

2. The electric field $\vec{E}$ and $\vec{dA}$ point in the same direction (outward normal) at all the points on the Gaussian surface.

3. The magnitude of E is also the same at all points due to the spherical symmetry of charge distribution.

4. $$E \oint_{\text{Gaussian Surface}} dA = \frac{Q}{\varepsilon_0}$$

5. Total area of the Gaussian surface $\oint dA = 4\pi r^2$

6. $$E \cdot 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

7. $$E = \frac{1}{4\pi\varepsilon_0} \frac{Q}{r^2}$$

8. In vector form , $$\boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{Q}{r^2} \hat{r}}$$

9. The electric field must point radially outward if $Q > 0$ and radially inward if $Q < 0$.

10. The electric field at a point outside the shell will be same if the entire charge Q is concentrated at the centre of the spherical shell.

Case ii : At a point on the surface of the spherical shell ($r = R$)

The electric field at points on the spherical shell ($r = R$) is given by

$$\boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{Q}{R^2} \hat{r}}$$

Case iii : At a point inside the spherical shell ($r < R$)

For point outside the spherical shell , a spherical Gaussian surface smaller than the spherical shell is drawn .

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Explanation :

1. Consider a point P inside the shell at a distance r from the centre.
2. A Gaussian sphere of radius r is constructed .
3. Applying Gauss law : $\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\varepsilon_0}$
4. Total area of the Gaussian surface $\int dA = 4 \pi r^2$
5. $E \cdot 4 \pi r^2 = \frac{Q}{\varepsilon_0}$
6. Gaussian surface encloses no charge , $Q = 0$ then $E = 0$ $(r < R)$
7. The electric field due to the uniformly charged spherical shell is zero at all points inside the shell.

Electric field versus distance for spherical shell of radius R

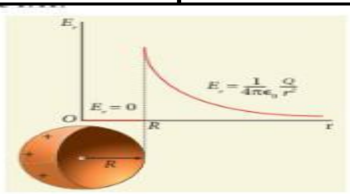

Figure 1.41 Electric field versus distance for a spherical shell of radius R

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14. Discuss the various properties of conductors in electrostatic equilibrium.

1. " The electric field is zero everywhere inside the conductor. This is true regardless of whether the conductor is solid or hollow ".

- If electric field is not zero inside the metal , there will be force on mobile charge.
- As a result , there will be net motion of mobile charge which contradicts with conductor in electrostatic equilibrium.
- Thus electric field is zero everywhere inside the conductor.
- Before applying external field , the free electrons in conductor are uniformly distributed.
- After applying external field , left plate be negatively charged and right plate be positively charged.
- Due to realignment of free electron internal electric field created inside the conductor.
- Internal electric field nullifies the external electric field.
- Conductor reach electrostatic equilibrium in the order of 10^{-16} s.

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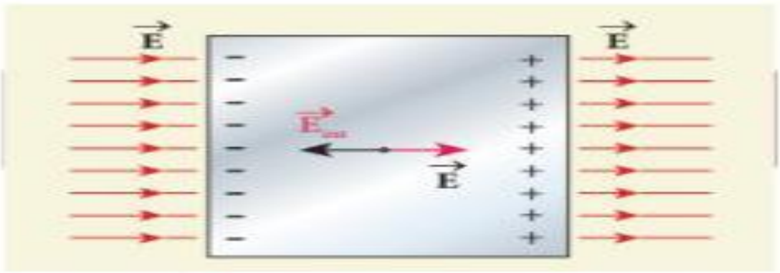

Figure 1.42 Electric field of conductors

2. " There is no net charge inside the conductor. The charges must reside only on the surface of the Conductor".

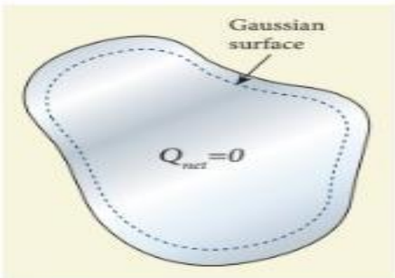

Figure 1.43 No net charge inside the conductor

Consider an arbitrarily shaped conductor.

- **Gaussian surface drawn inside the conductor which is very close to conductor.**
- **Electric field is zero everywhere inside the conductor , the net electric flux is also zero over this Gaussian surface.**
- **From Gauss's law , this implies that there is no net charge inside the conductor.**

Even if some charge is introduced inside the conductor , it immediately reaches the surface of the conductor.

3. " The electric field outside the conductor is perpendicular to the surface the conductor and has a magnitude of σ / ε_0 where σ is the surface charge density at that point ".

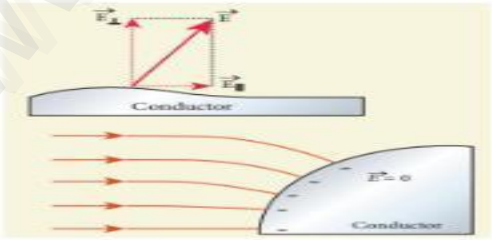

Figure 1.44 (a) Electric field is along the surface (b)Electric field is perpendicular to the surface of the conductor

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- **If electric field component has parallel to surface of conductor , then the free electron on the surface of the conductor experience acceleration . Then conductor is not in equilibrium.**

- **At electrostatic equilibrium , the electric field will be perpendicular to conductor surface.**

c) <u>Electric field on the surface of the conductor</u>

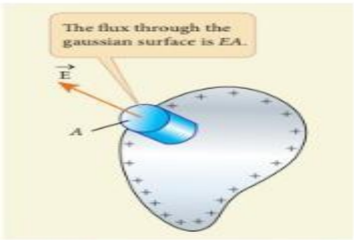

Figure 1.45 The electric field on the surface of the conductor

- **Consider a small cylindrical Gaussian surface and one half of this cylinder is embedded inside the conductor.**

- **Electric field is normal to the surface of the conductor.**

  i . <u>Curved part :</u> Electric flux is zero.

  ii . <u>Bottom part :</u> Electric flux is zero.

  iii . <u>Top part :</u> Electric flux is not zero.

- **By applying Gauss law , $E\ A = \frac{\sigma A}{\varepsilon_0}$**

- **In vector form , $E = \frac{\sigma}{\varepsilon_0}\hat{n}$**

4. " The electrostatic potential has same value on the surface and inside of the conductor ".

- **Conductor has no parallel electric component on the surface.**
- **Charges can be moved on surface without doing any work.**
- **It is possible only of electrostatic potential is constant.**
- **No potential difference between any points on the surface.**
- **Electric field is zero inside the conductor , potential is same.**
- **At electrostatic equilibrium , the conductor always be equipotential.**

---

15. Explain the process of electrostatic induction.

<u>Electrostatic induction :</u>

- **Charging without actual contact is called "*electrostatic* induction "**
- **Various steps to be followed in process of electrostatic induction.**

Diagram :

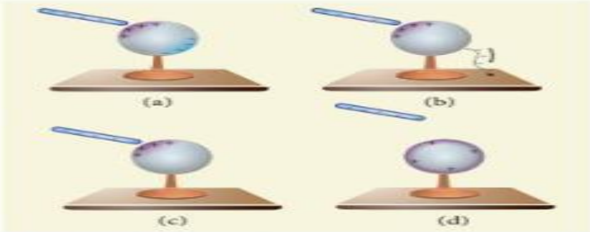

Figure 1.47 Various steps in electrostatic induction

Step 1 :

- Consider an uncharged (neutral) conducting sphere at rest on an insulating stand.
- Negatively charged rod bring near the conductor without touching it.
- Negative charged rod repels electron , positive charges induced near the region of rod.

Step 2 :

- Conducting sphere is connected to ground through a conducting wire. This is called grounding.
- Grounding removes electron from the conducting sphere.
- Positive charge not flow to ground because attracted by negative charge of the rod.

Step 3 :

When the grounding wire is removed from the conductor , the positive charges remain near the charged rod.

Step 4 :

- Now charged rod is taken away from the conductor.
- Positive charge gets distributed uniformly on the surface of the conductor.
- By this , neutral conducting sphere becomes positively charged.

---

16. Explain dielectrics in detail and how an electric field is induced inside a dielectric.

Dielectric or Insulators :

- A dielectric is a non-conducting material and has no free electrons.
- The electrons in a dielectric are bound within the atoms.
- It is made up of either polar molecule or non polar molecule.

Examples : Ebonite , glass and mica.

1. When an external electric field is applied on a *conductor*

- The charges are aligned in such a way that an internal electric field is created which tends to cancel the external electric field.

2. When an external electric field is applied on a *dielectric*

- It has no free electrons so the external electric field only realigns the charges so that an internal electric field is produced.

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- The magnitude of the internal electric field is smaller than that of external electric field.
- The net electric field inside the dielectric is not zero but is parallel to an external electric field with magnitude less than that of the external electric field.

3. For Example :

Let us consider a rectangular dielectric slab placed between two oppositely charged plates.

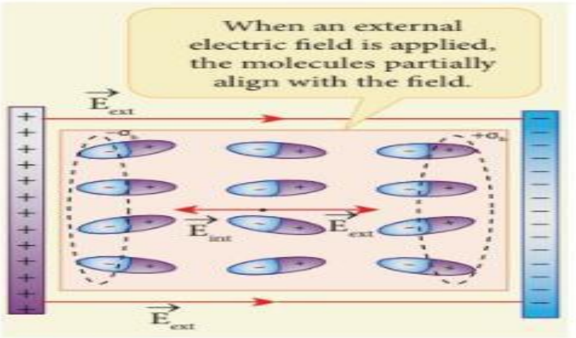

Figure 1.50 Induced electric field lines inside the dielectric

- The uniform electric field between the plates acts as an external field E_{ext} which polarizes the dielectric placed between plates.
- The positive charges are induced on one side surface and negative charges are induced on other side of surface.
- The dielectric in the external field is equivalent to two oppositely charged sheets with the surface charge densities $+\sigma_b$ and $-\sigma_b$.
- These charges are called *bound charges* .
- They are not free to move like free electrons in conductors.

Example :

The charged balloon after rubbing sticks or o wall. The reason is that the negatively charged balloon is brought near the wall , it polarizes pposite charges on the surface of the wall , which attracts the balloon.

---

17. Obtain the expression for capacitance for parallel plate capacitor.

Explanation :

Consider a capacitor with two parallel plat s.

- Cross – sectional area ⟶ A
- Distance between the plates ⟶ d
- Electric Field ⟶ E
- Surface charge density ⟶ σ

Diagram :

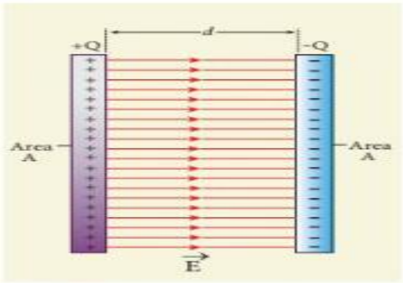

Figure 1.54 Capacitance of a parallel plate capacitor

Formula :

$$\boxed{C = \frac{\varepsilon_0 A}{d}}$$

Derivation :

1. Electric Field

The electric field between two infinitely parallel plates is uniform and is given by,

$$E = \frac{\sigma}{\varepsilon_0} \longrightarrow (1)$$

If the separation distance d is very much smaller than the size of the plate ($d^2 << A$) , then the above result can be used even for finite – sized parallel plate capacitor.

2. Surface Charge Density

Charge per unit area is known as surface charge density.

$$\sigma = \frac{Q}{A} \longrightarrow (2)$$

3. Substitute eqn (2) in eqn (1)

$$E = \frac{Q}{A\,\varepsilon_0}$$

4. Electric Potential Difference

$$V = E\,d = \frac{Q\,d}{A\,\varepsilon_0}$$

5. Capacitance of a Capacitor

$$C = \frac{Q}{V} = \frac{Q}{\frac{Q\,d}{A\,\varepsilon_0}} = \frac{\varepsilon_0 A}{d}$$

$$\boxed{C = \frac{\varepsilon_0 A}{d}}$$

- Capacitance is directly proportional to the area of cross section (A)
- Capacitance is inversely proportional to the distance between the plates . (d)

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18. Obtain the expression for energy stored in the parallel plate capacitor.

Explanation :

1. Capacitor not only stores charge but also it stores energy.
2. When battery connected to capacitor , electrons of charge -Q transfer from one plate to other plate.
3. To transfer the charge , work is done by the battery.
4. Work done is stored as electrostatic potential energy in the capacitor.

Derivation :

1. Work Done : $dW = V\,dQ$
2. Capacitance : $C = \frac{Q}{V}$
3. Potential : $V = \frac{Q}{C}$
4. Total Work done : $W = \int_0^Q \frac{Q}{C}\,dQ = \frac{1}{C}\int_0^Q Q\,dQ = \frac{Q^2}{2C}$
5. Electrostatic Potential Energy :

$$U_E = \frac{Q^2}{2C} \qquad (Q = CV)$$

$$U_E = \frac{(CV)^2}{2C} = \frac{1}{2}CV^2$$

The stored energy is directly proportional to the capacitance and square of the voltage between the plates of the capacitor.

6. We know that , $C = \frac{\varepsilon_0 A}{d}$ and $V = E\,d$

$$U_E = \frac{1}{2}CV^2 = \frac{1}{2}\frac{\varepsilon_0 A}{d}E^2 d^2$$

$$U_E = \frac{1}{2}\varepsilon_0 (A\,d)\,E^2$$

$$U_E = \frac{1}{2}\varepsilon_0 V E^2 \qquad (\text{Volume} = V = A\,d)$$

$$\boxed{u_E = \frac{U_E}{\text{Volume}} = \frac{1}{2}\varepsilon_0 E^2}$$

7. The energy stored per unit volume of space is defined as energy density .

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19. **Explain in detail the effect of dielectric placed in a parallel plate capacitor .**

The dielectric can be inserted into the plates in two different ways.

i) When the capacitor is disconnected from the battery.

ii) When the capacitor is connected to the battery.

i) When the capacitor is disconnected from the battery :

- **Consider a capacitor with two parallel plates.**
- **Cross – sectional area** $\longrightarrow$ **A**
- **Distance between plates** $\longrightarrow$ **d**
- **Voltage of battery** $\longrightarrow$ V_0
- **Stored charge value** $\longrightarrow$ Q_0 **(Remains constant)**

Capacitance of Capacitor without dielectric : $C_0 = \frac{Q_0}{V_0}$

Battery is disconnected from the capacitor and inserted dielectric

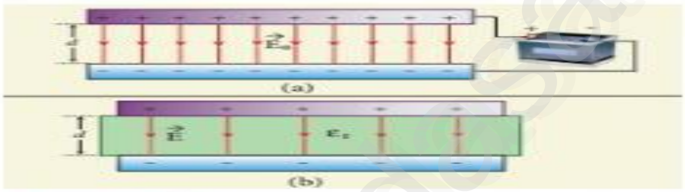

Figure 1.56 (a) Capacitor is charged with a battery (b) Dielectric is inserted after the battery is disconnected

1. **Electric Field :**

Without Dielectric : $E_0 = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$

With Dielectric : $E = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1 q_2}{r^2}$ $(\varepsilon_r > 1)$

$$\boxed{E = \frac{E_0}{\varepsilon_r}}$$

The introduction of dielectric between the plates will decrease the electric field. $(E < E_0)$

2. Electrostatic Potential :

Without Dielectric : $V = E_0 d$

With Dielectric : $V = E d$

$$V = \frac{E_0 d}{\varepsilon_r}$$

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$$\boxed{V = \frac{V_0}{\varepsilon_r}}$$

The insertion of dielectric between the plates will decrease the electrostatic potential . ($V < V_0$)

3. Capacitance :

Without Dielectric : $C_0 = \frac{Q_0}{V_0}$

With Dielectric : $C = \frac{Q_0}{V}$

$$C = \frac{Q_0\,\varepsilon_r}{V_0}$$

$$\boxed{C = C_0\ \varepsilon_r}$$

Insertion of dielectric increase capacitance . ($C > C_0$)

4. Energy :

Without Dielectric : $U_0 = \frac{1}{2}\frac{Q_0^2}{C_0}$

With Dielectric : $U = \frac{1}{2}\frac{Q_0^2}{C}$

$$U = \frac{1}{2}\frac{Q_0^{\ 2}}{\varepsilon_r\, C_0}$$

$$\boxed{U = \frac{U_0}{\varepsilon_r}}$$

Insertion of dielectric decrease the energy. ($U < U_0$)

ii) When the capacitor is connected to the battery :

- Voltage V_0 remains constant.
- Charge increased by $\varepsilon_r \longrightarrow Q = Q_0\ \varepsilon_r$

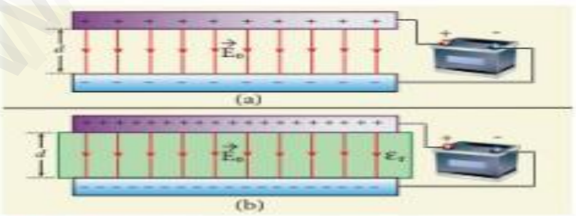

Figure 1.57 (a) Capacitor is charged through a battery (b) Dielectric is inserted when the battery is connected.

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1.**Capacitance :**

Without Dielectric : $C_0 = \frac{Q_0}{V_0}$

With Dielectric : $C = \frac{Q}{V_0}$

$$C = \frac{Q_0 \varepsilon_r}{V_0}$$

$$\boxed{C = C_0 \varepsilon_r}$$

2.**Energy :**

Without Dielectric : $U_0 = \frac{1}{2} C_0 V_0^2$

With Dielectric : $U = \frac{1}{2} C V^2$

$$U = \frac{1}{2} C_0 V_0^2 \varepsilon_r$$

$$\boxed{U = \varepsilon_r U_0}$$

Effects of dielectric in capacitors :

S.NO	Dielectric inserted	Charge Q	Voltage V	Electric Field E	Capacitance C	Energy U
1.	When Ba is disconnected	Constant	Decreases	Decreases	Increases	Decreases
2.	When Ba is connected	Increases	Constant	Constant	Increases	Increases

----

21. Explain in detail how charges are distributed in a conductor and the principle behind the lightning conductor.

Diagram :

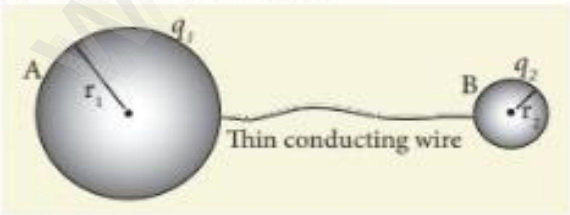

Figure 1.60 Two conductors are connected through conducting wire

Formula :

$$\boxed{\sigma \; r = \text{constant}}$$

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Explanation

1. Consider the conducting sphere A and B of radii r_1 and r_2.
2. They are connected by a thin conducting wire.
3. Distance between the spheres is much greater than radii of either sphere.
4. If a charge Q is introduced in any of the sphere , this charge Q is redistributed into both the spheres such that the electrostatic potential is same .
5. They are now uniformly charged and attain electrostatic equilibrium.
6. Let q_1 be the charge residing on the surface of sphere A .
7. Let q_2 be the charge residing on the surface of sphere B.
8. such that $Q = q_1 + q_2$. The charges are distributed only on the surface.
9. There is no net charge inside the conductor.

Derivation :

1. Electrostatic potential at the surface of the sphere A is given by $V_A = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1}$

2. Electrostatic potential at the surface of the sphere B is given by $V_B = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_2}$

3. The surface of the conductor is an *equipotential.* The spheres are connected by the conducting wire , the surfaces of both the spheres together form an equipotential surface. $V_A = V_B$

4. $$\frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1} = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_2}$$

$$\frac{q_1}{r_1} = \frac{q_2}{r_2}$$

5. Let the charge density on the surface of sphere A be σ_1 then $q_1 = 4\pi r_1^2 \sigma_1$

6. Let the charge density on the surface of sphere A be σ_2 then $q_2 = 4\pi r_2^2 \sigma_2$

7. $$\frac{4\pi r_1^2 \sigma_1}{r_1} = \frac{4\pi r_2^2 \sigma_2}{r_2}$$

8. $$r_1 \sigma_1 = r_2 \sigma_2$$

9. Surface charge density is inversely proportional to the radius of the sphere. $\boxed{\sigma r = \text{constant}}$

10. For a smaller radius , the charge density will be larger and vice versa.

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Lightning of conductor Working :

1. Consists of a long thick copper rod passing from top of the building to the ground.
2. The upper end of the rod has sharp spike and sharp needle.
3. The lower end of the rod is connected to copper plate.
4. Negatively charges cloud passing above the cloud , induces positive charge on the spike.
5. The induced charge density on thin sharp spike is large , it results in a *corona discharge.*
6. This positive charge ionizes the surrounding air which in turn neutralizes the negative charge in the cloud.
7. The negative charge pushed to the spike through the copper rod and is safely diverted to the earth.
8. The lightning arrester does not stop the lightning rather it diverts the lightning to the ground safely.

22.Explain in detail the construction and working of a Van de Graff generator.

Principle :

Based on the principle of 1. Electrostatic Induction 2. Action at points (Corona discharge)

Potential Difference :

It produces large amount of electrostatic potential difference 10^7 V.

Applications:

The high voltage produced in this Van de Graaff generator is used to accelerate positive ions (protons and deuterons) for nuclear disintegrations and other applications.

Construction :

1. A large hollow spherical conductor is fixed on the insulating stand.
2. A pulley B is mounted at the centre of the hollow sphere and pulley C is fixed at the bottom .
3. A belt made up of insulating materials like silk or rubber runs over both pulleys.
4. The pulley C is driven continuously by the electric motor.
5. Two comb shaped metallic conductors E and D are fixed near the pulleys.
6. The comb D is maintained at a positive potential of 10^4 V by a power supply.
7. The upper comb E is connected to the inner side of the hollow metal sphere.

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Diagram :

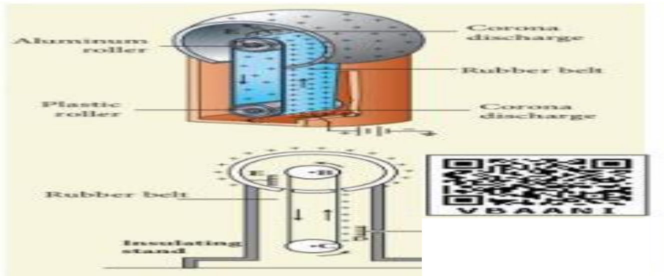

Figure 1.63 Van de Graaff

Working :

1. Due to high electric field at comb D air between belt and comb D gets ionized by *action of points.*

2. Positive charge pushed towards belt and negative charges are attracted towards the comb D.

3. The positive charges stick to the belt and move up.

4. When the positive charges on the on the belt reach the point near the comb E , it acquires negative charge and sphere acquires positive charge due to *electrostatic induction.*

5. As a result , the positive charges are pushed away from the comb E and they reach the outer surface of the sphere.

6. Since the sphere is a conductor, the positive charge are distributed uniformly on the outer surface of the hollow sphere.

7. At the same time, the negative charge nullify the positive charges in the belt due to corona discharge before it passes over the pulley

8. When the belt descends, it has almost no net charge.

9. At the bottom, it again gains a large positive charge.

10. The belt goes up and delivers the positive charges to the outer surface of the sphere.

11. This process continues until the outer surface produces the potential difference of the order of 10^7 which is the limiting value.

12. We cannot store charges beyond this limit since the extra charge starts leaking to the surrounding due to ionization of air.

13. The leakage of charges can be reduced by enclosing the machine in a gas filled steel chamber at very high pressure.

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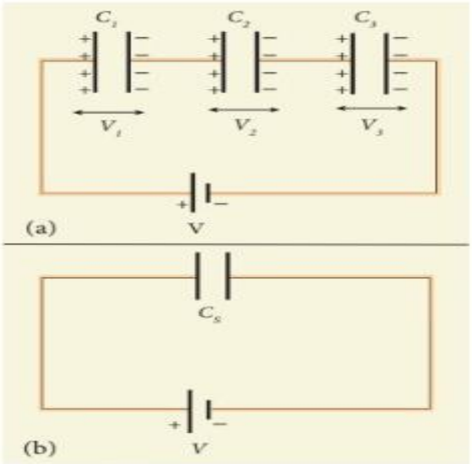
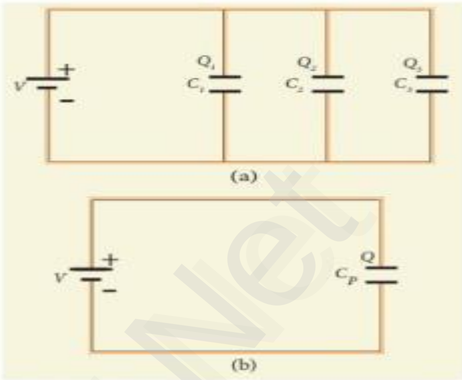
20. Derive the expression for resultant capacitance, when capacitors are connected in series and in parallel.

S.NO	Capacitance in series	Capacitance in parallel
1.	 Figure 1.58 (a) Capacitors connected in series (b) Equivalent capacitors C_s	 Figure 1.59 (a) capacitors in parallel (b) equivalent capacitance with the same total charge
2.	Three capacitance C_1 , C_2 and C_3 in series.	Three capacitance C_1 , C_2 and C_3 in parallel.
3.	Each capacitors stores same amount of charge. (Q)	Charge on each capacitor not same. (Q_1 Q_2 Q_3
4.	Voltage across each capacitor is differ. (V_1 V_2 V_3)	Voltage across each capacitor is same . (V)
5.	Sum of voltages across the capacitor $V = V_1 + V_2 + V_3$ $\frac{Q}{C} = \frac{Q_1}{C_1} + \frac{Q_2}{C_2} + \frac{Q_3}{C_3}$ $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	Sum of charges across the capacitor $Q = Q_1 + Q_2 + Q_3$ $C V = C_1 V + C_2 V + C_3 V$ $C_P = C_1 + C_2 + C_3$
6.	Inverse of equivalent capacitance C_S is equal to sum of inverse of each capacitance.	Equivalent capacitance C_p is equal to sum of individual capacitance.
7.	C_S is always less than the smallest individual capacitance	C_P is always greater than largest individual capacitance.

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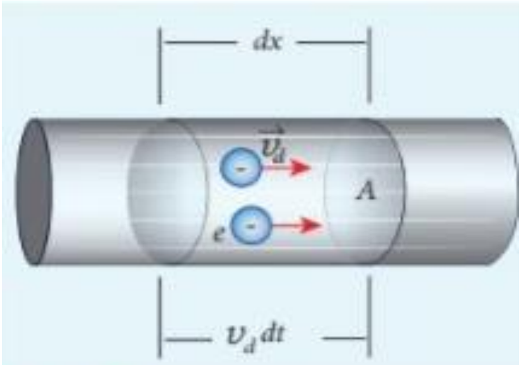
LESSON 2

1.Describe the microscopic model of current and obtain general form of Ohm's law.

Diagram :



Formula :

$$\boxed{\vec{J} = \sigma \vec{E}}$$

Theory :

- Let us consider a conductor .
- Area of cross section $\longrightarrow$ A
- Electrons per unit volume $\longrightarrow$ n
- Drift velocity of electron $\longrightarrow$ v_d
- Electron move through distance $\longrightarrow$ dx
- Small interval of time $\longrightarrow$ dt

Derivation :

1.Drift velocity $v_d = \frac{dx}{dt}$

2. Electrons move through a distance $dx = v_d \, dt$

3. Electrons available in volume element $= A\,dx \times n = A\,(v_d\,dt)\,n$

4. Total charge in volume element $dQ = e\,A\,(v_d\,dt)\,n$

5. Current : $I = \frac{dQ}{dt} = e\,A\,v_d\,n$

6. Current Density : $J = \frac{I}{A} = n\,e\,v_d$

7. We know that , $\vec{v}_d = -\frac{e\,\tau\,\vec{E}}{m}$

8. $\vec{J} = n\,e\,\vec{v}_d = n\,e\left(-\frac{e\,\tau}{m}\right)\vec{E} = -\frac{n\,e^2\,\tau\,\vec{E}}{m}$

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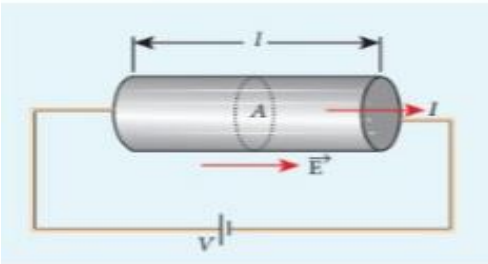
9. Conductivity : $\sigma = \frac{n e^2 \tau}{m}$

10. Microscopic form of Ohm's law : $\boxed{\vec{J} = \sigma \vec{E}}$

2.Obtain the macroscopic form of Ohm's law from its microscopic form and discuss its limitation.

Diagram :



Formula :

$\boxed{V = I R}$

Theory :

- Let us consider a segment of wire.
- Length of a wire → l
- Cross sectional area → A
- Potential area → V
- Electric field → E
- When a potential difference V is applied across the wire , a net electric field is created in the wire constitutes the current in the wire.
- We assume that the electric field is uniform in the entire length of the wire.

Derivation :

1. Microscopic Ohm's law : $J = \sigma E$

2. Potential Difference : $V = E\, l$

3. Electric Field : $E = \frac{V}{l}$

4. Current Density : $J = \frac{I}{A}$

5. $J = \sigma E$

$$\frac{I}{A} = \sigma \frac{V}{l}$$

$$V = I \left(\frac{l}{\sigma A} \right)$$

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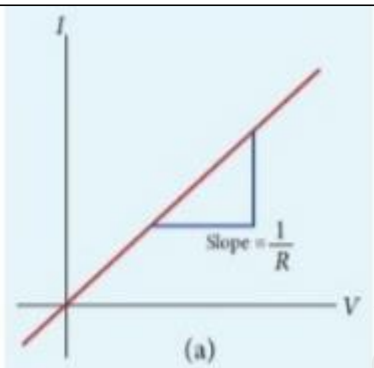
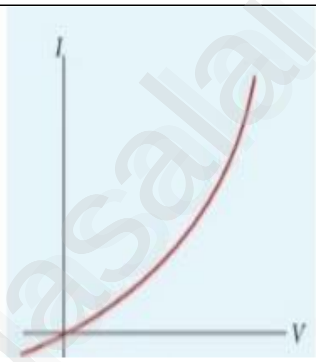
6. **Resistance of the conductor :** $R = \dfrac{l}{\sigma A}$

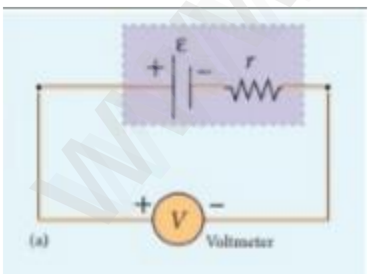
7. **Macroscopic form of Ohm's law :** $V = I R$

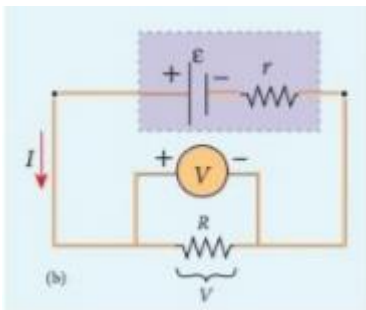
Limitation :

S . NO	Ohmic Device	Non Ohmic Device
1.	Obeys Ohms law.	Not obey Ohms law.
2.	Graph is straight line.	Graph is non linear.
3.		

4.Explain the determination of internal resistance of a cell using voltmeter.

Diagram :





Formula :

$$r = \left(\frac{\varepsilon - V}{V} \right) R$$

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Theory :

1. Emf of cell ε is measured by connecting high resistance voltmeter across it.

2. Without external resistance is open circuit.

3. Voltmeter draws very little current.

4. Voltmeter gives the emf of the cell.

5. The external resistance is included in the circuit.

6. With external resistance is closed circuit.

7. Current I is established in the circuit.

8. The potential difference across R is equal to potential difference across the cell V.

9. Due to internal resistance r of the cell , The voltmeter reads a value V , Which is less than the emf of cell ε.

10. Amount voltage I r has dropped across the internal resistance r.

Derivation :

1. Due to external resistance : $I R = V \quad \text{———} \quad (1)$

2. Due to internal resistance : $I r = \varepsilon - V \quad \text{———} \quad (2)$

3. $$\frac{I r}{I R} = \frac{\varepsilon - V}{V}$$

$$\boxed{r = \frac{\varepsilon - V}{V} R}$$

Since ε , V and are known internal resistance r can be determined.

Power delivered to the circuit :

$$P = I^2 R + I^2 r \qquad (I^2 r < < < I^2 R)$$

- Power delivered to electrical device.
- Power delivered to internal resistance.

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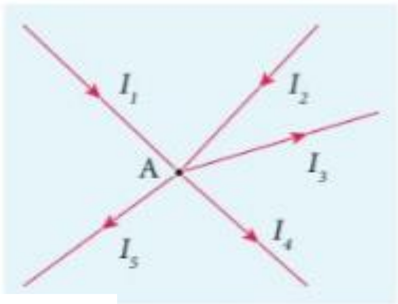
5. State and explain Kirchhoff's rules.

1. <u>Kirchhoff's First Rule:</u>

- **Current rule or junction rule.**
- **Law of conservation of electric charge.**
- **It states that the algebraic sum of currents of any junction of a circuit is zero.**
- **Charge enter a junction must leave the junction.**
- **Current entering the junction as positive, current leaving the junction as negative.**



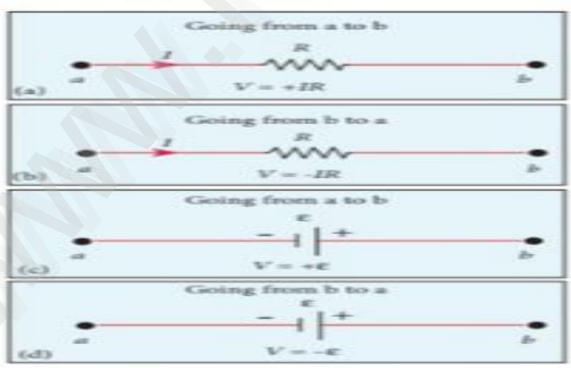
Kirchhoff's current rule

- $\mathbf{I_1 + I_2 - I_3 - I_4 - I_5 = 0}$

  $\mathbf{I_1 + I_2 = I_3 + I_4 + I_5}$

2. <u>Kirchhoff's Second Rule:</u>

- **Voltage rule or loop rule.**
- **It states that in a closed circuit the algebraic sum of the products of the current and resistance of each part of the circuit is equal to total emf included in the circuit.**
- **Law of conservation of energy.**



- **Product of current and resistance is taken as positive when the direction of current is followed.** $\mathbf{V = + I R}$

- **Product of current and resistance is taken as negative if the direction of current is opposite.** $\mathbf{V = - I R}$

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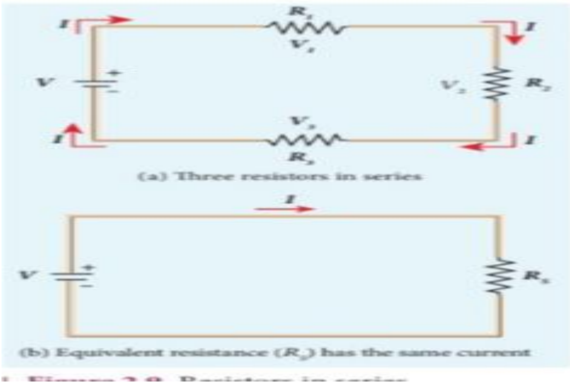
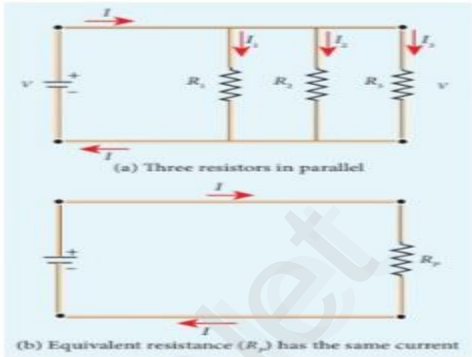
3. Explain the equivalent resistance of a series and parallel resistor network.

S. NO	Resistance in series	Resistance in parallel
1.		
2.	When two or more resistors (R_1 , R_2 , R_3) are connected end to end.	When two or more resistors (R_1 , R_2 , R_3) connected across same potential difference
3.	Current be same. (I)	Current is differ. (I_1 , I_2 , I_3)
4.	Potential difference vary. (V_1 , V_2 , V_3)	Potential difference is same. (V)
5.	$V = I R$ $V = I R_1$; $V = I R_2$; $V = I R_3$	$I = \frac{V}{R}$ $I_1 = \frac{V}{R_1}$; $I_2 = \frac{V}{R_2}$; $I_3 = \frac{V}{R_3}$
6.	$V = V_1 + V_2 + V_3$ $I R = I R_1 + I R_2 + I R_3$ $R_S = R_1 + R_2 + R_3$	$I = I_1 + I_2 + I_3$ $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$ $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
7.	The value of equivalent resistance in series connection will be greater than each individual resistance.	The value of equivalent resistance in parallel connection will be lesser than each individual resistance.

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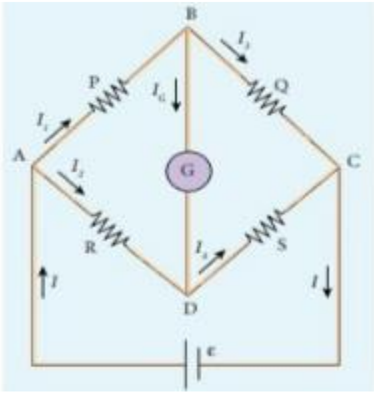
6. Obtain the condition for bridge balance in Wheatstone's bridge.

Wheatstone's Bridge:

1. Important application of Kirchhoff's rule.
2. It is used to compare resistance.
3. It is used to find unknown resistance.

Diagram :



Parts :

PQRS	–	Resistance
G	–	Galvanometer
ε	–	Battery
I	–	current

Formula:

$$\frac{P}{Q} = \frac{R}{S}$$

Circuit connection :

1. The bridge consists of four resistance P , Q , R and S.
2. A galvanometer is connected between the point B and D.
3. The battery is connected between A and C.
4. The current through the galvanometer is I_G and its resistance is G.

Kirchhoff's Current Rule

1. At junction B : $I_1 - I_G - I_3 = 0$

2. At junction D : $I_2 + I_G - I_4 = 0$

Kirchhoff's Voltage Rule

3. ABDA Loop : $I_1 P + I_G G - I_2 R = 0$

4. ABCDA Loop : $I_1 P + I_3 Q - I_4 S - I_2 R = 0$

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Balancing Condition $I_G = 0$

When B and D are at same potential , bridge is said to be balanced. As there is no potential difference between B and D, no current flows through galvanometer $I_G = 0$

$I_1 = I_3$	$I_1 P = I_2 R$
$I_2 = I_4$	$I_3 Q = I_4 S$

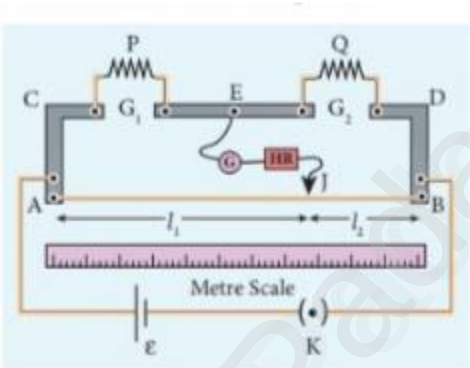
Condition for bridge balance : $\frac{I_1 P}{I_3 Q} = \frac{I_2 R}{I_4 S}$ $\boxed{\frac{P}{Q} = \frac{R}{S}}$

- **Only under this condition , the galvanometer shows null deflection.**
- **If we know the two adjacent resistances , the other two resistances can be compared.**
- **If three of the resistances are known , the value of unknown resistance can be determined.**

---

7. Explain the determination of unknown resistance using meter bridge.

Diagram:



Formula :

$$\boxed{P = Q \frac{l_1}{l_2}}$$

Construction :

1. **Meter bridge is another form of Wheatstone bridge.**
2. **AB is one meter length manganin wire.**
3. **A meter scale on wooden board.**
4. **Two copper strips C, D another strip is E.**
5. **Two gaps are G_1 and G_2.**

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6. Unknown resistance P and known resistance Q.
7. Jockey connected with G and HR.
8. Lechlance cell, key connected to end of bridge wire.

Working:

- The position of the jockey on the wire is adjusted.
- Adjust jockey on the wire, galvanometer shows zero deflection.
- Let the position of jockey at the wire is J.
- The resistances corresponding to AJ to JB of the bridge wire form the resistance R and S of the Wheatstone's bridge.

Bridge balance:

$$\frac{P}{Q} = \frac{R}{S} = \frac{r \cdot AJ}{r \cdot JB}$$

$$\frac{P}{Q} = \frac{AJ}{JB} = \frac{l_1}{l_2}$$

$$\boxed{P = Q \frac{l_1}{l_2}}$$

End Resistance :
The bridge wire is soldered at the ends of the copper strips. Due to imperfect contact , some resistance might be introduced at the contact . These are called " end resistance "

To Eliminate end resistance :
This error can be eliminated , if another set of readings is taken with P and Q interchanged and the average value of P is found.

Resistivity or specific resistance:
To find the specific resistance of the material of the wire, measure the following

- Radius of the wire " a "
- Length of the wire " l "
- Resistance $= \rho \frac{l}{A}$
- $\rho = \text{Resistance} \times \frac{A}{l}$ $\boxed{\rho = P \times \frac{\pi a^2}{l}}$

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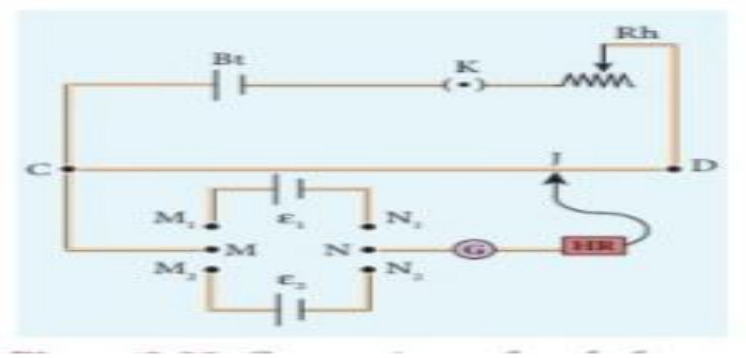
8. How the emf of two cells are compared using potentiometer?

Diagram:



Formula :

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$$

Theory:

1) Potentiometer wire is CD.
2) Battery Bt, key K, Rheostat in series.
3) This is the primary circuit.
4) DPDT double pole double throw switch.
5) Terminal M and N connected to DPDT.
6) Jockey J, Galvanometer G, high resistance HR.
7) The cells whose emf are ε_1 and ε_2.

Working:

1) DPDT switch pressed towards M_1 and N_1.
2) Cell ε_1 included in secondary circuit.
3) Balancing length is l_1 adjust jockey for zero deflection.
4) Cell ε_2 included in secondary circuit.
5) Balancing length is l_2 adjust jockey for zero deflection.

Derivation:

$$\varepsilon_1 = I \, r \, l_1 \quad \text{--------} \quad (1)$$

$$\varepsilon_2 = I \, r \, l_2 \quad \text{--------} \quad (2)$$

Equation (1) divide by (2)

$$\frac{\varepsilon_2}{\varepsilon_1} = \frac{I \, r \, l_1}{I \, r \, l_2}$$

$$\boxed{\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}}$$

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3. Magnetism & magnetic effects of electric current

1. Discuss Earth's magnetic field in detail.

1. Willam Gilbert

In 1600 proposed that Earth itself behaves like a gigantic powerful magnet.

2. Gover

- Earth's magnetic field due to hot rays coming out from the sun.
- These rays heat up the air near the equatorial region.
- Once air becomes hotter , it rises above and move towards northern and southern hemisphere and get electrified.
- This may be responsible to magnetize the ferromagnetic material near Earth surface.

3. Geographic Poles

- North pole of magnetic compass needle is attracted towards magnetic south pole of earth which near the geographic north pole.
- South pole of magnetic compass needle is attracted towards magnetic north pole of Earth which near the geographic south pole.

4. Terrestrial Magnetism

Branch of physics which deals with Earth's magnetic field is called " Geomagnetism or Terrestrial magnetism ".

5. Elements of Earth magnetic field

a . Magnetic Declination (D)

Angle between magnetic meridian at a point and geographical meridian.

b. Magnetic dip or inclination (I)

Angle subtended by Earth's total magnetic field with horizontal direction in the magnetic meridian.

c. Horizontal component of Earth magnetic field (B_H)

- Horizontal Component $B_H = B_E \cos I$
- Vertical Component $B_V = B_E \sin I$

$$\boxed{\tan I = \frac{B_V}{B_H}}$$

i) At magnetic equator

The Earth's magnetic field parallel to the surface of the Earth at an angle of dip $I = 0^0$

- $B_H = B_E$ **(Horizontal component maximum at equator)**
- $B_V = O$ **(Vertical component zero at equator)**

i) At magnetic poles

Earth's magnetic field perpendicular to the surface of the Earth at an angle of dip $I=90^0$

- $B_H = 0$ **(Horizontal component zero at poles)**
- $B_V = B_E$ **(Vertical component maximum at poles)**

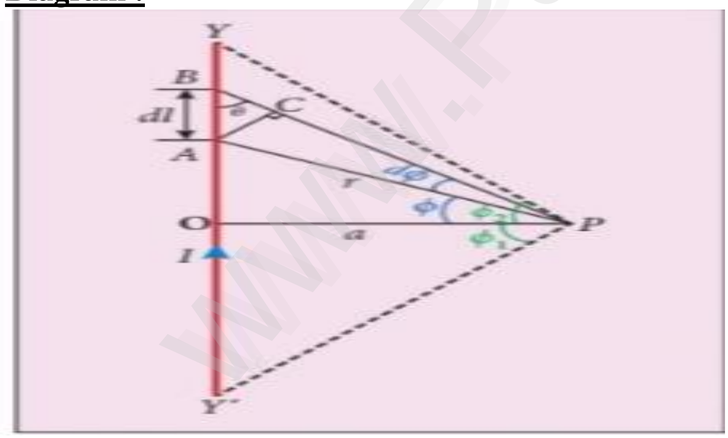
---

2. Deduce the relation for the magnetic field at a point due to infinitely long straight conductor carrying current.

Theory :

- **Let YY' be an infinitely long straight conductor.**
- **I be current through the conductor.**
- **dB be magnetic field at a point P which is at distance 'a'.**
- **Let us consider small line element dl be the segment AB.**

Diagram :



Formula :

$$\boxed{\vec{B} = \frac{\mu_0 I}{2\pi a}\hat{n}}$$

Biot Savart's Law :

$$\boxed{\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\ dl\ \sin\theta}{r^2}\hat{n}} \longrightarrow$$

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To apply trigonometry

Δ ABC

$$\sin\theta = \frac{AC}{AB}$$

$$\sin\theta = \frac{AC}{dl}$$

$$AC = dl\sin\theta$$

Δ APC

$$\sin d\phi = \frac{AC}{AP}$$

$$d\phi = \frac{AC}{r}$$

$$AC = r\,d\phi$$

Δ OPA

$$\cos\phi = \frac{OP}{AP}$$

$$\cos\phi = \frac{a}{r}$$

$$\frac{1}{r} = \frac{\cos\phi}{a}$$

$$dl\sin\theta = r\,d\phi \longrightarrow (2)$$

$$\frac{1}{r} = \frac{\cos\phi}{a} \longrightarrow (3)$$

Sub eqn (2) & (3) in (1)

1. $\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin\theta}{r^2}\hat{n}$

2. $\vec{dB} = \frac{\mu_0 I}{4\pi}\frac{r\,d\phi}{r^2}\hat{n}$

3. $\vec{dB} = \frac{\mu_0 I}{4\pi}\frac{1}{r}\,d\phi\,\hat{n}$

4. $\vec{dB} = \frac{\mu_0 I}{4\pi}\frac{\cos\phi}{a}\,d\phi\,\hat{n}$

5. $\int dB = \frac{\mu_0 I}{4\pi a}\int_{-\phi_1}^{\phi_2}\cos\phi\,d\phi\,\hat{n}$

6. $\vec{B} = \frac{\mu_0 I}{4\pi a}\left[\sin\phi\right]_{-\phi_1}^{\phi_2}\hat{n}$

7. $\vec{B} = \frac{\mu_0 I}{4\pi a}\left[\sin\phi_2 - (\sin(-\phi_1))\right]\hat{n}$

8. $\vec{B} = \frac{\mu_0 I}{4\pi a}\left[\sin\phi_2 + \sin\phi_1\right]\hat{n}$

9. For infinitely long conductor , $\phi_1 = \phi_2 = 90^0$ then $\sin 90^0 + \sin 90^0 = 1 + 1 = 2$

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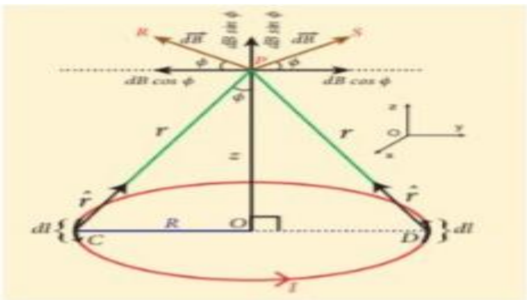
10. $\vec{B} = \frac{\mu_0 I}{4\pi a} \times 2\hat{n}$

11. $\boxed{\vec{B} = \frac{\mu_0 I}{2\pi a}\hat{n}}$

---

3. Obtain the relation for the magnetic field at a point along the axis of a circular coil carrying current.

Diagram :



Formula :

$\boxed{\vec{B} = \frac{\mu_0 N I}{2R}\hat{k}}$

Theory :

Consider a current carrying circular coil.

- **Radius of the loop** $\longrightarrow$ **R**
- **Current through the loop** $\longrightarrow$ **I**
- **Magnetic field at a point** $\longrightarrow$ **P**
- **Distance from O to P** $\longrightarrow$ **Z**
- **Line element of the coil** $\longrightarrow$ **dl**

Biot – Savart' s Law :

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin\theta}{r^2} \longrightarrow (1)$$

If angle between I $\vec{dl}$ and $\vec{r}$ is 90^0 then $\sin 90^0 = 1$

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2} \longrightarrow (2)$$

Component of dB :

- **dB cos ϕ along y - direction.**
- **dB sin ϕ along z - direction.**

Net Magnetic field :

- **Horizontal component cancel out each other.**
- **Vertical component contribute net magnetic field.**

$$\int d\vec{B} = \int dB \sin\phi \, \hat{k} \longrightarrow (3)$$

Sub eqn (2) in eqn (3)

$$\int d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{1}{r^2} \sin\phi \, \hat{k} \int dl \longrightarrow (4)$$

From triangle Δ O C P

$$Hyp^2 = Opp^2 + Adj^2$$

$$r^2 = R^2 + z^2$$

$$r = (R^2 + z^2)^{1/2}$$

$$\sin\phi = \frac{Opp}{Hyp}$$

$$\sin\phi = \frac{R}{(R^2 + z^2)^{1/2}}$$

$$\int dl = 2\pi R$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{1}{R^2 + z^2} \frac{R}{(R^2 + z^2)^{1/2}} \hat{k} \, 2\pi R$$

$$\vec{B} = \frac{\mu_0 I}{2} \frac{R^2}{(R^2 + z^2)^{3/2}} \hat{k}$$

- **If the circular coil contains N turns then ,**

$$\vec{B} = \frac{\mu_0 N I}{2} \frac{R^2}{(R^2 + z^2)^{3/2}} \hat{k}$$

The magnetic field at the centre of the coil is zero , z = 0 then $(R^2 + z^2)^{3/2} = R^3$

$$\vec{B} = \frac{\mu_0 N I}{2} \frac{R^2}{R^3} \hat{k}$$

$$\boxed{\vec{B} = \frac{\mu_0 N I}{2R} \hat{k}}$$

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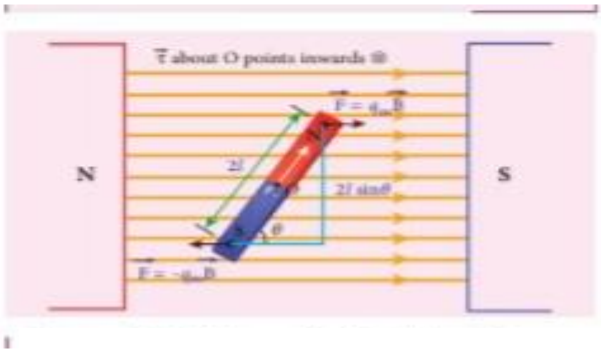
4. Compute the torque experienced by a magnetic needle in a uniform magnetic field.

Diagram :



Formula :

$$\boxed{\vec{\tau} = \vec{p}_m \times \vec{B}}$$

Theory :

1. Consider a magnet of length $2l$
2. Pole strength q_m kept in a uniform magnetic field.
3. Each pole experiences a force of magnitude $q_m \vec{B}$ and act in opposite direction.
4. Net force acting on the magnet is zero so there is no translatory motion.
5. Two equal and opposite forces constitute a couple tend to align magnet in B direction.

Derivation :

1. Force experienced by north pole $\vec{F}_N = q_m \vec{B}$
2. Force experienced by south pole $\vec{F}_S = - q_m \vec{B}$
3. Net force acting on dipole $\vec{F} = \vec{F}_N + \vec{F}_S = 0$

Moment of Force / Torque :

1. $\vec{\tau} = \vec{ON} \times \vec{F}_N + \vec{ON} \times \vec{F}_S$
2. $\vec{\tau} = \vec{ON} \times q_m \vec{B} + \vec{ON} \times (-q_m \vec{B})$
3. By using right hand cork screw rule

$$|\vec{ON}| = |\vec{OS}| = l$$

$$|q_m \vec{B}| = |-q_m \vec{B}| = l$$

4. $\tau = l \times q_m B \sin\theta + l \times q_m B \sin\theta$
5. $\tau = 2l \times q_m B \sin\theta$

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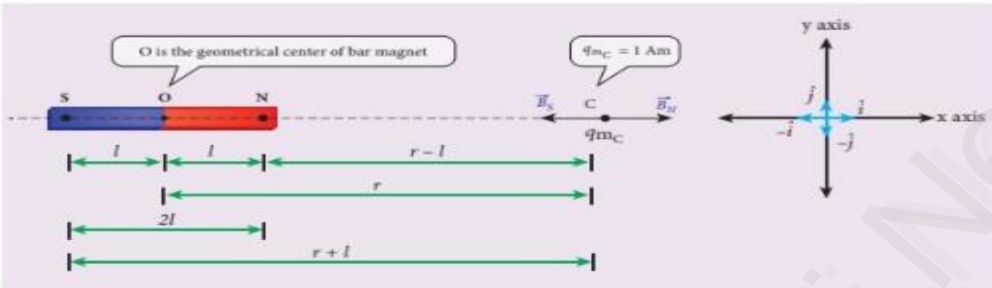
6. $\tau = p_m B \sin\theta \quad (p_m = q_m \times 2l)$

$$\boxed{\vec{\tau} = \vec{p}_m \times \vec{B}}$$

---

5. Calculate the magnetic field at a point on the axial line of a bar magnet.

Diagram :



Formula :

$$\boxed{\vec{B}_{axial} = \frac{\mu_0}{4\pi} \frac{2\vec{p}_m}{r^3}}$$

Theory :

1. Consider a bar magnet NS.
2. Let N be north pole and S be the south pole.
3. Each of pole strength q_m and are separated by a distance of 2 l.
4. Magnetic field at a point C at a distance r.
5. Geometrical centre ' O ' of the bar magnet.

Magnetic Field at C

1. Due to north pole : $\vec{B}_N = \frac{\mu_0}{4\pi} \frac{q_m}{(r-l)^2} \hat{i}$

2. Due to south pole : $\vec{B}_S = -\frac{\mu_0}{4\pi} \frac{q_m}{(r+l)^2} \hat{i}$

3. Net magnetic field : $\vec{B} = \vec{B}_N + \vec{B}_S$

4. $\vec{B} = \frac{\mu_0}{4\pi} \frac{q_m}{(r-l)^2} \hat{i} - \frac{\mu_0}{4\pi} \frac{q_m}{(r+l)^2} \hat{i}$

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5. $\vec{B} = \frac{\mu_0 \; q_m}{4\pi} \left[\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2} \right] \hat{i}$

6. $\vec{B} = \frac{\mu_0 \; q_m}{4\pi} \left[\frac{4 \; r \; l}{(r^2 - l^2)^2} \right] \hat{i}$

7. $\vec{B} = \frac{\mu_0}{4\pi} \left[\frac{2 \; r . \; 2 \; q_m \; l}{(r^2 - l^2)^2} \right] \hat{i}$

8 . $\vec{B} = \frac{\mu_0}{4\pi} \left[\frac{2 \; r \; p_m}{(r^2 - l^2)^2} \right] \hat{i}$ $\quad (p_m = 2 \; q_m \; l)$

9. If $r >>> l$ then $(r^2 - l^2)^2 = r^4$

$\vec{B} = \frac{\mu_0}{4\pi} \left[\frac{2 \; r \; p_m}{r^4} \right] \hat{i}$

10. $\vec{B} = \frac{\mu_0}{4\pi} \left[\frac{2 \; p_m}{r^3} \right] \hat{i}$

$$\boxed{\vec{B}_{axial} = \frac{\mu_0}{4\pi} \frac{2}{r^3} \vec{p}_m}$$

---

6. Obtain the magnetic field at a point on the equatorial line of a bar magnet.

Theory :

1. Consider a bar magnet NS .

2. Let N be the north pole and S be the south pole.

3. Pole strength q_m be separated by a distance 2l.

4. Magnetic field at point C at a distance r.

5. Geometrical centre of the bar magnet is O.

Formula :

$$\boxed{\vec{B}_{equatorial} = - \frac{\mu_0}{4\pi} \frac{\vec{p}_m}{r^3}}$$

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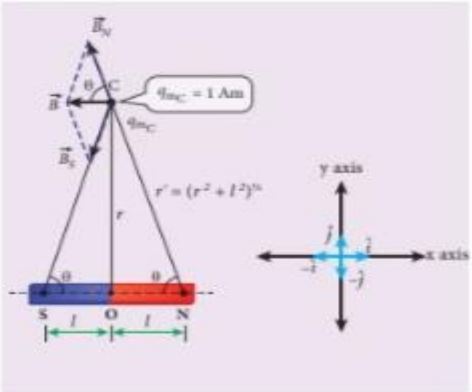
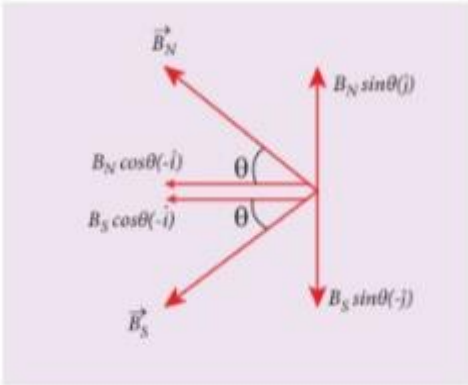
Diagram :





Magnetic Field at C :

1. Due to north pole : $\vec{B}_N = -B_N \cos\theta\, \hat{i} + B_N \sin\theta\, \hat{j}$

2. Due to south pole : $\vec{B}_S = -B_S \cos\theta\, \hat{i} - B_S \sin\theta\, \hat{j}$

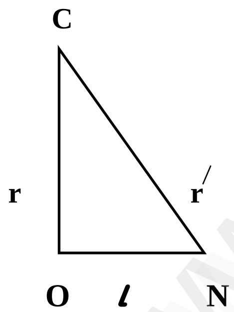
3. Net magnetic field : $\vec{B} = \vec{B}_N + \vec{B}_S$

4. Since $B_N = B_S$: $\vec{B} = -(B_N + B_S) \cos\theta\, \hat{i}$

5. Here , $B_N = B_S = -\dfrac{\mu_0}{4\pi}\dfrac{q_m}{r'^2}$

6. $B = \dfrac{-2\mu_0}{4\pi}\dfrac{q_m}{r'^2} \cos\theta\ i$

7. <u>In triangle ONC</u>



$Hyp^2 = Opp^2 + Adj^2$

$r'^2 = r^2 + l^2$

$r' = (r^2 + l^2)^{1/2}$

$\text{Cos}\ \theta = \dfrac{adj}{hyp}$

$\text{Cos}\ \theta = \dfrac{l}{(r^2 + l^2)^{1/2}}$

8. $\vec{B} = \dfrac{-2\mu_0}{4\pi}\dfrac{q_m}{r'^2} \cos\theta$

Substitute $\cos\theta$ and r'^2

$$\vec{B} = \frac{-2\mu_0}{4\pi}\ \frac{q_m}{(r^2 + l^2)}\ \frac{l}{(r^2 + l^2)^{1/2}}\ \hat{i}$$

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9. $B = - \frac{\mu_0}{4\pi} \frac{2 q_m l}{(r^2 + l^2)^{3/2}} \hat{i}$

10. If $r >>> l$ then $(r^2 + l^2)^{3/2} = r^3$ and magnetic dipole moment $p_m = 2 q_m l$

11. $\vec{B} = - \frac{\mu_0}{4\pi} \frac{p_m}{r^3} \hat{i}$

12. $\vec{B} = - \frac{\mu_0}{4\pi} \frac{\vec{p}_m}{r^3}$ $\quad (\vec{p}_m = p_m \hat{i})$

$$\boxed{\vec{B}_{equatorial} = - \frac{\mu_0}{4\pi} \frac{\vec{p}_m}{r^3}}$$

---

7. Find the magnetic field due to a long straight conductor using Ampere's circuit law.

Theory :

1. Consider a straight conductor of infinite length carrying current I.
2. The wire is geometrically cylindrical in shape and symmetrical about its axis.
3. We construct Amperian loop in the form of circular shape.
4. Current enclosed by Amperian loop is I.
5. Distance from centre of conductor is r.
6. Line element along Amperian loop is dl.

Diagram :

Formula :

$$\boxed{\vec{B} = \frac{\mu_0 I}{2\pi r} \hat{n}}$$

By Ampere's Law :

1. $\oint_c \vec{B} \cdot \vec{dl} = \mu_0 I$

2. The angle between magnetic field vector and line element is zero.

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3. $\oint_c B\,dl = \mu_0 I$

4. Due to the symmetry , the magnitude of the magnetic field is uniform over the Amperian loop.

5. $B \oint_c dl = \mu_0 I$

6. For a circular loop , the circumference is $2\pi r$.

7. $B \cdot 2\pi r = \mu_0 I$

8. $B = \dfrac{\mu_0 I}{2\pi r}$

9. In vector form , the magnetic field is $\boxed{\vec{B} = \dfrac{\mu_0 I}{2\pi r}\hat{n}}$

---

8. Discuss the working of cyclotron in detail.

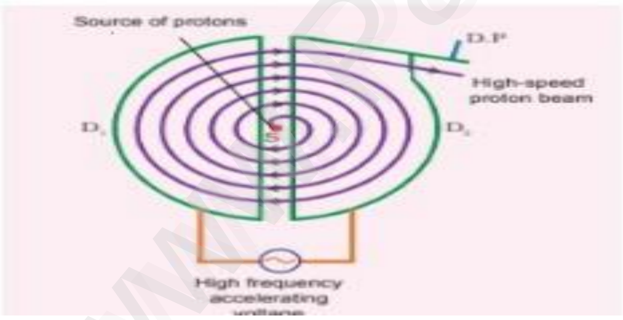
Cyclotron :

1. It is device used to accelerate the charged particle to gain large kinetic energy.

2. It is also called as high energy accelerator.

3. It was invented by Lawrence and Livingston in 1934.

Diagram :



Formula :

$$\boxed{f_{osc} = \frac{B q}{2\pi m}}$$

Principle :

When a charged particle moves perpendicular to the magnetic field , it experiences magnetic Lorentz force.

Construction :

1. The particles are allowed to move in between two semi circular metal container called DEES (hollow D – shaped objects)

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2. Dees are enclosed in an evacuated chamber.

3. And kept in a region with uniform magnetic field controlled by an electromagnet.

4. Two Dees are kept separated with a gap and source S.

5.The source S is which ejects the particle to be accelerated.

6. Dees are connected to high frequency alternating potential difference.

Working :

1. The ion ejected from source S is positively charged.

2. The ion is ejected it is accelerated towards a Dee which is at negative potential.

3. Magnetic field is normal to the plane of the Dees , the ion moves in the circular path.

4. After one semi – circular path inside Dee – 1 , the ion reaches gap between the Dees.

5. A this time the particles of the Dees are reversed so that the ion is now accelerated towards Dee – 2 with the greater velocity.

Derivation :

1. For circular motion : Centripetal Force $= \frac{m\ v^2}{r}$

2. For uniform magnetic field : Lorentz Force $= B\,q\,v$

$$B\,q\,v = \frac{m\ v^2}{r}$$

$$r = \frac{m}{q\ B}\ v$$

$$\boxed{r \ \alpha \ v}$$

3. Velocity increases , radius increases .

4. Particle moves in spiral path of increasing radius.

5. Particle taken out with the help of deflector plate and allowed to hit the target.

Resonance condition in Cyclotron :

When the frequency f at which the positive ion circulates in the magnetic field must be equal to constant frequency of the electrical oscillator f_{osc} . This is called " Resonance condition "

$$\omega = 2\ \pi\ f$$

$$f = \frac{\omega}{2\ \pi}$$

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$$f = \frac{v / r}{2 \pi} \qquad (v = r \omega)$$

$$\boxed{f_{osc} = \frac{B q}{2 \pi m}}$$

Time period of oscillation :

$$T = \frac{1}{f} = \frac{2 \pi m}{B q}$$

Kinetic Energy of charged particle :

$$K.E = \frac{1}{2} m v^2$$

$$v = \frac{B q r}{m}$$

$$K.E = \frac{1}{2} m \frac{B^2 q^2 r^2}{m^2}$$

$$\boxed{K.E = \frac{1}{2m} B^2 q^2 r^2}$$

---

9. What is tangent law ? Discuss in detail.

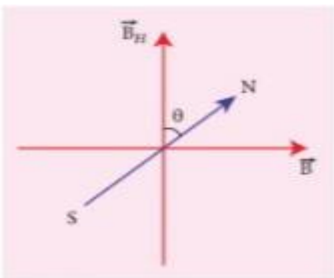
Tangent Law :

When a magnetic needle is freely suspended in two mutually perpendicular uniform magnetic fields , it will come to rest in the direction of the resultant of two fields.

$$\boxed{B = B_H \tan \theta}$$

Tangent Galvanometer :

- **T G is a device used to detect very small current.**
- **It is a moving magnet type galvanometer.**
- **Its working based on tangent law.**



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Construction :

1. T G consists of copper coil of turns wound on a non-magnetic circular frame.
2. The frame is made up of brass or wood which is mounted vertically.
3. A horizontal base table with three levelling screws.
4. In lab experiments contains coils on 2 turns , 5 turns and 50 turns.
5. At the centre of turn table , a compass box is placed.
6. Compass box consists of two needle as magnetic needle and aluminium pointer.
7. Centres of both magnetic needle and circular coil exactly coincide.
8. Thin aluminium pointer attached perpendicular to magnetic needle over graduated circular scale.
9. Circular scale divided into four quadrant and graduated in degrees 0^0 to 90^0.
10. To avoid parallax error in measurement , mirror is placed below aluminium pointer.

Precautions :

1. Avoid magnetic material away from instrument.
2. Using sprit level , Adjust levelling screw.
3. Rotate compass box reads 0^0 - 0^0.
4. Coil remains in magnetic meridian.

Theory :

- When no current is passed through coil , magnetic needle lies along horizontal component of earth's magnetic field.
- When the circuit is closed , the electric current pass through the circular coil and produce magnetic field at the centre of the coil.

Two Fields :

1. The magnetic field (B) due to the electric current in the coil acting normal to the plane of the coil.
2. The horizontal component of Earth magnetic field (B_H)

Derivation :

1. From tangent law : $B = B_H \tan \theta$

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2. Magnitude of magnetic field at the centre : $B = \frac{\mu_0 N I}{2R}$

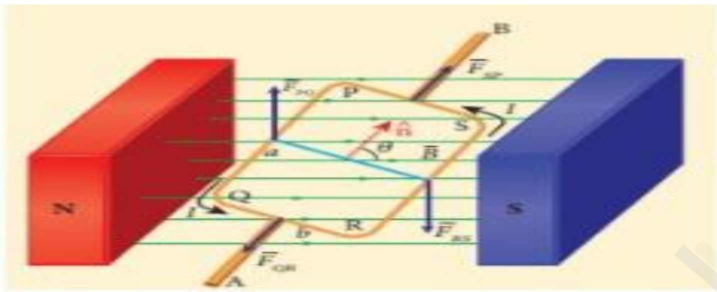
3. $B_H \tan\theta = \frac{\mu_0 N I}{2R}$

$$\boxed{B_H = \frac{\mu_0 N}{2R} \frac{I}{\tan\theta}}$$

---

10. Derive the expression for the torque on a current carrying coil in a magnetic field.

Diagram :



Formula :

$$\vec{\tau} = \vec{p}_m \times \vec{B}$$
$$\tau = N I B \sin\theta$$

Theory :

- Consider a rectangular loop P Q R S.
- Current through the coil is I.
- Uniform magnetic field is B.
- Length of the rectangular loop is 'a'.
- Breadth of the rectangular loop is 'b'.

Magnitude of magnetic force :

1. On the arm $F_{PQ} = I a B \sin(\pi/2) = I a B$
2. On the arm $F_{QR} = I b B \sin(\pi/2 - \theta) = I b \cos\theta$
3. On the arm $F_{RS} = I a B \sin(\pi/2) = I a B$
4. On the arm $F_{SP} = I b B \sin(\pi/2 + \theta) = I b \cos\theta$
5. The forces F_{QR} and F_{SP} are equal, opposite and collinear, they cancel each other.
6. The forces F_{PQ} and F_{RS}, which are equal in magnitude and opposite in direction not acting along the straight line.
7. F_{PQ} and F_{RS} constitute the couple which exerts a torque on the loop.

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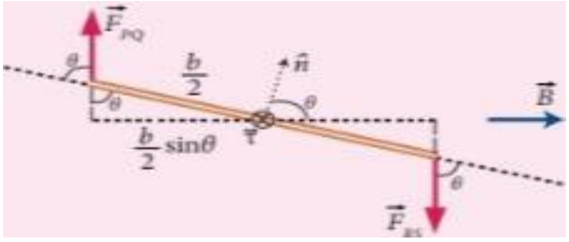
Magnitude of Torque :

1. On the arm PQ about AB is $\tau_{PQ} = \left(\frac{b}{2} \sin\theta\right) I a B$

2. On the arm RS about AB is $\tau_{RS} = \left(\frac{b}{2} \sin\theta\right) I a B$



Total Torque acting on the loop

1. $\tau = \left(\frac{b}{2} \sin\theta\right) I a B + \left(\frac{b}{2} \sin\theta\right) I a B$

2. $\tau = 2 \frac{b}{2} \sin\theta \; I a B$

3. $\tau = I (a b) B \sin\theta$

4. $\tau = I A B \sin\theta$

5. $\vec{\tau} = (I \vec{A}) \times \vec{B}$

6. $\vec{\tau} = \vec{p}_m \times \vec{B}$ where $\vec{p}_m = I\vec{A}$

If there are N turns in the rectangular loop , then the toque is $\boxed{\tau = N I A B \sin\theta}$

Cases :

Plane of the loop parallel to magnetic field	$\theta = 90^0$	$\tau_{max} = I A B$	Torque is maximum
Plane of the loop perpendicular to magnetic field	$\theta = 0^0 / 180^0$	$\tau = 0$	Torque is zero

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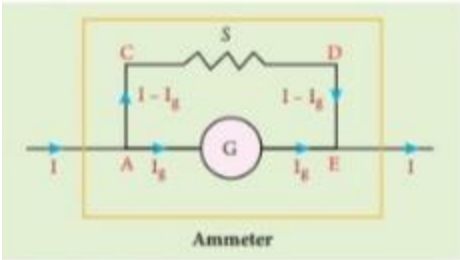
11. Discuss the conversion of galvanometer into an ammeter and also voltmeter.

<u>Diagram :</u>



<u>Galvanometer to ammeter:</u>

1. Used to measure the current flows in circuit.

2. Connect low resistance parallel with galvanometer is as ammeter.

3. Low parallel resistance is "*shunt resistance* "

4. Current through the circuit is I .

5. Current through galvanometer is I_g .

6. Resistance of galvanometer is R_g.

7. Current along the path ACDE is $I - I_g$.

8. Value of shunt resistance is S .

<u>Derivation :</u>

1. $V_{galvanometer} = V_{shunt}$

2. $I_g R_g = (I - I_g) S$

3. $I_g R_g = I S - I_g S$

4. $I_g S + I_g R_g = I S$

5. $(S + R_g) I_g = I S$

6. $I_g = \frac{S}{S + I_g} I$

<u>Deflection on galvanometer :</u>

- **Deflection produced in the galvanometer is a measure of current through the circuit.**

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- **Deflection in the galvanometer is proportional to the current passing through it.**

$$\theta \propto I$$
$$\theta = \frac{I_g}{G}$$

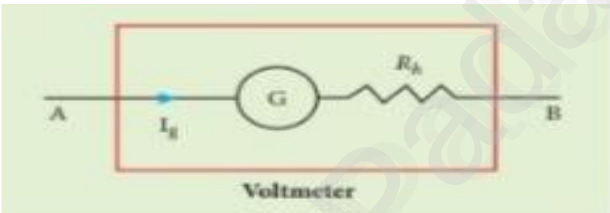
Resistance of Ammeter :

- **Shunt resistance is connected in *parallel* to galvanometer.**
- $$\frac{1}{R_{eff}} = \frac{1}{R_g} + \frac{1}{S} = \frac{R_g S}{R_g + S}$$

$$\boxed{R_a = R_{eff} = \frac{R_g S}{R_g + S}}$$

- **Shunt resistance is a very low resistance , R_a is small.**
- **Resistance offered by the ammeter is small.**
- **An ammeter is a low resistance instrument , always connected in *series* .**
- **Ammeter will not change the current in the circuit.**

Galvanometer to a voltmeter :



1. Used to measure potential difference.

2. Connect high resistance series with galvanometer act as voltmeter.

3. Current through the circuit is I .

4. Current through galvanometer is I_g .

5. High resistance is denoted as R_h.

6. Voltmeter resistance is denoted as $R_v = R_g + R_h$

Derivation :

Current through the circuit is same as current pass through galvanometer.

$$I = I_g$$

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$$I_g = \frac{V}{R_g + R_h}$$

$$R_g + R_h = \frac{V}{I_g}$$

$$R_h = \frac{V}{I_g} - R_g$$

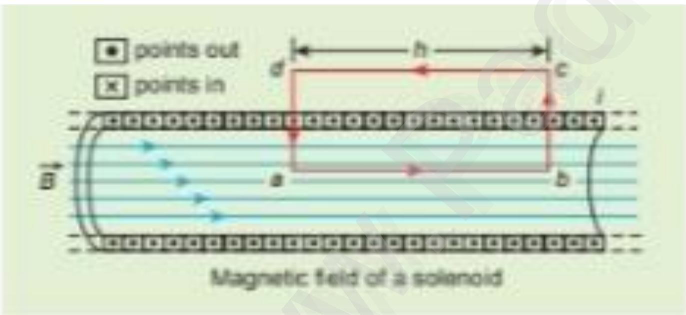
$$\boxed{I_g \ \alpha \ V}$$

- **Deflection in galvanometer is proportional to current I_g.**
- **Current I_g is proportional to potential difference.**
- **Resistance of voltmeter is *large.***
- **Voltmeter is high resistance instrument connected in *parallel* with circuit.**

---

12. Calculate the magnetic field inside and outside of the long solenoid using Ampere's circuital law.

Diagram :



Formula :

$$\boxed{B = \mu_0 n I}$$

Consider a solenoid of length L having N turns.

- ➢ **Consider rectangular loop a b c d.**
- ➢ **Diameter of solenoid is assumed to be much smaller when compared to its length.**

Ampere's Circuital Law :

1. $\oint_C \vec{B} \cdot \vec{dl} = \mu_0 \, I_{enclosed}$

2. $\oint_C B \cdot dl = \mu_0 \times$ **(Total current enclosed by Amperian loop)**

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3. $\oint_{c} B.dl = \int_{a}^{b} B.dl + \int_{b}^{c} B.dl + \int_{c}^{d} B.dl + \int_{d}^{a} B.dl$

4. The element length along b c and d a are perpendicular to magnetic field which is along the axis of solenoid the integrals are,

5. $\int_{b}^{c} B.dl = \int_{b}^{c} B\,dl \cos 90^0 = 0$

6. $\int_{d}^{a} B.dl = \int_{d}^{a} B\,dl \cos 90^0 = 0$

7. Since magnetic field outside the solenoid is zero.

8. $\int_{c}^{d} B.dl = 0$

9. For the path along a b , the integral is

$$\int_{a}^{b} B.dl = B \int_{a}^{b} dl \cos 0^0 = B \int_{a}^{b} dl$$

10. Length of the loop a b is h but the length of the loop is arbitrary. We can take very large loop such that it is equal to the length of the solenoid is L.

11. $B \int_{a}^{b} dl = B\ L$

12. Let I be the current passing through the solenoid of N turns.

13. $B\ L = \mu_0\ N\ I$

14. $B = \mu_0 \dfrac{N\ I}{L}$

15. Number of turns per unit length $N / L = n$ $\boxed{B = \mu_0\, n\, I}$

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13. **Derive the expression for the force between two parallel , current carrying conductors.**

Theory :

Consider two conductor long straight parallel current carrying conductor.

- **Two parallel long conductors** ⟶ **A , B**
- **Current through the conductor** ⟶ I_1 , I_2
- **Distance between the conductor** ⟶ **r**
- **Magnetic Field along conductor** ⟶ B_1 , B_2
- **Force between two conductor** ⟶ **F**

S. NO	On Conductor A	On Conductor B
1.	Magnetic Field : $\vec{B_1} = \frac{\mu_0 I_1}{2\pi r}(-\hat{i})$ $\vec{B_1} = \frac{-\mu_0 I_1}{2\pi r}\hat{i}$	Magnetic Field : $\vec{B_2} = \frac{\mu_0 I_2}{2\pi r}(\hat{i})$ $\vec{B_2} = \frac{\mu_0 I_2}{2\pi r}\hat{i}$
2.	Lorentz force on the element dl $\vec{dF} = I_1 \vec{dl} \times \vec{B_2}$ $\vec{dF} = I_1 dl \frac{\mu_0 I_2}{2\pi r}(\hat{k} \times \hat{i})$ $\vec{dF} = \frac{\mu_0 I_1 I_2 dl}{2\pi r}\hat{j}$	Lorentz force on the element dl $\vec{dF} = I_2 \vec{dl} \times \vec{B_1}$ $\vec{dF} = -I_2 dl \frac{\mu_0 I_2}{2\pi r}(\hat{k} \times \hat{i})$ $\vec{dF} = -\frac{\mu_0 I_1 I_2 dl}{2\pi r}\hat{j}$
3.	Force per unit length : $\int \vec{dF} = \frac{\mu_0 I_1 I_2 \hat{j}}{2\pi r}\int dl$ $\vec{F} = \frac{\mu_0 I_1 I_2 \hat{j}\, l}{2\pi r}$ $\frac{\vec{F}}{l} = \frac{\mu_0 I_1 I_2 \hat{j}}{2\pi r}$	Force per unit length : $\int \vec{dF} = \frac{\mu_0 I_1 I_2 \hat{j}}{2\pi r}\int dl$ $\vec{F} = \frac{\mu_0 I_1 I_2 \hat{j}\, l}{2\pi r}$ $\frac{\vec{F}}{l} = \frac{\mu_0 I_1 I_2 \hat{j}}{2\pi r}$

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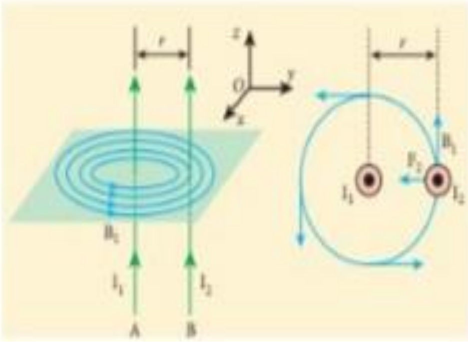
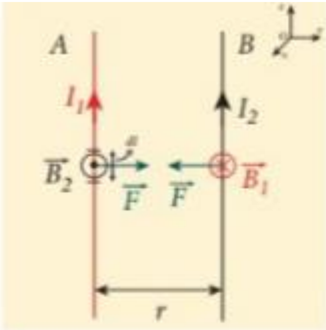
Diagram :





Formula :

$$\frac{\vec{F}}{l} = \frac{\mu_0 I_1 I_2}{2 \pi r} \hat{j}$$

- The force between two parallel current carrying conductors is *attractive* if they carry current in *same* current.
- The force between two parallel current carrying conductors is *repulsive* if they carry current in *opposite* current.

---

14. Give an account of magnetic Lorentz force.

Lorentz Force :

1. When an electric charge q is kept at rest in a magnetic field , no force acts on it. At the same time , if the charge moves in the magnetic field it experience a force.
2. This force is different from Coulomb force and known as magnetic force. $\vec{F} = q (\vec{v} \times \vec{B})$
3. If the charge is moving in both electric and magnetic fields , the total force experienced by the charge is given by , $\vec{F} = q (\vec{E} + \vec{v} \times \vec{B})$. It is known as " Lorentz Force " .

Force on a moving charge in a magnetic field :

- When an electric charge q is moving with velocity $\vec{v}$ in the magnetic field $\vec{B}$, it experiences a force called *magnetic* force $\vec{F}_m$.

$$\boxed{\vec{F}_m = q (\vec{v} \times \vec{B}) = q \; v \; B \sin\theta}$$

1. $\vec{F}_m$ is directly proportional to the magnetic field $\vec{B}$.
2. $\vec{F}_m$ is directly proportional to the velocity $\vec{v}$ of the moving charge.
3. $\vec{F}_m$ is directly proportional to the sine of the angle between the velocity and magnetic field.
4. $\vec{F}_m$ is directly proportional to the magnitude of the charge q.

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5. The direction of $\vec{F}_m$ is always perpendicular to $\vec{v}$ and $\vec{B}$ as $\vec{F}_m$ is the cross product of $\vec{v}$ and $\vec{B}$.

6. The direction of $\vec{F}_m$ on negative charge is opposite to the direction of $\vec{F}_m$ on positive charge provided other factors are identical.

7. If velocity $\vec{v}$ of the charge q is long magnetic field $\vec{B}$ then , $\vec{F}_m$ is zero.

---

15. Compare the properties of soft and hard ferromagnetic materials.

S.No	Properties	Soft Ferromagnetic	Hard Ferromagnetic
1.	When external field is removed	Magnetisation disappears	Magnetisation Persists
2.	Area of the loop	Small	Large
3.	Retentivity	Low	High
4.	Coercivity	Low	High
5.	Susceptibility , magnetic permeability	High	Low
6.	Hysteresis Loop	Less	More
7.	Uses	Solenoid core, Transformer Core	Permanent Magnets.
8.	Examples	Soft iron , Mumetal , Stalloy.	Carbon steel , Alnico , Lodestone

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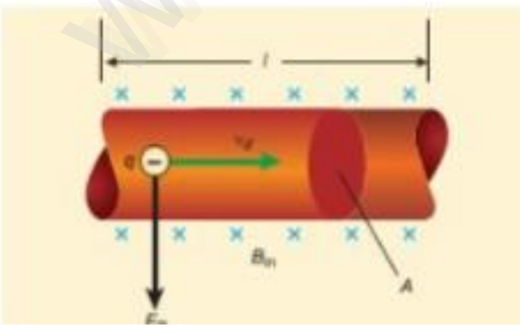
16. Derive the expression for the force on a current carrying conductor in a magnetic field.

Diagram :



Formula :

$$F_{total} = I\, l \times B = B\, I\, l \sin\theta$$

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Theory :

- When a current carrying conductor is placed in a magnetic field , the force experienced by the conductor is equal to the sum of Lorentz forces on the individual charge carriers in the conductor.
- Consider a small segment of conductor of length dl , with cross – sectional area A and current I . The free electrons drift opposite to the direction of current.

Derivation :

1. Relation between current and drift velocity : $I = n e A v_d$
2. If the conductor is kept in a magnetic field , then average force experienced by the charge in the conductor, $\vec{F} = - e (\vec{v_d} \times \vec{B})$
3. If n is the number of free electrons in the unit volume , $n = \frac{N}{V}$
4. Lorentz force on the elementary section of length dl is the product of the number of electrons and the force acting on each electron.

$$\vec{F} = - N e (\vec{v_d} \times \vec{B})$$

$$\vec{F} = - n V e (\vec{v_d} \times \vec{B})$$

$$\vec{F} = - n A l e (\vec{v_d} \times \vec{B})$$

$$\vec{F} = - e n A dl (\vec{v_d} \times \vec{B})$$

5. The current element in the conductor is $I \vec{dl} = n e A \vec{v_d} \vec{dl}$
6. The force on the small elemental section of the current carrying conductor is

$$\vec{dF} = I \vec{dl} \times \vec{B}$$

7. The force on a straight current carrying conductor of length placed in a uniform magnetic field is,

$$\boxed{F_{total} = I l \times B = B I l \sin \theta}$$

Cases :

Conductor is placed along the direction of the magnetic field	$\theta = 0^0$	Force experienced by the conductor is zero.
Conductor is placed along the direction of the magnetic field	$\theta = 90^0$	Force experienced by the conductor is maximum. $F_{total} = B I l$

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17. Explain the principle and working of a moving coil galvanometer.

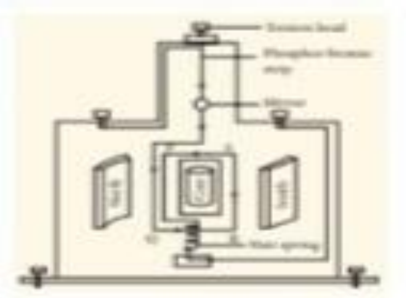
Moving Coil Galvanometer :

Used to detect the flow of current in an electrical circuit.

Principle :

When a current carrying loop is placed in a uniform magnetic field it experiences a torque.

Diagarm :



Construction :

1. **Moving coil galvanometer consists of rectangular coil P Q R S of insulated thin copper wire.**
2. **A cylindrical soft – iron core is placed symmetrically inside the coil.**
3. **Rectangular coil is suspended freely between two pole pieces of horse – shoe magnet.**
4. **Upper end of the coil is attached to phosphor bronze and lower end of the coil connected to hair spring.**
5. **Small plane mirror is attached to measure the deflection of coil with help of lamp and scale arrangement.**
6. **Other end of the mirror is connected to torsion head.**

Working :

Consider the rectangular coil P Q R S .

- **Length of the coil P Q = R S = l**
- **Breadth of the coil Q R = S P = b**
- **Current through coil is I .**

Magnetic Field :

➢ **Horse shoe magnet has hemi spherical magnetic poles , produce radial magnetic field.**

Sides Q R and S p are always parallel to magnetic field and experience no force .

- Sides Q R and S P are always parallel to magnetic field and experience no force.
- Sides P Q and R S are always perpendicular to magnetic field and experience equal forces in opposite direction . Due to this , torque is produced.

Deflecting Torque :

1. $\tau = b\ F = b\ B\ I\ l = (l\ b)\ B\ I = A\ B\ I$
2. For coil with N turns $\tau = N\ A\ B\ I$
3. Due to deflecting torque , coil gets twisted and restoring torque is developed. $\tau = K\ \theta$
4. At equilibrium , The deflecting couple is equal to restoring couple.

$$\tau = N\ A\ B\ I = K\ \theta$$

$$I = \frac{K\ \theta}{N A B}$$

$$I = G\ \theta$$

5. Galvanometer constant or current reduction factor of the galvanometer.

$$\boxed{G = \frac{K}{N A B}}$$

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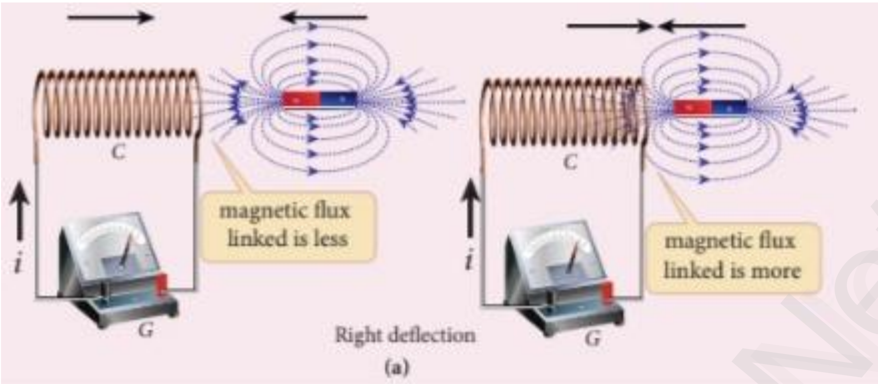
4 . Electromagnetic induction & Alternating Current

1. Establish the fact that relative motion between the coil and the magnet induces an emf in the coil of a closed circuit.

Diagram :



Theory :

1. Whenever the magnetic flux linked with a closed coil changes an emf is induced and hence an electric flows in the circuit.

2. This current is called an induced current and the emf giving rise to such current is called an induced emf. This phenomenon is known as " *electromagnetic induction* ".

3. A bar magnet is placed closed to a coil , some of the magnetic lines force of the bar magnet pass through the coil i.e the magnetic flux is linked with the coil . When the bar magnet and the coil approach each other , the magnetic flux linked with the coil increases.

4. The increases in magnetic flux induces an emf and hence transient electric current flows in the circuit in one direction . At the same time , when they recede away from one another , the magnetic flux linked with the coil decreases.

5. The decrease in magnetic flux again induces an emf in opposite direction . So there is deflection in the galvanometer when there is a relative motion between the coil and the magnet.

---

2. Give an illustration of determining direction of induced current by using Lenz's law.

Lenz's Law :

" The direction of the induced current is such that it always opposes the cause responsible for its production ".

$$\boxed{\varepsilon = -\frac{d\,(N\,\phi_B)}{dt}}$$

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Diagram :

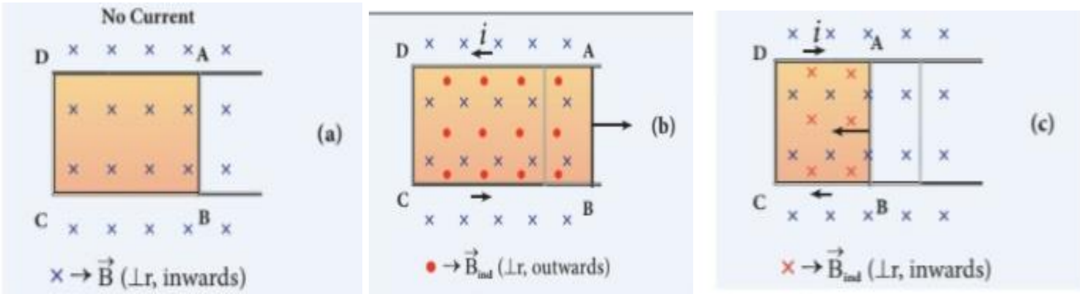

Illustration :

1. Consider a uniform magnetic field , with its field lines perpendicular to the plane of the paper and pointing inwards and represented by cross (x) .

2. A rectangular metallic frame A B C D is placed in this magnetic field , with its plane perpendicular to the field . Arm A B is movable it can slide towards right or left.

3. If the arm A B slides to our right side , the number of field lines passing through the frame A B C D increases and a current is induced.

4. By Lenz's law , the induced current opposes this flux increase and it tries to reduce it by producing another magnetic field pointing outwards i.e opposite to the existing magnetic field.

5. The magnetic lines of this induced field are represented by dots . From the direction of the magnetic field thus produced , the direction of induced current is found to be anti - clockwise by using right hand thumb rule.

6. The leftward motion of arm A B decreases the magnetic flux. The induced current produces magnetic field in the inward direction i.e in the direction of existing magnetic field.

7. The flux decrease is opposed by the flow of induced current . From this , it is found that induced current flows in clockwise direction.

---

3. Show that Lenz's law is in accordance with the law of conservation of energy.

1. It is on the basis of the law of conservation of energy.

2. According to Lenz's law , when the magnet is moved either towards or away from the coil , the induced current opposes its motion.

3. As a result , there will be a resisting force on the moving magnet . Work has to be done by some external agency to move the magnet against this resisting force.

4. Mechanical energy of the moving magnet is converted into electrical energy gets converted into joule heat in the coil energy is converted from one form to another.

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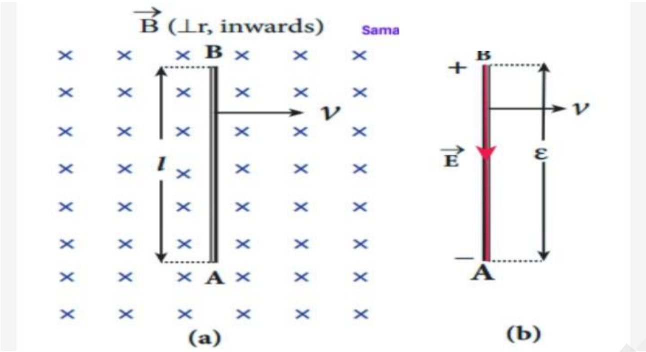
5. When we push the magnet little bit towards the coil , the induced current helps the movement of the magnet towards the coil. Then the magnet starts moving towards the coil without any expense of energy. This becomes a perpetual motion machine.

6. Hence Lenz's law is an excellent example of conservation of energy.

---

4. Obtain an expression for motional emf from Lorentz force.

Diagram :



Formula :

$$\boxed{\varepsilon = B\,l\,v}$$

Theory :

1. Consider a straight conducting rod A B of length l in a uniform magnetic field $\vec{B}$.
2. Let the rod move with a constant velocity $\vec{v}$ towards right side.
3. When the rod moves , the free electrons present in it also moves with same velocity $\vec{v}$ in $\vec{B}$.
4. Lorentz force acts on free electrons in the direction from B to A and accumulates the free electrons at the end A.
5. This accumulation of free electrons produces a potential difference across the rod which produces electric field $\vec{E}$ directed along BA .
6. Due to the electric field $\vec{E}$, The Coulomb force starts acting on the free electrons along AB .
7. The magnitude of the electric field $\vec{E}$ keeps on increasing as long as accumulation of electrons at the end A continues.
8. The force $\vec{F}_E$ also increases until equilibrium is reached.
9. At equilibrium , the magnetic Lorentz force $\vec{F}_B$ and the Coulomb force $\vec{F}_E$ balance each other.
10. No further accumulation of free electrons at the end A takes place.

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Derivation :

1. Lorentz force : $\vec{F_B} = - e (\vec{v} \times \vec{B})$
2. Coulomb force : $\vec{F_E} = - e \vec{E}$
3. $|\vec{F_B}| = |\vec{F_E}|$
4. $|- e (\vec{v} \times \vec{B})| = |- e \vec{E}|$
5. $v B \sin 90^0 = E$
6. $v B = E$
7. Potential difference : $V = E l$

$V = v B l$

$$\boxed{\varepsilon = B l v}$$

This emf is produced due to the movement of the rod , called as " *Motional emf* ".

---

5. Give the uses of Foucault current.

1. Induction Stove :

1. Used to cook food quickly and safely with less energy consumption.
2. Below cooking zone , there is a tightly wound coil of insulated wire.
3. When the stove is switched on , an alternating current flowing in the coil produce magnetic field which induces eddy current.
4. The eddy current in the pan produce so much heat due to joule heating which is used to cook the food.

2. Eddy current brake:

1. Used in high speed train and roller coaster.
2. Strong electromagnets are fixed just above the rails.
3. To stop train , electromagnets are switched on.
4. Magnetic field of these magnets induces eddy current.
5. Eddy currents in the rails which oppose or resist the movement of current called as eddy current linear brake.

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3. Eddy current testing :

1. Non – destructive testing methods to find defects like surface cracks , air bubbles present in a specimen.
2. A coil of insulated wire is given an alternating electric current produces an alternating magnetic field.
3. When the coil brought near the test surface eddy current is induced.
4. The presence of defects causes the change in phase and amplitude of eddy current.
5. The defects present in the specimen are identified.

4. Electromagnetic damping :

1. The armature of galvanometer coil is wound on soft iron cylinder.
2. The relative motion between soft iron cylinder and radial magnetic field induces eddy current.
3. The damping force due to the flow of eddy current brings armature to rest immediately and shows steady deflection.
4. This is called electro magnetic damping.

---

6. Define self – inductance of a coil in terms of i) magnetic flux ii) induced emf

1. If i = 1 A then $L = N\,\phi_B$ Self induction of a coil is defined as flux linkage of the coil when 1 A current flows through it.

2. When the current I changes with time , an emf is induced in it. From Faraday's law electromagnetic induction , the self induced emf is given by ,

$$\varepsilon = -\frac{d\,(N\,\phi_B)}{dt}$$

$$\varepsilon = -\frac{d\,(L\,i)}{dt}$$

$$\varepsilon = -L\,\frac{di}{dt}$$

$$\boxed{L = \frac{-\,\varepsilon}{di\,/\,dt}}$$

3. The negative sign in the above equation means that the self – induced emf always opposes the change in current with respect time. If di / dt = A s^{-1} then L = - ε.

4. Inductance of a coil is also defined as the opposing emf induced in the coil when the rate of change of current through the coil is 1 A s^{-1} .

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7. How will you define the unit of inductance ?

i) <u>Unit of Inductance :</u>

1. Inductance is a scalar.
2. Unit is Wb^{-1} or $V\,s\,A^{-1}$
3. Henry $1\ H = 1\ Wb\ A^{-1} = V\,s\ A^{-1}$
4. Dimensional formula $M L^{2} T^{-2} A^{-2}$

ii) $$L = \frac{N \phi_B}{i}$$

If $i = 1\,A$ and $N\,\phi_B = 1$ Wb turns then $L = 1\ H$. Therefore the inductance of the coil is said to be one henry if current of 1 A produces unit flux linkage in the coil.

iii) $$L = \frac{-\ \varepsilon}{di\ /\ dt} = -\ \frac{\varepsilon\ dt}{di}$$

If $di / dt = 1\ A\,s^{-1}$ and $\varepsilon = -1\ V$ then $L = 1\,H$. Therefore the inductance of the coil is one henry if a current changing at the rate of $1\ A\,s^{-1}$ induces an opposing emf of 1 V in it.

$$\boxed{1\ H = 1\ Wb\ A^{-1} = 1\ V\ s\ A^{-1}}$$

---

8. What do you understand by self induction of a coil ? Give its physical significance .

<u>Self Induction :</u>

1. If magnetic flux is changed by changing the current , an emf is induced in the same coil .

   This phenomenon is known as " Self induction "

2. Self induction of a coil is defined as the flux linkage with the coil when 1 A current flows

   through it.

$$\varepsilon = \frac{-\ d\ (N\,\phi_B)}{dt}$$

$$\varepsilon = -\ \frac{d\ (L\,i)}{dt}$$

$$\varepsilon = -\ L\ \frac{di}{dt}$$

$$\boxed{L = \frac{-\ \varepsilon}{di\ /\ dt}}$$

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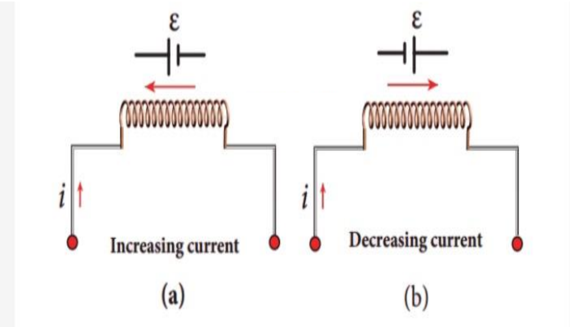
Physical Significance :



1. **When a circuit is switched on**

   The increasing current induces an emf which opposes the growth of current in a circuit.

2. **When a circuit is switched off**

   The decreasing current induces an emf in the reverse direction . This emf now opposes the decay of current.

3. **Inductance of the coil opposes any change in current & tries to maintain the original state.**

---

9. Assuming that the length of the solenoid is large when compared to its diameter , find the equation for its solenoid.

Theory :

1. Consider a long solenoid of length l and cross – sectional area A .

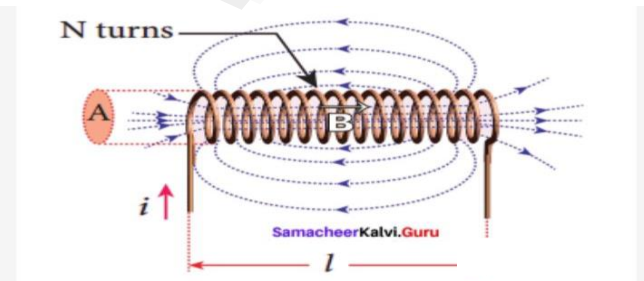
2. Let n be the turns per unit length of the solenoid.

3. When an electric current i passed through solenoid.

4. Magnetic field produced inside is almost uniform.

5. It is directed along the axis of the solenoid.

Diagram :



Formula :

$$\boxed{L = \mu \; n^2 A l}$$

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Derivation :

1. **Magnetic field inside the solenoid : $B = \mu_0\ n\ i$ -------- (1)**
2. **Magnetic flux through the solenoid : $\phi_B = \int B \cdot dA$**

$$\phi_B = B\,A\,\cos\theta$$

$$\phi_B = B\,A \qquad \text{since } \theta = 0^0$$

$$\phi_B = B\,A \text{ ------------------- (2)}$$

3. **Substitute eqn (2) in (1)**

$$\phi_B = (\mu_0\ n\ i)\ A$$

4. **Total flux linkage of the solenoid with N turns ($N = n\,l$)**

$$N\ \phi_B = (n\,l)\ (\mu_0\ n\ i)\ A$$

$$N\ \phi_B = (\mu_0\ n^2 A\,l)\ i \text{ ------------- (3)}$$

5. **We know that $N\ \phi_B = L\ i$ ----------------------- (4)**

6. **Substitute eqn (4) in (3)**

$$L\ i = (\mu_0\ n^2 A\,l)\ i$$

$$L = \mu_0\ n^2 A\,l$$

7. **If the solenoid is filled with dielectric medium of relative permeability μ_r**

$$L = \mu_0\ \mu_r\ n^2 A\,l$$

8. $$\mu = \mu_0\ \mu_r$$

9. $$L = \mu\ n^2 A\,l$$

---

10. An inductor of inductance L carries an electric current i . How much energy is stored while establishing the current in it .

Theory :

1. **Whenever current is established in the circuit ,inductance opposes the growth of the current.**
2. **In order to establish a current in the circuit , work is done against this opposition by some external agency. This work done is stored as magnetic potential energy.**

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Derivation :

1. Work done : $dW = -\varepsilon\, dq = -\varepsilon\, i\, dt$ ----------- (1)

2. Induced emf : $\varepsilon = -L \frac{di}{dt}$ ------------ (2)

3. Substitute eqn (2) in (1)

$$dW = \frac{-(-L\, di)\, i\, dt}{dt}$$

$$dW = L\, i\, dt$$

$$\int dW = L \int i\, di$$

$$W = L\frac{i^2}{2}$$

4. Work done is stored as magnetic potential energy $U_B = L\frac{i^2}{2}$ ----------(3)

5. Energy stored in an inductor : $\boxed{U_B = L\frac{i^2}{2}}$

6. Energy Density : Energy stored per unit volume is known as " energy density "

$$u_B = \frac{U_B}{V} = \frac{U_B}{A\,l} \quad \text{-------------------------- (4)}$$

7. Substitute eqn (3) in (4)

$$u_B = \frac{L\, i^2}{2A\,l}$$

8. Self inductance of a long solenoid $L = \mu_0 n^2 A\, l$ --------------------- (5)

9. Substitute eqn (5) in eqn (4)

$$u_B = \frac{(\mu_0 n^2 A\, l)\, i^2}{2A\,l} = \frac{\mu_0 n^2 i^2}{2}$$

10 . Multiply and divide by μ_0

$$u_B = \frac{\mu_0 n^2 i^2}{2} \times \frac{\mu_0}{\mu_0}$$

$$u_B = \frac{\mu_0^2 n^2 i^2}{2\mu_0} \quad \text{-------------------- (6)}$$

11. Magnetic field : $B = \mu_0 n i$ ---------------- (7)

12. Substitute eqn (7) in (6)

Energy Density : $\boxed{u_B = \frac{B^2}{2\mu_0}}$

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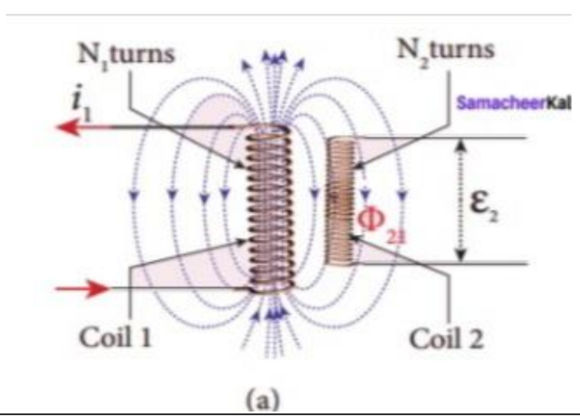
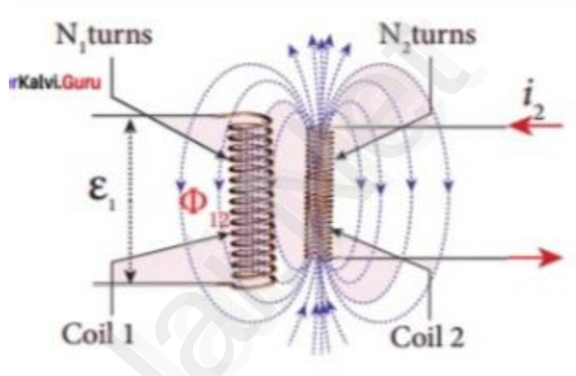
11. Show that the mutual inductance between a pair of coils is same ($M_{12} = M_{21}$)

Mutual induction :

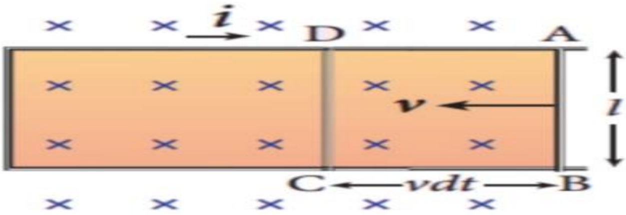
When an electric current passing through a coil changes with time , an emf is induced in the neighbouring coil. This phenomenon is known as mutual induction and the emf induced is called mutually induced emf.

S. NO	Coil 1	Coil 2
	 (a)	 (b)
1.	Electric current sent through coil 1 is i_1	Electric current sent through coil 1 is i_2
2.	Magnetic flux linked with each turn of the coil 2 of N_2 turns due to the current in coil 1 is ϕ_{21}.	Magnetic flux linked with each turn of the coil 1 of N_1 turns due to the current in coil 1 is ϕ_{12}.
3.	Total flux linked with coil 2 of N_2 ϕ_{21} is proportional to the current i_1 in the coil 1.	Total flux linked with coil 1 of N_1 ϕ_{12} is proportional to the current i_2 in the coil 2.
4.	$N_2 \phi_{21} \propto i_1$ $N_2 \phi_{21} = M_{21} i_1$ $M_{21} = \frac{N_2 \phi_{21}}{i_1}$	$N_1 \phi_{12} \propto i_2$ $N_1 \phi_{12} = M_{12} i_2$ $M_{12} = \frac{N_1 \phi_{12}}{i_2}$
5.	$\varepsilon_2 = - \frac{d(N_2 \phi_{21})}{dt}$ $\varepsilon_2 = - \frac{M_{21} di_1}{dt}$ $M_{21} = \frac{-\varepsilon_2}{di_1 / dt}$	$\varepsilon_1 = - \frac{d(N_1 \phi_{12})}{dt}$ $\varepsilon_1 = - \frac{M_{12} di_2}{dt}$ $M_{12} = \frac{-\varepsilon_1}{di_2 / dt}$

---

12. How will you induce an emf by changing the area enclosed by the coil ?

Diagram :



Formula :

$$\boxed{\varepsilon = B\, l\, v}$$

Theory :

- Consider a conducting rod of length l moving with velocity v towards left on a rectangular fixed metallic framework.
- The whole arrangement is placed in a uniform magnetic field B whose magnetic lines are perpendicularly directed into the plane of the paper.
- As the rod moves from A B to D C in a time dt , the area enclosed by the loop .
- Hence the magnetic flux through the loop decreases.

Derivation :

1. Change in magnetic flux in time dt ,

$$d\phi_B = B \times \text{Change in area } (dA)$$

$$d\phi_B = B \times \text{Area } ABCD \text{ ------- } (1)$$

2. Area of A B C D = $l\,(v\, dt)$ -------------- (2)

3. Substitute eqn (2) in (1)

$$d\phi_B = B\, l\, v\, dt$$

$$\frac{d\phi_B}{dt} = B\, l\, v$$

4. As a result of change in flux , an emf is generate in the loop.

5. The magnitude of the induced emf is ,

$$\varepsilon = \frac{d\phi_B}{dt}$$

$$\varepsilon = B\, l\, v$$

6. This emf is known as " motional emf " $\boxed{\varepsilon = B\, l\, v}$

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13. Show mathematically that the rotation of a coil in a magnetic field over one rotation induces an alternating emf of one cycle. (or)

Obtain the expression for the induced emf by changing relative orientation of the coil with the magnetic field.

Theory :

1. Consider a rectangular coil N turns kept in a uniform magnetic field $\vec{B}$.

2. The coil rotates in anti – clockwise direction with an angular velocity ω about an axis , perpendicular to the field and to the plane of the paper.

3. At time t = 0 , the plane of the coil is perpendicular to the field.

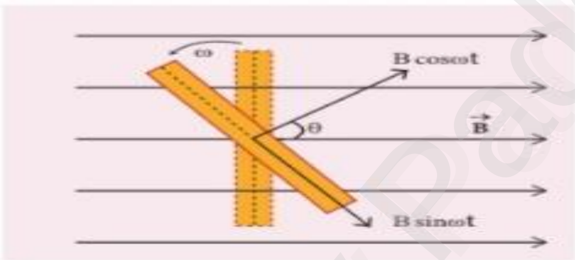
4. The flux linked with the coli has its maximum value : $\Phi_m = N B A$

5. In a time t sec , the coil is rotated through an angle θ (= ω t) in anti – clockwise direction.

6. In this position , the flux linked N B A cos ω t is due to the component of $\vec{B}$ normal to the plane of the coil.

7. The component B sin ω t parallel to the plane has no role in electromagnetic induction.

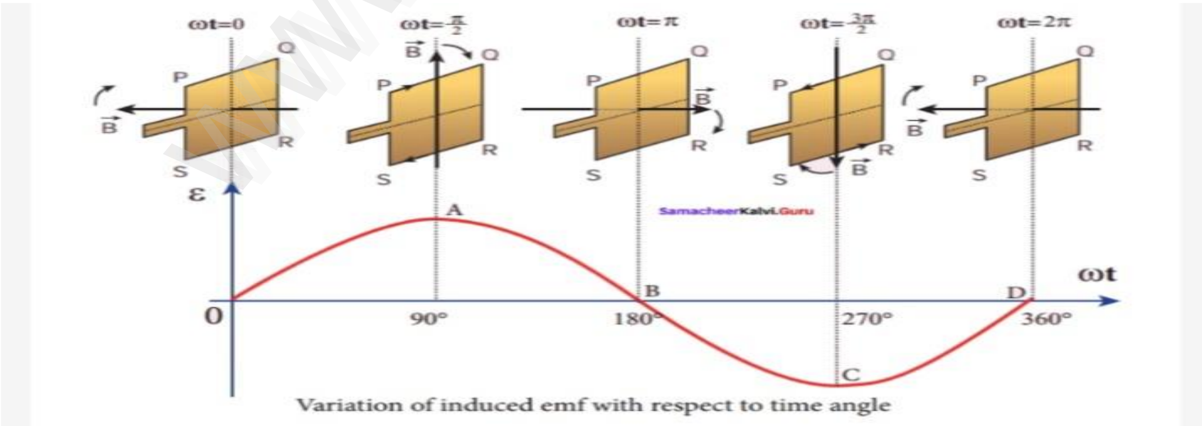
Diagram :



Formula :

$$\boxed{\varepsilon = \varepsilon_m \sin \omega t}$$

Variation of induced emf as a function of ω t :



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Derivation :

The flux linkage with the coil at this deflected position is ,

1. $N \phi_B = N B A \cos \theta$

2. $N \phi_B = N B A \cos \omega t$

3. By Faraday's law , the emf induced at that instant is ,

$$\varepsilon = -\frac{d(N \phi_B)}{dt}$$

$$\varepsilon = \frac{-d}{dt}(N B A \cos \omega t)$$

$$\varepsilon = - N B A (-\sin \omega t) \omega$$

$$\varepsilon = N B A \omega \sin \omega t$$

4. When the coil is rotated through 90^0 from initial position , $\sin \omega t = 1$

5. The maximum value of induced emf $\varepsilon_m = N B A \omega$

6. Sinusoidal emf or alternating emf $\varepsilon = \varepsilon_m \sin \omega t$

7. The induced emf varies as sine function of the time angle ω t.

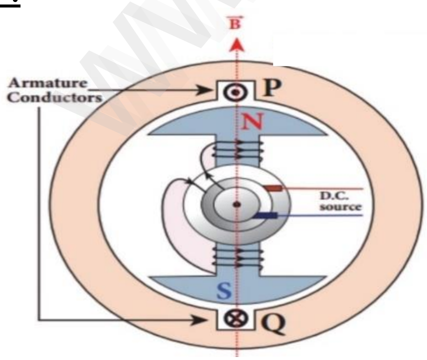
---

14. Elaborate the standard construction details of AC generator.

Construction of AC generator :

- Alternator consists of two major parts : 1. Stator 2 . Rotar
- Stator is stationary while rotor rotates inside the stator.
- Armature winding is mounted on stator and the field magnet on rotor.

Diagram :



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i) Stator :

1. The stationary part which has armature windings mounted in it .
2. It has two components namely stator core and armature winding.
3. stator core or armature core is made up iron or steel alloy.
4. It is a hollow cylinder and is laminated to minimize eddy current loss.
5. The slots are cut on inner surface of the core to accommodate armature windings.
6. Armature winding is the coil , wound on slots provided in the armature core.

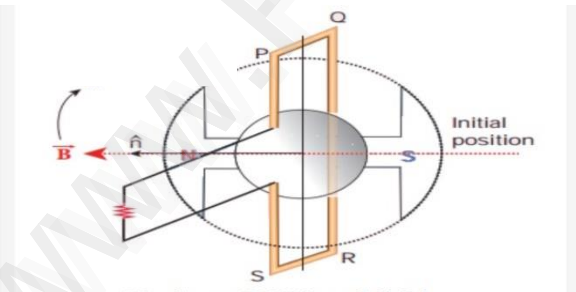
ii) Rotor :

1. Rotor contains magnetic field windings .
2. The magnetic poles are magnetized by D C source .
3. The ends of field windings are connected to a pair of slip rings.
4. It is attached to a common shaft about which rotor rotates.
5. Slip rings rotate along with rotor.
6. To maintain connection between the D C source and field windings .
7. Two brushes are used which continuously slide over the slip rings.

---

15. Explain the working of a single - phase A C generator with necessary diagram.

Diagram :



The loop PQRS and field magnet in its initial position

Construction :

1. The armature conductors are connected in series to form a single circuit which generates single phase emf . So it is called single phase alternator.

2. A single - turn rectangular loop P Q R S mounted on the stator.

3. The field winding is fixed inside the stator and it can be rotated about an axis.

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4. The loop P Q R S is stationary and is also perpendicular to the plane of the paper.

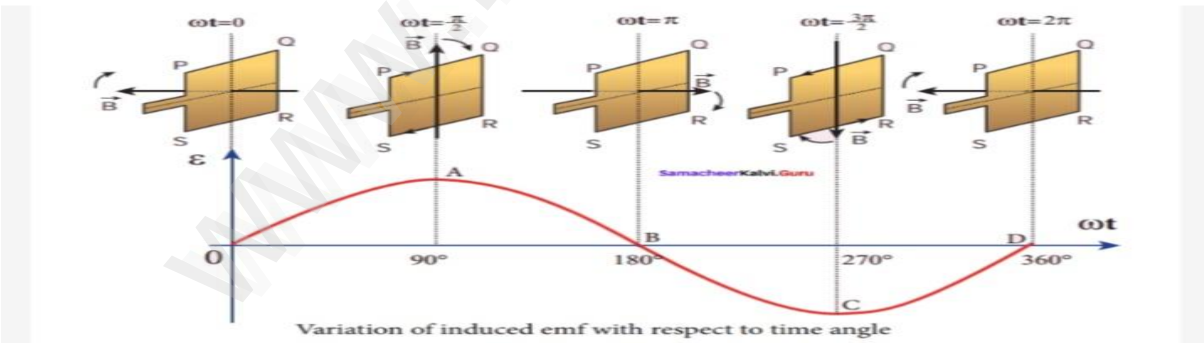
5. When field windings are excited , magnetic field is produced around it.

6. Let the field magnet be rotated in clockwise direction .

Working :

Angle	Position of loop PQRS	Induced emf		Point on Graph	Direction of Current
		Magnitude	Direction		
0^0	Magnetic field $\perp$r PQRS	Zero		Origin O	
90^0	Magnetic field $\parallel$ P QRS	Max	PQ downwards RS upwards	Point A	Along PQRS
180^0	Magnetic field $\perp$r PQRS	Zero		Point B	
270^0	Magnetic field $\parallel$ P QRS	Max	PQ upwards RS downwards	Point C	Along SRQP
360^0	Magnetic field $\perp$r PQRS	Zero		Point D	

Variation of induced emf w.r.t time angle :



Variation of induced emf with respect to time angle

The direction of induced emfs across PQ & RS is maximum at an angle of 90^0 and 270^0 .

They are connected in series , emfs are added up and the direction of emf is given by

Fleming's right hand rule. From the graph , emf induced in PQRS is alternating in nature.

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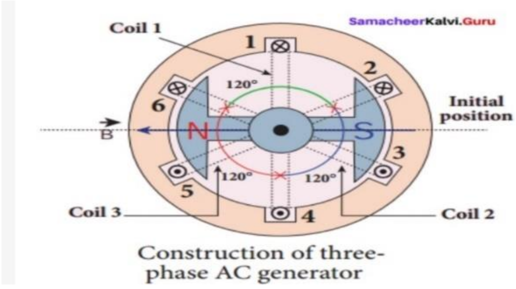
16. How are the three different emfs generated in a three - phase AC generator ? Show the graphical representation of these three emfs.

Three - phase AC generator :

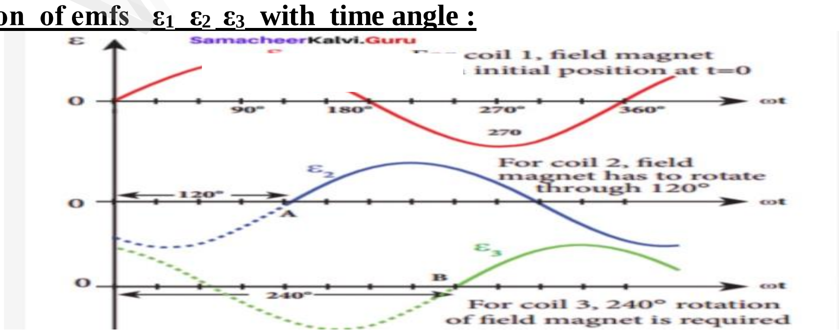


Construction of three-phase AC generator

Theory :

1. Three - phase A C generator the armature , the armature core has 6 slots .
2. Each slot is 60^0 away from one another.
3. Six armature conductors are mounted in these slots.
4. The conductors 1 and 4 are joined in series to coil 2 while the conductors 5 and 2 from coil 3.
5. These coils are rectangular in shape and are 120^0 apart from one another.
6. The initial position of the field magnet is horizontal and field direction is perpendicular to the plane of the coil 1.
7. When field magnet is rotated from that position in clockwise direction , alternating emf ε_1 in coil 1 begins cycle from origin O.
8. The corresponding cycle for alternating emf ε_2 in coil 2 starts at point A after field magnet has rotated through 120^0 .
9. The phase difference between ε_1 and ε_2 is 120^0 .
10. The emf ε_3 in coil 3 would begin its cycle at point B after 240^0 rotation of field magnet from initial position.
11. These emfs produced in the three phase AC generator have 120^0 phase difference between one another.

Variation of emfs ε_1 ε_2 ε_3 with time angle :



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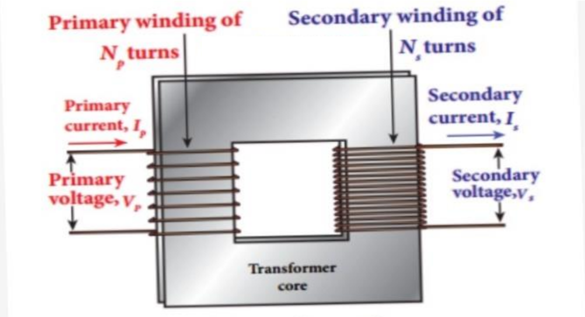
17. Explain the construction and working of transformer.

Diagram :



Construction of transformer

Principle :

- **Mutual induction between two coils .**
- **When an electric current passing through a coil changes with time , an emf is induced in the neighbouring coil.**

Construction :

1. **There are two coils of high mutual inductance wound over the transformer core.**
2. **Core is generally laminated and is made up of magnetic material like silicon steel.**
3. **Coils are electrically insulated but magnetically linked via transformer core.**
4. **The coil across which alternating voltage is applied called *primary coil P.***
5. **The coil from which output power is drawn is called *secondary coil* Q.**
6. **The core and coil are kept in a container which is filled with suitable medium for better insulation and cooling purpose.**

Working :

1. **If the primary coil is connected to a source of alternating voltage , an alternating magnetic flux is set up in the laminated core.**
2. **If the there is no magnetic flux leakage , magnetic flux linked with the primary coil is also linked with secondary coil.**
3. **The rate at which magnetic flux changes through each turn is same for both primary and secondary coils.**

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S . NO	Primary Coil	Secondary Coil
1.	Induced emf or Back emf $\varepsilon_p = - N_p \frac{d\phi_B}{dt}$	Induced emf or Back emf $\varepsilon_s = - N_s \frac{d\phi_B}{dt}$
2.	Voltage across primary coil $v_p = - N_p \frac{d\phi_B}{dt}$	Voltage across primary coil $v_s = - N_s \frac{d\phi_B}{dt}$
3.	Voltage Transformation ratio : $\frac{V_S}{V_P} = \frac{N_S}{N_P} = K$	
4.	INPUT POWER = OUTPUT POWER $V_P\, i_P = V_S\, i_S$	
5.	$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{i_P}{i_S} = K$	

Cases :

$N_S > N_P$	$V_S > V_P$	$I_S < N_P$	$K > 1$	Voltage increases	Current increases	Step up transformer
$N_S < N_P$	$V_S < V_P$	$I_S > I_P$	$K < 1$	Voltage decreases	Current decreases	Step down transformer

Efficiency of transformer : (η)

$$\eta = \frac{\text{output power}}{\text{input power.}} \times 100\ \%$$

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18. Mention the various energy losses in a transformer.

i) Core loss or Iron loss :

1. **This loss takes place in transformer core.**
2. ***Hysteresis loss and eddy current loss* are known as " core loss " or " Iron loss "**

Hysteresis Loss :

- **When transformer core is magnetized and demagnetized repeatedly by the alternating voltage applied across primary coil .**
- **Hysteresis takes place due to which some energy is lost in the form of heat.**
- **It is minimized by using high silicon content in making transformer core.**

Eddy current Loss :

- **Alternating magnetic flux in the core induces eddy currents in it.**
- **There is energy loss due to the flow of eddy current loss.**
- **It is minimized by using very thin lamination of transformer core .**

i i) Copper loss :

1. **Transformer windings have electrical resistance.**
2. **When an electric current flows through them , some amount of energy is dissipated due to joule heating.**
3. **This energy loss is called " *copper loss* ".**
4. **It is minimized by using wires of larger diameter.**

iii) Flux leakage :

1. **When the magnetic lines of primary coil are not completely linked with secondary coil .**
2. **It is minimized by windings coils one over the other.**

---

19. Give the advantages of AC in long distance power transmission with an illustration.

1. Electric power is produced in a large scale at electric power stations with the help of AC generators.

2. Most of the power stations are located at remote places. Hence the electric power generated is

transmission over long distances through transmission lines to reach towns or cities where it is actually consumed . This process is called " *power transmission* ".

3. During power transmission , electric power is lost due to Joule heating (I^2 R) in transmission lines which are hundreds kilometre long.

4. This power loss reduced by reducing current I or by reducing R.

5. The resistance R can be reduced with *thick wires of copper or aluminium.*

6. The cost of production is expense so it is not economically viable.

7. Most important property of alternating voltage can be stepped up and stepped down by using transformer could be exploited in reducing current and power losses.

8. The voltage is increased and the current is decreased by using *step up transformer.*

9. The voltage is decreased and the current is increased by using *step down transformer.*

10. Thus power transmission is done efficiently and economically.

Diagram :

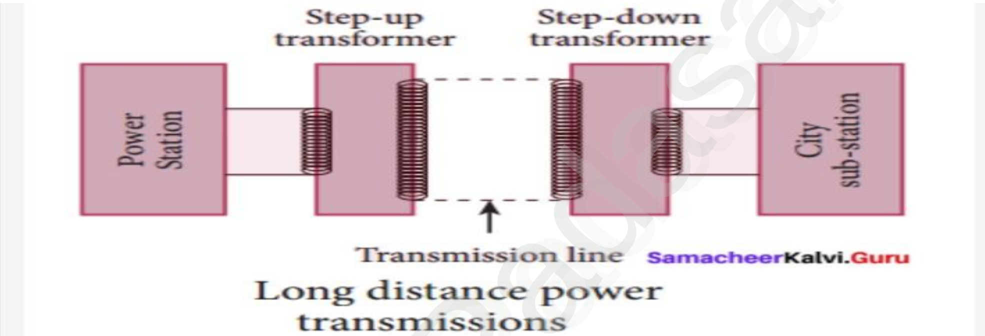

Illustration :

An electric power of 2 M W is transmitted to a place through transmission lines of total Resistance R = 40 Ω at lower voltage 10 K V and 100 K V.

Given :

$P = 2 \text{ MW} = 2 \times 10^6 \text{ W}$

$R = 40\ \Omega$

$V = 10 \text{ KV} = 10 \times 10^3 \text{ V}$

$V = 100 \text{ KV} = 100 \times 10^3 \text{ V}$

Power loss in case i :

Current : $I = \frac{P}{V}$

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$$I = \frac{2 \times 10^6}{10 \times 10^3} = 200 \text{ A}$$

Power Loss = Heat produced

$$I^2 R = (200)^2 \times 40 = 1.6 \times 10^6 \text{ W}$$

$$\% \text{ Power Loss} = \frac{1.6 \times 10^6}{2 \times 10^6} \times 100 \% = 80 \%$$

Power loss in case ii :

$$\text{Current : } I = \frac{P}{V}$$

$$I = \frac{2 \times 10^6}{100 \times 10^3} = 20 \text{ A}$$

Power Loss = Heat produced

$$I^2 R = (20)^2 \times 40 = 0.016 \times 10^6 \text{ W}$$

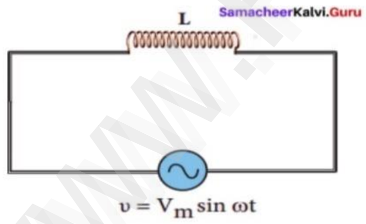
$$\% \text{ Power Loss} = \frac{0.016 \times 10^6}{2 \times 10^6} \times 100 \% = 0.8 \%$$

Thus , when an electric power is transmitted at higher voltage , the power loss is reduced to large extent.

---

20 . Find out the phase relationship between the applied voltage and current in a pure inductive circuit.

Diagram :



AC circuit with inductance

Formula :

$$i = I_m \sin (\omega t - \pi / 2)$$

$$X_L = \omega L$$

Theory :

1. Consider a circuit containing a pure inductor of inductance L connected across an alternating voltage source.

2. The instantaneous value of alternating voltage is given by $v = V_m \sin \omega t$

3. The alternating current flowing through the inductor induces a self - induced emf or back emf in the circuit.

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4. The back emf is given by , $\varepsilon = -L \frac{di}{dt}$

5. By applying Kirchhoff's loop to the purely inductive circuit ,

$$v + \varepsilon = 0$$

$$v = -\varepsilon$$

$$V_m \sin \omega t = -\left(-L \frac{di}{dt}\right)$$

$$di = \frac{V_m}{L} \sin \omega t \, dt$$

6. Integrating both sides , we get

$$i = \frac{V_m}{L} \int \sin \omega t \, dt$$

$$i = \frac{V_m}{L\omega} (-\cos \omega t) + \text{constant}$$

$$i = \frac{V_m}{L\omega} (\sin (\omega t - \pi/2)) t$$

$$\boxed{i = I_m (\sin (\omega t - \pi/2)) t}$$

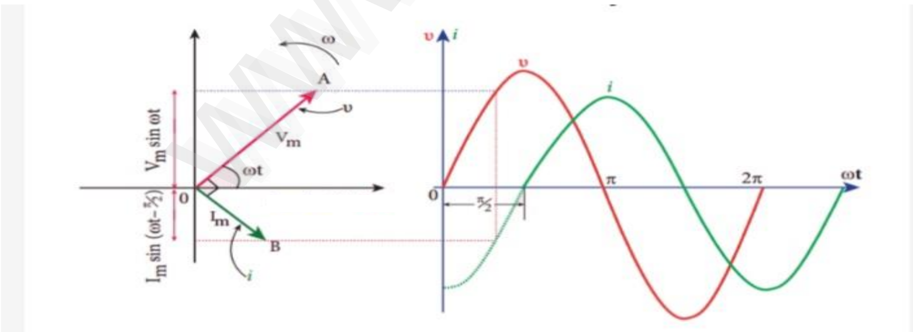
7. Peak value of alternating current in the circuit is $I_m = V_m / L\omega$

8. The current lags behind the applied voltage by $\pi / 2$ in an inductive circuit.

Inductive reactance : $\boxed{X_L = \omega L}$

The quantity ωL is the resistance offered by the inductor is called as *inductive reactance*

Phasor and Wave diagram :



Phasor diagram and wave diagram for AC circuit with L

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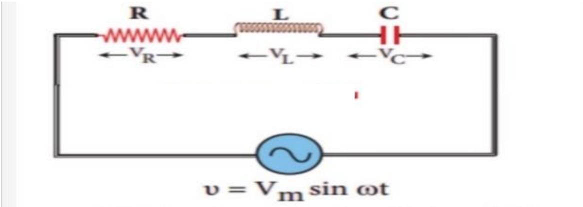
21. Derive an expression for phase angle between the applied voltage and current in a series R L C circuit.

Diagram :



AC circuit containing *R*, *L* and *C*

Theory :

1. Consider a circuit containing a resistor of resistance R, an inductor L and a capacitor C connected across an alternating voltage source.

2. Let i be the current in the circuit at that instant.

3. The voltage is developed across R, L and C.

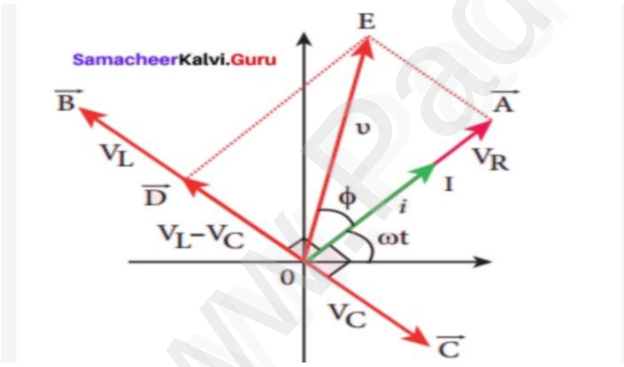
4. Voltage across R (V_R) is in phase with i.

5. Voltage across L (V_L) leads i by $\pi / 2$.

6. Voltage across R (V_R) lags behind i by $\pi / 2$.

Phasor Diagram :

The phasor diagram is drawn with the current as the reference phasor.



1. Current is represented by the phasor $\overrightarrow{OI}$.

2. V_R by $\overrightarrow{OA}$; V_L by $\overrightarrow{OB}$; V_C by $\overrightarrow{OC}$;

3. Length of these phasors :

   $OI = I_m$; $OA = I_m R$; $OB = I_m X_L$; $OC = I_m X_C$;

4. Let us assume that $V_L > V_C$.

5. Net voltage drop across L – C combination is $V_L - V_C = \overrightarrow{OD}$.

6. By parallelogram law , OE gives resultant voltage $OE = V_m$

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Derivation :

1. $V_m^2 = V_R^2 + (V_L - V_C)^2$

2. $V_m = \sqrt{(I_m R)^2 + (I_m X_L - I_m X_C)^2}$

3. $V_m = I_m \sqrt{(R)^2 + (X_L - X_C)^2}$

4. $I_m = \dfrac{V_m}{\sqrt{(R)^2 + (X_L - X_C)^2}}$

5. $I_m = V_m / Z$ Where $Z = \sqrt{(R)^2 + (X_L - X_C)^2}$

6. Z is called *impedance* of the circuit which refers to the effective opposition to the current by the series R L C circuit.

Voltage triangle & Impedance triangle :

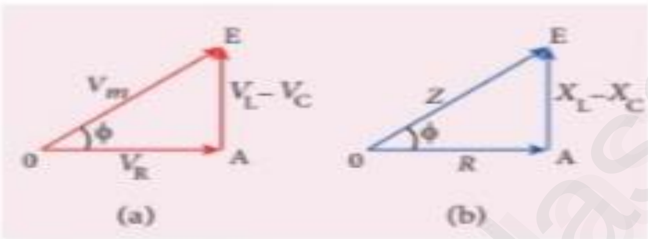

Figure 4.48 Voltage and impedance triangle when $X_L > X_C$

Phase Angle :

$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$$

Special Cases :

S. NO	$X_L > X_C$	$X_L < X_C$	$X_L = X_C$
1.	$X_L - X_C$ is positive.	$X_L - X_C$ is negative.	$X_L - X_C$ is zero.
2.	Phase angle ϕ positive.	Phase angle ϕ is negative.	Phase angle ϕ is negative.
3.	Voltage leads current by ϕ	Current leads voltage by ϕ	Currentvoltage same phase.
4.	The circuit is inductive.	The circuit is capacitive.	The circuit is resistive.
5.	$v = V_m \sin \omega t$; $i = I_m \sin(\omega t - \phi)$	$v = V_m \sin \omega t$; $i = I_m \sin(\omega t + \phi)$	$v = V_m \sin \omega t$; $i = I_m \sin \omega t$

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22. Define inductive and capacitive reactance . Give their units.

Inductive Reactance :

1. The peak value of current I_m is given by $I_m = V_m / \omega L$.

2. The quantity ωL plays the same role as the resistance in resistive circuit.

3. This is the resistance offered by the inductor called inductive reactance.

4. It is measured in ohm.

$$\boxed{X_L = \omega L}$$

Capacitive Reactance :

1. The peak value of current I_m is given by $I_m = V_m / 1 / C\omega$.

2. The quantity $1 / \omega C$ plays the same role as the resistance in resistive circuit.

3. This is the resistance offered by the inductor called capacitive reactance.

4. It is measured in ohm.

$$\boxed{X_C = \frac{1}{\omega C}}$$

5. The capacitive reactance varies inversely as the frequency .

6. For a steady current , f = 0 .

$$\boxed{X_C = \frac{1}{\omega C} = \frac{1}{2\pi C} = \frac{1}{0} = \infty}$$

7. Thus a capacitive circuit offers infinite resistance to the steady current.

8. So that current cannot flow through the capacitor.

---

23. Obtain an expression for average power of AC over a cycle. Discuss its special cases.

Power of a circuit :

1. The rate of consumption of electric energy in that circuit.

2. It is given by the product of the voltage and current.

3. Alternating voltage and alternating current in the series inductive R L C circuit

$$\boxed{v = V_m \sin \omega t \; ; \text{ and } \; i = I_m \sin(\omega t + \phi)}$$

Instantaneous Power :

1. $P = v\,i$

2. $P = V_m\ I_m \sin \omega t \sin(\omega t + \phi)$

3. $P = V_m\ I_m \sin \omega t\ (\sin \omega t \cos \phi + \cos \omega t \sin \phi)$

4. $P = V_m\ I_m\ (\cos \phi \sin^2 \omega t + \sin \omega t \cos \omega t \sin \phi)$

5. Average of $\sin^2 \omega t$ over a cycle is ½.

6. $\sin \omega t \cos \omega t$ value is zero.

Average Power :

1. $P_{av} = V_m\ I_m \cos \phi \times 1/2$

2. $P_{av} = \dfrac{V_m}{\sqrt{2}}\ \dfrac{I_m}{\sqrt{2}} \cos \phi$

3. $P_{av} = V_{RMS}\ I_{RMS} \cos \phi$

4. $V_{RMS}\ I_{RMS}$ is called *apparent power* .

5. $\cos \phi$ is called *power factor.*

6. Average power is called true power .

Special cases :

S. NO	Circuit	Phase Angle	Cos ϕ value	Average Power
1.	Purely Resistive	Zero	$\cos 0 = 1$	$P_{av} = V_m\ I_m$
2.	Purely Inductive	$\pm \pi / 2$	$\cos(\pm \pi / 2)$	$P_{av} = 0$
3.	Series RLC circuit	$\phi = \tan^{-1}\left[\dfrac{X_L - X_C}{R}\right]$	If $\phi = 0$ $\cos \phi = 1$	$P_{av} = V_m\ I_m \cos \phi$ $P_{av} = V_m\ I_m$

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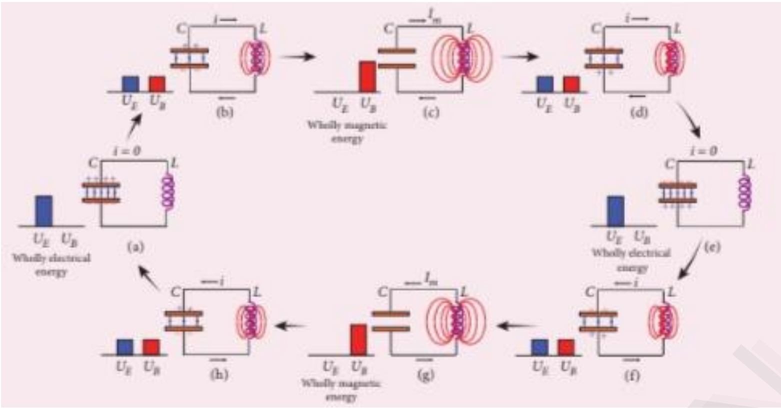
24. **Explain the generation of LC oscillations in a circuit containing an inductor of inductance L and a capacitor of capacitance C.**

Diagram :



Generation of LC oscillation :

1. **Capacitor is fully charged with maximum charge Q_m :**

   - **Energy stored in capacitor is $U_E = Q^2 / 2C$.**
   - **No current in the inductor.**
   - **Energy stored in inductor is $U_B = 0$.**
   - **Total energy is wholly electrical.**

2. **Capacitor begins to discharge through inductor :**

   - **Current i in clockwise direction.**
   - **Current produces magnetic field around inductor.**
   - **Energy stored in inductor is $U_B = L i^2 / 2$.**
   - **Charge in the capacitor decreases .**
   - **Energy stored in capacitor is $U_E = q^2 / 2C$.**
   - **Total energy is the sum of electrical and magnetic energies.**

3. **Charges in the capacitor are exhausted :**

   - **Energy stored in capacitor is $U_E = 0$.**

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- **Energy is fully transferred to magnetic field of inductor.**
- **Energy stored in inductor is $U_B = L\ I_m{}^2 / 2$.**
- **I_m is the maximum current flowing in the circuit .**
- **Total energy is wholly magnetic energy.**

4. <u>Capacitor begins to charge in opposite direction</u> :

- **Even though the charge in the capacitor is zero.**
- **Current is made to flow with decreasing magnitude.**
- **A part of energy is transferred from inductor back to the capacitor .**
- **Charge in the capacitor decreases .**
- **Total energy is the sum of electrical and magnetic energies.**

5. <u>Capacitor begins to fully charged in the opposite direction</u> :

- **Even when the Current in circuit reduces to zero.**
- **The energy stored in the capacitor becomes maximum.**
- **Energy stored in inductor is $U_B = 0$.**
- **Total energy is wholly electrical .**

6. <u>Capacitor starts to discharge through inductor</u> :

- **The state of circuit is similar to the initial state .**
- **Capacitor discharge through inductor with anti-clockwise current.**
- **Total energy is the sum of electrical and magnetic energies.**

<u>L C oscillations :</u>

- **The processes are repeated in opposite direction .**
- **Finally the circuit returns to the initial state.**
- **The circuit goes through these stages , an alternating current flows in the circuit.**

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- **As this process is repeated again and again , the electrical oscillations of definite frequency are generated.These are known as *LC oscillation.***

- **Oscillations will continue indefinitely such oscillations are called *undamped oscillation.***

---

25 . Prove that the total energy is conserved during LC oscillations.

- **During LC oscillations in LC circuits , the energy of the system oscillates between the electric field of the capacitor and magnetic field of the inductor.**

- **Total energy remains constant .**

- **LC oscillations takes place in accordance with law of conservation of energy.**

$$\boxed{U = U_E + U_B = \frac{q^2}{2C} + \frac{1}{2} L i^2}$$

<u>Case i :</u>

<u>When charge q = Q_m and current i = 0</u>

- **Total energy is wholly electrical.**

$$U = \frac{Q_m^{\ 2}}{2C} + 0 = \frac{Q_m^{\ 2}}{2C}$$

<u>Case ii :</u>

<u>When charge q = 0 and current i = I_m</u>

- **Total energy is wholly magnetic.**

$$U = 0 + \frac{1}{2} L I_m^{\ 2} = \frac{1}{2} L I_m^{\ 2}$$

<u>Case iii :</u>

<u>When charge = q and current = i</u>

- **Total energy remains constant .**

$$U = \frac{q^2}{2C} + \frac{1}{2} L i^2$$

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- $q = Q_m \cos \omega t$; $i = -\frac{dq}{dt} = Q_m \omega \sin \omega t$

- $U = \frac{Q_m^2 \cos^2 \omega t}{2C} + \frac{L \omega^2 Q_m^2 \sin^2 \omega t}{2}$

- $U = \frac{Q_m^2 \cos^2 \omega t}{2C} + \frac{L Q_m^2 \sin^2 \omega t}{2LC}$

- Here , $\omega^2 = \frac{1}{LC}$

- $U = \frac{Q_m^2}{2C} (\cos^2 \omega t + \sin^2 \omega t)$

- $U = \frac{Q_m^2}{2C}$

---

26. Compare the electromagnetic oscillation of LC circuit with the mechanical oscillations of block spring system qualitatively to find the expression for angular frequency of LC oscillator.

Qualitative treatment :

- The electromagnetic oscillations of LC system compared with mechanical oscillations of a spring - mass system.

- There are two forms of energy involved in LC oscillations. One is electrical energy of the charged capacitor. The other magnetic energy of the inductor carrying current.

- The mechanical energy of the spring mass system exists in two forms. The potential energy of the compressed or extended spring and kinetic energy of the mass.

- Angular frequency of oscillations of a spring – mass is given by

$$\omega = \sqrt{\frac{k}{m}}$$

- Angular frequency of LC oscillations is given by

$$\omega = \sqrt{\frac{1}{LC}}$$

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Lesson – 5

1. Write down Maxwell equation in integral form.

First equation : Gauss's Law of electricity

* It relates the net electric flux to net electric charge enclosed in a surface.

$$\oint_S \vec{E} \cdot \vec{dA} = \frac{Q_{enclosed}}{\epsilon_0}$$

1. $\vec{E}$ is the electric field.
2. Q enclosed is net charge enclosed by the surface S.
3. It is true for both discrete and continuous distribution of charges.
4. Electric field lines start from positive charge and terminate at negative charge.
5. Electric field lines do not form continuous closed path.
6. An isolated positive charge or negative charge can exist.

Second equation : Gauss's law for magnetism

* The surface integral of magnetic field over a closed surface is zero.

$$\oint_S \vec{B} \cdot \vec{dA} = 0$$

$\vec{B}$ is the magnetic field.

1. Magnetic lines of force form continuous closed path.
2. No isolated magnetic monopole exists.

Third equation : Faraday's law for magnetism :

* This relates electric field with the changing magnetic flux.

$$\oint_l \vec{E} \cdot \vec{dl} = -\frac{d\Phi_B}{dt}$$

- The line integral of electric field around any closed path is equal to the rate of change of magnetic flux through the closed path bounded by the surface.

Fourth equation: Ampere's circuital law:

1. This is also known as Ampere – Maxwell law.

2. **This law relates the magnetic field around any closed path to the conduction current and displacement current through the path.**

$$\oint_l \vec{B} \cdot \vec{dl} = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d}{dt} \oint_S \vec{E} \cdot \vec{dA}$$

---

2. Write short notes on a) Microwave b) X - ray c) Radio waves d) Visible spectrum

a) Microwaves :

- **It is produced by special vacuum tubes such as klystron , magnetron and Gunn diode.**
- **The frequency range is from 10^9 Hz to 10^{11} Hz.**
- **They undergoes reflection and can be polarised.**
- **It is used in radar systems for aircraft navigation.**
- **It is used in speed of vehicle , microwave oven for cooking and very long distance wireless communication through satellites.**

b) X- ray :

- **It is produced when there is sudden stopping of high speed electrons at high atomic number target and also by electronic transitions among the innermost orbits of atoms.**
- **The frequency range is from 10^{17} Hz to 10^{19} Hz.**
- **X- rays have more penetrating power than ultra violet radiation.**
- **They are used in extensively in studying structures of inner atomic electron shells and crystal structures.**
- **It is used in detecting fractures , diseased organs , formation of bones and stones**
- **It is used in observing the progress of healing bones.**
- **It is used to detect faults , cracks , flaws and holes.**

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c) Radio waves :

- They are produced by accelerated motion of charges in conducting wires.
- The frequency range is from a few Hz to 10^9 Hz.
- They show reflection and refraction.
- They are used in radio and television systems.
- They are used in cellular phones to transmit voice communication in the ultra high frequency band.

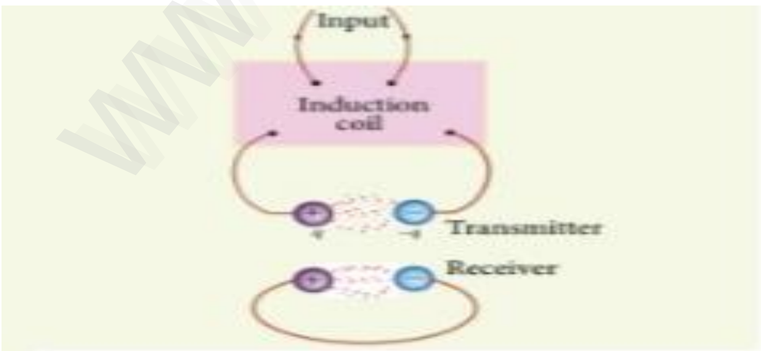
d) Visible Spectrum :

- It is produced by incandescent bodies and also it is radiated by excited atoms in gases.
- The frequency range is from a 4×10^{14} Hz to 8×10^{14} Hz.
- It obeys law of reflection and refraction.
- It undergoes interference , diffraction and can be polarised.
- It exhibits photo – electric effect also.
- It can be used to study the structure of molecules , arrangement of electron in external shells of atoms.
- It causes sensation of vision.

---

3. Discuss the Hertz experiment.

Hertz Experiment : Production of EM waves



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Theory :

1. **It consists of two metal electrodes.**
2. **They are made of small spherical metals.**
3. **These are connected to larger sphere.**
4. **The end of the sphere connected to induction coil.**
5. **Coil with large number of turns to produce very high emf.**
6. **Since the coil is maintained at high potential.**
7. **Air between electrodes gets ionized and spark is produced.**
8. **Discharge of electricity affects another electrode which is kept at far distance.**
9. **The energy is transmitted from electrode to the receiver in the form of waves, known as electromagnetic waves.**
10. **If the receiver is rotated by 90^o, then no spark is observed by the receiver.**
11. **This confirms that electromagnetic waves are transverse waves as predicted by Maxwell.**
12. **Hertz detected radio waves and also computed the speed of radio waves which is equal to speed pf light.**

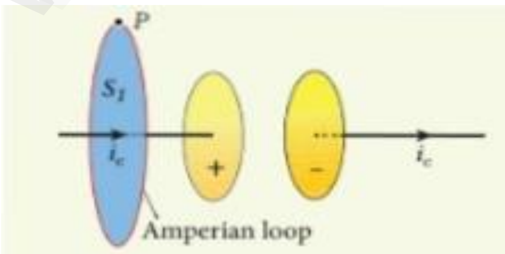
---

4. Explain the Maxwell's modification of Ampere's circuital law.

Maxwell modification of Ampere's circuital law:

- **Let us consider charging a parallel plate capacitor which contains medium between the plates.**
- **Ampere's circuital law can be used to find magnetic field produced around the current carrying wire.**

i) On the surface S_1



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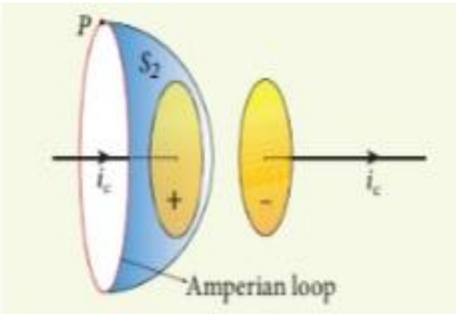
1. Time dependent current i_c called as conduction current.
2. To calculate the magnetic field at a point P near the wire and outside the capacitor.
3. Let us draw a circular Amperian loop which encloses the circular surface S_1.

Using Ampere's circuital law,

$$\oint_{\text{enclosing } S_1} \vec{B} \cdot \vec{dl} = \mu_0 \; i_c$$

$\mu_0 \longrightarrow$ Permeability of free space.

ii) On surface S_2



1. The same loop is enclosed by balloon shaped surface S_2.
2. The boundaries of two surfaces S_1 and S_2 same.
3. But the shape of the surface is different.

By applying Ampere's circuital law,

$$\oint_{\text{enclosing } S_2} \vec{B} \cdot \vec{dl} = 0$$

4. Because the surface S_2 now where touches the wire carrying conduction current.
5. There is no current flows between the plates of capacitor.
6. So, the magnetic field at point p is zero .

iii) Maxwell Theory

1. While the capacitor charged up, varying electric field is produced.
2. The current associated with the changing electric field between capacitor plates.

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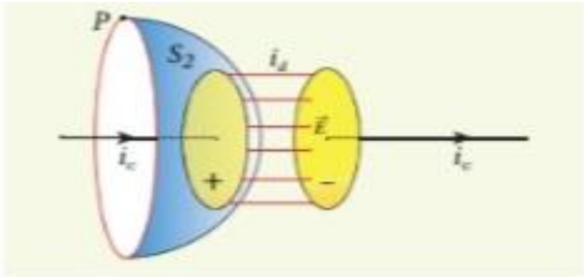
3. Time varying electric field produces the current known as "Displacement current".



i v) From Gauss's law:

$$\Phi_E = \int_S E \cdot dA = EA$$

$$\Phi_E = \frac{q}{\varepsilon_0}$$

$$\frac{d\Phi_E}{dt} = \frac{1}{\varepsilon_0}\frac{dq}{dt}$$

$$\frac{dq}{dt} = \varepsilon_0 \frac{d\Phi_E}{dt}$$

Displacement Current :

$$\boxed{i_d = \varepsilon_0 \frac{d\Phi_E}{dt}}$$

V)Maxwell modified Ampere's law :

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 \, i = \mu_0 \, (i_c + i_d)$$

$$\oint_l \vec{B} \cdot \vec{dl} = \mu_0 \, i_c + \mu_0 \, €_0 \frac{d\Phi_E}{dt}$$

---

5. Explain the importance of Maxwell's correction.

1. Earth receives radiations from sun and other stars. These radiations travel through empty space. So, there is no electric change and no electric current.

2. Ampere's Law :

Time - varying electric field or the displacement current produce magnetic field . Though the conduction current is zero in an empty space , displacement current does exist.

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3. Maxwell's Law :

$$\oint_{l} \vec{B} \cdot \vec{dl} = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$$

Maxwell correction term $\longrightarrow$ $\mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$

In stars , due to thermal excitation of atoms , time varying electric field is produced which in turn produce time – varying magnetic field.

4. Faraday's Law :

Time – varying magnetic field again produces time – varying electric field.

5. Em Waves :

The coupled time – varying electric and magnetic fields travel through empty space with the speed of light and is called as " electromagnetic waves "

Maxwell correction term explains one of the important aspects of the universe , namely the existence of electromagnetic waves.

---

6. Write down the properties of electromagnetic waves.

1. EM waves are produced by any accelerated charge.

2. EM waves do not require any medium for propagation. EM waves is non – mechanical wave.

3. EM waves do not deflected by electric or magnetic field.

4. EM waves can exhibit interference , diffraction and polarization.

5. EM waves also carry energy , linear momentum and angular momentum.

6. EM waves are transverse in nature. The oscillating electric field vector , oscillating magnetic field vector and propagation vector are mutually perpendicular to each other.

7. EM waves travel with speed which is equal to speed of light in vacuum.

$$C = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = 3 \times 10^8 \ m s^{-1}$$

ϵ_0 $\longrightarrow$ **Permittivity of free space or vacuum**

μ_0 $\longrightarrow$ **Permeability of free space or vacuum**

8.In a medium with permittivity € and permeability μ , the speed of EM wave V is less than that in free space or vacuum . V < C

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$$n = \frac{C}{V} = \frac{1 / \sqrt{€_0 \mu_0}}{\sqrt{€_0 \mu_0}} = \sqrt{€_r \mu_r}$$

$€_r$ $\longrightarrow$ Relative permittivity of free space or vacuum

μ_r $\longrightarrow$ Relative permeability of free space or vacuum

9. If the electromagnetic wave incident on a material surface completely absorbed , then the energy delivered is U and momentum imparted on the surface is $p = \frac{U}{c}$

10. If the incident electromagnetic wave of energy U is totally reflected from the surface, then the momentum delivered to the surface is $\Delta p = \frac{U}{c} - \left(-\frac{U}{c}\right) = 2\frac{U}{c}$

---

7. Discuss the source of electromagnetic waves.

1. When the charges move with uniform velocity , it produces steady current which gives rise to magnetic field around the conductor in which charge flows.
2. If the charged particle accelerates , it produces magnetic field in addition to electric field.
3. Both electric and magnetic fields are time varying fields.
4. The electromagnetic waves are transverse waves , the direction of propagation of electromagnetic waves is perpendicular to the planes containing electric and magnetic field vectors.
5. Any oscillatory motion is also an accelerated motion.
6. When the charge oscillates about their mean position produces electromagnetic waves.
7. The electromagnetic field in free space propagates along z – direction and if the electric field vector points along x – axis , then the magnetic field vector will be mutually perpendicular to both electric field and the direction of wave propagation.

$$\boxed{\begin{aligned} E_x &= E_o \sin(kz - \omega t) \\ B_y &= B_o \sin(kz - \omega t) \end{aligned}}$$

8. E_o and B_o are amplitudes of oscillating electric and magnetic field.

   K is a wave number and ω is the angular frequency of the wave.
9. The both electric field and magnetic field oscillate with a frequency which is equal to the frequency of the source.
10. In free space or in vacuum , the ratio between E_o and B_o is equal to the speed of electromagnetic wave and is equal to speed of light c.

$$\boxed{C = \frac{E_o}{B_o}}$$

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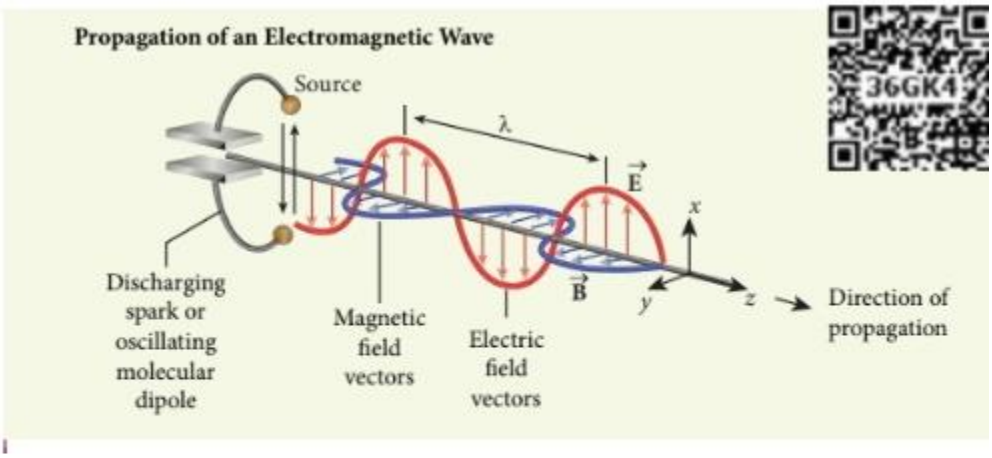


11. In any medium , the ratio E_0 and B_0 is equal to the speed of electromagnetic wave in that medium.

$$\boxed{V = \frac{E_0}{B_0} < C}$$

12. The energy of electromagnetic waves comes from the energy of the oscillating charge.

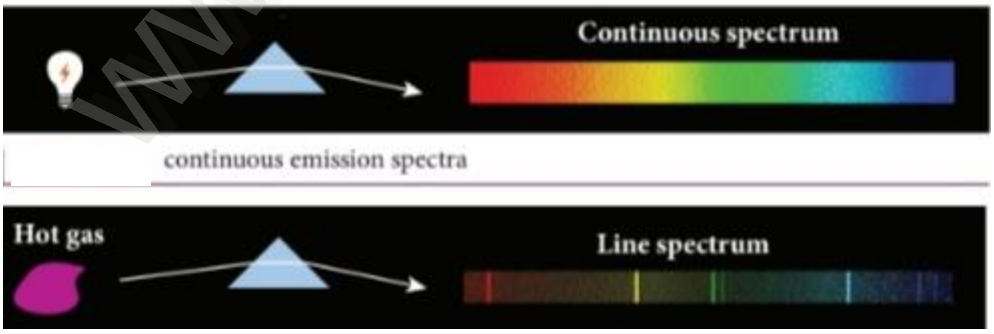
8.Explain the types of emission spectrum.

<u>Emission Spectrum :</u>

- When the spectrum of self luminous source is taken , we get emission spectrum.
- Each source has its own characteristics emission spectrum.

i) <u>Continuous emission spectrum :</u>

- If the light from incandescent lamp is allowed to pass through prism , it splits up into seven colours.
- It consists of wavelength containing all visible colours ranging from violet to red.
- Example : Spectrum obtain from carbon arc and incandescent solids.



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ii) Line emission spectrum :

- Light from hot gas is allowed to pass through prism , line spectrum is observed .
- Line spectra are also known as discontinuous spectra.
- It consists of sharp lines of definite wavelength or frequency.
- Such spectra arise due to excited atoms of elements.
- These lines are characteristics of the element and different elements.
- Example : Spectra of atomic hydrogen , helium.

iii) Band emission spectrum :

- Band spectrum consists of several number of very closely spaced spectral lines.
- It overlap together forming specific bands which are separated by dark spaces.
- Spectrum has sharp edge at one end and fades at other end.
- Such spectra arise when the molecules are excited.
- It is the characteristics of the molecule.
- The structure of the molecules be studied.
- Example : Spectra of ammonia gas in discharge tube.

---

9. Explain the types of absorption spectrum.

Emission Spectrum :

- When light is allowed to pass through a medium or an absorbing substance then the spectrum obtained is known as absorption spectrum.

i) Continuous absorption spectrum :

- When we pass white light through a blue glass plate , it absorbs all colours except blue and gives continuous absorption spectrum.

ii) Line absorption spectrum :

- When light from the incandescent lamp is passed through cold gas.
- The spectrum obtained through the dispersion due to prism is line absorption spectrum.
- If the light from the carbon arc is made to pass through sodium vapour , a continuous spectrum of carbon arc with two dark lines in the yellow region are obtained.

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Figure 5.15 line absorption spectra

iii) **Band absorption spectrum :**

- **When white light is passed through the iodine vapour , dark bands on continuous bright background is obtained.**
- **This type of band is also obtained when white light is passed through diluted solution of blood or chlorophyll or through certain solutions of organic or inorganic compounds.**

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6. Gravitation

1. State Kepler's three laws.

Law of orbits :

Each planet moves around the sun in an elliptical orbit with the sun at one of the foci.

- **Closet point of planet to sun $\longrightarrow$ Perihelion**
- **Farthest point of planet to sun $\longrightarrow$ Aphelion**

2. Law of area :

The radial vector (line joining the sun to a planet) sweeps equal areas in equal intervals of time.

- **The planets travel *faster* when they *nearer* to the sun.**
- **The planets travel *slower* when they *farther* to the sun.**
- **To cover equal area (Δ A) in equal in equal intervals of time (Δ t)**

3 Law of period :

The square of the time period of revolution of a planet around the sun in its elliptical orbit is directly proportional to the cube semi - major axis of the ellipse.

$$\boxed{T^2 \ \alpha \ a^3}$$

---

2. State Newtons Universal law of gravitation.

Newtons law of gravitation states that a particle of mass M_1 attracts any other particle of mass M_2 in the universe with an attractive force. The strength of this force of attraction was found to be directly proportional to the product of their masses and is inversely proportional to the square of the distance between them.

$$\boxed{\vec{F} = -\frac{G M_1 M_2}{r^2}\hat{r}}$$

$$G = 6.67 \times 10^{-11} \ N\,m^2\,kg^{-2}$$

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3. Will the angular momentum of a planet be conserved ? Justify your answer.

The torque experienced by the Earth due to the gravitational force of the sun is given by

$$\vec{\tau} = \vec{r} \times \vec{F} = \vec{r} \times -\left(\frac{G\, M_S\, M_E\, \hat{r}}{r^2}\right) = 0$$

$$\tau = \frac{d\vec{L}}{dt} = 0 \qquad \text{since } \vec{r} = r\,\hat{r}\ ,\ \hat{r} \times \hat{r} = 0$$

- **Angular momentum $\vec{L}$ is a constant vector.**
- **Angular momentum of the Earth about the sun is constant throughout the motion.**

---

4. Define the gravitational field . Give its unit.

- **The gravitational field due to a mass m at a point which is at a distance r from mass m is given by ,**

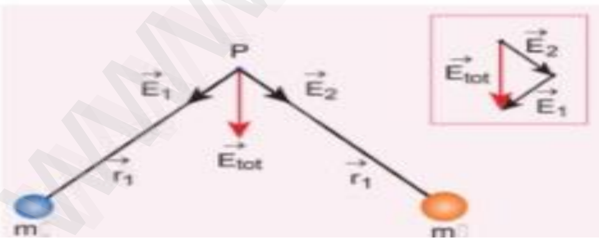
$$\boxed{\vec{E} = -\frac{G\,m}{r^2}\,\hat{r}}$$

- **The gravitational field is defined as the gravitational force experienced by unit mass placed at that point. It is a vector quantity.**

---

5. What is meant by superposition of gravitational field ?

Consider ' n ' particles of masses m_1 , m_2 ,….. m_n distributed in space at positions r_1 , r_2 ,….. r_n with respect to point P. The total gravitational field at a point P due to all the masses is given by the vector sum of the gravitational field due to the individual masses. This principle is known as superposition of gravitational fields.



$$\vec{E}_{total} = \vec{E}_1 + \vec{E}_2 + \ldots\ \vec{E}_n$$

$$\vec{E}_{total} = -\frac{G\,m_1}{r_1^2}\,\hat{r}_1 - \frac{G\,m_1}{r_2^2}\,\hat{r}_2 \ldots\ldots\ \frac{G\,m_n}{r_n^2}\,\hat{r}_n = -\sum_{i=1}^{n} \frac{G\,m_i}{r_i^2}\,\hat{r}_i$$

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6. Define gravitational potential energy.

The gravitational potential energy of a system of two masses m_1 and m_2 separated by a distance r as the amount of work done to take the mass m_2 from a distance r to infinity assuming m_1 to be fixed in its position .

$$\boxed{U = -\frac{G\, m_1\, m_2}{r}}$$

---

7. Is potential energy the property of a single object ? Justify.

No , potential energy is a property of a system rather than of a single object due to its physical position. Because gravitation potential energy depends on relative position. So a reference level at which to set the potential energy equal to zero.

---

8. Define gravitational potential.

The gravitational potential at a distance r due to a mass m is defined as the amount of work required to bring unit mass from infinity to the distance r.

$$\boxed{V = -\frac{G\, m}{r}}$$

---

9. What is the difference between gravitational potential and gravitational potential energy .

S.NO	Gravitational potential	Gravitational potential energy
1.	The amount of work required to bring unit mass from infinity to the distance .	The amount of work done to take the mass m_2 from a distance r to infinity assuming m_1 to be fixed in its position .
2.	$V = -\frac{G\, m}{r}$	$U = -\frac{G\, m_1\, m_2}{r}$
3.	Unit : J kg^{-1}	Unit : Joule

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10. What is meant by escape speed in the case of the earth ?

The escape speed is defined as the minimum speed required by an object to escape from earth ' s gravitational field.

- Escape speed of the earth is V_e = 11.2 km s^{-1}
- Radius of the earth is R_e = 6400 km
- Acceleration due to gravity 9.8 m s^{-2} .

$$\boxed{V_e = \sqrt{2 g R_e}}$$

---

11. Why is the energy of a satellite (or any other planet) negative ?

1. Implies that the satellite is bound to the Earth and it cannot escape from the Earth.
2. As h approaches ∞ the total energy tends to zero. Its physical meaning is that the satellite is completely free from the influence of Earth's gravity and is not bound to Earth at large distances.

---

12. What are geostationary and polar satellites ?

Geostationary Satellite :

1. Geostationary satellites appear to be stationary , when seen from Earth.
2. Distance h turns out be 36,000 km.
3. India uses the INSAT group of satellites that are basically geostationary satellite.
4. They are used for purpose of telecommunication.

Polar Satellite :

1. Another type satellite which is placed at a distance of 500 to 800 km.
2. This type satellite that orbits Earth from pole to south pole .
3. The time period of polar satellite is nearly 100 minutes.
4. The satellites completes many revolution in a day.
5. A polar satellite covers small strip of area from pole to pole during one revolution.

---

13. Define weight.

The weight of an object W is defined as the that of upward force that must be applied to the object to hold it at rest or at constant velocity relative to the earth.

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14. Why is there no lunar eclipse and solar eclipse every month ?

Moon's orbit is tilted 5^0 with respect to earths orbit. Due to this 5^0 tilt, only during certain periods of the year , the sun , earth and moon align in straight line leading to either lunar eclipse or solar eclipse depending on the alignment.

---

15. How will you prove that earth itself is spinning ?

The earth's spinning motion can be proved by observing star's position over a night. Due to earth's spinning motion , the stars in sky appear to move in circular motion about the pole star.

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7. Properties of Matter

1. Define stress and strain.

Stress :

The force per unit area is called " stress " . Stress = $\frac{\text{Force}}{\text{Area}}$

$$\boxed{\sigma = \frac{F}{A}}$$

SI Unit : $N\,m^{-2}$ Dimension : $M\,L^{-1}\,T^{-2}$

Strain :

The fractional change in the size of the object , when a force is applied , strain measures the degree of deformation.

Strain = $\frac{\text{Change in size}}{\text{Original size}}$

$$\boxed{\varepsilon = \frac{\Delta l}{l}}$$

---

2. State Hooke's law of elasticity.

Hooke's law is for a small deformation , when the stress and strain are proportional to each other.

$$\boxed{\text{Stress} \propto \text{strain}}$$

---

3. Define Poisson's ratio.

It is defined as the of relative contraction (Lateral strain) to relative expansion (longitudinal strain) . It is denoted by the symbol μ .

Poisson's ratio = $\frac{\text{lateral strain}}{\text{Longitudinal strain}}$

$$\boxed{\mu = \frac{d / D}{l / L} = -\frac{L}{l} \times \frac{d}{D}}$$

---

4. Explain elasticity using intermolecular forces.

- In a solid , interatomic forces bind two or more atoms together and the atoms occupy the positions of stable equilibrium.
- When a deforming force is applied on a body ,atoms are pulled apart or pushed closer.
- When deforming force is removed , interatomic forces of attraction or repulsion restore the atoms to their equilibrium positions.
- If a body regains its original shape / size after the removal of deforming force is called elastic and the property is called " elasticity "

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5. Which one of these is more elastic , steel or rubber ? Why ?

- Steel is more elastic than rubber .
- An equal stress is applied to both steel and rubber , the steel produces less strain .
- So the Young's modulus is higher for steel than rubber.
- The object which higher Young's modulus is more elastic.

---

6. A spring balance shows wrong readings after using for a long time . Why ?

This is because of continuous usage , the wire loses its elasticity and does not regain it original dimension . (Length) Because of this , it shows wrong readings.

---

7. What is the effect of temperature on elasticity ?

As the temperature of substance increases , its elasticity decreases.

---

8. Write down the expression for the elastic potential energy of a stretched wire.

Elastic Energy :

When a body is stretched , work is done against the restoring force. This work done is stored in the body in the form of " Elastic energy "

Explanation :

Let us consider a unstretched wire.

- Length of the wire $\longrightarrow$ L
- Force on the wire $\longrightarrow$ F
- Area of cross section $\longrightarrow$ A
- Extension in length $\longrightarrow$ l

Derivation :

Work done by the force F is equal to the energy gained by the wire.

1. Work done : $W = \int_0^l F\, dl$

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2. Young's Modulus : $Y = \frac{F}{A} \times \frac{L}{l}$

3. Force : $F = \frac{Y A l}{L}$

4. Work done : $W = \int_0^l \frac{Y A l}{L} dl$

5. $W = \frac{Y A}{L} \int_0^l l\, dl$

6. $W = \frac{Y A}{L} \left(\frac{l}{2}\right)^2$

7. $W = \frac{1}{2} \frac{Y A l}{L} l$

8. $W = \frac{1}{2} F l$

9. Work done = Elastic potential energy

10. Energy Density : Energy per unit volume = $\frac{\text{Elastic potential energy}}{\text{Volume}}$

$u = \frac{1}{2} \frac{F}{A} \frac{l}{L}$

$$\boxed{u = \frac{1}{2} \times \text{Stress} \times \text{Strain}}$$

---

9. State Pascal's law in fluids.

" If the pressure in a liquid is changed at a particular point , the change is transmitted to the entire liquid without being diminished in magnitude".

---

10. State Archimedes principle.

It states that when a body is partially or wholly immersed in a fluid , it experiences an upward thrust equal to weight of the fluid displaced by it and its upthrust acts through the centre of gravity of the liquid displaced.

Upthrust or Buoyant force = Weight of liquid displaced

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11. What do you mean by upthrust or buoyancy ?

The upward force exerted by a fluid that opposes the weight of an immersed object in a fluid is called upthrust.

---

12. State the law of floatation.

A body will float in a liquid if the weight of the liquid displaced by the immersed part of the body equals the weight of the body.

Example :

A wooden object 300 kg (about 3000 N) floats in water displaces 300 kg of water.

---

13. Define coefficient of viscosity of a liquid.

The viscous force acting tangentially per unit area of a liquid layer having a unit velocity gradient in a direction perpendicular of flow the liquid.

$$\boxed{F = -\eta A \frac{dv}{dx}}$$

---

14. Distinguish between streamlined flow and turbulent flow.

Streamlined Flow :

1. When a liquid flows such that each particle of the liquid passing through a point moves along the same path with the same velocity as it predecessor then the flow of liquid .

2. Velocity of the particle at any point is constant.

3. It is steady or laminar flow.

4. The actual path taken by the particle of the moving fluid is called a streamline , which is a curve , the tangent to which at any point gives the direction of the flow of the fluid at that point.

Turbulent Flow :

1. When the speed of the moving fluid exceeds the critical speed v_c the motion becomes turbulent.

2. The velocity changes both in magnitude and direction from particle to particle.

3. The path taken by the particles in turbulent flow becomes erratic and whirlpool like circles called eddy current or eddies.

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15. What is Reynold's number ? Give its significance .

Reynold's number is dimensionless number which is used to find out the nature of the liquid Whether it is streamline or turbulent.

- **Density of liquid - ρ**
- **Velocity of liquid - V**
- **Diameter of pipe - D**
- **Coefficient of viscosity - η**

$$\boxed{R_C = \frac{\rho V D}{\eta}}$$

---

16. Define terminal velocity.

The maximum constant velocity acquired by a body while falling freely through a viscous medium is called terminal velocity.

---

17. Write down the expression for the stoke's force and explain the symbols involved in it.

Viscous force F acting on a spherical body of radius r depends directly on

i) Radius (r) of the sphere

ii) Velocity (v) of the sphere

iii) Coefficient of viscosity (η)

$$\boxed{F = 6 \pi \eta r v}$$

---

18. State Bernoulli's theorem.

The sum of pressure energy , kinetic energy and potential energy , kinetic energy and potential energy per unit mass of an incompressible non – viscous fluid in a streamlined flow remains a constant.

$$\boxed{\frac{P}{\rho} + \frac{1}{2} v^2 + g h = \text{constant}}$$

19.What are the energies possessed by a liquid ? Write down their equations.

A liquid in a steady flow can possess three kinds of energy.

i) Kinetic Energy : $K E = \frac{1}{2} m v^2$ ii) Potential Energy : $P E = m g h$

iii) Pressure Energy : $E_P = \frac{P}{\rho} m$

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20. Two streamlines cannot cross each other . Why ?

If two streamlines cross each other , the fluid particle at the point of intersection will have two different directions of flow . This will destroy the steady nature of the fluid flow.

---

21. Define surface tension of a liquid . Mention its S.I unit and dimension.

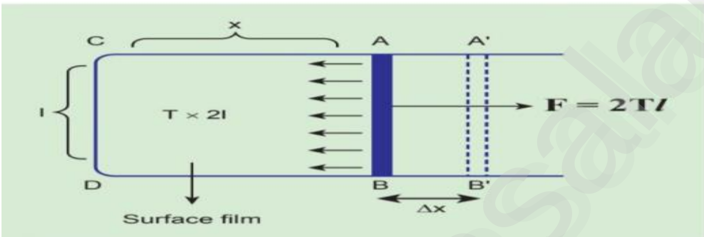
The surface tension of a liquid is defined as the energy per unit area of the surface of a liquid

$\boxed{T = F / l}$ S . I Unit : $N \ m^{-1}$ Dimension : $M T^{-1}$.

---

22. How is surface tension related to surface energy ?

Consider a rectangular frame of wire ABCD in a solution. Let AB be the movable wire. Suppose the frame is dipped in soap solution , soap film is formed which pulls the wire AB inward due to surface tension . Let F be the force due to surface tension.



1. <u>Force</u> : $F = (2T)\, l$

Here , 2 is introduced because it has two free surfaces.

<u>2. Work done</u> : $W = (2T)\, l \ \Delta x$

<u>3. Increase in area :</u> $\Delta A = (2l)\ \Delta x$

<u>4. Surface Energy :</u> $\dfrac{W}{\Delta A} = \dfrac{(2T)\, l\ \Delta x}{(2l)\ \Delta x} = T$

5. Surface energy per unit area is numerically equal to surface tension.

---

23. Define angle of contact for a given pair of solid and liquid.

The angle between the tangent to the liquid surface at the point of contact and the solid surface inside the liquid is known as the angle of contact between the solid and the liquid.

---

24. Distinguish between cohesive and adhesive forces.

<u>Cohesive Force :</u>

The force between the like molecules which holds the liquid together is called " cohesive"

Adhesive Force :

When the liquid is in contact with a solid , the molecules of these solid and liquid will experience an attractive force which is called " Adhesive force "

---

25. What are the factors affecting the surface tension of a liquid ?

1. Presence of contamination or impurities :

- Surface tension depends the degree of contamination.

2. Presence of dissolved substances :

- It can also affect the value of surface tension.
- When Nacl dissolved in H_2O increases the surface tension of water.

3. Electrification :

- When a liquid is electrified , surface tension decreases.

4. Temperature :

- The surface tension decreases linearly with the rise of temperature. $T_t = T_0 \ 1 - \alpha t)$

---

26. What happens to the pressure inside a soap bubble when air is blown into it ?

Pressure is greater inside the small build.

---

27. What do you mean by capillarity or capillary action ?

The rise or fall of a liquid in a narrow tube is called capillarity or capillary action.

---

28. A drop of oil placed on the surface of water spreads out. But a drop of water place on oil contracts to a spherical shape. Why ?

i) A drop of oil placed on the surface of water spreads . Since the force of adhesion between the water molecules dominates the cohesive force of the oil molecule. So oil drop in water spreads.

ii) The cohesive force of water molecule dominate the adhesive force between water & oil molecules. So drop of water contracts to spherical shape.

---

29. State the principle and usage of Venturi meter.

This device is used to measure the rate of flow of the incompressible fluid flowing through pipe. It works on the principle of Bernoulli's theorem.

UNIT - 8

1. " An object contains more heat " - is it a right statement ? If not why ?

- Heat is the energy in transits and which flows from an object at higher temperature to an object at lower temperature.
- " An object has more heat " is wrong instead " object is hot " will be appropriate "

---

2. Obtain an ideal gas law from Boyle's and Charle's law.

Boyle's Law :

When the gas is kept at constant temperature , the pressure of the gas is inversely proportional to the volume. $\boxed{P \propto \frac{1}{V}}$

Charle's Law :

When the gas is kept at constant pressure , the volume of the gas is directly proportional to the absolute temperature. $\boxed{V \propto T}$

By combining these two equations : $PV = CT$

- The constant C as k times the number of particles N.
- K is the Boltzmann constant 1.381×10^{-23} J K^{-1}.

Ideal Gas Law : $PV = NkT$

---

3. Define one mole.

One mole of any substance is the amount of that substance which contains Avogadro's number (N_A) of particles . (Such as atoms or molecules)

---

4. Define specific heat capacity and give its unit.

Amount of heat energy required to raise the temperature of 1 kg of a substance by 1 kelvin

- or 1^0 C. S I Unit : J Kg^{-1} K^{-1}
  - Amount of heat energy ⟶ ΔQ
  - Change in temperature ⟶ ΔT
  - Mass of the substance ⟶ m

$$\boxed{S = \frac{1}{m}\left(\frac{\Delta Q}{\Delta T}\right)}$$

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5. Define molar specific heat capacity .

Amount of heat energy required to increase the temperature of 1 mole of a substance by 1 kelvin or 1^0 C. S I Unit : J mol^{-1} K^{-1}

$$\boxed{C = \frac{1}{\mu} \frac{\Delta Q}{\Delta T}}$$

---

6. What is a thermal expansion ?

- The tendency of matter to change in shape , area and volume due to a change in temperature.
- All three states of matter (solid , liquid and gas) expand when heated.
- When solid is heated , its atoms vibrate with higher amplitude about their fixed points.
- The relative change in the size of solids is small.

---

7. Give the expressions for linear , area and volume thermal expansions.

1. Linear Expansion : $\alpha_L = \frac{\Delta L}{L_0 \Delta T}$

2. Areal Expansion : $\alpha_A = \frac{\Delta A}{A_0 \Delta T}$

3. Volume Expansion: $\alpha_V = \frac{\Delta V}{V_0 \Delta T}$

4. Coefficient of expansion → α_L, α_A , α_V

5. Change in length , Area , Volume → ΔL , ΔA , ΔV

---

8. Define latent heat capacity . Give its unit.

The amount of heat energy required to change the state of a unit mass of the material.

- Latent heat capacity → L
- Amount of heat → Q
- Mass of substance → m

$$\boxed{L = \frac{Q}{m}}$$

S I Unit : J Kg^{-1}

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9. State Stefan - Boltzmann law.

Total amount of heat radiated per second per unit area of a black body is directly proportional to the fourth power of its absolute temperature.

$$\boxed{E = \sigma T^4} \qquad \sigma = 5.67 \times 10^{-8} \ W\ m^{-2}\ K^{-4}$$

---

10. What is Wein's law ?

The wavelength of maximum intensity of emission of a black body radiation is inversely proportional to temperature of the black body.

$$\boxed{\lambda_m = \frac{b}{T}} \qquad b = 2.898 \times 10^{-3}\ m\ K$$

---

11. Define thermal conductivity. Give its unit.

The quantity of heat transferred through a unit length of a material in a direction normal to unit surface area due to a unit temperature difference under steady state conditions is known as " thermal conductivity " of a material.

$$\boxed{\frac{Q}{t} = \frac{K A \Delta T}{L}}$$

- **Coefficient of thermal conductivity → K**
- **S I unit : $J\ s^{-1}\ m^{-1}\ K^{-1}$ or $W\ m^{-1}\ K^{-1}$**

---

12. What is a black body ?

- **A black body is an object that absorbs all electro magnetic radiations .**
- **It is a perfect absorber and radiator of energy with no reflecting power.**
- **The sun is approximately taken as a black body.**
- **Any object above 0 K will emit radiation , sun also emits radiation.**

---

13. What is a thermodynamic system ? Give examples.

A thermodynamic system is a finite part of the universe. It is a collection of large

number of particles (atoms and molecules) specified by certain parameters called pressure (P) , Volume (V) and temperature (T) . The remaining part of the universe is called surrounding . Both are separated by a boundary.

Ex : Bucket of water , Fish in the sea.

---

14. What are the different types of thermodynamic systems ?

Open System :

It can exchange both matter and energy with the environment.

Closed System :

It can exchange energy but not matter with the environment.

Isolated System :

It can exchange neither energy nor matter with the environment.

---

15. What is meant by " thermal equilibrium " ?

Two systems are said to be in thermal equilibrium with each other if they are at the same temperature , Which will not change with time.

---

16. What is meant by state variable ? Give example.

- In thermodynamics , the state of a thermodynamic system is represented by a set of variables called thermodynamic variable.
- The values of these variables completely describe the equilibrium state of a thermodynamic system.

Ex : Pressure , Temperature , Volume.

---

17. What are intensive and extensive variables ?

Extensive Variable :

It depends on the size or mass of the system.

Ex : Volume , Entropy , Total mass

Intensive Variable :

It do not depend on the size or mass of the system.

Ex : Density , Pressure , Temperature

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18. What is an equation of state ? Give an example.

- The equation which connects the state variables in a specific manner is called " equation of state "
- A thermodynamic equilibrium is completely specified by these state variables by the equation of state.
- If the system is not in thermodynamic equilibrium then these equation cannot specify the state of the system.

Ex : Equation of state of Van der Walls equation. Real gases obey this equation at thermodynamic equilibrium.

---

19. State Zeroth law of thermodynamic equilibrium.

If two systems A and B are in thermodynamic equilibrium with a third system C then A and B are in thermodynamic equilibrium with each other.

---

20 . Define the internal energy of the system.

- The internal energy of a thermodynamic system is the sum of kinetic and potential energies of all the molecules of the system with respect to the center of mass of the system.
- Energy due to molecular motion including translational , rotational and vibrational motion is called internal kinetic energy (E_K)
- Energy due to molecular interaction is called internal potential energy (E_P).

Ex : Bond energy $U = E_K + E_P$

---

21. Are internal energy and heat energy the same ? Explain .

- No , but they are related . If heat energy is added to substance , its internal energy will increase.
- Internal energy is a measure of kinetic & potential energy possessed by particles

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in a substance.

- Heat energy concerns only transfer of internal energy from the hotter to colder body.

---

22. Define one calorie.

One calorie is defined as the amount of heat required at a pressure of 1std atmosphere to raise the temperature of 1 g of water at 1^0 C.

---

23. Did Joule converted mechanical energy to heat energy ? Explain.

- Yes , in his experiment , two masses were attached with a rope and a paddle wheel. When these masses fall through a distance h due to gravity , both the masses lose potential energy equal to 2 m g h.
- When the masses fall , the paddle wheel turns . Due to the turning of wheel inside water , frictional force comes in between the water and paddle wheel.
- This cause a rise in temperature of the water. This implies that gravitational potential energy is converted to internal energy of water.
- The temperature of water increases due to the work done by the masses . Joule was able to show that the mechanical work has the same effect as giving heat.

---

24. State the first law of thermodynamics .

Change in internal energy (ΔU) of the system is equal to heat supplied to the system (Q) minus the work done by the system (W) on the surroundings.

$$\boxed{\Delta U = Q - W}$$

---

26. Give the sign convention for Q and W.

- System gains heat → Q is positive
- System loses heat → Q is negative
- Work done on the system → W is positive
- Work done by the system → W is negative

---

27. Define the quasi - static process.

- **A quasi - static process is an *infinitely slow process* in which the system changes its variables (P , V , T) so slowly.**
- **Such that it remains in thermal , mechanical and chemical equilibrium with its surroundings through out.**
- **By this infinite slow variation the system is always almost close to equilibrium state.**

---

28. Give the expression for work done by the gas.

In general the work done by he gas by increasing the volume from V_i to V_f is given by

$$\boxed{W = \int_{V_i}^{V_f} P\,dV}$$

---

29. What is P V diagram ?

- **P V diagram is a graph between pressure P and volume V of the system .**
- **P V diagram is used to calculate the amount of work done by the gas during expansion or on the gas during compression.**

---

30. Explain why the specific heat capacity at constant pressure is greater than the specific heat capacity at constant volume.

- **Because when heat is added at constant pressure the substance expands & work.**
- **More amount of energy has to be supplied to a constant pressure to increase the system temperature by the same amount .**
- **Some of this energy is lost due to expansion work done by the system.**

---

31. Give the equation of state for an isothermal process.

The equation of state for isothermal process is given by P V = Constant

---

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32. Give an expression for work done in an isothermal process.

$$W = \mu R T \ln\left(\frac{V_f}{V_i}\right)$$

---

33. Express the change in internal energy in terms of molar specific heat capacity.

If Q is the heat supplied to mole of a gas at constant volume and if the temperature changes by an amount ΔT, We have

$$Q = \mu C_V \Delta T \rightarrow (1)$$

By applying the first law of thermodynamics for this constant volume process $W = 0$ since $dV = 0$ We have

$$Q = \Delta U - 0 \rightarrow (2)$$

Comparing the equations (1) and (2)

$$\Delta U = \mu C_V \Delta T$$

$$\mu C_V \Delta T = \Delta U$$

$$C_V = \frac{1}{\mu} \frac{\Delta U}{\Delta T}$$

$$\boxed{C_V = \frac{1}{\mu} \frac{dU}{dT}}$$

---

34. Apply first law for a) isothermal b) adiabatic c) isobaric processes.

S.No	Process	First Law
1.	Isothermal	$Q = W$
2.	Adiabatic	$\Delta U = W$
3.	Isobaric	$\Delta U = Q - P \Delta V$

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35. Give the equation of state for an adiabatic process.

$$P V^{\gamma} = \text{Constant}$$

- $\gamma \rightarrow$ Adiabatic exponent ($\gamma = C_P / C_V$)

---

36. Give an equation state for an isochoric process.

$$P = \left(\frac{\mu R}{V}\right) T$$

---

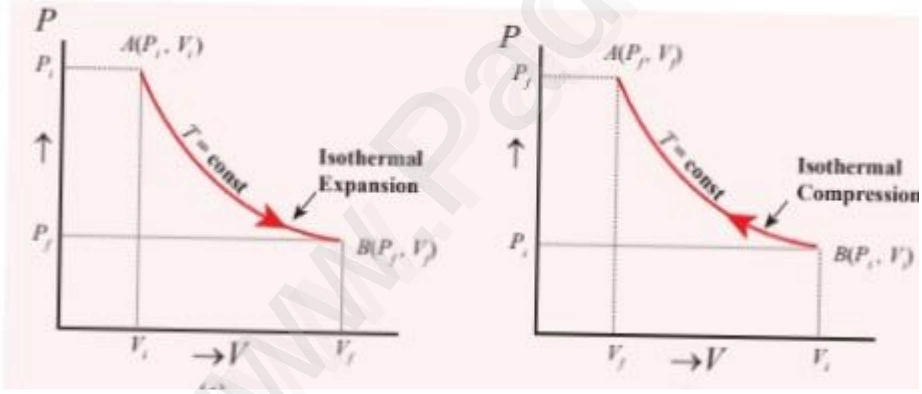
37. If the piston of a container is pushed fast inward . Will the ideal gas equation be valid in the intermediate stage ? If not , Why ?

- Decrease in volume leading to increase in temperature work is done on the gas.
- Ideal gas equation $PV = RT$
- When piston be pushed further the parameters V & R are taken as constant.
- The equation becomes $P = KT$ i.e ., $P \alpha T$

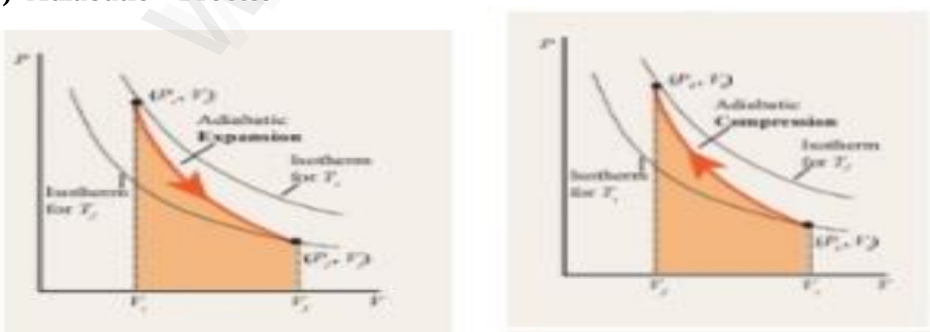
---

38. Draw the P V diagram for : a) Isothermal Process b) Adiabatic Process c) Isobaric Process d) Isochoric Process

a) Isothermal Process



b) Adiabatic Process



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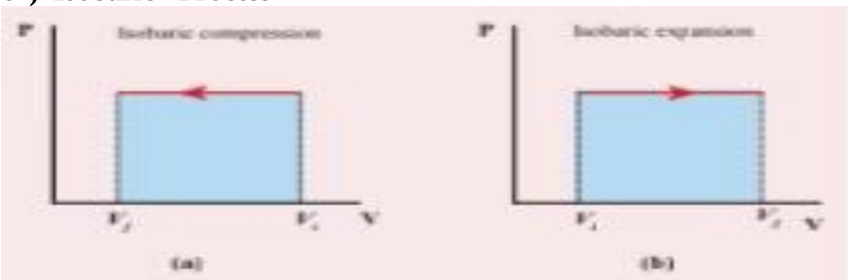
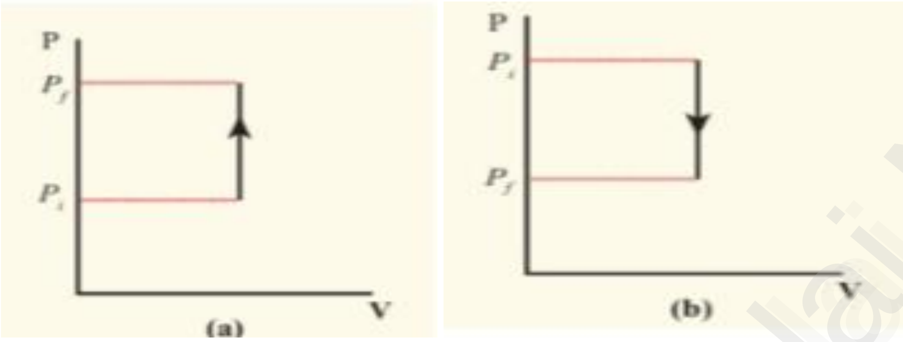
c) Isobaric Process



d) Isochoric Process



---

39. What is a cyclic process ?

- The thermodynamic system returns to its initial state after undergoing a series of changes.
- The system comes back to initial state , change in the internal energy is zero.
- Heat can flow in to system and flow in to system and flow out of the system.

---

40. What is meant by a reversible and irreversible processes ?

__Reversible Processs:__

- If it possible to retrace the path in the opposite direction in such a way that the system and surroundings pass through the same as in the initial , direct process.

__EX__ : A quasi static isothermal expansion of gas , slow compression and expansion of a spring.

__Irreversible Process:__

- All natural processes are irreversible.
- Irreversible process cannot be plotted in a P V diagram.

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- These process cannot have unique values of pressure , temperature at every stage of the process.

---

41. State Clausius form of the second law of thermodynamics.

" Heat always flows from hotter object to colder object spontaneously " This is known as the Clausius form of the second law of thermodynamics.

---

42. State Kelvin - Planck statement of second law of thermodynamics.

It is impossible to construct a heat engine that operates in a cycle whose sole effect is to convert the heat completely into work . This implies that no heat engine in the universe can have 100 % efficiency.

---

43. Define heat engine .

Heat engine is a device which takes which takes heat as input and converts this heat in to work by undergoing a cyclic process.

---

44. What are processes involves in a Carnot engine ?

There are four reversible processes involved in Carnot's engine. There are

1. <u>Step A to B :</u> Quasi -static isothermal expansion from (P_1, V_1, T_H) to (P_2, V_2, T_H)
2. <u>Step B to C :</u> Quasi -static adiabatic expansion from (P_2, V_2, T_H) to (P_3, V_3, T_L)

#. <u>Step C to D :</u> Quasi -static isothermal compression from (P_3, V_3, T_L) to (P_4, V_4, T_L)

4. <u>Step D to A :</u> Quasi -static adiabatic compression from (P_4, V_4, T_L) to (P_1, V_1, T_H)

---

45. Can the given heat energy be completely converted to work in a cyclic process ? If not , when can the heat can completely converted to work ?

i) No , in a cyclic process the complete energy is not completely converted into work , as it violate second law of thermos dynamics.

ii) In an isothermal process the whole heat can be converted into work . For an isothermal process d Q = d T which shows that whole heat can be converted into work.

---

46. State the second law of thermodynamics in terms of entropy .

" For all the processes that occur in nature (Irreversible process) the entropy always increases . For reversible process entropy will not change " .

Entropy determines the direction in which natural process should occur.

---

47. Why does heat flow from a hot object to a cold object ?

Because entropy increases when heat flows from hot object to cold object.

---

48. Define the coefficient of performance .

It is defined as the ratio of heat extracted from the cold body to the external from the cold body to the external work done by the compressor .

$$\boxed{COP = \beta = \frac{Q_L}{W}}$$

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UNIT - 9

1. What is the microscopic origin of pressure ?

With the help of kinetic theory of gases , the pressure is linked to the velocity of molecules.

$$\boxed{P = \frac{1}{3} \frac{N}{V} m \overline{v}^2}$$

- Mass of the molecule → m
- Avogadro number → N
- Average velocity → $\overline{v}$
- Volume of molecule → V

---

2. What is the microscopic origin of temperature ?

Average K.E / molecule K.E = $\varepsilon = \frac{3}{2} N k T$

---

3. Why moon has no atmosphere ?

The escape speed of gasses on the surface of moon is much less than the root mean square speeds of gases due to low gravity . Due to this , all the gases escape from the surface of the moon.

---

4. Write the expression for rms speed , average speed and most probable speed of a gas molecule.

RMS Speed : $V_{rms} = \sqrt{\frac{3KT}{m}} = 1.732\sqrt{\frac{KT}{m}}$

Average Speed : $\overline{V} = \sqrt{\frac{8KT}{m}} = 1.60\sqrt{\frac{KT}{m}}$

Most Probable Speed : $V_{mp} = \sqrt{\frac{2KT}{m}} = 1.414\sqrt{\frac{KT}{m}}$

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5. What is the relation between the average kinetic energy and pressure ?

The internal energy of the gas is given by

$$U = \frac{3}{2} N K T$$

$$U = \frac{3}{2} P V T \quad (P V = N K T)$$

$$P = \frac{2}{3} \frac{U}{V}$$

$$P = \frac{2}{3} u \quad (u = U / V)$$

Pressure of the gas is equal to two thirds of internal energy per unit volume or internal energy density.

Pressure of the gas :

$$P = \frac{1}{3} n m \overline{v}^2$$

$$P = \frac{1}{3} \rho \overline{v}^2 \quad (\rho = n m)$$

Multiply and divide R . H . S of eqn by 2

$$P = \frac{2}{3} \left(\frac{\rho \overline{v}^2}{2} \right)$$

$$\boxed{P = \frac{2}{3} \overline{K.E}}$$

---

6 . Define the term degrees of freedom.

The minimum number of independent coordinates needed to specify the position and configuration of a thermodynamical system in space is called the degree of freedom of the system.

---

7. State the law of equipartition of energy .

According to kinetic theory , the average kinetic energy of system of molecules in thermal equilibrium at temperature T is uniformly distributed to all degrees of freedom so that

each degree of freedom will get 1 / 2 K T of energy . This is called law of equipartition of energy.

---

8. Define mean free path and write down its expression.

Average distance travelled by the molecule between collisions is called is called mean free path (λ)

$$\text{Mean free path} = \frac{\text{Distance travelled}}{\text{Number of collisions}}$$

$$\boxed{\lambda = \frac{1}{\sqrt{2}\,\pi\, d^2\, \rho}}$$

---

9. Deduce Charle's law based on kinetic theory .

From the equation ,

$$P = \frac{2}{3}\frac{U}{V}$$

$$P = \frac{2}{3}u \quad (u = U / V)$$

We get , $P\,V = \frac{2}{3}U$

For a fixed pressure , the volume of the gas is proportional to internal energy of the gas and the average kinetic energy of the gas and the average kinetic energy is directly proportional to absolute temperature .

$$\boxed{\begin{array}{c} V \;\alpha\; T \\ \frac{V}{T} = \text{Constant} \end{array}}$$

---

9. Deduce Boyle's law based on kinetic theory .

From the equation ,

$$P = \frac{2}{3}\frac{U}{V}$$

$$P = \frac{2}{3}u \quad (u = U / V)$$

We get , $PV = \frac{2}{3} U$

But the internal energy of an ideal gas is equal to N times the average kinetic energy (ε) of each molecule , $U = N\varepsilon$

For a fixed temperature , the average translational kinetic energy ε will remain constant. It implies that ,

$$\boxed{\begin{aligned} PV &= \frac{2}{3} N\varepsilon \\ PV &= \text{Constant} \end{aligned}}$$

---

11 . Deduce Avogadro's law based on kinetic theory.

- This law states that at constant temperature and pressure , equal volumes of all gases contain the same number of molecules . For two different gases at the same temperature and pressure .
- According to kinetic theory of gases ,

$$P = \frac{1}{3}\frac{N_1}{V} m_1 \overline{v_1}^2 = \frac{1}{3}\frac{N_2}{V} m_2 \overline{v_2}^2 \quad \text{--------} \quad (1)$$

Where $\overline{v_1}^2$ and $\overline{v_2}^2$ are the mean square speed for two gases and N_1 and N_2 are the number of gas molecules in two different gases.

- At the same temperature , average kinetic energy per molecule is the same for two gases.

$$\frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_2 v_2^2 \quad \text{--------} \quad (2)$$

- Dividing (1) by (2) We get $N_1 = N_2$. This is Avogadro's law.

---

12. List the factors affecting the mean free path.

1. Mean free path increases with increasing temperature . As the temperature increases , the average speed of each molecule will increase. It is the reason why the smell of hot sizzling food reaches several meter away than smell of cold food.
2. Mean free path increases with decreasing pressure of the gas and diameter of the gas molecule.

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13. What is the reason for Brownian motion ?

1. **According to kinetic theory , any particle suspended in a liquid or gas is continuously bombarded from all the directions so that the mean free path is almost negligible.**
2. **This leads to the motion of the particles in a random and zig - zag manner.**

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UNIT - 10

1. What is meant by periodic and non - periodic motion ? Give any two examples for each motion.

Periodic Motion :

Any motion which repeats itself in a fixed time interval is known as periodic motion.

EX : 1. Hands in pendulum clock 2. Heart beat of a person

Non - Periodic Motion :

Any motion which does not repeats itself after regular interval of time is known as Non - periodic motion.

EX : 1. Oscillations of loaded spring 2. Vibrations of tuning fork

---

2. What is meant by force constant of a spring ?

Force constant is defined as force per unit displacement.

Ex : 1. Oscillations of loaded spring 2. Vibrations of a tuning fork

---

3. Define time period of simple harmonic motion.

The time period is defined as the time taken by a particle to complete one oscillation . It is usually denoted by T . For one complete revolution , the time taken is t = T

$$\boxed{T = \frac{2\pi}{\omega}}$$

---

4. Define frequency of simple harmonic motion.

- The number of oscillations produced by the particle per second is called frequency. $f = 1 / T$. S I Unit is hertz (Hz) or s^{-1}.
- The number of revolutions per sec is called angular frequency .
- Angular frequency and frequency are related by $\omega = 2\pi f$. S I unit is rad s^{-1}.

---

5. What is an epoch.

The displacement time t = 0 s , the phase $\phi = \phi_o$ is called epoch (initial epoch)

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ϕ_o is called the angle of epoch.

---

6. Write short notes on two springs connected in series.

Consider only two springs whose spring constant are k_1 and k_2 and which can be attached to a mass m. The results thus obtained can be generalized for any number of springs in series.

For springs in series connection : $-k_1 x_1 = -k_2 x_2 = F$

$$x_1 = -\frac{F}{k_1} \qquad x_1 = -\frac{F}{k_2}$$

Effective spring constant : $-\frac{F}{k_1} - \frac{F}{k_2} = -\frac{F}{k_s}$

$$\boxed{k_s = \frac{k_1 k_2}{k_1 + k_2}}$$

---

7. Write short notes on two springs connected in parallel.

Consider only two springs of spring constants k_1 and k_2 attached to a mass m. The results can be generalized to any number of springs in parallel.

$$F = -k_1 x - k_2 x$$

$$F = -k_p x$$

$$\boxed{K_p = k_1 + k_2}$$

---

8. Write down the time period of simple pendulum.

The angular frequency of this oscillator is ,

$$\omega^2 = \frac{g}{l} \qquad \omega = \sqrt{\frac{g}{l}} \qquad \text{rad } s^{-1}$$

Frequency of oscillation

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}} \qquad \text{in Hz}$$

Time period of oscillation

$$T = 2\pi\sqrt{\frac{l}{g}} \qquad \text{in sec}$$

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9. State the laws of simple pendulum.

i) Law of length :

For a given value of acceleration due to gravity , the time period of a simple pendulum is directly proportional to the square root of length of the pendulum.

$$\boxed{T \propto \sqrt{l}}$$

ii) Law of acceleration :

For a fixed length , the time period of a simple pendulum is inversely proportional to the square root of acceleration due to gravity.

$$\boxed{T \propto \frac{l}{\sqrt{g}}}$$

---

10. Write down the equation of time period for linear period for linear harmonic oscillator.

From Newton's second law , we can write the equation for the particle executing simple harmonic motion

$$m \frac{d^2 x}{d t^2} = - k x$$

$$\frac{d^2 x}{d t^2} = - \frac{k}{m} x$$

$$a = \frac{d^2 x}{d t^2} = - \omega^2 x$$

1. **Angular Frequency** : $\omega = \sqrt{\frac{k}{m}}$

2. **Frequency** : $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

3. **Time Period** : $T = 2\pi\sqrt{\frac{m}{K}}$

---

11. What is meant by free oscillation ?

When the oscillator is allowed to oscillate by displacing its position from equilibrium position , it oscillates with a frequency which is equal to the natural frequency which is equal to the oscillator . Such an oscillation is known as free oscillation .

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12. Explain damped oscillation . Give an example.

1. Due to the presence of friction and air drag , the amplitude of oscillation decreases as time progresses.
2. It implies that the oscillation is not sustained and the energy of the S H M decreases gradually indicating the loss of energy.
3. The energy lost is absorbed by the surrounding medium . This type of oscillatory motion is known as damped oscillation.

Examples :

1. Oscillation of a pendulum (including air friction)
2. Electromagnetic oscillation in a tank circuit.
3. Oscillations in a dead beat and ballistic galvanometers.

---

13. Define forced oscillation . Give an example.

In this type of vibration , the body executing vibration initially vibrates with its natural frequency and due to the presence of external periodic force , the body later vibrates with the frequency of the applied periodic force. Such vibrations are known as forced vibration.

Ex : Sound board of stringed instruments.

---

14. What is meant by maintained oscillations ? Give an example.

While playing in swing , the oscillations will stop after a few cycles , this is due to damping. To avoid damping we have to supply a push to sustained oscillations. By supplying energy from an external source , the amplitude of the oscillation can be made constant. Such vibrations are known maintained vibration.

Ex : The vibration of a tunning fork getting energy from a battery or from external power supply.

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15. Explain resonance . Give an example.

The frequency of external periodic force matches with the natural frequency of the vibrating body. As a result the oscillating body begins to vibrate such that its amplitude increases at each step and ultimately it has a large amplitude.

Ex : **The breaking of glass due to sound.**

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UNIT - 11

1. What is meant by waves ?

The disturbance which carries energy and momentum from one point in space to another point in space without the transfer of the medium is known as a wave.

---

2. Write down the types of waves.

i) **Mechanical Wave :**

Waves which require a medium for propagation are known as mechanical wave.

EX : Sound waves , Ripples formed on water surface.

ii) **Non - mechanical Wave :**

Waves which do not require medium for propagation are known as mechanical wave.

EX : Light waves , Infra red rays

Waves can be classified into two types :

1. Transverse wave 2. Longitudinal wave

---

3. What are transverse wave ? Give one example.

In transverse wave motion , the constituent of the medium oscillate or vibrate about their mean position in a direction perpendicular to the direction of propagation of waves.

EX : Light (Electromagnetic wave)

---

4. What are longitudinal wave ? Give one example.

In longitudinal wave motion , the constituent of the medium oscillate or vibrate about their mean position in a direction parallel to the direction of propagation of waves.

Ex : Sound waves travelling in air

---

5. Define wavelength.

- For transverse waves , the distance between two neighbouring crests or trough is known as the " wavelength ".

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- For longitudinal waves , the distance between two neighbouring compressions or rarefactions is known as the wavelength .
- S I unit of wave length is meter.

---

6. Write down the relation between frequency , wavelength and velocity of a wave.

Dimension of wave length is $[\lambda] = L$

$$\text{Frequency} = \frac{1}{\text{Time period}}$$

Dimension of frequency is $[f] = \frac{1}{[T]} = T^{-1}$

Relation between frequency & wavelength :

$$[\lambda f] = [\lambda][f] = L\ T^{-1} = [\text{Velocity}]$$

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

- Wave velocity is the distance travelled by a wave in one second.
- Wave velocity is called as " phase velocity "

---

7. What is meant by interfere of waves ?

Interference is a phenomenon in which two waves superimpose to form a resultant wave of greater , lower or the same amplitude.

---

8. Explain the beat phenomenon.

- When two or more waves superimpose each other with slightly different frequencies , then a sound of periodically varying amplitude at a point is observed . This phenomenon is known as beats .
- The number o f amplitude maxima per second is called beat frequency.
- If we have two sources , then their difference in frequency gives the beat frequency.
- Number of beats per second $n = |f_1 - f_2|$ per second

9. Define intensity of sound and loudness of sound .

- The sound power transmitted per unit area taken normal to the propagation of the sound wave.
- The loudness of sound is defined as " the degree of sensation of sound produced in the ear or the perception of sound by the listener .

---

10. Explain Doppler effect.

When the source and the observer are in relative motion with respect to each other and to the medium in which sound propagates , the frequency of the sound wave observed is different from the frequency of the source. This phenomenon is called " Doppler effect ".

---

11. Explain red shift and blue shift in Doppler effect.

The spectral lines of the star are found to shift towards red end of the spectrum then the star is receding away from the earth. Similarly if the spectral lines of the star are found to shift towards the blue end of the spectrum then the star is approaching earth.

---

12. What is meant by end correction in resonance air column apparatus ?

The antinodes is not exactly formed at the open end , but a small distance above be open end. This is called " end correction "

To computer the end correction : $L_1 + e = \frac{\lambda}{4}$ and $L_2 + e = \frac{3\lambda}{4}$

---

13. Sketch the function y = x + a . Explain your sketch.

i) A combination of constant and direct.

ii) A fixed amount is added at regular intervals.

iii) y = x + a , a suitable conclusion statement would be that,

1. y is linear with a
2. y varies linearly with x.
3. Y is a linear function of x y is the intercept.

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14. Write down the factors affecting velocity of sound in gases.

1. Pressure 2. Temperature 3. Density 4. Humidity 5. Wind

---

15. What is meant by an echo ? Explain.

1. An echo is a reception of sound produced by the reflection of sound waves from a wall , mountain or other obstructing surfaces. The speed of sound in air at 20^0 C is 344 m s^{-1} .

2. If we shout at a wall which is at 344 m away , then the sound will take 1 second to reach the wall.

3. After reflection , the sound will take one more second to reach us.

4. We hear the echo after two seconds only.

5. Time gap or time interval between each sound is $(1/10)^{th}$ of second is 0.1 s

6. The minimum distance from a sound reflecting wall to hear an echo at 20^0 C is 17.2 m .

$$\text{Velocity} = \frac{\text{Distance Travelled}}{\text{Time taken}} = \frac{2d}{t}$$

$$2d = 344 \times 0.1 = 34.4$$

$$d = 17.2 \text{ m}$$

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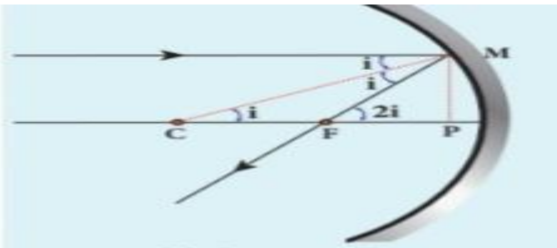
6. RAY OPTICS

1.What is angle of deviation due to reflection ?

The angle between the incident ray and deviated ray of light is called " angle of deviation ".

---

2. Derive the relation between f and R for a spherical mirror.



(a) Concave mirror

$$\boxed{2f = R}$$

Consider a ray of light parallel to the principal axis is incident on the mirror at M.

- Centre of curvature - C
- Principal Focus - F
- Angle of incidence - i
- Angle of reflection - r
- MP perpendicular from M
- $\angle MCP = i$ and $\angle MFP = 2i$

$\triangle$ MCP	$\triangle$ MFP
$\tan i = \frac{PM}{PC}$	$\tan 2i = \frac{PM}{PF}$
$i = \frac{PM}{PC}$	$2i = \frac{PM}{PF}$

- Angles are small , tan i = i and tan 2i = 2i.

$$2i = \frac{PM}{PF}$$

$$2\frac{PM}{PC} = \frac{PM}{PF}$$

$$2\,PF = PC$$

- Focal length PF = f ; Radius of curvature PC = R

$$\boxed{2f = R}$$

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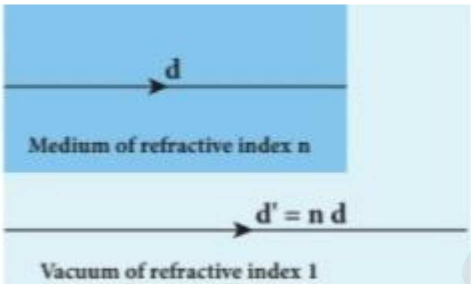
3. What are the Cartesian sign conventions for spherical mirrors ?

1. **Incident light is taken from left to right.**
2. **All distances are measured from pole of the mirror.**
3. **Distance measured to right of the pole is positive and to the left is negative.**
4. **Heights measured in the upward perpendicular direction is positive and downward is negative.**

---

4. What is optical path ? Obtain the equation for optical path.

Optical path of a medium is defined as the distance d' light travels in vacuum in the same time it travels a distance d in the medium.



- **Refractive index of a medium = n**
- **Thickness of a medium = d**

Speed of light through medium

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

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

Speed of light through vacuum

$$c = \frac{d'}{t}$$

$$t = \frac{d'}{c}$$

$$\frac{d'}{c} = \frac{d}{v}$$

$$d' = \frac{c}{v}\, d$$

$$d' = n\, d$$

$$\boxed{d' = n\ d}$$ **Here $n > 1$ then $d > d'$**

---

5. State Snell's law / law of refraction.

1. **The incident ray , refracted ray and normal to the refracting surface are all coplanar . (lie in same plane)**

2.The ratio of sine of angle of incident i in the first medium to the angle of reflection r in the second medium is equal to the ratio of refractive index n_2 of the second medium to the

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refractive index n_1 of the first medium.

$$\frac{\text{Sin } i}{\text{Sin } r} = \frac{n_2}{n_1} \quad ; \quad n_2 \sin i = n_1 \sin r$$

---

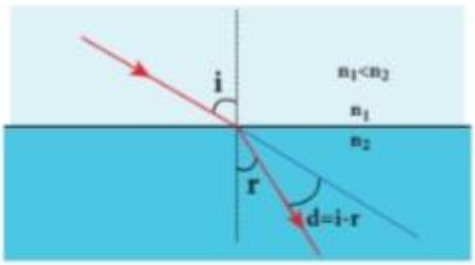
6. What is the angle of deviation due to refraction ?

- **When light travels from rarer to denser medium , it deviates towards normal.**

Angle of deviation $\boxed{d = i - r}$

- **When light travels from denser to rarer medium , it deviates towards normal.**

Angle of deviation $\boxed{d = r - i}$



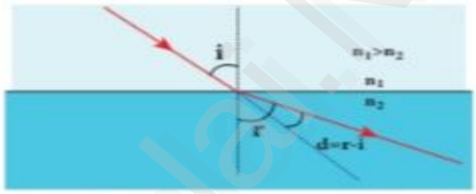


Figure 6.17 Angle of deviation due to refraction from denser to rarer medium

---

7. What is principle of reversibility ?

The principle of reversibility states that light will follow exactly the same path if its direction of travel is reversed.

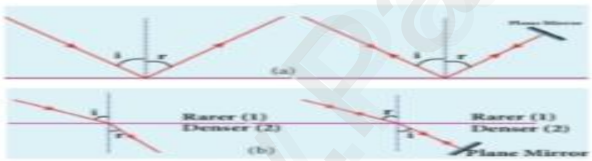


Figure 6.19 Principle of reversibility in (a) reflection and (b) refraction

---

8. What is relative refractive index ?

From Snell's law , $\frac{\text{Sin } i}{\text{Sin } r} = \frac{n_2}{n_1}$ $\boxed{n_{21} = \frac{n_2}{n_1}}$

- **The term (n_2 / n_1) is called relative refractive index of second medium with respect to first medium which is denoted as n_{21}.**

---

9. Obtain the equation for apparent depth.

Light from the object O at the bottom of the tank passes from denser medium to rarer medium to reach our eyes for viewing the object.

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- Refractive index of denser medium ⟶ n_1
- Refractive index of rarer medium ⟶ n_2
- Angle of incidence ⟶ i
- Angle of refraction ⟶ r

Diagram :

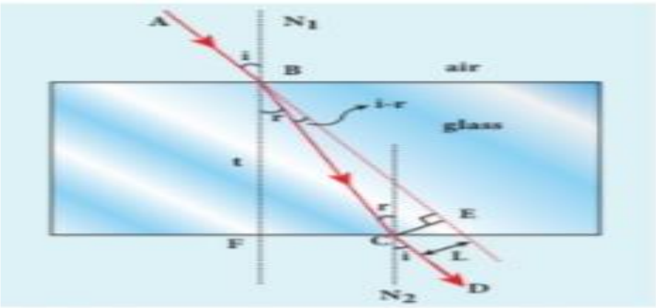

Figure 6.30 Refraction in glass slab

- Snell's law in product form of reflection : $n_1 \sin i = n_2 \sin r$
- If angles are small then $\sin i = \tan i$; $\sin r = \tan r$.

$$n_1 \tan i = n_2 \tan r$$

$\triangle$ DOB	$\triangle$ DIB
$\tan i = \frac{DB}{DO}$	$\tan r = \frac{DB}{DI}$

$$n_1 \tan i = n_2 \tan r$$

$$n_1 \frac{DB}{DO} = n_2 \frac{DB}{DI}$$

$$n_1 \frac{1}{d} = n_2 \frac{1}{d'}$$

$$\frac{d'}{d} = \frac{n_2}{n_1}$$

$$\boxed{d' = d \frac{n_2}{n_1}}$$

---

10. Why do stars twinkle ?

- The stars actually do not twinkle.
- Due to refraction of light through different layers of atmosphere which vary in

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refractive index , the path of light deviates continuously when it passes through atmosphere.

---

11. What are critical angle and total internal reflection ?

Critical Angle :

The angle of incidence in the denser medium for which the angle of refraction is 90^0 (or) the refracted ray graces the boundary between the two media is called "critical angle" i_c .

$$\boxed{i_c = \sin^{-1} (1/n)}$$

Total internal reflection :

For any angle of incidence greater than the critical angle , the entire light is reflected back into the denser medium itself. This phenomenon is called " total internal reflection "

Condition for total internal reflection :

1. Light travel from denser to rarer medium.
2. Angle of incidence in the denser medium must be greater than critical angle. ($i > i_c$)

---

12. Obtain the equation for critical angle.

- When ray passes from an optically denser medium to rarer medium . ($r > i$)
- i gradually increased , r increases it becomes 90^0. ($r = 90^0$)
- Refracted ray graces the boundary between the two media is called "critical angle" $i = i_c$

Snell's law in product form

$$n_1 \sin i = n_2 \sin r$$

$$n_1 \sin i_c = n_2 \sin 90^0$$

$$n_1 \sin i_c = n_2$$

$$\sin i_c = \frac{n_2}{n_1}$$

$$\boxed{i_c = \sin^{-1} (n_2 / n_1)}$$

If $n_2 = 1$ and $n_1 = n$ then ,

$$\boxed{i_c = \sin^{-1} (1/n)}$$

---

13 . Explain the reason for glittering of diamond.

1. Diamond appears dazzling because of total internal reflection happens inside it.
2. Refractive index of diamond is about 2.417 much greater than glass is about 1.5
3. Critical angle of diamond is about 24.4^0 much less than ordinary glass.
4. A skilled diamond cutter makes use of this large range of angle of incidence 24.4^0 to 90^0.

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5. To ensure that light entering the diamond is total internally reflected from the many cut faces before getting out.

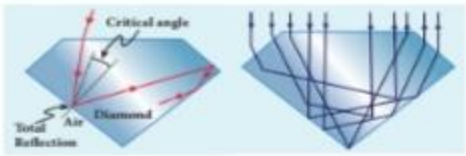
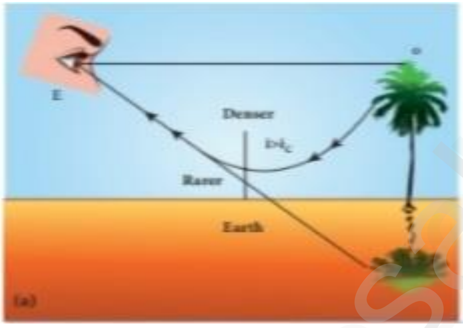


Figure 6.22 Total internal reflection in diamond

14.What are mirage and looming ?

<u>Mirrage :</u>



1. In hot places , air near the ground is hotter than air at height. Hot air is less dense.
2. Refractive index of air increases with height and its density.
3. Light from tall objects like a tree , try to pass through medium whose refractive index decreases towards ground.
4. Ray of light deviates away from normal at different layer of air.
5. It undergoes total internal reflection when the angle of incidence near the ground exceeds critical angle.
6. This gives an illusion as if the light comes from somewhere below the ground.
7. The shaky nature of the layers of air , the observer feels as if the object is getting reflected by pool of water.

<u>Looming :</u>

1. In cold regions like glaciers and frozen lakes , the reverse effect of mirage will happen.
2. Hence an inverted image is formed little above the surface .
3. This phenomenon is called “ looming “
4.It is also called as “ superior mirage “ towering and stooping .

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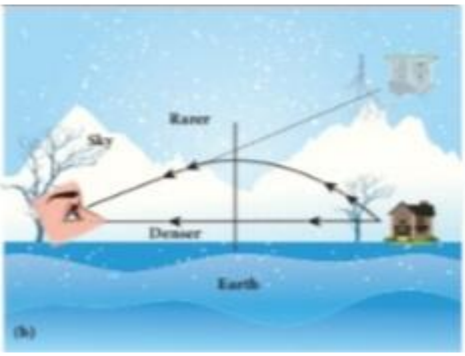

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15. Write short note on the prism making use of total internal reflections.

- Prisms can be designed to reflect light by 90^0 or 180^0 by making use of total internal reflection .
- $i_c > 45^0$, the critical angle i_c for the material of the prism must be less than 45^0.

---

16. What is Snell's window ?

When the light entering the water from outside is seen from inside the water , the view is restricted to a particular angle equal to the critical angle i_c . The restricted illuminated circular area is called " Snell's window "

17.How does an endoscope work ?

- An endoscope which has a bundle of optical fibres is an instrument used by doctors to see inside of a patient's body.
- Endoscope work on the phenomenon of total internal reflection.
- Optical fibres are inserted into the body through mouth , nose (or) special hole made in the body.
- Even operations could be carried out with the endoscope cables which have the necessary instruments attached at their ends.

---

18. What are primary focus and secondary focus of a lens ?

Primary Focus :

The primary focus F_1 is defined as a point where a point source kept produces a parallel emergent rays to the principal axis after passing through lens.

Secondary Focus :

The secondary focus F_2 is defined as a point where all the parallel rays travelling close to the principal axis converge to form an image on the principal axis after passing through lens.

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19. What are the sign conventions followed for lenses ?

1) Incident light is taken from left to right.
2) All the distances measured from the pole.
3) Distance measured to the right of pole along the principal axis taken as positive.
4) Distance measured to the left of pole along the principal axis taken as negative.
5) Heights measured in the upward perpendicular direction to the principal axis taken as positive.
6) Heights measured in the downward perpendicular direction to the principal axis taken as negative.

---

20. Arrive lens equation from lens maker's formula.

1. Len's maker's lens :

$$\boxed{\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

2. General equation for refraction at a spherical surface :

$$\boxed{\frac{1}{v} - \frac{1}{u} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

3. Len's Equation :

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

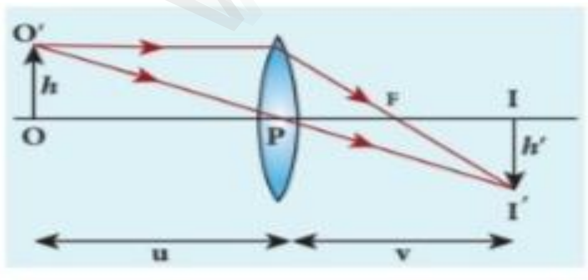
---

21. Obtain the equation for lateral magnification of thin lens.

Theory :

- Object → O O'
- Image → I I'
- Height → h , h'

Diagram :



Formula :

$$\boxed{m = \frac{f}{f+u} = \frac{f-v}{f}}$$

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<u>Lateral Magnification or Transverse magnification :</u>

It is defined as the ratio of the height of the image to height of the object.

- **Similar triangles Δ P O O' and Δ P I I'**

$$m = \frac{I\,I'}{O\,O'} = \frac{P\,I'}{PO}$$

- **On applying sign convention**

$$m = -\frac{h'}{h} = \frac{v}{-u}$$

- **Magnification :**

$$m = \frac{h'}{h} = \frac{v}{u}$$

- **Magnification is negative for real image.**
- **Magnification is positive for virtual image.**
- **Magnification always positive for concave lens and less than one.**

---

22. What is power of a lens ?

1. The power of a lens is a measure of the degree of convergence or divergence the lens produces on the light falling on it.

$$P = \frac{1}{f} \qquad \text{S I Unit : dioptre}$$

2. The power of lens P is the reciprocal of focal length.

---

23. Derive the effective focal length for lenses in contact.

<u>Diagram :</u>

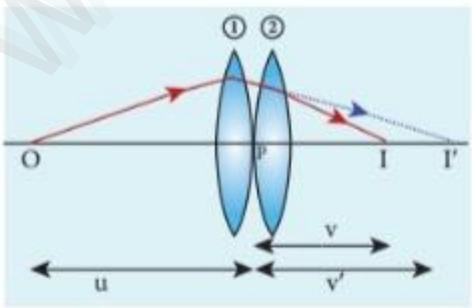

Figure. 6.37 Lenses in contact

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Theory :

1. Consider two lenses of focal length f_1 and f_2 in contact with each other and have a common principal axis.

2. An object placed at O beyond the focus of first lens , an image is formed by it at $I^{/}$.

3.This image acts as an object for the second lens and the final image is formed at I.

4. As two lenses are thin , P is common optical centre in the middle of the two lenses.

Len's equation for lens 1

$$\frac{1}{v^{/}} - \frac{1}{u} = \frac{1}{f_1} \longrightarrow (1)$$

Len's equation for lens 2

$$\frac{1}{v} - \frac{1}{v^{/}} = \frac{1}{f_2} \longrightarrow (2)$$

Adding equation (1) & (2)

$$\frac{1}{v^{/}} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v^{/}} = \frac{1}{f_1} + \frac{1}{f_2} \longrightarrow (3)$$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$$

we know that , $\boxed{\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}}$

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

---

25. What is dispersion ?

Dispersion is splitting of white light into its constituent colours. This band of colours of light is called its spectrum.

---

26. How are rainbows formed ?

1. Rainbow is an example of dispersion of sunlight through droplets of water during rainy days.

2.When sunlight falls on the water drop suspended in air , it splits into its constituent seven colours . Thus , water drop suspended in air behaves as a glass prism.

3.There are two types primary rainbow and secondary rainbow.

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27. What is Rayleigh's scattering ?

1. If the scattering of light is by atoms and molecules which have size ' a ' very much less than that of the wavelength ' λ ' of light , (a < < λ) then the scattering is called " Rayleigh's scattering "

2. The intensity of Rayleigh's scattering is inversely proportional to fourth power of wavelength.

$$\boxed{I \;\alpha\; \frac{1}{\lambda^4}}$$

----

28. Why does sky appear blue ?

1. Violet colour which has the shortest wavelength gets much scattered during day time.

2. The next scattered colour is blue.

3. As our eyes are more sensitive to blue colour than violet colour the sky appears blue during day time.

----

29. What is the reason for reddish appearance of sky during sunset and sunrise ?

1. During sunrise and sunset , the light from sun travels a greater distance through the atmosphere.

2.Hence , the blue light which has shorter wavelength is scattered away and the less scattered red light of longer wavelength to reach our eye.

----

30. Why do clouds appear white ?

1. Clouds contains large amount of dust and water droplets.

2. Thus , in clouds all the colours get equally scattered irrespective of wavelength .

3. So it appears white.

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7. Wave Optics

1.What are the salient features of corpuscular theory of light ?

1.Light is emitted as tiny , massless and perfectly elastic particles called " corpuscles "

2. As the corpuscles are very small , the source of light does not suffer loss of mass even if it emits light for long time.

3.They are unaffected by the force of gravity and their path is a straight line in a medium of uniform refractive index.

4.The energy of light is the K.E of these corpuscles. It impinge on the retina of the eye , the vision is produced.

5. When it approach surface between two media , they are either repel or attract.

i) Reflection due to repulsion ii) Refraction due to attraction.

2.What are the important points of wave theory of light ?

1. Light is a disturbance from source travels that as longitudinal mechanical waves through the ether medium , as mechanical wave requires medium for propagation.

2.The wave theory explain the phenomenon of reflection , refraction , interference and diffraction of light.

---

3. What is the significance of electromagnetic wave theory of light ?

1. Maxwell proved that light is an em wave which is transverse in nature.

2.No medium is necessary for the propagation of em waves.

3. All the phenomenon of light could be successfully explained by this theory.

4.Write a short note on quantum theory of light.

1). It explain photoelectric effect in which light interacts with matter as photons to eject the electrons.

2). A photon is a discrete packet of energy $E = h\gamma$

- Planck's constant $h = 6.625 \times 10^{-34}$ J s . Frequency of em wave $\longrightarrow \gamma$

3.As light has both wave as well as particle nature it is said to have dual nature.

4.It is concluded that light propagates as a wave and interacts with matter as a particle.

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5. Define wave front.

A wave front is the locus of points which are in the same state or phase of vibration.

---

6. What are the shapes of wavefronts for a) source at infinite b) Point source c) Line source.

1. Source at infinite :

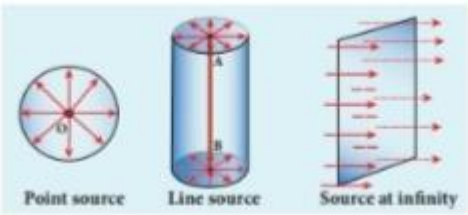
Source is located at infinity gives plane wave front.

2.Point Source :

A point source located at a finite distance gives spherical wavefronts.

3.Line Source :

An extended (or) line source at finite distance gives cylindrical wavefront.



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7. State Huygen's principle.

- **According to Huygen's principle , each point of the wave front is the source of secondary wavelets .**
- **These wavelets are spreading out in all directions with the speed of the wave .**
- **These are called as secondary wavelets.**

---

8. What is the interference of light ?

The phenomenon of super position of two light waves which produces increases in intensity at some points and decreases in intensity at some points called interference of light.

---

9. What is the phase of a wave ?

- **Phase is the angular position of a vibration.**
- **When a wave is progresses , there is a relation between phase of the vibration and path travelled by the wave.**

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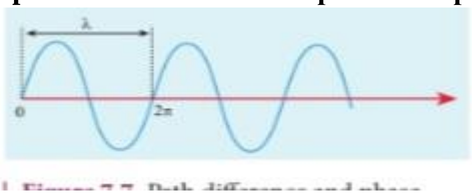
10. Obtain the relation between phase difference and path difference.

1. In the path of the wave , one wavelength λ corresponds to a phase of 2 π .

2.A path difference δ corresponds to a phase difference Φ.



$$\Phi = \frac{2\pi}{\lambda} \times \delta$$

---

11. What are coherent sources ?

Two light sources are said to be coherent if they produce waves which have same phase or constant phase difference , same frequency or wavelength , same waveform and preferably same amplitude.

---

12. How does wavefront division provide coherent sources ?

1. Most common method to produce coherent source.

2.A point source produces spherical wavefront .

3.All the points on the wavefront are at the same phase.

4. If two points are chosen on the wavefront by using double slit , act as coherent source.

---

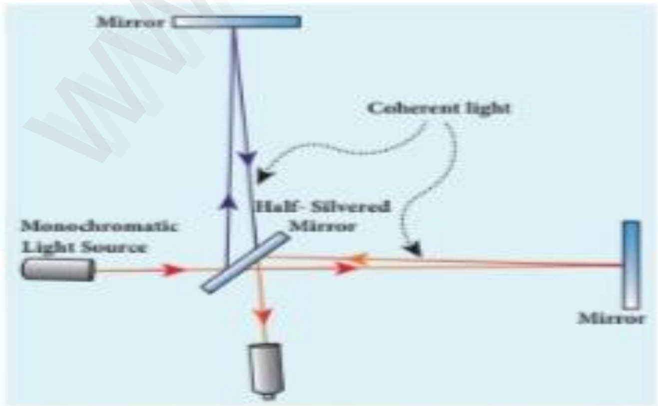
13. What is intensity (or) amplitude division ?

1. If we allow light to pass through partially silvered , both reflection and refraction take place.

2. As the two light beams obtain from same source , two divided light beams are coherent.

3. They will be in-phase or at constant phase difference.

Ex : 1. Michelson's Interferometer 2. Fabray – Perrot Etalon



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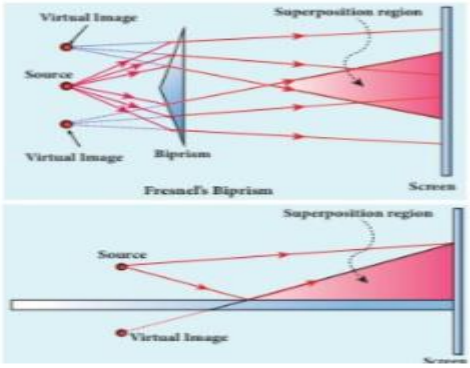
14. How do source and images behave as coherent source ?

1. Source and its image will have waves in phase or constant phase differences.

2. Fresnel's biprism uses two virtual images of the source as two coherent source.

3. Lloyd's mirror uses source and its one virtual image as two coherent source.



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15. What is bandwidth of interference pattern ?

The bandwidth (β) is defined as the distance between any two consecutive bright or dark fringes.

$$\beta = \frac{D\lambda}{d}$$

β → Bandwidth , λ → Wavelength

D → Distance between coherent source and screen

d → Distance between two coherent sources

---

16. What is diffraction ?

Diffraction is bending of waves around sharp edges into the geometrically shadowed region.

---

18. Discuss the special cases on first minimum in Fraunhofer diffraction.

- **The slit is to be divided into even number of equal parts for minimum condition in diffraction.**

Condition for first minimum

$$\delta = \frac{a}{2} \sin\theta = \frac{\lambda}{2}$$

$$a \sin\theta = \lambda$$

Condition for first minimum

$$\delta = \frac{a}{4} \sin\theta = \frac{\lambda}{2}$$

$$a \sin\theta = 2\lambda$$

Condition for n^{th} minimum $a \sin\theta = n\lambda$

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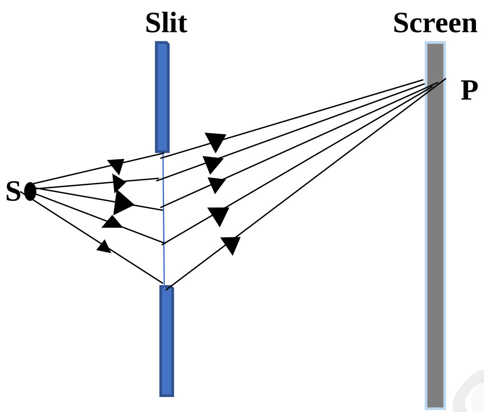
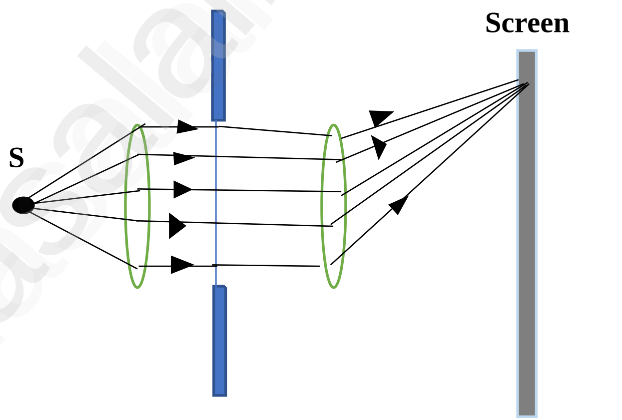
17. Difference between Fresnel diffraction and Fraunhofer diffraction ?

S.NO	Fresnel Diffraction	Fraunhofer Diffraction
1.	Spherical or cylindrical wavefront undergoes diffraction.	Plane wavefront undergoes diffraction.
2.	Light wave is from a source at finite distance.	Light wave is from a source at infinity.
3.	For laboratory conditions , convex lenses need not be used .	For laboratory conditions , convex lenses need to be used .
4.	Difficult to observe and analyse.	Easy to observe and analyse.
5.		

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19. What is Fresnel's distance ? Obtain the equation for Fresnel's distance .

Fresnel's distance is the distance up to which the ray optics is obeyed and beyond which the ray optics is not obeyed. But , the wave optics becomes significant.

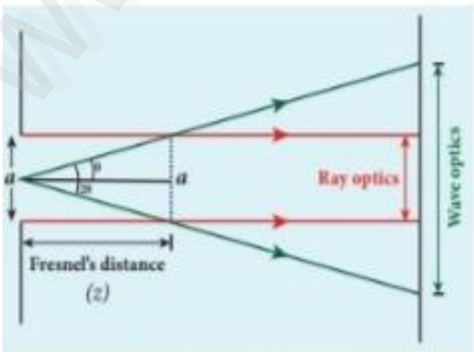

Figure 7.19 Fresnel's distance

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Diffraction equation for first minimum

$$a \sin\theta = \lambda$$

$$\sin\theta = \frac{\lambda}{a}$$

When θ is small , $\theta = \frac{\lambda}{a} \longrightarrow (1)$

From the definition of Fresnel's distance ,

$$2\theta = \frac{a}{z}$$

$$\theta = \frac{a}{2z} \longrightarrow (2)$$

Equating equation (1) and (2)

$$\theta = \frac{\lambda}{a} = \frac{a}{2z}$$

Fresnel Distance : $z = \frac{a^2}{2\lambda}$

---

20. Mention the differences between interference and diffraction.

S.NO	Interference	Diffraction
1.	Super position of two waves .	Bending waves around edges.
2.	Equally spaced bright and dark fringes.	Central bright is double the size of other.
3.	Equal intensity for all bright fringes.	Intensity falls rapidly for higher order fringes.
4.	Large number of fringes are obtained.	Less number of fringes are obtained.

---

21. What is a diffraction grating ?

- **The combined width of a ruling and a slit is called grating element** $e = a + b$.
- **The points on the slit separated by a distance equal to the grating element are called corresponding points.**

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22. What is resolution ?

- Resolution is the quality of image which is decided by diffraction effect and Rayleigh's criterion.
- Resolution is measured by the smallest distance which could be seen clearly without the blur due to diffraction.

---

23. What is Rayleigh's criterion ?

According to Rayleigh's criterion , the two points on the image are said to be just resolved when the central maximum of one diffraction pattern coincides with the first minimum of the other and vice versa.

---

24. Difference between resolution and magnification ?

<u>Resolution :</u>

- Quality of image which is decided by diffraction effect and Rayleigh's criterion.
- Measured by the smallest distance which could be seen clearly without the blur due to diffraction.

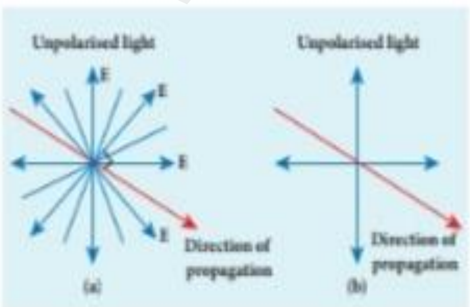
Resolution	Magnification
• Ability of optical instruments to produce clear , fine and sharper image.	• Ability of optical instruments to make an object bigger.

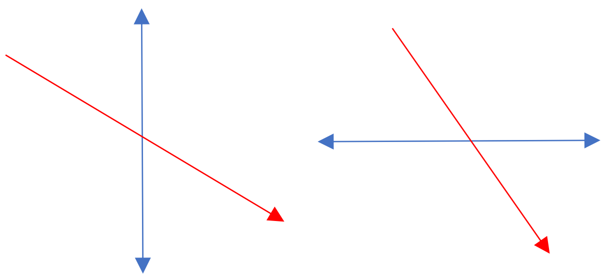
---

25. What is polarization ?

The phenomenon of restricting the vibrations of light to any one direction perpendicular to the direction of propagation of wave is called polarization of light.

26.Difference between polarized and unpolarized light.





Polarised light

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S.NO	Polarized Light	Unpolarized Light
1.	Consists of waves having their electric and magnetic field vibrations in a single normal to the direction of ray.	Consists of waves having their electric and magnetic field vibrations in all direction of ray.
2.	Asymmetrical about ray direction .	Symmetrical about the ray direction .
3.	Obtain by convert unpolarized light using polaroid.	Produced by conventional light sources.

---

27. Discuss polarization by selective absorption.

1. It is the property of a material which transmit waves.

2. The electric field vibrations are in a plane parallel to certain direction of orientation.

3. It absorbs all other vibration. 4. It is also called as " Dichroism ".

5. Polaroids or polariser which make use of property of selective absorption to produce plane polarized light.

EX : 1. Tourmaline 2. Quinine iodosulphate 3. Polyvinyl Alcohol

---

28. What are polariser and analyser ?

Polariser :

The polaroid which polarises the light passing through it is called polariser.

Analyser :

The polaroid which is used to examine whether a light is polarised or not is called an analyser.

---

29. What are plane polarised , unpolarised and partially polarised light ?

Plane polarised light

A light is said to be plane polarised if the intensity varies from maximum to zero for 90^0 rotation of the analyser.

Partially Polarised Light

If the intensity of light varies between maximum and minimum for every 90^0 rotation of the

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analyser , the light is said to be partially polarised light.

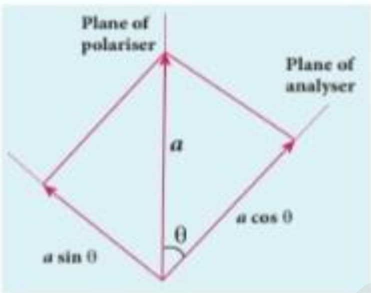
<u>Unpolarised Light</u>

An unpolarised light is a transverse wave which has vibrations in all directions in all directions in a plane perpendicular to the direction of propagation of wave.

---

30. State and obtain Maul's law.

In 1809 , Maull's discovered that when a beam of plane polarised light of intensity I_0 is incident on an analyser , the intensity of light I transmitted from the analyser varies directly as the square of the cosine of the angle θ between the transmission axes of polariser and analyser. This is known as " Maul's law "



$$\boxed{I = I_0 \cos^2 \theta}$$

---

31. List the uses of polaroid.

1. Used in googles and cameras to avoid glare of light.

2. Used to take 3D pictures i.e holography .

3. Used in optical stress analysis.

4. Used as window glasses to control the intensity of incoming light.

5. Used to improve contrast in old oil paintings.

6. Polarised light is used in LCD.

7. Polarised laser beam acts as needle to read / write in compact discs CD.

---

32. State Brewster's law.

Brewster's law states that the tangent of the polarising angle for a transparent medium is equal to refractive index.

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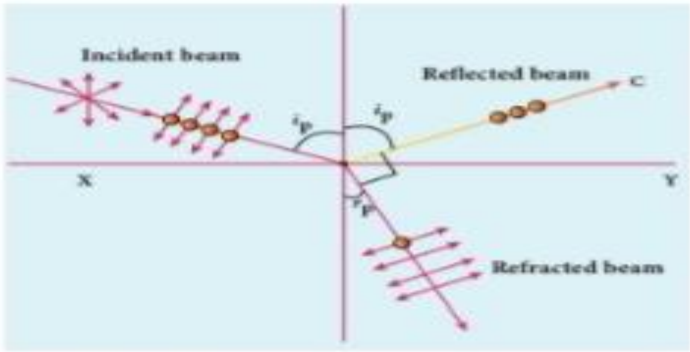


Brewster 's Law

$$\boxed{\tan i_p = n}$$

The polarising angle is known as Brewster's angle which depends on the nature of the refracting medium.

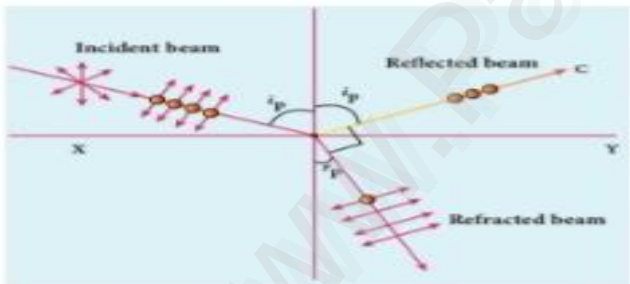
---

33. What is angle of polarisation and obtain the equation for angle of polarisation.

Angle of polarisation :

The angle of incidence for which the reflected light is found to be plane polarised is called polarising angle i_p.

Brewster 's Law



$$\boxed{\tan i_p = n}$$

From geometry : $r_p = 90^0 - r_p$

From Snell's law : $n = \dfrac{\sin i_p}{\sin r_p}$

$$n = \frac{\sin i_p}{\sin(90^0 - i_p)}$$

$$n = \frac{\sin i_p}{\cos i_p}$$

$$n = \tan i_p$$

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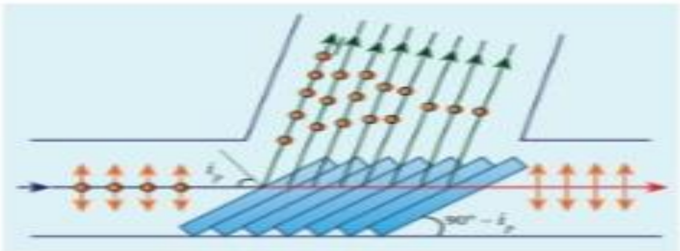
34. Discuss the piles of plates.



1. Pile of plates makes use of Brewster's law to convert the partially polarised refracted light into plane polarised light.

2. It consists of several plates kept one behind the other at an angle 90^0 - i_p with the horizontal surface.

3. This arrangement ensures that the parallel falls on these plates at i_p.

4. Unpolarised light passes through these plates, few parallel vibrations to the surface which may present in refracted light further reflections at the succeeding plates.

5. Both reflected and refracted lights are found to be plane polarised.

---

35. What is double refraction ?

When a ray of unpolarised light is incident on a calcite crystal , two refracted rays are produced. Hence , two images of an object are formed. This phenomenon is called double refraction or birefringence.

---

36. Mention the types of optically active crystals with example.

S.NO	Uniaxial Crystal	Biaxial Crystal
1.	Having only one optic axis.	Having two optic axes.
2.	Ex : Calcite , Quartz , Tourmaline	Ex : Mica , Topaz , Selenite

---

37. Discuss about Nicol prism.

<u>Nicol Prism :</u>

1. **Nicol prism is an optical device .**
2. **It producing plane polarised light and also anlaysing.**

<u>Principle :</u>

- **Based on double refraction.**

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Construction :

1. Nicol prism is a calcite crystal .
2. Its length is three times of breadth.
3. Angles are 72^0 and 108^0.
4. It is cut into two halves along a diagonal .
5. And then pasted by Canada balsam cement.
6. Unpolarised light is incident on it.
7. Double refraction takes place.
8. The ray is split into ordinary ray and exordinary ray.

S.NO	Rays	Refractive Index
1.	Ordinary Ray	1.658
2.	Exordinary Ray	1.486
3.	Canada Balsam	1.523

---

38. How is polarisation of light obtained by scattering of light ?

1. Sunlight gets scattered by atmospheric molecules.
2. Electrons of the molecules influenced by vibrating component of electric field.
3. Unpolarised sunlight produces vibrations in all directions.
4. Vibrating electrons radiate energy only in perpendicular direction.
5. An observer views a beam of sun light perpendicular to its direction to travel.
6. Hence , light reaching the observer is plane polarised.

---

39. What are near point and normal focussing ?

Near point focussing :

- The eye is least strained when image is formed at near point , i.e 25 cm
- The near point is also called as " least distance of distinct "

$$\boxed{m = 1 + \frac{D}{f}}$$

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Normal Focussing :

- **The eye is most relaxed when the image is formed at infinity.**
- **The focussing is called normal focussing when the image is formed at infinity.**

$$\boxed{m = \frac{D}{f}}$$

---

40. Why is oil immersed objective preferred in a microscope ?

1. Oil immersed objective contributes fine resolution and brightness.

2. These characteristics are most critical under high magnification.

3. So the objectives are designed for oil immersion.

---

41. What are the advantages and disadvantages of reflecting telescope ?

Advantages of reflecting telescope :

1. Only one surface is to be polished and maintained.

2.Support can be given from the entire back of the mirror rather than only at the rim for lens.

3.Mirrors weigh much less compared to lens.

Disadvantages of reflecting telescope :

1.The objective mirror would focus the light inside the telescope tube.

2.One must have an eye piece obstructing some light.

3. This problem could be overcome by introducing secondary mirror which would take the light outside the tube for view.

---

42. What is the use of an erecting lens in a terrestrial telescope ?

A terrestrial telescope has an additional erecting lens to make the final image to erect.

---

43. What is the use of collimator in a spectrometer ?

The collimator is used for producing parallel beam of light.

---

44. What are the uses of spectrometer ?

1. To analyse the spectra of different sources of light .

2. To measure the wavelength of different colours.

3.To measure the refractive indices of materials of prism.

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45. What is myopia ? What is its remedy ?

Myopia :

- **A person suffering from near sightedness.**
- **A person who can not see distant objects clearly.**
- **Due to thickening of eye lens.**
- **Due to larger diameter of eye ball.**

Remedy : **By wearing concave lens.**

---

46. What is hypermetropia ? What is its remedy ?

Hypermetropia :

- **A person suffering from far sightedness.**
- **A person who can not see close objects clearly.**
- **Due to thinning of eye lens.**
- **Due to shortening of eye ball.**

Remedy : **By wearing convex lens.**

---

47. What is astigmatism ? What is remedy ?

Astigmatism :

- **A person can not see all the directions equally well.**
- **Due to different curvature along different planes in the eye lens.**
- **This more serious than myopia and hypermetropia.**

Remedy :

- **Lenses with different curvatures in different in different planes to rectify this defect.**
- **Generally these lenes are called as cylindrical lenses.**

---

48. What is presbyopia ?

Presbyopia :

Far sightedness arising due to aging is called " Presbyopia ".

Remedy : **By wearing convex lens.**

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8.Dual nature of radiation & matter

1.Why do metals have a larger number of free electrons ?

- **In metals the electrons in the outer most shells are loosely bound to the nucleus.**
- **Even at room temperature , there are large number of free electrons which are moving inside the metal in a random manner.**

2.Define work function of a metal. Give its unit.

- **The minimum energy for an electron to escape from metal surface is called " work function " of that metal.**
- **It is denoted by Φ_0. Measured in e V.**

3.What is photo electric effect?

The ejection of electrons from a metal plate when illuminated by light or any other electromagnetic radiation of suitable wavelength is called " Photo electric effect ".

---

4. How does photo current vary with the intensity of the incident light ?

Photo current which is the number of electrons emitted per second is directly proportional to the intensity of the incident light.

---

5. Give the definition of intensity of light according to quantum concept and its unit

Intensity of light is the energy delivered per unit area per unit time. Unit : W m^{-2} or candela.

6.How will you define threshold frequency ?

For a given surface , the emission of photo electrons takes place only if the frequency of incident light is greater than a certain minimum frequency called " threshold frequency "

---

7. What is photo cell ? Mention the different types of photo cells.

<u>Photo electric cell / Photo cell :</u>

A device which converts light energy into electrical energy.

<u>Types of photo cell :</u>

1. Photo emissive cell 2. Photo voltaic cell 3. Photo conductive cell.

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8. Write the expression for the de Broglie wavelength associated with a charged particle of charge q and mass m when it is accelerated through potential V.

1. An electron of mass m is accelerated through a potential difference of V volt.

2. Kinetic Energy = Potential Difference

$$\frac{1}{2} m v^2 = e V$$

3. Speed of electron

$$v = \sqrt{\frac{2 e V}{m}}$$

4. de Broglie wavelength

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2meV}} = \frac{12.27}{\sqrt{V}} Å$$

---

9. State de Broglie hypothesis.

According to de Broglie hypothesis ,

- All matter particles like electron , protons , neutrons in motion are associated with waves.
- These waves are called de Broglie waves or matter waves.

$$\boxed{\lambda = \frac{h}{p} = \frac{h}{mv}}$$

---

10. Why do not see the wave properties of base ball ?

1. de Broglie wavelength : $\lambda = \frac{h}{p} = \frac{h}{mv}$

2. Wavelength associated with base ball is small in the order of 10^{-34} and is difficult to observe.

3. As the value of Planck's constant is very small i.e h = 6.626×10^{-34}

4. Momentum of base ball is very low.

5. So , We can not see the wave properties of base ball.

---

11. A proton and an electron have same kinetic energy. Which one has greater de Broglie wavelength . Justify.

1. de Broglie wavelength : $\lambda = \frac{h}{\sqrt{2 m K.E}}$

2. Kinetic energy : $K.E = \frac{h^2}{2 m \lambda}$

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3. Kinetic energy of proton : $K.E_p = \frac{h^2}{2 m_p \lambda_p}$

4. Kinetic energy of electron : $K.E_e = \frac{h^2}{2 m_e \lambda_e}$

5. Proton and an electron have same kinetic energy.

$$K.E_p = K.E_e$$

$$\frac{h^2}{2 m_p \lambda_p} = \frac{h^2}{2 m_e \lambda_e}$$

$$\frac{\lambda_e}{\lambda_p} = \frac{m_p}{m_e}$$

6. m_p / m_e is greater than one then $\lambda_e > \lambda_p$.

7. Hence , electron has greater de Broglie wavelength.

---

12. Write the relationship of de Broglie wavelength λ associated with a particle of mass m in terms of its kinetic energy K.

1. Kinetic Energy = Potential Difference

$$\frac{1}{2} m v^2 = e V$$

2. Speed of electron

$$v = \sqrt{\frac{2 e V}{m}}$$

3. de Broglie wavelength

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2meV}}$$

$$\lambda = \frac{h}{\sqrt{2 m K}}$$

4. Kinetic energy of electron $K = e V$.

---

13. An electron and alpha particle have same kinetic energy . How are the de Broglie wavelength associated with them related.

1. de Broglie wavelength : $\lambda = \frac{h}{\sqrt{2mK}}$

2. For electron : $\lambda_e = \frac{h}{\sqrt{2 m_e K_e}}$

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3. For alpha particle : $\lambda_\alpha = \dfrac{h}{\sqrt{2m_\alpha K_\alpha}}$

4. An electron and alpha particle have same kinetic energy .

$$\frac{h}{\sqrt{2\, m_e\, K_e}} = \frac{h}{\sqrt{2\, m_\alpha\, K_\alpha}}$$

5. $\lambda_e = \lambda_\alpha$ then $m_e < m_\alpha$ and $K_e > K_\alpha$

6. Kinetic energy of electron is greater than kinetic energy of alpha particle.

---

14. Define stopping potential.

The minimum negative potential given to the anode which stops the emission of photo electrons and make photo electric current zero.

---

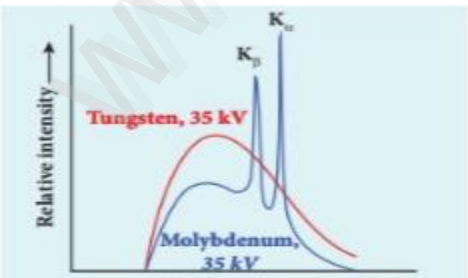
15. What is surface barrier ?

The potential barrier which prevents free electrons from leaving the metallic surface is called " surface barrier ".

---

16. Mention the two features of x- ray spectra , not explained by classical electromagnetic theory.

1. For a given accelerating voltage , the lower limit for the wavelength of continuous X – ray spectra is same for all targets. This minimum wavelength is called " cut – off wavelength ".
2. The intensity of X – ray is increased at certain well defined wavelength of characteristics X – ray spectra for molybdenum.



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17. What is Bremsstrahlung ?

In continuous X – ray spectra :

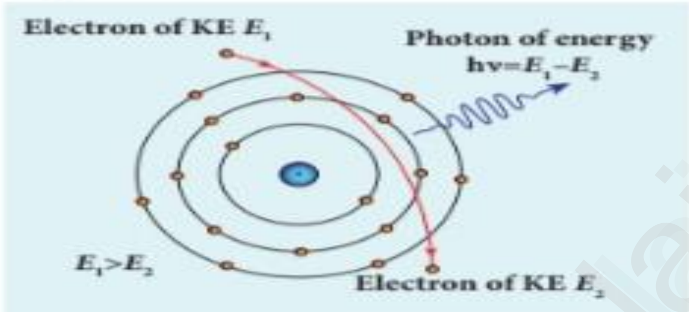
1. When a fast moving electron penetrates and approaches a target nucleus.

2. The interaction between electron and nucleus either accelerates or decelerates.

3. In which results in a change of path of the electron.

4. The radiation produced from such decelerating electron is called " Bremsstrahlung ".

5. It is also known as " braking radiation "



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9. Atomic And Nuclear Physics

1. What are cathode rays ?

1. In the discharge tube , when the pressure reaches to around 0. 01 mm of Hg , positive column disappears .

2. At this time , dark space is formed between cathode and anode.

3. It is known as " Crooke's dark space ".

4. The walls of the tube appear with green colour.

5. Invisible rays emanate from cathode called as cathode rays i.e beam of electrons.

---

2. Write the properties of cathode rays.

1. Cathode rays ionize the gas through which they pass.

2.The speed of cathode rays is up to (1 / 10 th) of the speed of light.

3. When cathode rays fall on a material of high atomic weight , X – rays are produced .

4. When the cathode rays are allowed to fall on matter , heat is produced. It affect the photographic plate and produce fluorescence.

5. Cathode rays posses energy and momentum and travel in a straight line with high speed 10^7 ms^{-1} . It can be deflected by the application of electric and magnetic field. It indicates negatively charged particle.

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3. Give the results of Rutherford alpha scattering experiment.

1. Most of the alpha particles were in deflected through the gold foil and went straight.

2. Some of the alpha particles were deflected through a small angle.

3. A few alpha particles were deflected through the angle more than 90^0.

---

4. Write down the postulates of Bohr atom model.

1. The electron in an atom moves around the nucleus in circular orbit under the influence of Coulomb electrostatic force of attraction . This Coulomb force gives necessary centripetal force for the electron to under go circular motion.

2. Electrons in an atom revolve around the nucleus only in certain discrete orbits called stationary orbits and electron in such orbits do not radiate electromagnetic energy . Only those discrete orbits allowed are stable orbits.

---

5. What is meant by excitation energy ?

The energy required to excite an electron from lower energy state to higher energy state is known as " Excitation energy "

For hydrogen atom $E = E_2 - E_1 = -3.4\ eV - (-13.6\ eV) = 10.2\ eV$.

---

6. Define ionization energy and ionization potential.

<u>Ionization Energy :</u>

The minimum energy required to remove an electron from an atom in the ground state is known as binding energy or ionization energy.

$$I_{ionization} = E_{\infty} - E_1 = 0 - (-13.6\ eV) = 13.6\ eV$$

<u>Ionization Potential :</u>

Ionization energy per unit charge is called as ionization potential.

$$V_{ionization} = \frac{1}{e} E_{ionization} = \frac{13.6}{n^2} Z^2\ V$$

---

7. Write down the drawbacks of Bohr atom model.

1. Bohr atom model is valid only for hydrogen atom or but not for complex atoms.

2. When spectral lines are closely examined , individual lines of hydrogen spectrum are accompanied by a number of faint lines. This is called fine structure. This can not be explained by Bohr atom model.

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3. Bohr atom model fails to explain the intensity variations in the spectral lines.

4. The distribution of electrons in various levels cannot be completely explained by Bohr atom model.

---

8. What is distance of closest approach ?

- **The minimum distance between the centre of the nucleus and alpha particle just before it gets reflected back through 180^0 .**
- **It is the defined as the distance of "closest approach" (r_0) .**
- **Also known as " contact distance "**

$$\boxed{r_0 = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{E_K}}$$

9.Define impact parameter.

The impact parameter is defined as the perpendicular distance between the centre of the gold nucleus and the direction of velocity vector of alpha particle when it is at a large distance.

$$\boxed{b = K \cot(\theta / 2)}$$

---

10. Write a general notation of nucleus of element X . What does each term denotes.

General notation of nucleus of element : $_ZX^A$

A - Mass number Z - Atomic number

---

11. What is isotope ? Give an example.

Isotopes are the atoms of the same element having same atomic number Z but different mass number A .

<u>Example :</u> **$_1H^1$ (Hydrogen) , $_1H^2$ (Deuterium) , $_1H^3$ (Tritium)**

---

12. What is isotone ? Give an example.

Isotones are the atoms of the different element having same number of neutrons .

<u>Example :</u> **$_5B^{12}$ and $_6C^{13}$ which has 7 neutrons.**

---

13. What is isobar ? Give an example.

Isobar are the atoms of the different elements having same mass number A but different atomic number Z .

<u>Example :</u> **$_{16}S^{40}$ and $_{17}Cl^{40}$.**

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14. Define atomic mass unit.

One atomic mass unit (u) defined as the 1 / 12th of the mass of the isotope of carbon $_6Cl^{12}$ which is more abundant in naturally occurring isotope of carbon.

$$\boxed{1\ u = 1.66 \times 10^{-27}\ kg}$$

$$\text{One amu} = 1\ u = \frac{\text{mass of } _6Cl^{12} \text{ atom}}{12} = \frac{1.9926 \times 10^{-26}}{12} = 1.66 \times 10^{-27}\ kg.$$

---

15. Show that nuclear density is almost constant for nuclei with Z > 10.

1. The nuclei of atoms are found to be approximately spherical in shape .

2. It is experimentally found that radius of nuclei for Z > 10 , satisfies the empirical formula

$$\boxed{R = R_0\ A^{1/3}}$$

Mass number → A ; R_0 = 1.2 F = 1.2×10^{-15} m

$$\text{3. Nuclear density} = \frac{\text{Mass of the nuclei}}{\text{Volume of the nuclei}} = \frac{m}{\frac{4}{3}\pi R_0^{\ 3}}$$

4. Nuclear density is independent of the mass number A.

5. All the nuclei Z > 10 have same density and it is an important characteristics property of all nuclei.

---

16. What is mass defect ?

The mass of any nucleus is less than the sum of the mass of its individual constituents. This difference in mass Δ m is called as " mass defect ".

$$\boxed{\text{Mass Defect : } \Delta m = (Z m_p + N m_n) - M}$$

- **m_p → Mass of the proton m_e → Mass of the electron**
- **M → Mass of the nucleus Z → Atomic number**

---

17. What is the binding energy of a nucleus ? Give its expression.

- **When the protons and neutrons combine to form a nucleus , mass equal to mass defect disappears and the corresponding energy is released .**
- **The energy equivalent of mass defect is known as " Binding energy ".**
- **From the Einstein mass – energy relation : B.E = $\Delta m c^2$**

$$\boxed{B.E = \Delta m c^2 = (Z m_p + N m_n - M) c^2}$$

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18. Calculate the energy equivalent of 1 atomic mass unit ?

From the Einstein mass – energy relation we can able to calculate the energy equivalent of one atomic mass unit .

$$E = m\,c^2 = 1.66 \times 10^{-27} \times 3 \times 10^8 = 14.94 \times 10^{11}\ J.$$

$$E = \frac{14.94 \times 10^{11}}{1.6 \times 10^{-19}}\ eV = 931 \times 10^6\ eV = 931\ MeV.$$

---

19. Give the physical meaning of binding energy per nucleon.

The average binding energy per nucleon is the energy required to separate single nucleon from the particular nucleus.

$$\overline{B.E} = \Delta m c^2 = \frac{(Z m_p + N m_n - M)\ c^2}{A}$$

---

20. What is meant by radioactivity ?

The phenomenon of spontaneous emission of highly penetrating radiations such as α , β and γ Rays by an element is called " radioactivity " and the substances which emit these radiations are called as radioactivity elements . (Z > 82)

---

21. Give the symbolic representation of alpha decay , beta decay and gamma emission.

1. Alpha Decay :

$${}_Z X^A \longrightarrow {}_{Z-2} Y^{A-4} + {}_4 He^2$$

X ⟶ **Parent nucleus**

Y ⟶ **Daughter nucleus**

$_4He^2$ ⟶ **Alpha particle**

2. Beta Decay :

$${}_Z X^A \longrightarrow {}_{Z+1} Y^A + e^- + \bar{\upsilon}$$

e^- ⟶ **Positron**

$\bar{\upsilon}$ ⟶ **Anti neutrino**

3. Gamma Emission :

$${}_Z X^{*A} \longrightarrow {}_Z X^A + \gamma \text{ rays}$$

X^* ⟶ **Excited state of nucleus**

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22. In alpha decays , why the unstable nucleus emits $_4He^2$ nucleus ? Why it does not emit four separate nucleons ?

1. $_4He^2$ nucleus consists of two protons and two neutrons.

2. If $_{92}U^{228}$ nucleus decay into $_{90}Th^{224}$ by emits four separate nucleons then disintegration energy Q for this process turn to negative.

3. It implies that the total mass of product is greater than that of parent nucleus.

4. This kind of process cannot occur in nature because it would violate conservation of energy.

5. In any decay process , the conservation of energy , conservation of linear momentum and angular momentum must be obeyed.

---

23. What is mean life of a radioactive nucleus ? Give its expression.

The mean life of radioactive nucleus is defined as the ratio of sum or integration of life times of all nuclei to the total number nuclei present initially.

$$\boxed{\tau = \frac{\int^{t} t\,[\lambda N_0 e^{-\lambda t}\,dt]}{N_0}}$$

---

24. What is half – life of a radioactive nucleus ? Give the expression.

The half – life of radioactive nucleus is defined as the time required for the number of atoms initially present to reduce to one half of the initial amount.

$$\boxed{T_{1/2} = \frac{0.6931}{\lambda} = 0.6931\,\tau}$$

---

25. What is meant by activity or decay rate ? Give its unit.

At any instant t , the number of decay per unit time called rate of decay is proportional to the number of nuclei at the same instant.

$$\boxed{\frac{dN}{dt} \propto N \quad ; \quad \frac{dN}{dt} = -\lambda N}$$

λ Decay constant

---

26. Define curie.

Number of decays per second in 1 gram of radius is defined as one curie and is equal to 3.7×10^{10} decays per second

1 Curie = 1 Ci = 3.7×10^{10} decays per second = 3.7×10^{10} Becquerel.

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27.What are constituent particles of neutron and proton ?

- **Protons and neutrons are not fundamental particles.**
- **They are made up of quarks.**
- **There are six types of quarks.**
- **They are namely up , down , charm , strange , top and bottom and their anti particles.**

---

10. Electronics and Communication

1.Define forbidden energy .

The energy gap between valence band and conduction band is called " forbidden energy gap".

$$\boxed{E_g = E_c - E_v}$$

---

2. Why is temperature co – efficient of resistance of resistance for semiconductor ?

1. The resistivity value of semiconductor is from 10^{-5} Ω m to 10^{6} Ω m.

2. When the temperature is increased further more number of electrons are promoted to the conduction band and increase conduction.

3. Electrical conduction increases with the increase in temperature.

4. Resistance decreases with increase in temperature.

5. So, semiconductors said to have negative temperature co efficient of resistance.

---

3. What do you mean by doping ?

1. Process of adding impurities to the intrinsic semiconductors.

2. The impurity atoms are called dopants in 100 ppm.

---

5. A diode is called as unidirectional device. Explain.

1. Current flows in only one direction.

2. When forward voltage is applied the diode conducts and when reverse voltage is applied there is no conduction.

3. So , diode conducts only one direction , it is a unidirectional device.

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4. Distinguish between intrinsic and extrinsic semiconductors .

S. NO	Intrinsic semiconductors	Extrinsic Semiconductors
1.	Pure form of semiconductor without any impurity.	Adding impurity to intrinsic semiconductors
2.	No doping takes place here.	Here , doping takes place.
3.	It has bad electrical characteristics.	It has good electrical conductivity.
4.	Number of free electrons in conduction is equal to number of holes in valence band.	Number of free electrons and holes are not equal.
5.	Ex : Pure Si , Pure Ge	Ex : n – type semiconductor , p - type semiconductor

---

6. What do you mean by leakage current in diode ?

1. When the junction diode is under reverse bias condition , a very small current in the range of μ A , flows across the junction.

2. This is due to flow of minority charge carrier.

3.This current is called as leakage current or reverse saturation current.

4. Leakage current is independent of applied voltage.

---

7. Draw the input and output of a full wave rectifier.

<u>Input and output waveforms:</u>

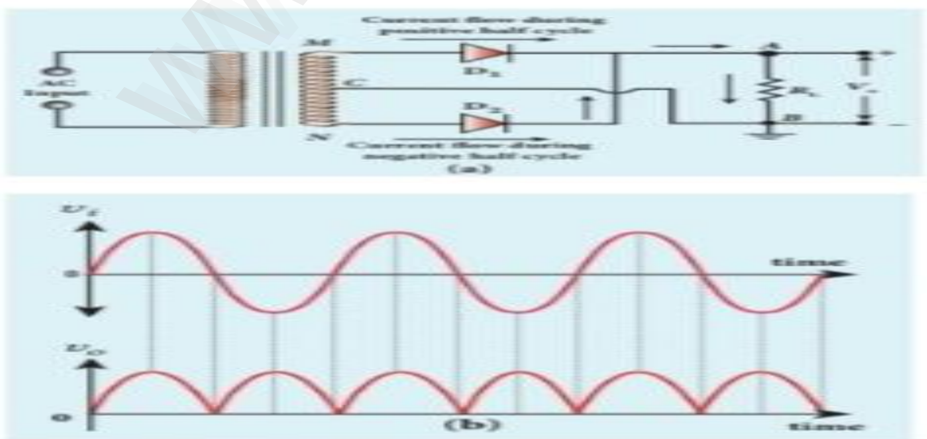

Figure 10.18 (a) Full wave rectifier circuit (b) Input and output waveforms

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8. Distinguish between avalanche breakdown and Zener breakdown.

S.NO	Avalanche Breakdown	Zener Breakdown
1.	It occurs in lightly doped p-n junction.	It occurs in heavily doped p-n junction.
2.	It has wide depletion layer.	It has narrow depletion layer. (> 10^{-6} m)
3.	Electric field is weak.	Electric field is strong. (3×10^{7} V m^{-1})
4.	Breakdown voltage vary.	Breakdown voltage constant.

---

9. Give the Barkhausen conditions for sustained oscillations.

1. There should be positive feedback.
2. Loop phase shift must be 0^0 .
3. Integral multiples of 2π .
4. Loop gain must be unity $|A\beta| = 1$.
5. Voltage gain of amplifier $\longrightarrow$ A
6. Feed back ratio $\longrightarrow$ β (the fraction of the output that is fed back to the input)

---

10. Explain the current flow in a N P N transistor.

1. In N P N transistor electron flow from emitter to collector. So conventional current flow from collector to emitter.
2. Electrons from emitter region flow towards base region constitute emitter current (I_E)
3. Electrons after reaching base region recombine with holes.
4. Most of electrons reach collector region.
5. This constitute collector current . (I_C).
6. After recombination of holes in base region by bias voltage constitute base current . (I_B)

$$\boxed{I_E = I_B + I_C}$$

---

11. What are logic gates ?

1. A logic gate is an electronic circuit whose function is biased on digital signals. They are binary in nature.
2. The logic gates are considered as the basic building blocks of most of the digital systems.
3. They have one output with one or more inputs.

4. There are three types of basic logic gates : AND , OR , NOT

5. There are two types of universal logic gates : NAND , NOR.

---

12. Explain the need for a feedback circuit in a transistor oscillator.

1. Feedback is the fraction of output from an amplifier circuit is returned or fed to the input.
2. If the portion of the output fed to the input is in phase with the input , then the magnitude of the input signal increases.
3. It is necessary for sustained oscillations.

---

13. Write a short note on diffusion current across p-n junction.

1. A single piece of semiconductor crystal is suitably doped such that its one side is p – type semiconductor and the other side is n – type semiconductor.
2. The contact surface between the two sides is called p-n junction.
3. Whenever p-n junction is formed , some of the free electron diffuse from the n – side to the p – side while the holes from p – side to the n – side.
4. The diffusion of the majority charge carriers across the junction gives to an electric current called diffusion current.

---

14. What is meant by biasing ? Mention its types.

Biasing :

Biasing means providing external energy to charge carriers to overcome the barrier potential and make them move in a particular direction.

Types of biasing :

1. Forward Bias 2. Reverse Bias

---

15. Why can't we interchange the emitter and collector even though they are made up of the same type of semiconductor material ?

1. Emitter is more heavily doped than the other two regions.
2. Collector is made physically larger than the other two as it has to dissipate more power. It is moderately doped.
3. Because of the differing size and the amount of doping , the emitter and collector cannot be interchanged.

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16. Why are NOR and NAND gates called universal gates ?

1. NOR and NAND gates are called universal gates because they perform all the logical operations of basic gates like AND , OR , NOT.

2. It can be used to form any other logic or Boolean function.

---

17. Define barrier potential.

The internal repulsion of the depletion layer stops further diffusion of free electrons across the junction. This difference in potential across the depletion layer is called " barrier potential "

---

18. What is rectification ?

The process in which alternating voltage or alternating current is converted into direct voltage or direct current is known as " rectification ".

---

19. List the application of light emitting diode.

1. Remote controller of television , air conditioner etc. 2. Seven segment displays.

3. Traffic signals , emergency vehicle lighting. 4. Indicator lamps on the front of scientific lab.

---

20. Give the principle of solar cells.

1. A solar cell also known as photovoltaic cell works on the principle of " photovoltaic effect "

2. Accordingly , the p-n junction of the solar cell generates emf when solar radiation falls on it.

---

21. What is an integrated circuit ?

1. An integrated circuit is also referred as an IC or a chip or a microchip.

2. It consists of thousands to millions of transistors , resistors , capacitors etc.

3. They are integrated on a small flat piece of semiconductor material that is normally silicon.

4. Main merits over ordinary circuits : 1.cost & performance. 2. size , speed capacity of chips.

---

22. What is modulation ?

For long distance transmission , the low frequency base band signal is superimposed onto a high frequency radio signal by a process called " modulation ".

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23. Define bandwidth of transmission system.

The range of frequencies required to transmit a piece of specified information in a particular channel is called " bandwidth " or the bandwidth of the transmission system.

---

24. What do you mean by skip distance ?

The shortest distance between the transmitter and the point of reception of the sky wave along the surface is called as the " skip distance ".

---

25. Give applications of RADAR.

1. Used for locating and detecting the targets.

2. Used to locate and rescue people in emergency situations.

3. Used to measure precipitation rate and wind speed in meteorological observations.

4. Used in navigation systems such as ship borne surface search , air search and missile guidance systems.

---

26. Explain centre frequency or resting frequency in frequency modulation.

When the frequency of the baseband signal is zero , there is no change in the frequency of the carrier wave. It is at its normal frequency and is called as " centre frequency " or " resting frequency " .

---

27. What des RADAR stand for ?

Radio Detection And Ranging system stands for RADAR.

---

11. Recent Development In Physics

1. Distinguish between Nanoscience and Nanotechnology.

Nanoscience	Nanotechnology
Nanoscience is the science of objects with typical sizes of 1 – 100 nm. One nano meter = 10^{-9} meter	Nanotechnology is a technology involving in the design , production , characterization and application of nano structured materials

---

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2. What is the difference between Nanomaterials and bulk materials ?

Nanomaterial	Bulk material
If the particle of a solid is of size less than 100 nm , it is said to be a non solid or nano materials.	When the particle size exceeds 100 nm , it is a bulk solid or bulk material.

---

3. Give any two examples for nano in nature.

Single strand of DNA , peacock feather , morpho butterfly , parrot fish and lotus leaf surface.

---

4. Mention any two advantages and disadvantages of robotics.

Advantages of Robotics :

1. The robots are much cheaper than humans.

2. Robots never get tired like humans.

3. Stronger and faster than humans.

4. IN warfare , robots can save human lives.

5. Robots are more precise and error free in performing the task.

Disadvantage of Robotics :

1. Robots have no sense of emotions or conscience.

2. They lack empathy and hence create an emotionless workplace.

3. Unemployment problem will increase.

4. The robots are well programmed to do a job and if a small thing goes wrong it ends up in a big loss to the company.

5. Human cannot be replaced by robots in decision making.

---

5. Why steel is preferred in making robots ?

In general robots are made up of common metals like aluminium and steel which are the most common metals . Aluminium is a softer metal and is therefore easier to work with , but steel is several times stronger.

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6. What are black holes ?

1. Black holes are end stage of stars which are highly dense massive object.

2. Its mass range from 20 times mass of the sun to 1 million times mass of the sun.

3. It has very strong gravitational force such that no particle or even light cannot escape from it.

4. The existence of black holes is studied when the stars orbiting the black hole behave differently from the other stars.

5. Every galaxy has black hole at its centre.

6. Sagittarius A* is the black hole at the center of the Mliky Way galaxy.

7. Black holes are the source of gravitational waves.

---

7. What are sub atomic particles?

Electron, proton, and neutron.

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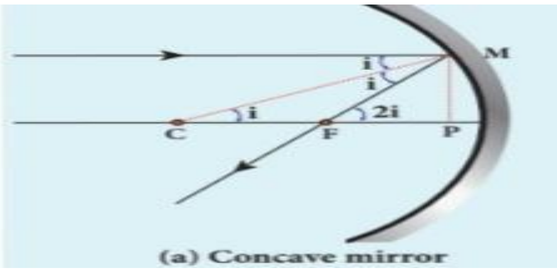
6. RAY OPTICS

1.What is angle of deviation due to reflection ?

The angle between the incident ray and deviated ray of light is called " angle of deviation ".

---

2. Derive the relation between f and R for a spherical mirror.



$\boxed{2f = R}$

Consider a ray of light parallel to the principal axis is incident on the mirror at M.

- **Centre of curvature - C**
- **Principal Focus - F**
- **Angle of incidence - i**
- **Angle of reflection - r**
- **MP perpendicular from M**
- **< MCP = i and < MFP = 2 i**

$\triangle$ MCP	$\triangle$ MFP
$\tan i = \frac{PM}{PC}$	$\tan 2i = \frac{PM}{PF}$
$i = \frac{PM}{PC}$	$2i = \frac{PM}{PF}$

- **Angles are small , tan i = i and tan 2i = 2i.**

$$2i = \frac{PM}{PF}$$

$$2\frac{PM}{PC} = \frac{PM}{PF}$$

$$2\,PF = PC$$

- **Focal length PF = f ; Radius of curvature PC = R**

$\boxed{2f = R}$

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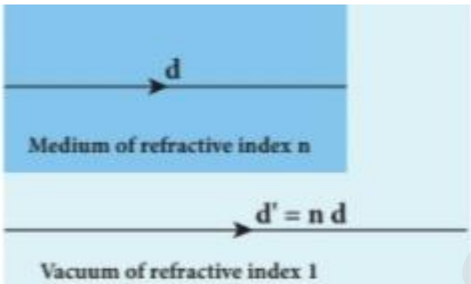
3. What are the Cartesian sign conventions for spherical mirrors ?

1. Incident light is taken from left to right.
2. All distances are measured from pole of the mirror.
3. Distance measured to right of the pole is positive and to the left is negative.
4. Heights measured in the upward perpendicular direction is positive and downward is negative.

---

4. What is optical path ? Obtain the equation for optical path.

Optical path of a medium is defined as the distance d' light travels in vacuum in the same time it travels a distance d in the medium.



- Refractive index of a medium = n
- Thickness of a medium = d

Speed of light through medium

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

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

Speed of light through vacuum

$$c = \frac{d'}{t}$$

$$t = \frac{d'}{c}$$

$$\frac{d'}{c} = \frac{d}{v}$$

$$d' = \frac{c}{v}\, d$$

$$d' = n\, d$$

$$\boxed{d' = n\, d}$$ Here $n > 1$ then $d > d'$

---

5. State Snell's law / law of refraction.

1. The incident ray , refracted ray and normal to the refracting surface are all coplanar . (lie in same plane)

2.The ratio of sine of angle of incident i in the first medium to the angle of reflection r in the second medium is equal to the ratio of refractive index n_2 of the second medium to the refractive index n_1 of the first medium.

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} \quad ; \quad n_2 \sin i = n_1 \sin r$$

---

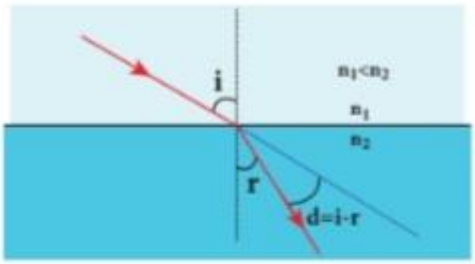
6. What is the angle of deviation due to refraction ?

- **When light travels from rarer to denser medium , it deviates towards normal.**

Angle of deviation $\boxed{d = i - r}$

- **When light travels from denser to rarer medium , it deviates towards normal.**

Angle of deviation $\boxed{d = r - i}$



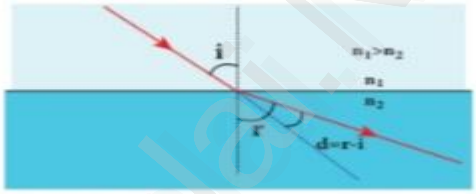


Figure 6.17 Angle of deviation due to refraction from denser to rarer medium

---

7. What is principle of reversibility ?

The principle of reversibility states that light will follow exactly the same path if its direction of travel is reversed.

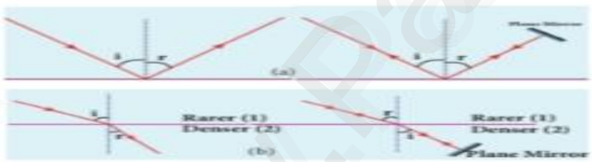


Figure 6.19 Principle of reversibility in (a) reflection and (b) refraction

---

8. What is relative refractive index ?

From Snell's law , $\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$ $\boxed{n_{21} = \frac{n_2}{n_1}}$

- **The term** (n_2 / n_1) **is called relative refractive index of second medium with respect to first medium which is denoted as** n_{21}.

---

9. Obtain the equation for apparent depth.

Light from the object O at the bottom of the tank passes from denser medium to rarer medium to reach our eyes for viewing the object.

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- Refractive index of denser medium ⟶ n_1
- Refractive index of rarer medium ⟶ n_2
- Angle of incidence ⟶ i
- Angle of refraction ⟶ r

Diagram :

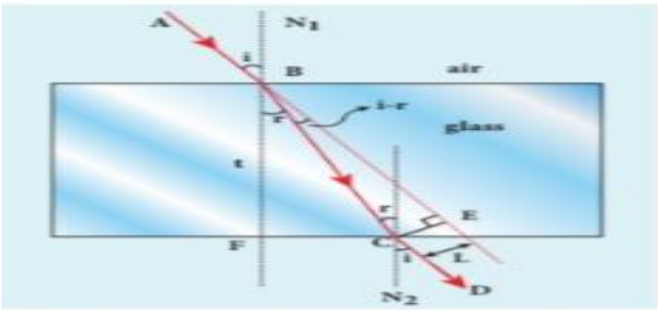

Figure 6.30 Refraction in glass slab

- Snell's law in product form of reflection : $n_1 \sin i = n_2 \sin r$
- If angles are small then $\sin i = \tan i$; $\sin r = \tan r$.

$$n_1 \tan i = n_2 \tan r$$

$\triangle$ DOB	$\triangle$ DIB
$\tan i = \dfrac{DB}{DO}$	$\tan r = \dfrac{DB}{DI}$

$$n_1 \tan i = n_2 \tan r$$

$$n_1 \frac{DB}{DO} = n_2 \frac{DB}{DI}$$

$$n_1 \frac{1}{d} = n_2 \frac{1}{d'}$$

$$\frac{d'}{d} = \frac{n_2}{n_1}$$

$$\boxed{d' = d \frac{n_2}{n_1}}$$

---

10. Why do stars twinkle ?

- The stars actually do not twinkle.
- Due to refraction of light through different layers of atmosphere which vary in

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refractive index , the path of light deviates continuously when it passes through atmosphere.

---

11. What are critical angle and total internal reflection ?

Critical Angle :

The angle of incidence in the denser medium for which the angle of refraction is 90^0 (or) the refracted ray graces the boundary between the two media is called "critical angle" i_c .

$$\boxed{i_c = \sin^{-1} (1 / n)}$$

Total internal reflection :

For any angle of incidence greater than the critical angle , the entire light is reflected back into the denser medium itself. This phenomenon is called " total internal reflection "

Condition for total internal reflection :

1. Light travel from denser to rarer medium.

2. Angle of incidence in the denser medium must be greater than critical angle. ($i > i_c$)

---

12. Obtain the equation for critical angle.

- **When ray passes from an optically denser medium to rarer medium . (r > i)**
- **i gradually increased , r increases it becomes 90^0. ($r = 90^0$)**
- **Refracted ray graces the boundary between the two media is called "critical angle" $i = i_c$**

Snell's law in product form

$$n_1 \sin i = n_2 \sin r$$

$$n_1 \sin i_c = n_2 \sin 90^0$$

$$n_1 \sin i_c = n_2$$

$$\sin i_c = \frac{n_2}{n_1}$$

$$\boxed{i_c = \sin^{-1} (n_2 / n_1)}$$

If $n_2 = 1$ and $n_1 = n$ then ,

$$\boxed{i_c = \sin^{-1} (1 / n)}$$

---

13 . Explain the reason for glittering of diamond.

1. Diamond appears dazzling because of total internal reflection happens inside it.

2. Refractive index of diamond is about 2.417 much greater than glass is about 1.5

3. Critical angle of diamond is about 24.4^0 much less than ordinary glass.

4.A skilled diamond cutter makes use of this large range of angle of incidence 24.4^0 to 90^0.

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5. To ensure that light entering the diamond is total internally reflected from the many cut faces before getting out.

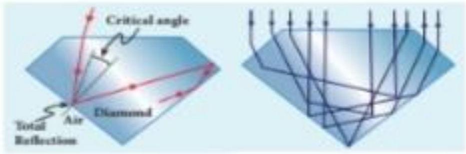
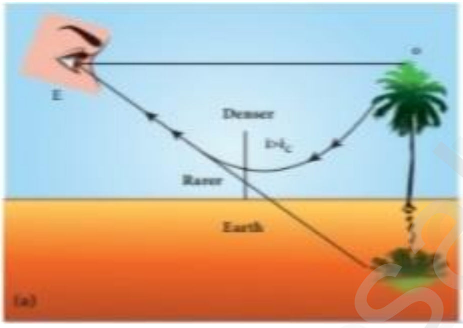


Figure 6.22 Total internal reflection in diamond

14.What are mirage and looming ?

Mirrage :



1. In hot places , air near the ground is hotter than air at height. Hot air is less dense.
2. Refractive index of air increases with height and its density.
3. Light from tall objects like a tree , try to pass through medium whose refractive index decreases towards ground.
4. Ray of light deviates away from normal at different layer of air.
5. It undergoes total internal reflection when the angle of incidence near the ground exceeds critical angle.
6. This gives an illusion as if the light comes from somewhere below the ground.
7. The shaky nature of the layers of air , the observer feels as if the object is getting reflected by pool of water.

Looming :

1. In cold regions like glaciers and frozen lakes , the reverse effect of mirage will happen.
2. Hence an inverted image is formed little above the surface .
3. This phenomenon is called " looming "
4.It is also called as " superior mirage " towering and stooping .

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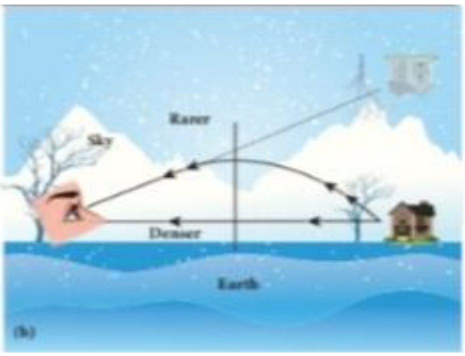

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15. Write short note on the prism making use of total internal reflections.

- **Prisms can be designed to reflect light by 90^0 or 180^0 by making use of total internal reflection .**
- **$i_c >$ 45^0 , the critical angle i_c for the material of the prism must be less than 45^0.**

---

16. What is Snell's window ?

When the light entering the water from outside is seen from inside the water , the view is restricted to a particular angle equal to the critical angle i_c . The restricted illuminated circular area is called " Snell's window "

17.How does an endoscope work ?

- **An endoscope which has a bundle of optical fibres is an instrument used by doctors to see inside of a patient's body.**
- **Endoscope work on the phenomenon of total internal reflection.**
- **Optical fibres are inserted into the body through mouth , nose (or) special hole made in the body.**
- **Even operations could be carried out with the endoscope cables which have the necessary instruments attached at their ends.**

---

18. What are primary focus and secondary focus of a lens ?

<u>Primary Focus :</u>

The primary focus F_1 is defined as a point where a point source kept produces a parallel emergent rays to the principal axis after passing through lens.

<u>Secondary Focus :</u>

The secondary focus F_2 is defined as a point where all the parallel rays travelling close to the principal axis converge to form an image on the principal axis after passing through lens.

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19. What are the sign conventions followed for lenses ?

1) **Incident light is taken from left to right.**
2) **All the distances measured from the pole.**
3) **Distance measured to the right of pole along the principal axis taken as positive.**
4) **Distance measured to the left of pole along the principal axis taken as negative.**
5) **Heights measured in the upward perpendicular direction to the principal axis taken as positive.**
6) **Heights measured in the downward perpendicular direction to the principal axis taken as negative.**

---

20. Arrive lens equation from lens maker's formula.

1. Len's maker's lens :

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

2. General equation for refraction at a spherical surface :

$$\frac{1}{v} - \frac{1}{u} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

3. Len's Equation :

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

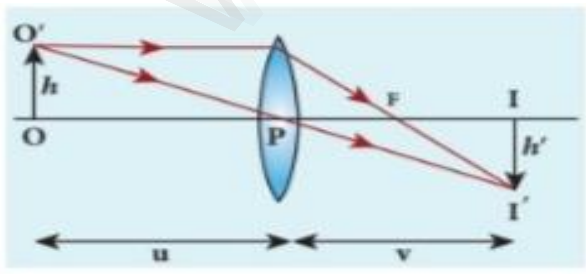
---

21. Obtain the equation for lateral magnification of thin lens.

Theory :

- **Object** → **O O'**
- **Image** → **I I'**
- **Height** → **h , h'**

Diagram :



Formula :

$$m = \frac{f}{f+u} = \frac{f-v}{f}$$

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Lateral Magnification or Transverse magnification :

It is defined as the ratio of the height of the image to height of the object.

- **Similar triangles Δ P O O' and Δ P I I'**

$$m = \frac{I\,I'}{O\,O'} = \frac{P\,I}{PO}$$

- **On applying sign convention**

$$m = -\frac{h'}{h} = \frac{v}{-u}$$

- **Magnification :**

$$m = \frac{h'}{h} = \frac{v}{u}$$

- **Magnification is negative for real image.**
- **Magnification is positive for virtual image.**
- **Magnification always positive for concave lens and less than one.**

---

22. What is power of a lens ?

1. The power of a lens is a measure of the degree of convergence or divergence the lens produces on the light falling on it.

$$P = \frac{1}{f}$$ **S I Unit : dioptre**

2. The power of lens P is the reciprocal of focal length.

---

23. Derive the effective focal length for lenses in contact.

Diagram :

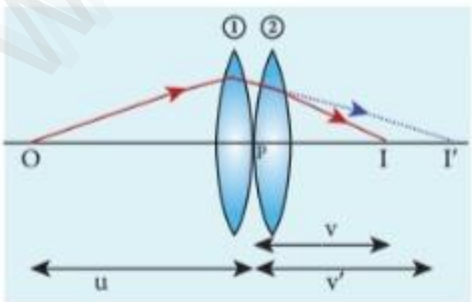

Figure. 6.37 Lenses in contact

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Theory :

1. Consider two lenses of focal length f_1 and f_2 in contact with each other and have a common principal axis.

2. An object placed at O beyond the focus of first lens , an image is formed by it at $I^{/}$.

3.This image acts as an object for the second lens and the final image is formed at I.

4. As two lenses are thin , P is common optical centre in the middle of the two lenses.

Len's equation for lens 1

$$\frac{1}{v^{/}} - \frac{1}{u} = \frac{1}{f_1} \longrightarrow (1)$$

Len's equation for lens 2

$$\frac{1}{v} - \frac{1}{v^{/}} = \frac{1}{f_2} \longrightarrow (2)$$

Adding equation (1) & (2)

$$\frac{1}{v^{/}} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v^{/}} = \frac{1}{f_1} + \frac{1}{f_2} \longrightarrow (3)$$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$$

we know that , $\boxed{\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}}$

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

---

25. What is dispersion ?

Dispersion is splitting of white light into its constituent colours. This band of colours of light is called its spectrum.

---

26. How are rainbows formed ?

1. Rainbow is an example of dispersion of sunlight through droplets of water during rainy days.

2.When sunlight falls on the water drop suspended in air , it splits into its constituent seven colours . Thus , water drop suspended in air behaves as a glass prism.

3.There are two types primary rainbow and secondary rainbow.

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27. What is Rayleigh's scattering ?

1. If the scattering of light is by atoms and molecules which have size ' a ' very much less than that of the wavelength ' λ ' of light , (a < < λ) then the scattering is called " Rayleigh's scattering "

2. The intensity of Rayleigh's scattering is inversely proportional to fourth power of wavelength.

$$\boxed{I \ \alpha \ \frac{1}{\lambda^4}}$$

----

28. Why does sky appear blue ?

1. Violet colour which has the shortest wavelength gets much scattered during day time.

2. The next scattered colour is blue.

3. As our eyes are more sensitive to blue colour than violet colour the sky appears blue during day time.

----

29. What is the reason for reddish appearance of sky during sunset and sunrise ?

1. During sunrise and sunset , the light from sun travels a greater distance through the atmosphere.

2.Hence , the blue light which has shorter wavelength is scattered away and the less scattered red light of longer wavelength to reach our eye.

----

30. Why do clouds appear white ?

1. Clouds contains large amount of dust and water droplets.

2. Thus , in clouds all the colours get equally scattered irrespective of wavelength .

3. So it appears white.

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7. Wave Optics

1.What are the salient features of corpuscular theory of light ?

1.Light is emitted as tiny , massless and perfectly elastic particles called " corpuscles "

2. As the corpuscles are very small , the source of light does not suffer loss of mass even if it emits light for long time.

3.They are unaffected by the force of gravity and their path is a straight line in a medium of uniform refractive index.

4.The energy of light is the K.E of these corpuscles. It impinge on the retina of the eye , the vision is produced.

5. When it approach surface between two media , they are either repel or attract.

i) Reflection due to repulsion ii) Refraction due to attraction.

2.What are the important points of wave theory of light ?

1. Light is a disturbance from source travels that as longitudinal mechanical waves through the ether medium , as mechanical wave requires medium for propagation.

2.The wave theory explain the phenomenon of reflection , refraction , interference and diffraction of light.

---

3. What is the significance of electromagnetic wave theory of light ?

1. Maxwell proved that light is an em wave which is transverse in nature.

2.No medium is necessary for the propagation of em waves.

3. All the phenomenon of light could be successfully explained by this theory.

4.Write a short note on quantum theory of light.

1). It explain photoelectric effect in which light interacts with matter as photons to eject the electrons.

2). A photon is a discrete packet of energy $E = h\gamma$

- **Planck's constant $h = 6.625 \times 10^{-34}$ J s . Frequency of em wave $\longrightarrow \gamma$**

3.As light has both wave as well as particle nature it is said to have dual nature.

4.It is concluded that light propagates as a wave and interacts with matter as a particle.

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5. Define wave front.

A wave front is the locus of points which are in the same state or phase of vibration.

---

6. What are the shapes of wavefronts for a) source at infinite b) Point source c) Line source.

1. Source at infinite :

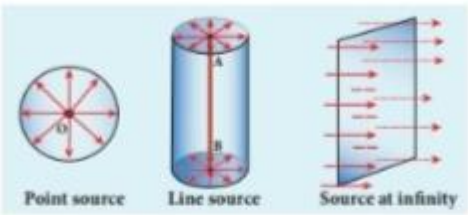
Source is located at infinity gives plane wave front.

2.Point Source :

A point source located at a finite distance gives spherical wavefronts.

3.Line Source :

An extended (or) line source at finite distance gives cylindrical wavefront.



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7. State Huygen's principle.

- **According to Huygen's principle , each point of the wave front is the source of secondary wavelets .**
- **These wavelets are spreading out in all directions with the speed of the wave .**
- **These are called as secondary wavelets.**

---

8. What is the interference of light ?

The phenomenon of super position of two light waves which produces increases in intensity at some points and decreases in intensity at some points called interference of light.

---

9. What is the phase of a wave ?

- **Phase is the angular position of a vibration.**
- **When a wave is progresses , there is a relation between phase of the vibration and path travelled by the wave.**

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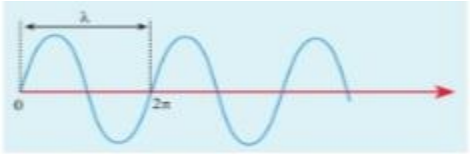
10. Obtain the relation between phase difference and path difference.

1. In the path of the wave , one wavelength λ corresponds to a phase of 2 π .

2.A path difference δ corresponds to a phase difference Φ.



$$\Phi = \frac{2\pi}{\lambda} \times \delta$$

---

11. What are coherent sources ?

Two light sources are said to be coherent if they produce waves which have same phase or constant phase difference , same frequency or wavelength , same waveform and preferably same amplitude.

---

12. How does wavefront division provide coherent sources ?

1. Most common method to produce coherent source.

2.A point source produces spherical wavefront .

3.All the points on the wavefront are at the same phase.

4. If two points are chosen on the wavefront by using double slit , act as coherent source.

---

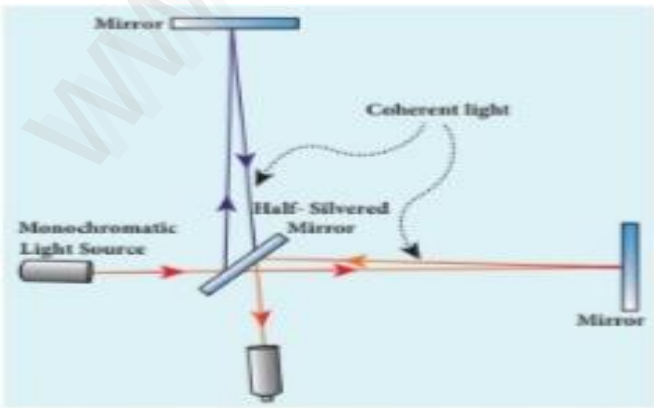
13. What is intensity (or) amplitude division ?

1. If we allow light to pass through partially silvered , both reflection and refraction take place.

2. As the two light beams obtain from same source , two divided light beams are coherent.

3. They will be in-phase or at constant phase difference.

Ex : 1. Michelson's Interferometer 2. Fabray – Perrot Etalon



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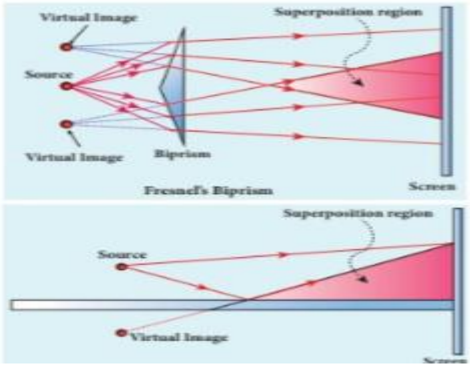
14. How do source and images behave as coherent source ?

1. Source and its image will have waves in phase or constant phase differences.

2. Fresnel's biprism uses two virtual images of the source as two coherent source.

3. Lloyd's mirror uses source and its one virtual image as two coherent source.



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15. What is bandwidth of interference pattern ?

The bandwidth (β) is defined as the distance between any two consecutive bright or dark fringes.

$$\boxed{\beta = \frac{D\lambda}{d}}$$

β → Bandwidth , λ → Wavelength

D → Distance between coherent source and screen

d → Distance between two coherent sources

---

16. What is diffraction ?

Diffraction is bending of waves around sharp edges into the geometrically shadowed region.

---

18. Discuss the special cases on first minimum in Fraunhofer diffraction.

- **The slit is to be divided into even number of equal parts for minimum condition in diffraction.**

Condition for first minimum	**Condition for first minimum**
$\delta = \frac{a}{2}\sin\theta = \frac{\lambda}{2}$	$\delta = \frac{a}{4}\sin\theta = \frac{\lambda}{2}$
$a\sin\theta = \lambda$	$a\sin\theta = 2\lambda$

Condition for n^{th} minimum $a\sin\theta = n\lambda$

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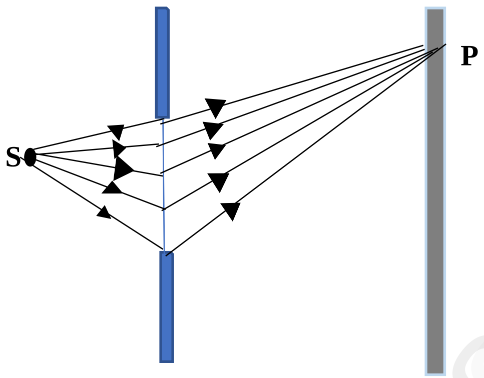
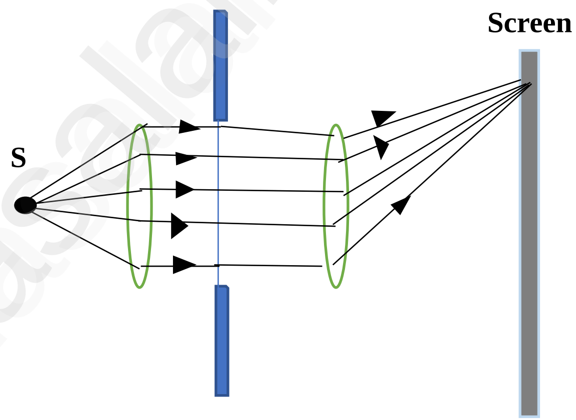
17. Difference between Fresnel diffraction and Fraunhofer diffraction ?

S.NO	Fresnel Diffraction	Fraunhofer Diffraction
1.	Spherical or cylindrical wavefront undergoes diffraction.	Plane wavefront undergoes diffraction.
2.	Light wave is from a source at finite distance.	Light wave is from a source at infinity.
3.	For laboratory conditions , convex lenses need not be used .	For laboratory conditions , convex lenses need to be used .
4.	Difficult to observe and analyse.	Easy to observe and analyse.
5.		

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19. What is Fresnel's distance ? Obtain the equation for Fresnel's distance .

Fresnel's distance is the distance up to which the ray optics is obeyed and beyond which the ray optics is not obeyed. But , the wave optics becomes significant.

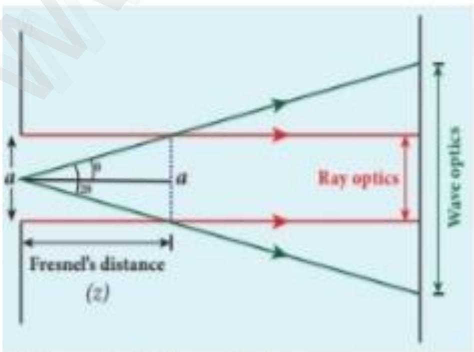

Figure 7.19 Fresnel's distance

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Diffraction equation for first minimum

$$a \sin\theta = \lambda$$

$$\sin\theta = \frac{\lambda}{a}$$

When θ is small, $\theta = \frac{\lambda}{a} \longrightarrow (1)$

From the definition of Fresnel's distance ,

$$2\theta = \frac{a}{z}$$

$$\theta = \frac{a}{2z} \longrightarrow (2)$$

Equating equation (1) and (2)

$$\theta = \frac{\lambda}{a} = \frac{a}{2z}$$

Fresnel Distance : $z = \frac{a^2}{2\lambda}$

---

20. Mention the differences between interference and diffraction.

S.NO	Interference	Diffraction
1.	Super position of two waves .	Bending waves around edges.
2.	Equally spaced bright and dark fringes.	Central bright is double the size of other.
3.	Equal intensity for all bright fringes.	Intensity falls rapidly for higher order fringes.
4.	Large number of fringes are obtained.	Less number of fringes are obtained.

---

21. What is a diffraction grating ?

- **The combined width of a ruling and a slit is called grating element $e = a + b$.**
- **The points on the slit separated by a distance equal to the grating element are called corresponding points.**

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22. What is resolution ?

- **Resolution is the quality of image which is decided by diffraction effect and Rayleigh's criterion.**
- **Resolution is measured by the smallest distance which could be seen clearly without the blur due to diffraction.**

---

23. What is Rayleigh's criterion ?

According to Rayleigh's criterion , the two points on the image are said to be just resolved when the central maximum of one diffraction pattern coincides with the first minimum of the other and vice versa.

---

24. Difference between resolution and magnification ?

<u>Resolution :</u>

- **Quality of image which is decided by diffraction effect and Rayleigh's criterion.**
- **Measured by the smallest distance which could be seen clearly without the blur due to diffraction.**

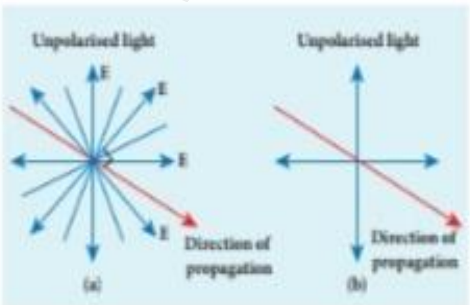
Resolution	Magnification
• Ability of optical instruments to produce clear , fine and sharper image.	• Ability of optical instruments to make an object bigger.

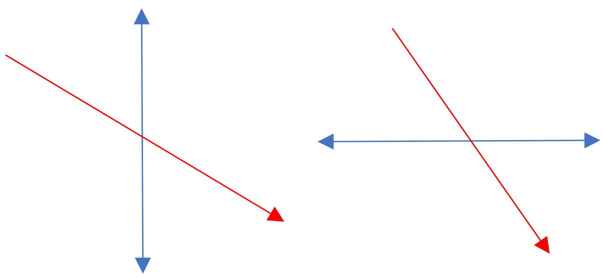
---

25. What is polarization ?

The phenomenon of restricting the vibrations of light to any one direction perpendicular to the direction of propagation of wave is called polarization of light.

26.Difference between polarized and unpolarized light.





Polarised light

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S.NO	Polarized Light	Unpolarized Light
1.	Consists of waves having their electric and magnetic field vibrations in a single normal to the direction of ray.	Consists of waves having their electric and magnetic field vibrations in all direction of ray.
2.	Asymmetrical about ray direction .	Symmetrical about the ray direction .
3.	Obtain by convert unpolarized light using polaroid.	Produced by conventional light sources.

---

27. Discuss polarization by selective absorption.

1. It is the property of a material which transmit waves.

2. The electric field vibrations are in a plane parallel to certain direction of orientation.

3. It absorbs all other vibration. 4. It is also called as " Dichroism ".

5. Polaroids or polariser which make use of property of selective absorption to produce plane polarized light.

EX : 1. Tourmaline 2. Quinine iodosulphate 3. Polyvinyl Alcohol

---

28. What are polariser and analyser ?

Polariser :

The polaroid which polarises the light passing through it is called polariser.

Analyser :

The polaroid which is used to examine whether a light is polarised or not is called an analyser.

---

29. What are plane polarised , unpolarised and partially polarised light ?

Plane polarised light

A light is said to be plane polarised if the intensity varies from maximum to zero for 90^0 rotation of the analyser.

Partially Polarised Light

If the intensity of light varies between maximum and minimum for every 90^0 rotation of the

analyser , the light is said to be partially polarised light.

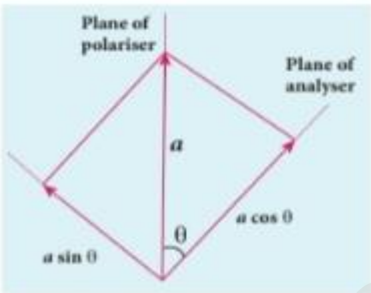
Unpolarised Light

An unpolarised light is a transverse wave which has vibrations in all directions in all directions in a plane perpendicular to the direction of propagation of wave.

---

30. State and obtain Maul's law.

In 1809 , Maull's discovered that when a beam of plane polarised light of intensity I_0 is incident on an analyser , the intensity of light I transmitted from the analyser varies directly as the square of the cosine of the angle θ between the transmission axes of polariser and analyser. This is known as " Maul's law "



$$\boxed{I = I_0 \cos^2 \theta}$$

---

31. List the uses of polaroid.

1. Used in googles and cameras to avoid glare of light.

2. Used to take 3D pictures i.e holography .

3. Used in optical stress analysis.

4. Used as window glasses to control the intensity of incoming light.

5. Used to improve contrast in old oil paintings.

6. Polarised light is used in LCD.

7. Polarised laser beam acts as needle to read / write in compact discs CD.

---

32. State Brewster's law.

Brewster's law states that the tangent of the polarising angle for a transparent medium is equal to refractive index.

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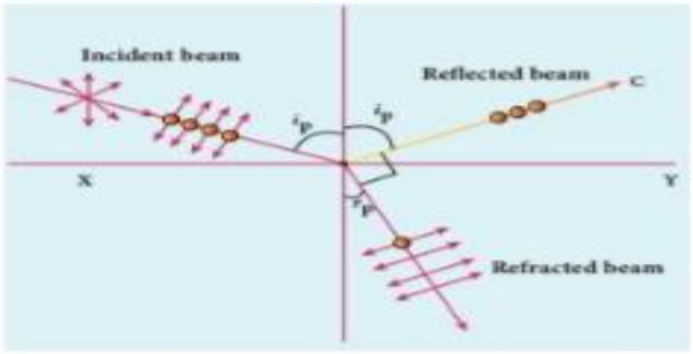


Brewster 's Law

$$\boxed{\tan\ i_p = n}$$

The polarising angle is known as Brewster's angle which depends on the nature of the refracting medium.

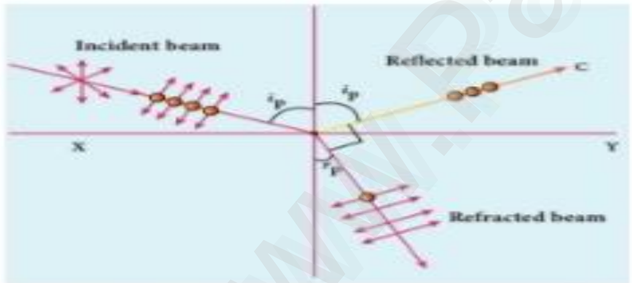
---

33. What is angle of polarisation and obtain the equation for angle of polarisation.

Angle of polarisation :

The angle of incidence for which the reflected light is found to be plane polarised is called polarising angle i_p.

Brewster 's Law



$$\boxed{\tan\ i_p = n}$$

From geometry : $r_p = 90^0 - r_p$

From Snell's law : $n = \dfrac{\sin i_p}{\sin r_p}$

$$n = \frac{\sin i_p}{\sin(90^0 - i_p)}$$

$$n = \frac{\sin i_p}{\cos i_p}$$

$$n = \tan i_p$$

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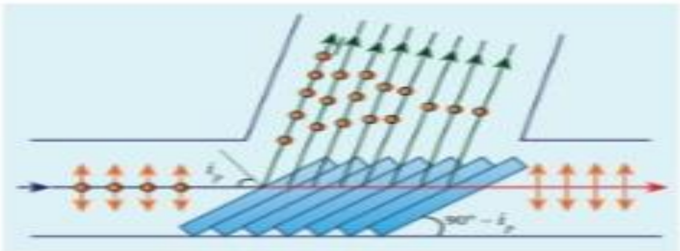
34. Discuss the piles of plates.



1. Pile of plates makes use of Brewster's law to convert the partially polarised refracted light into plane polarised light.

2. It consists of several plates kept one behind the other at an angle 90^0 - i_p with the horizontal surface.

3. This arrangement ensures that the parallel falls on these plates at i_p.

4. Unpolarised light passes through these plates, few parallel vibrations to the surface which may present in refracted light further reflections at the succeeding plates.

5. Both reflected and refracted lights are found to be plane polarised.

---

35. What is double refraction ?

When a ray of unpolarised light is incident on a calcite crystal , two refracted rays are produced. Hence , two images of an object are formed. This phenomenon is called double refraction or birefringence.

---

36. Mention the types of optically active crystals with example.

S.NO	Uniaxial Crystal	Biaxial Crystal
1.	Having only one optic axis.	Having two optic axes.
2.	Ex : Calcite , Quartz , Tourmaline	Ex : Mica , Topaz , Selenite

---

37. Discuss about Nicol prism.

Nicol Prism :

1. **Nicol prism is an optical device .**
2. **It producing plane polarised light and also anlaysing.**

Principle :

- **Based on double refraction.**

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Construction :

1. Nicol prism is a calcite crystal .
2. Its length is three times of breadth.
3. Angles are 72^0 and 108^0.
4. It is cut into two halves along a diagonal .
5. And then pasted by Canada balsam cement.
6. Unpolarised light is incident on it.
7. Double refraction takes place.
8. The ray is split into ordinary ray and exordinary ray.

S.NO	Rays	Refractive Index
1.	Ordinary Ray	1.658
2.	Exordinary Ray	1.486
3.	Canada Balsam	1.523

---

38. How is polarisation of light obtained by scattering of light ?

1. Sunlight gets scattered by atmospheric molecules.
2. Electrons of the molecules influenced by vibrating component of electric field.
3. Unpolarised sunlight produces vibrations in all directions.
4. Vibrating electrons radiate energy only in perpendicular direction.
5. An observer views a beam of sun light perpendicular to its direction to travel.
6. Hence , light reaching the observer is plane polarised.

---

39. What are near point and normal focussing ?

Near point focussing :

- The eye is least strained when image is formed at near point , i.e 25 cm
- The near point is also called as " least distance of distinct "

$$\boxed{m = 1 + \frac{D}{f}}$$

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Normal Focussing :

- **The eye is most relaxed when the image is formed at infinity.**
- **The focussing is called normal focussing when the image is formed at infinity.**

$$m = \frac{D}{f}$$

---

40. Why is oil immersed objective preferred in a microscope ?

1. Oil immersed objective contributes fine resolution and brightness.

2. These characteristics are most critical under high magnification.

3. So the objectives are designed for oil immersion.

---

41. What are the advantages and disadvantages of reflecting telescope ?

Advantages of reflecting telescope :

1. Only one surface is to be polished and maintained.

2.Support can be given from the entire back of the mirror rather than only at the rim for lens.

3.Mirrors weigh much less compared to lens.

Disadvantages of reflecting telescope :

1.The objective mirror would focus the light inside the telescope tube.

2.One must have an eye piece obstructing some light.

3. This problem could be overcome by introducing secondary mirror which would take the light outside the tube for view.

---

42. What is the use of an erecting lens in a terrestrial telescope ?

A terrestrial telescope has an additional erecting lens to make the final image to erect.

---

43. What is the use of collimator in a spectrometer ?

The collimator is used for producing parallel beam of light.

---

44. What are the uses of spectrometer ?

1. To analyse the spectra of different sources of light .

2. To measure the wavelength of different colours.

3.To measure the refractive indices of materials of prism.

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45. What is myopia ? What is its remedy ?

<u>Myopia :</u>

- **A person suffering from near sightedness.**
- **A person who can not see distant objects clearly.**
- **Due to thickening of eye lens.**
- **Due to larger diameter of eye ball.**

<u>Remedy :</u> By wearing concave lens.

---

46. What is hypermetropia ? What is its remedy ?

<u>Hypermetropia :</u>

- **A person suffering from far sightedness.**
- **A person who can not see close objects clearly.**
- **Due to thinning of eye lens.**
- **Due to shortening of eye ball.**

<u>Remedy :</u> By wearing convex lens.

---

47. What is astigmatism ? What is remedy ?

<u>Astigmatism :</u>

- **A person can not see all the directions equally well.**
- **Due to different curvature along different planes in the eye lens.**
- **This more serious than myopia and hypermetropia.**

<u>Remedy :</u>

- **Lenses with different curvatures in different in different planes to rectify this defect.**
- **Generally these lenes are called as cylindrical lenses.**

---

48. What is presbyopia ?

<u>Presbyopia :</u>

Far sightedness arising due to aging is called " Presbyopia ".

<u>Remedy :</u> By wearing convex lens.

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8.Dual nature of radiation & matter

1.Why do metals have a larger number of free electrons ?

- **In metals the electrons in the outer most shells are loosely bound to the nucleus.**
- **Even at room temperature , there are large number of free electrons which are moving inside the metal in a random manner.**

2.Define work function of a metal. Give its unit.

- **The minimum energy for an electron to escape from metal surface is called " work function " of that metal.**
- **It is denoted by Φ_0. Measured in e V.**

3.What is photo electric effect?

The ejection of electrons from a metal plate when illuminated by light or any other electromagnetic radiation of suitable wavelength is called " Photo electric effect ".

---

4. How does photo current vary with the intensity of the incident light ?

Photo current which is the number of electrons emitted per second is directly proportional to the intensity of the incident light.

---

5. Give the definition of intensity of light according to quantum concept and its unit

Intensity of light is the energy delivered per unit area per unit time. Unit : W m^{-2} or candela.

6.How will you define threshold frequency ?

For a given surface , the emission of photo electrons takes place only if the frequency of incident light is greater than a certain minimum frequency called " threshold frequency "

---

7. What is photo cell ? Mention the different types of photo cells.

<u>Photo electric cell / Photo cell :</u>

A device which converts light energy into electrical energy.

<u>Types of photo cell :</u>

1. Photo emissive cell 2. Photo voltaic cell 3. Photo conductive cell.

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8. Write the expression for the de Broglie wavelength associated with a charged particle of charge q and mass m when it is accelerated through potential V.

1. An electron of mass m is accelerated through a potential difference of V volt.

2. Kinetic Energy = Potential Difference

$$\frac{1}{2} m v^2 = e\ V$$

3. Speed of electron

$$v = \sqrt{\frac{2\ e\ V}{m}}$$

4. de Broglie wavelength

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2meV}} = \frac{12.27}{\sqrt{V}}\ Å$$

---

9. State de Broglie hypothesis.

According to de Broglie hypothesis ,

- **All matter particles like electron , protons , neutrons in motion are associated with waves.**
- **These waves are called de Broglie waves or matter waves.**

$$\boxed{\lambda = \frac{h}{p} = \frac{h}{mv}}$$

---

10. Why do not see the wave properties of base ball ?

1. de Broglie wavelength : $\lambda = \frac{h}{p} = \frac{h}{mv}$

2. Wavelength associated with base ball is small in the order of 10^{-34} and is difficult to observe.

3. As the value of Planck's constant is very small i.e h = 6.626×10^{-34}

4. Momentum of base ball is very low.

5. So , We can not see the wave properties of base ball.

---

11. A proton and an electron have same kinetic energy. Which one has greater de Broglie wavelength . Justify.

1. de Broglie wavelength : $\lambda = \frac{h}{\sqrt{2\ m\ K.E}}$

2. Kinetic energy : $K.E = \frac{h^2}{2\ m\ \lambda}$

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3. Kinetic energy of proton : $K.E_p = \frac{h^2}{2 m_p \lambda_p}$

4. Kinetic energy of electron : $K.E_e = \frac{h^2}{2 m_e \lambda_e}$

5. Proton and an electron have same kinetic energy.

$$K.E_p = K.E_e$$

$$\frac{h^2}{2 m_p \lambda_p} = \frac{h^2}{2 m_e \lambda_e}$$

$$\frac{\lambda_e}{\lambda_p} = \frac{m_p}{m_e}$$

6. m_p / m_e is greater than one then $\lambda_e > \lambda_p$.

7. Hence , electron has greater de Broglie wavelength.

---

12. Write the relationship of de Broglie wavelength λ associated with a particle of mass m in terms of its kinetic energy K.

1. Kinetic Energy = Potential Difference

$$\frac{1}{2} m v^2 = e V$$

2. Speed of electron

$$v = \sqrt{\frac{2 eV}{m}}$$

3. de Broglie wavelength

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2meV}}$$

$$\lambda = \frac{h}{\sqrt{2 m K}}$$

4. Kinetic energy of electron K = e V.

---

13. An electron and alpha particle have same kinetic energy . How are the de Broglie wavelength associated with them related.

1. de Broglie wavelength : $\lambda = \frac{h}{\sqrt{2mK}}$

2. For electron : $\lambda_e = \frac{h}{\sqrt{2 m_e K_e}}$

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3. For alpha particle : $\lambda_\alpha = \dfrac{h}{\sqrt{2m_\alpha K_\alpha}}$

4. An electron and alpha particle have same kinetic energy .

$$\frac{h}{\sqrt{2\ m_e\ K_e}} = \frac{h}{\sqrt{2\ m_\alpha\ K_\alpha}}$$

5. $\lambda_e = \lambda_\alpha$ then $m_e < m_\alpha$ and $K_e > K_\alpha$

6. Kinetic energy of electron is greater than kinetic energy of alpha particle.

---

14. Define stopping potential.

The minimum negative potential given to the anode which stops the emission of photo electrons and make photo electric current zero.

---

15. What is surface barrier ?

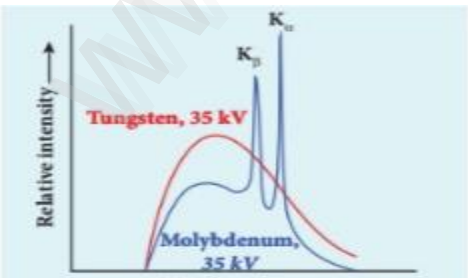
The potential barrier which prevents free electrons from leaving the metallic surface is called " surface barrier ".

---

16. Mention the two features of x- ray spectra , not explained by classical electromagnetic theory.

1. For a given accelerating voltage , the lower limit for the wavelength of continuous X – ray spectra is same for all targets. This minimum wavelength is called " cut – off wavelength ".

2. The intensity of X – ray is increased at certain well defined wavelength of characteristics X – ray spectra for molybdenum.



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17. What is Bremsstrahlung ?

In continuous X – ray spectra :

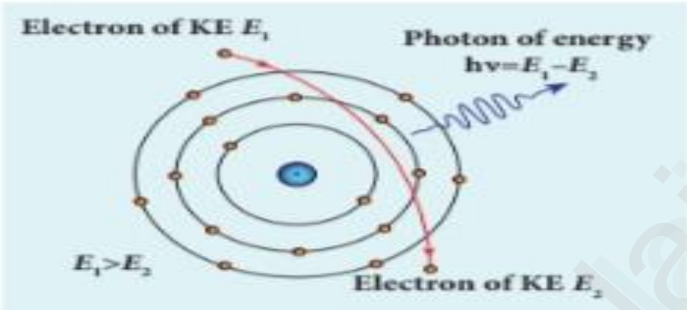
1. When a fast moving electron penetrates and approaches a target nucleus.

2. The interaction between electron and nucleus either accelerates or decelerates.

3. In which results in a change of path of the electron.

4. The radiation produced from such decelerating electron is called " Bremsstrahlung ".

5. It is also known as " braking radiation "



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9. Atomic And Nuclear Physics

1. What are cathode rays ?

1. In the discharge tube , when the pressure reaches to around 0. 01 mm of Hg , positive column disappears .

2. At this time , dark space is formed between cathode and anode.

3. It is known as " Crooke's dark space ".

4. The walls of the tube appear with green colour.

5. Invisible rays emanate from cathode called as cathode rays i.e beam of electrons.

----

2. Write the properties of cathode rays.

1. Cathode rays ionize the gas through which they pass.

2.The speed of cathode rays is up to (1 / 10 th) of the speed of light.

3. When cathode rays fall on a material of high atomic weight , X – rays are produced .

4. When the cathode rays are allowed to fall on matter , heat is produced. It affect the photographic plate and produce fluorescence.

5. Cathode rays posses energy and momentum and travel in a straight line with high speed 10^7 ms^{-1} . It can be deflected by the application of electric and magnetic field. It indicates negatively charged particle.

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3. Give the results of Rutherford alpha scattering experiment.

1. Most of the alpha particles were in deflected through the gold foil and went straight.

2. Some of the alpha particles were deflected through a small angle.

3. A few alpha particles were deflected through the angle more than 90^0.

---

4. Write down the postulates of Bohr atom model.

1. The electron in an atom moves around the nucleus in circular orbit under the influence of Coulomb electrostatic force of attraction . This Coulomb force gives necessary centripetal force for the electron to under go circular motion.

2. Electrons in an atom revolve around the nucleus only in certain discrete orbits called stationary orbits and electron in such orbits do not radiate electromagnetic energy . Only those discrete orbits allowed are stable orbits.

---

5. What is meant by excitation energy ?

The energy required to excite an electron from lower energy state to higher energy state is known as " Excitation energy "

For hydrogen atom $E = E_2 - E_1 = -3.4\ eV - (-13.6\ eV) = 10.2\ eV$.

---

6. Define ionization energy and ionization potential.

<u>Ionization Energy :</u>

The minimum energy required to remove an electron from an atom in the ground state is known as binding energy or ionization energy.

$$I_{ionization} = E_\infty - E_1 = 0 - (-13.6\ eV) = 13.6\ eV$$

<u>Ionization Potential :</u>

Ionization energy per unit charge is called as ionization potential.

$$V_{ionization} = \frac{1}{e} E_{ionization} = \frac{13.6}{n^2} Z^2\ V$$

---

7. Write down the drawbacks of Bohr atom model.

1. Bohr atom model is valid only for hydrogen atom or but not for complex atoms.

2. When spectral lines are closely examined , individual lines of hydrogen spectrum are accompanied by a number of faint lines. This is called fine structure. This can not be explained by Bohr atom model.

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3. Bohr atom model fails to explain the intensity variations in the spectral lines.

4. The distribution of electrons in various levels cannot be completely explained by Bohr atom model.

---

8. What is distance of closest approach ?

- **The minimum distance between the centre of the nucleus and alpha particle just before it gets reflected back through 180^0 .**
- **It is the defined as the distance of "closest approach" (r_0) .**
- **Also known as " contact distance "**

$$\boxed{r_0 = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{E_K}}$$

9.Define impact parameter.

The impact parameter is defined as the perpendicular distance between the centre of the gold nucleus and the direction of velocity vector of alpha particle when it is at a large distance.

$$\boxed{b = K\cot(\theta/2)}$$

---

10. Write a general notation of nucleus of element X . What does each term denotes.

General notation of nucleus of element : $_ZX^A$

A - Mass number Z - Atomic number

---

11. What is isotope ? Give an example.

Isotopes are the atoms of the same element having same atomic number Z but different mass number A .

<u>Example :</u> **$_1H^1$ (Hydrogen) , $_1H^2$ (Deuterium) , $_1H^3$ (Tritium)**

---

12. What is isotone ? Give an example.

Isotones are the atoms of the different element having same number of neutrons .

<u>Example :</u> **$_5B^{12}$ and $_6C^{13}$ which has 7 neutrons.**

---

13. What is isobar ? Give an example.

Isobar are the atoms of the different elements having same mass number A but different atomic number Z .

<u>Example :</u> **$_{16}S^{40}$ and $_{17}Cl^{40}$.**

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14. Define atomic mass unit.

One atomic mass unit (u) defined as the 1 / 12th of the mass of the isotope of carbon $_6Cl^{12}$ which is more abundant in naturally occurring isotope of carbon.

$$\boxed{1\ u = 1.66 \times 10^{-27}\ kg}$$

$$\text{One amu} = 1\ u = \frac{\text{mass of } _6Cl^{12} \text{ atom}}{12} = \frac{1.9926 \times 10^{-26}}{12} = 1.66 \times 10^{-27}\ kg.$$

---

15. Show that nuclear density is almost constant for nuclei with Z > 10.

1. The nuclei of atoms are found to be approximately spherical in shape .

2. It is experimentally found that radius of nuclei for Z > 10 , satisfies the empirical formula

$$\boxed{R = R_0\ A^{1/3}}$$

Mass number $\rightarrow$ **A ; R_0 = 1.2 F = 1.2 X 10^{-15} m**

$$\text{3. Nuclear density} = \frac{\text{Mass of the nuclei}}{\text{Volume of the nuclei}} = \frac{m}{\frac{4}{3}\pi R_0^{\ 3}}$$

4. Nuclear density is independent of the mass number A.

5. All the nuclei Z > 10 have same density and it is an important characteristics property of all nuclei.

---

16. What is mass defect ?

The mass of any nucleus is less than the sum of the mass of its individual constituents. This difference in mass Δ m is called as " mass defect ".

$$\boxed{\text{Mass Defect : } \Delta m = (Z m_p + N m_n) - M}$$

- **m_p $\rightarrow$ Mass of the proton** **m_e $\rightarrow$ Mass of the electron**
- **M $\rightarrow$ Mass of the nucleus** **Z $\rightarrow$ Atomic number**

---

17. What is the binding energy of a nucleus ? Give its expression.

- **When the protons and neutrons combine to form a nucleus , mass equal to mass defect disappears and the corresponding energy is released .**
- **The energy equivalent of mass defect is known as " Binding energy ".**
- **From the Einstein mass – energy relation : B.E = $\Delta m c^2$**

$$\boxed{B.E = \Delta m c^2 = (Z m_p + N m_n - M)\ c^2}$$

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18. Calculate the energy equivalent of 1 atomic mass unit ?

From the Einstein mass – energy relation we can able to calculate the energy equivalent of one atomic mass unit .

$$E = m c^2 = 1.66 \times 10^{-27} \times 3 \times 10^8 = 14.94 \times 10^{11} J.$$

$$E = \frac{14.94 \times 10^{11}}{1.6 \times 10^{-19}} eV = 931 \times 10^6 eV = 931 MeV.$$

---

19. Give the physical meaning of binding energy per nucleon.

The average binding energy per nucleon is the energy required to separate single nucleon from the particular nucleus.

$$\boxed{\overline{B.E} = \Delta m c^2 = \frac{(Z m_p + N m_n - M) c^2}{A}}$$

---

20. What is meant by radioactivity ?

The phenomenon of spontaneous emission of highly penetrating radiations such as α , β and γ Rays by an element is called " radioactivity " and the substances which emit these radiations are called as radioactivity elements . (Z > 82)

---

21. Give the symbolic representation of alpha decay , beta decay and gamma emission.

1. Alpha Decay :

$${}_Z X^A \longrightarrow {}_{Z-2} Y^{A-4} + {}_4 He^2$$

$X \longrightarrow$ **Parent nucleus**

$Y \longrightarrow$ **Daughter nucleus**

${}_4 He^2 \longrightarrow$ **Alpha particle**

2. Beta Decay :

$${}_Z X^A \longrightarrow {}_{Z+1} Y^A + e^- + \bar{\upsilon}$$

$e^- \longrightarrow$ **Positron**

$\bar{\upsilon} \longrightarrow$ **Anti neutrino**

3. Gamma Emission :

$${}_Z X^{*A} \longrightarrow {}_Z X^A + \gamma \text{ rays}$$

$X^* \longrightarrow$ **Excited state of nucleus**

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22. In alpha decays , why the unstable nucleus emits $_4He^2$ nucleus ? Why it does not emit four separate nucleons ?

1. $_4He^2$ nucleus consists of two protons and two neutrons.

2. If $_{92}U^{228}$ nucleus decay into $_{90}Th^{224}$ by emits four separate nucleons then disintegration energy Q for this process turn to negative.

3. It implies that the total mass of product is greater than that of parent nucleus.

4. This kind of process cannot occur in nature because it would violate conservation of energy.

5. In any decay process , the conservation of energy , conservation of linear momentum and angular momentum must be obeyed.

---

23. What is mean life of a radioactive nucleus ? Give its expression.

The mean life of radioactive nucleus is defined as the ratio of sum or integration of life times of all nuclei to the total number nuclei present initially.

$$\boxed{\tau = \frac{\int^{t} t\,[\lambda N_0 e^{-\lambda t}\ dt]}{N_0}}$$

---

24. What is half – life of a radioactive nucleus ? Give the expression.

The half – life of radioactive nucleus is defined as the time required for the number of atoms initially present to reduce to one half of the initial amount.

$$\boxed{T_{1/2} = \frac{0.6931}{\lambda} = 0.6931\,\tau}$$

---

25. What is meant by activity or decay rate ? Give its unit.

At any instant t , the number of decay per unit time called rate of decay is proportional to the number of nuclei at the same instant.

$$\boxed{\frac{dN}{dt} \propto N \quad ; \quad \frac{dN}{dt} = -\lambda N}$$

λ Decay constant

---

26. Define curie.

Number of decays per second in 1 gram of radius is defined as one curie and is equal to 3.7×10^{10} decays per second

1 Curie = 1 Ci = 3.7×10^{10} decays per second = 3.7×10^{10} Becquerel.

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27.What are constituent particles of neutron and proton ?

- **Protons and neutrons are not fundamental particles.**
- **They are made up of quarks.**
- **There are six types of quarks.**
- **They are namely up , down , charm , strange , top and bottom and their anti particles.**

---

10. Electronics and Communication

1.Define forbidden energy .

The energy gap between valence band and conduction band is called " forbidden energy gap".

$$\boxed{E_g = E_c - E_v}$$

---

2. Why is temperature co – efficient of resistance of resistance for semiconductor ?

1. The resistivity value of semiconductor is from 10^{-5} Ω m to 10^{6} Ω m.

2. When the temperature is increased further more number of electrons are promoted to the conduction band and increase conduction.

3. Electrical conduction increases with the increase in temperature.

4. Resistance decreases with increase in temperature.

5. So, semiconductors said to have negative temperature co efficient of resistance.

---

3. What do you mean by doping ?

1. Process of adding impurities to the intrinsic semiconductors.

2. The impurity atoms are called dopants in 100 ppm.

---

5. A diode is called as unidirectional device. Explain.

1. Current flows in only one direction.

2. When forward voltage is applied the diode conducts and when reverse voltage is applied there is no conduction.

3. So , diode conducts only one direction , it is a unidirectional device.

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4. Distinguish between intrinsic and extrinsic semiconductors .

S. NO	Intrinsic semiconductors	Extrinsic Semiconductors
1.	Pure form of semiconductor without any impurity.	Adding impurity to intrinsic semiconductors
2.	No doping takes place here.	Here , doping takes place.
3.	It has bad electrical characteristics.	It has good electrical conductivity.
4.	Number of free electrons in conduction is equal to number of holes in valence band.	Number of free electrons and holes are not equal.
5.	Ex : Pure Si , Pure Ge	Ex : n – type semiconductor , p - type semiconductor

---

6. What do you mean by leakage current in diode ?

1. When the junction diode is under reverse bias condition , a very small current in the range of μ A , flows across the junction.
2. This is due to flow of minority charge carrier.
3. This current is called as leakage current or reverse saturation current.
4. Leakage current is independent of applied voltage.

---

7. Draw the input and output of a full wave rectifier.

<u>Input and output waveforms:</u>

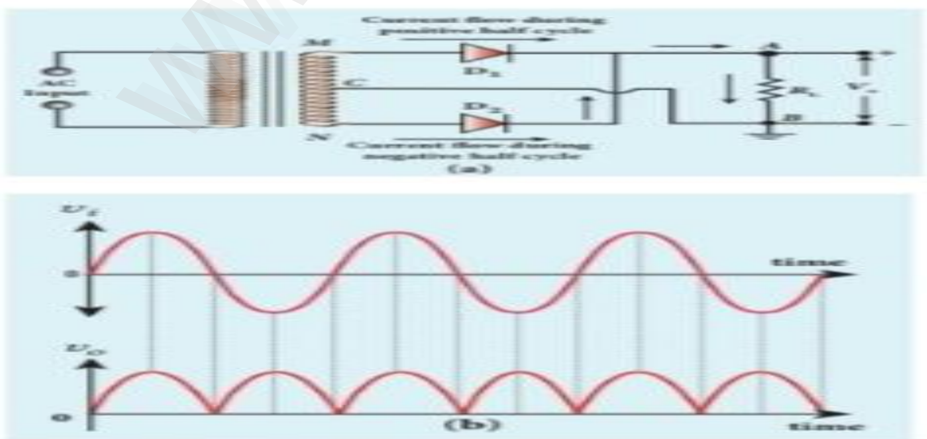

Figure 10.18 (a) Full wave rectifier circuit (b) Input and output waveforms

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8. Distinguish between avalanche breakdown and Zener breakdown.

S.NO	Avalanche Breakdown	Zener Breakdown
1.	It occurs in lightly doped p-n junction.	It occurs in heavily doped p-n junction.
2.	It has wide depletion layer.	It has narrow depletion layer. (> 10^{-6} m)
3.	Electric field is weak.	Electric field is strong. (3×10^{7} V m^{-1})
4.	Breakdown voltage vary.	Breakdown voltage constant.

---

9. Give the Barkhausen conditions for sustained oscillations.

1. There should be positive feedback.
2. Loop phase shift must be 0^0 .
3. Integral multiples of 2π .
4. Loop gain must be unity $|A\beta| = 1$.
5. Voltage gain of amplifier $\longrightarrow$ A
6. Feed back ratio $\longrightarrow$ β (the fraction of the output that is fed back to the input)

---

10. Explain the current flow in a N P N transistor.

1. In N P N transistor electron flow from emitter to collector. So conventional current flow from collector to emitter.
2. Electrons from emitter region flow towards base region constitute emitter current (I_E)
3. Electrons after reaching base region recombine with holes.
4. Most of electrons reach collector region.
5. This constitute collector current . (I_C).
6. After recombination of holes in base region by bias voltage constitute base current . (I_B)

$$\boxed{I_E = I_B + I_C}$$

---

11. What are logic gates ?

1. A logic gate is an electronic circuit whose function is biased on digital signals. They are binary in nature.
2. The logic gates are considered as the basic building blocks of most of the digital systems.
3. They have one output with one or more inputs.

4. There are three types of basic logic gates : AND , OR , NOT

5. There are two types of universal logic gates : NAND , NOR.

---

12. Explain the need for a feedback circuit in a transistor oscillator.

1. Feedback is the fraction of output from an amplifier circuit is returned or fed to the input.

2. If the portion of the output fed to the input is in phase with the input , then the magnitude of the input signal increases.

3. It is necessary for sustained oscillations.

---

13. Write a short note on diffusion current across p-n junction.

1. A single piece of semiconductor crystal is suitably doped such that its one side is p – type semiconductor and the other side is n – type semiconductor.

2. The contact surface between the two sides is called p-n junction.

3. Whenever p-n junction is formed , some of the free electron diffuse from the n – side to the p – side while the holes from p – side to the n – side.

4. The diffusion of the majority charge carriers across the junction gives to an electric current called diffusion current.

---

14. What is meant by biasing ? Mention its types.

<u>Biasing :</u>

Biasing means providing external energy to charge carriers to overcome the barrier potential and make them move in a particular direction.

<u>Types of biasing :</u>

1. Forward Bias 2. Reverse Bias

---

15. Why can't we interchange the emitter and collector even though they are made up of the same type of semiconductor material ?

1. Emitter is more heavily doped than the other two regions.

2. Collector is made physically larger than the other two as it has to dissipate more power. It is moderately doped.

3. Because of the differing size and the amount of doping , the emitter and collector cannot be interchanged.

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16. Why are NOR and NAND gates called universal gates ?

1. NOR and NAND gates are called universal gates because they perform all the logical operations of basic gates like AND , OR , NOT.

2. It can be used to form any other logic or Boolean function.

---

17. Define barrier potential.

The internal repulsion of the depletion layer stops further diffusion of free electrons across the junction. This difference in potential across the depletion layer is called " barrier potential "

---

18. What is rectification ?

The process in which alternating voltage or alternating current is converted into direct voltage or direct current is known as " rectification ".

---

19. List the application of light emitting diode.

1. Remote controller of television , air conditioner etc. 2. Seven segment displays.

3. Traffic signals , emergency vehicle lighting. 4. Indicator lamps on the front of scientific lab.

---

20. Give the principle of solar cells.

1. A solar cell also known as photovoltaic cell works on the principle of " photovoltaic effect "

2. Accordingly , the p-n junction of the solar cell generates emf when solar radiation falls on it.

---

21. What is an integrated circuit ?

1. An integrated circuit is also referred as an IC or a chip or a microchip.

2. It consists of thousands to millions of transistors , resistors , capacitors etc.

3. They are integrated on a small flat piece of semiconductor material that is normally silicon.

4. Main merits over ordinary circuits : 1.cost & performance. 2. size , speed capacity of chips.

---

22. What is modulation ?

For long distance transmission , the low frequency base band signal is superimposed onto a high frequency radio signal by a process called " modulation ".

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23. Define bandwidth of transmission system.

The range of frequencies required to transmit a piece of specified information in a particular channel is called " bandwidth " or the bandwidth of the transmission system.

---

24. What do you mean by skip distance ?

The shortest distance between the transmitter and the point of reception of the sky wave along the surface is called as the " skip distance ".

---

25. Give applications of RADAR.

1. Used for locating and detecting the targets.

2. Used to locate and rescue people in emergency situations.

3. Used to measure precipitation rate and wind speed in meteorological observations.

4. Used in navigation systems such as ship borne surface search , air search and missile guidance systems.

---

26. Explain centre frequency or resting frequency in frequency modulation.

When the frequency of the baseband signal is zero , there is no change in the frequency of the carrier wave. It is at its normal frequency and is called as " centre frequency " or " resting frequency " .

---

27. What des RADAR stand for ?

Radio Detection And Ranging system stands for RADAR.

---

11. Recent Development In Physics

1. Distinguish between Nanoscience and Nanotechnology.

Nanoscience	Nanotechnology
Nanoscience is the science of objects with typical sizes of 1 – 100 nm. One nano meter = 10^{-9} meter	Nanotechnology is a technology involving in the design , production , characterization and application of nano structured materials

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2. What is the difference between Nanomaterials and bulk materials ?

Nanomaterial	Bulk material
If the particle of a solid is of size less than 100 nm , it is said to be a non solid or nano materials.	When the particle size exceeds 100 nm , it is a bulk solid or bulk material.

---

3. Give any two examples for nano in nature.

Single strand of DNA , peacock feather , morpho butterfly , parrot fish and lotus leaf surface.

---

4. Mention any two advantages and disadvantages of robotics.

Advantages of Robotics :

1. The robots are much cheaper than humans.

2. Robots never get tired like humans.

3. Stronger and faster than humans.

4. IN warfare , robots can save human lives.

5. Robots are more precise and error free in performing the task.

Disadvantage of Robotics :

1. Robots have no sense of emotions or conscience.

2. They lack empathy and hence create an emotionless workplace.

3. Unemployment problem will increase.

4. The robots are well programmed to do a job and if a small thing goes wrong it ends up in a big loss to the company.

5. Human cannot be replaced by robots in decision making.

---

5. Why steel is preferred in making robots ?

In general robots are made up of common metals like aluminium and steel which are the most common metals . Aluminium is a softer metal and is therefore easier to work with , but steel is several times stronger.

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6. What are black holes ?

1. Black holes are end stage of stars which are highly dense massive object.

2. Its mass range from 20 times mass of the sun to 1 million times mass of the sun.

3. It has very strong gravitational force such that no particle or even light cannot escape from it.

4. The existence of black holes is studied when the stars orbiting the black hole behave differently from the other stars.

5. Every galaxy has black hole at its centre.

6. Sagittarius A* is the black hole at the center of the Mliky Way galaxy.

7. Black holes are the source of gravitational waves.

---

7. What are sub atomic particles?

Electron, proton, and neutron.

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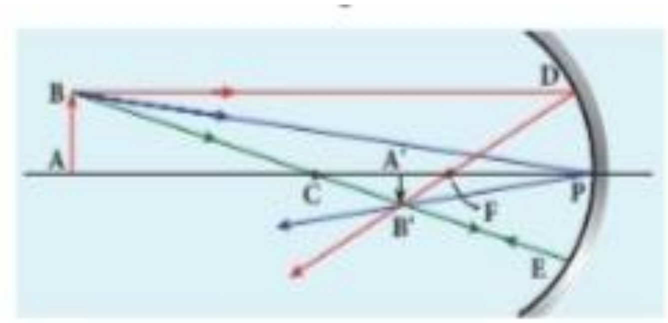
LESSON 6

1.Derive the mirror equation and the equation for lateral magnification.

Mirror Equation :

It relates object distance u , image distance v and focal length f.

Diagram :



Formula :

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

Theory :

1. A B is object and $A'B'$ is an image.
2. BD is first paraxial ray.
3. BP is second paraxial ray.
4. BC is third paraxial ray.

Derivation :

1. Δ B P A and Δ $B'PA'$

$$\frac{A'B'}{AB} = \frac{PA'}{PA}$$

2. Δ D P F and Δ $B'A'F$

$$\frac{A'B'}{PD} = \frac{A'F}{PF}$$

3. $$\frac{A'B'}{AB} = \frac{PA'}{PF}$$

4. $$\frac{PA'}{PA} = \frac{A'F}{PF}$$

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5. $$\frac{PA'}{PA} = \frac{PA - PF}{PF}$$

6. $PA = -u$; $PA' = -v$; $PF = f$;

7. $$\frac{-v}{-u} = \frac{-v-(-f)}{-f}$$

8. $$\frac{v}{u} = \frac{-v+f}{-f}$$

9. $$\frac{v}{u} = \frac{-v}{-f} + \frac{f}{-f}$$

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

11. Dividing both sides with v

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

12. $$\boxed{\frac{1}{f} = \frac{1}{u} + \frac{1}{v}}$$

Lateral Magnification Equation

1. Magnification = $\frac{\text{Height of the image}}{\text{Height of the object}}$

2. $$m = \frac{h'}{h} = \frac{-v}{u}$$

3. $$m = \frac{f-v}{f} = \frac{f}{f-u}$$

---

2. Describe the Fizeau's method to determine the speed of light.

Theory :

1. The light from the source is S .
2. Partially silvered glass plate is G.
3. The light is fall on the glass plate.

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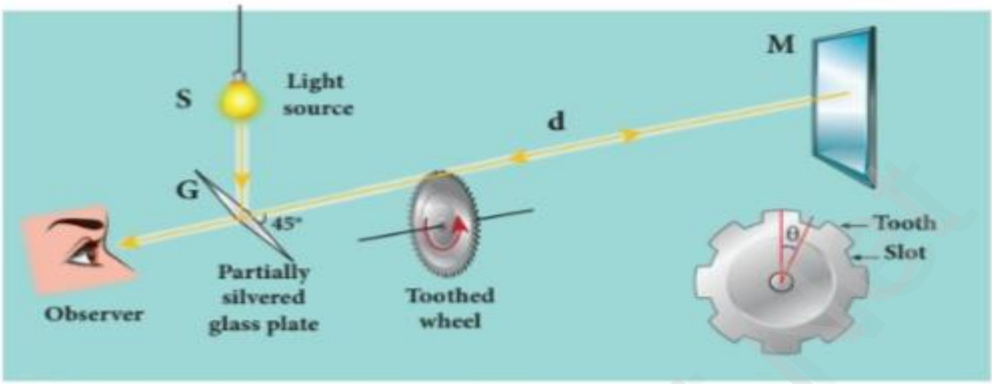
4. The angle produced is 45^0 .

5. Toothed wheel with N teeth and N cuts.

6. Mirror is kept a distance about 8 km.

Diagram :



Working :

1. Angular speed of rotation increased from 0 to ω .

2. Light pass through one cut completely blocked by tooth.

3. Light disappearing while looking through glass plate.

Speed of light :

$$\boxed{V = \frac{2\,d\,N\,\omega}{\pi} = 2.99792 \times 10^{8}\ m\,s^{-1}}$$

Derivation:

1. $V = \frac{2\,d}{t}$

2. $\omega = \frac{\Theta}{t}$

3. $\Theta = \frac{\text{Total angle of circle in radian}}{\text{No of teeth + No of cuts}}$

4. $\Theta = \frac{2\pi}{2N} = \frac{\pi}{N}$

5. $\omega = \frac{\pi}{Nt}$

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6. $t = \frac{\pi}{N\,\omega}$

7. $V = \frac{2\,d\,N\,\omega}{\pi} = 2.99792 \times 10^{8}\ m\,s^{-1}$

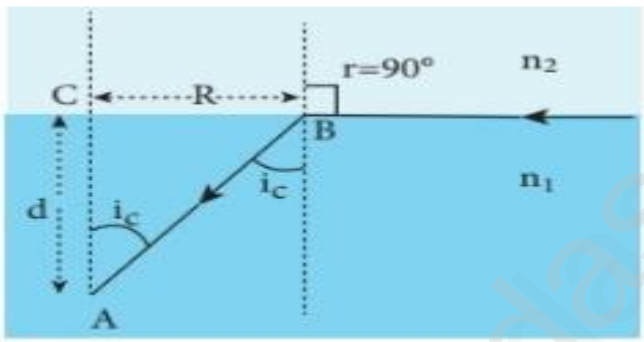
---

4. Obtain the equation for radius of illumination or Snell's window.

Snell's window

When light entering the water form outside is seen from inside the water , the view is restricted to a particular angle equal to critical angle. The restricted circular area is called " Snell's window ".

Diagram :



Formula :

$$R = \frac{d}{\sqrt{n^2 - 1}}$$

Theory :

- **The angle of view for water is restricted to twice the critical angle.**
- **Critical angle for water is 48. 6^0 .**
- **The angle of view is 97.2 ^{0} .**
- **Light seen from point at A.**
- **Refractive index of medium is n .**
- **Radius of circular area is R.**
- **It depends on depth d.**

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Radius of illumination :

Snell ' s law in product form

1. $n_1 \sin i = n_2 \sin r$
2. $n_1 \sin i_c = n_2 \sin 90^0$
3. $n_1 \sin i_c = n_2$
4. $\sin i_c = \dfrac{n_2}{n_1}$

From Triangle ABC

5. $\sin i_c = \dfrac{R}{\sqrt{d^2 + R^2}}$
6. $\dfrac{n_2}{n_1} = \dfrac{R}{\sqrt{d^2 + R^2}}$
7. Squaring on both sides.

$$\frac{R^2}{d^2 + R^2} = \frac{n_2^2}{n_1^2}$$

8. Take reciprocal

$$\frac{d^2 + R^2}{R^2} = \frac{n_1^2}{n_2^2}$$

9. Further simplification

$$\frac{d^2}{R^2} + \frac{R^2}{R^2} = \frac{n_1^2}{n_2^2}$$

10. $\dfrac{d^2}{R^2} + 1 = \dfrac{n_1^2}{n_2^2}$
11. $\dfrac{d^2}{R^2} = \dfrac{n_1^2}{n_2^2} - 1$
12. $\dfrac{d^2}{R^2} = \dfrac{n_1^2 - n_2^2}{n_2^2}$

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13. Again taking reciprocal

$$\frac{R^2}{d^2} = \frac{n_2^2}{n_1^2 - n_2^2}$$

14. Take square root on both sides

$$\frac{R}{d} = \sqrt{\frac{n_2^2}{n_1^2 - n_2^2}}$$

15. <u>Radius of illumination</u>

$$R = d\sqrt{\frac{n_2^2}{n_1^2 - n_2^2}}$$

16. If rarer medium is air, then $n_2 = 1$ and $n_1 = n$

$$R = d\sqrt{\frac{1}{n^2 - 1}}$$

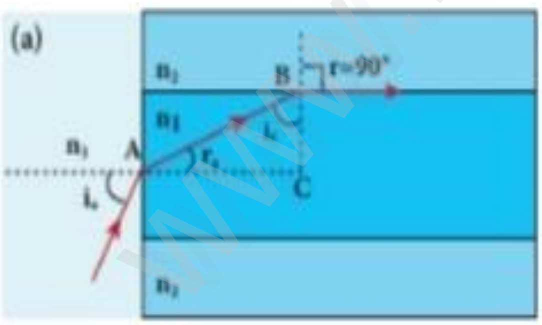
---

4. Derive the equation for acceptance angle and numerical aperture of optical fibre.

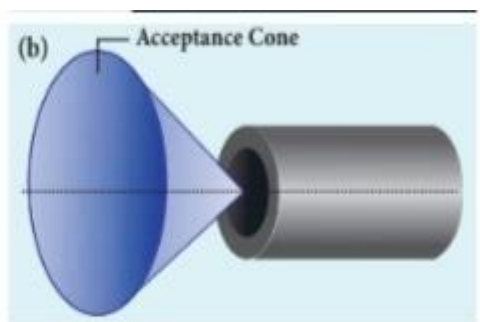
<u>Acceptance Angle :</u>

To ensure the critical angle incidence in the core cladding inside the optical fibre , the light should be incident at a certain angle called " acceptance angle " .

<u>i . Acceptance Angle</u>



<u>ii . Acceptance Cone</u>



Formula :

$$\boxed{i_a = \sin^{-1}\left(n_1^2 - n_2^2 \right)}$$

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Theory :

1. Refractive index of core → n_1
2. Refractive index of cladding → n_2
3. Refractive index of outer → n_3
4. Acceptance Angle → i_a
5. Critical Angle → i_c

Derivation :

1. Snell's law in product form , at point A

$$n_3 \sin i_a = n_1 \sin r_a \longrightarrow (1)$$

2. Snell's law in product form , at point B

$$n_1 \sin i_c = n_2 \sin 90^0 \longrightarrow (2)$$

3. $n_1 \sin i_c = n_2$

4. $$\sin i_c = \frac{n_2}{n_1} \longrightarrow (3)$$

5. From triangle Δ A B C

$$i_c = 90^0 - r_a \longrightarrow (4)$$

6. sub eqn (4) in eqn (2)

$$\sin (90^0 - r_a) = \frac{n_2}{n_1}$$

7. $$\cos r_a = \frac{n_2}{n_1} \longrightarrow (5)$$

8. $$\sin r_a = \sqrt{1 - \cos^2 r_a}$$

9. $$\sin r_a = \sqrt{1 - \left(\frac{n_2}{n_1}\right)^2} = \sqrt{\frac{n_1^2 - n_2^2}{n_1^2}} \longrightarrow (6)$$

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10. sub eqn (6) in eqn (1)

$$n_3 \sin i_a = n_1 \sqrt{\frac{n_1^2 - n_2^2}{n_1^2}} = \sqrt{n_1^2 - n_2^2}$$

11. $$\sin i_a = \sqrt{\frac{n_1^2 - n_2^2}{n_3}} = \sqrt{\frac{n_1^2 - n_2^2}{n_3^2}}$$

12. $$i_a = \sin^{-1}\left[\sqrt{\frac{n_1^2 - n_2^2}{n_3^2}}\right]$$

13. If outer medium is air $n_3 = 1$ then

$$i_a = \sin^{-1}\left(\sqrt{n_1^2 - n_2^2}\right)$$

14. **Acceptance Cone :**

Light can have angle of incidence from 0 to i_a with the normal at the end of the optical fibre forming conical shape called " Acceptance cone "

15. **Numerical Aperture :**

The term $n_3 \sin i_a$ is called as " Numerical Aperture " NA

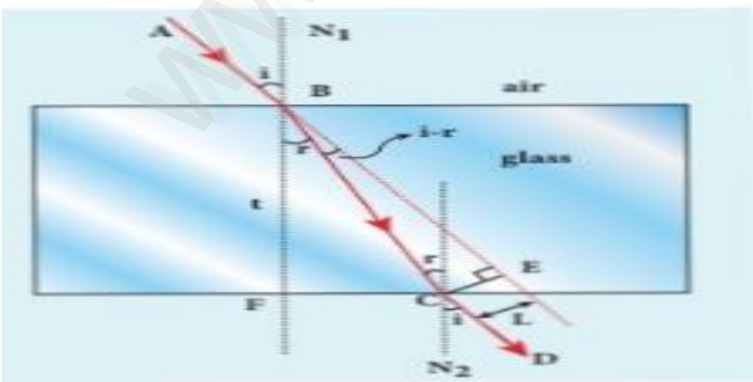
$$NA = n_3 \sin i_a = \sqrt{n_1^2 - n_2^2}$$

If $n_3 = 1$ then $NA = \sin i_a = \sqrt{n_1^2 - n_2^2}$

---

5. Obtain the equation for lateral displacement of light passing through a glass slab.

Diagram :



Formula :

$$L = t\,\frac{\sin(i - r)}{\cos r}$$

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Theory :

Let us consider a light passing through glass slab.

- Thickness of glass slab → t
- Refractive Index → n
- Path of light → A B C D
- Angle of incidence → i
- Angle of refraction → r
- Lateral Displacement → L
- Normal → N_1 , N_2

In Δ B C E

- $\sin(i - r) = \dfrac{L}{BC}$
- $BC = \dfrac{L}{\sin(i - r)}$
- $\dfrac{L}{\sin(i - r)} = \dfrac{t}{\cos r}$

In Δ B C E

$\cos r = \dfrac{t}{BC}$

$BC = \dfrac{t}{\cos r}$

Lateral Displacement :

$$\boxed{L = t\,\frac{\sin(i - r)}{\cos r}}$$

Lateral Displacement Depends on

- Thickness of the slab (t)
- Angle of incidence (i)
- Refractive index (n)
- Angle of refraction (r)

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Larger lateral displacement

- Thicker the slab
- Greater angle of incidence
- Higher refractive index

---

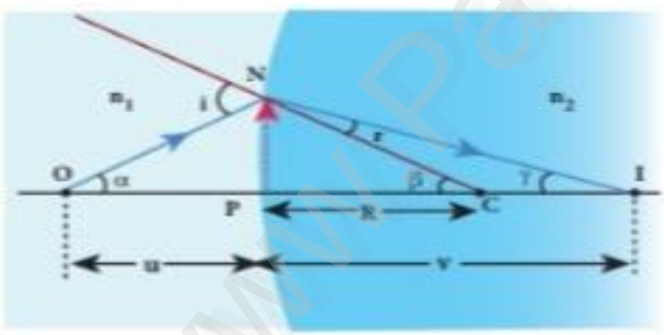
6. **Derive the equation for refraction at single single spherical surface.**

Theory :

Let us consider a single spherical surface.

- Refractive Indices ⟶ n_1 , n_2
- Centre of curvature ⟶ C
- Principal Axis ⟶ OC
- Pole point ⟶ P
- Point object ⟶ O
- Point image ⟶ I

Diagram :



Formula :

$$\frac{n}{v} - \frac{1}{u} = \frac{(n - 1)}{R}$$

Snell's law in product form

$$n_1 \sin i = n_2 \sin r$$

If the angles are small then sin i = i and sin r = r

$$n_1 \, i = n_2 \, r \longrightarrow (1)$$

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Let the angles be,

$< NOP = \alpha$; $< NCP = \beta$; $< NIP = \gamma$

Δ NOP	Δ NCP	Δ NIP
$\tan\alpha = \frac{PN}{PO}$	$\tan\beta = \frac{PN}{PC}$	$\tan\gamma = \frac{PN}{PI}$
$\alpha = \frac{PN}{PO}$	$\beta = \frac{PN}{PC}$	$\gamma = \frac{PN}{PI}$

Δ ONC , $i = \alpha + \beta$

Δ INC , $\beta = r + \gamma$, $r = \beta - \gamma$

<u>Sub i and r values in snell eqn</u>

$$n_1 (\alpha + \beta) = n_2 (\beta - \gamma)$$

$$n_1 \alpha + n_1 \beta = n_2 \beta - n_2 \gamma$$

$$n_1 \alpha + n_2 \gamma = n_2 \beta - n_1 \beta$$

$$n_1 \alpha + n_2 \gamma = (n_2 - n_1) \beta$$

<u>sub α , β and γ values,</u>

$$n_1 \left(\frac{PN}{PO} \right) + n_2 \left(\frac{PN}{PI} \right) = (n_2 - n_1) \left(\frac{PN}{PC} \right)$$

Further simplifying by cancelling PN

$$\frac{n_1}{PO} + \frac{n_2}{PI} = \frac{(n_2 - n_1)}{PC}$$

By sign conventions

$PO = - u$; $PI = V$; $PC = R$

$$\frac{n_1}{-u} + \frac{n_2}{v} = \frac{(n_2 - n_1)}{R}$$

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$$\frac{n_1}{-u} + \frac{n_2}{v} = \frac{(n_2 - n_1)}{R}$$

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R}$$

If $n_1 = 1$ then $n_2 = n$ then,

$$\boxed{\frac{n}{v} - \frac{1}{u} = \frac{(n - 1)}{R}}$$

---

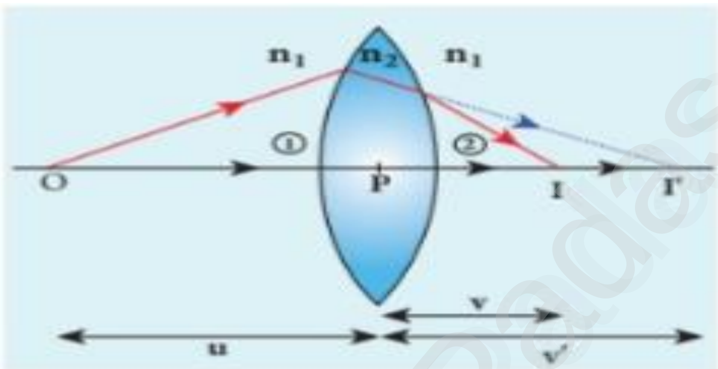
7. Obtain lens maker's formula and mention its significance.

Theory :

Let us consider a thin lens made up of a medium of refractive index n_2 placed in a medium of refractive index n_1.

- Radii curvature of two spherical surfaces → R_1 , R_2

Diagram :



Formula :

$$\boxed{\frac{1}{f} = (n - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

Derivation :

1. General eqn for refraction at a single spherical surface

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R}$$

2. For refracting surface (1), Light goes from n_1 to n_2

$$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R_1} \longrightarrow (1)$$

3. For refracting surface (2), Light goes from n_2 to n_1

$$\frac{n_1}{v} - \frac{n_2}{v'} = \frac{(n_1 - n_2)}{R_2} \longrightarrow (2)$$

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$$\frac{n_1}{v} - \frac{n_2}{v} = \frac{-(n_2 - n_1)}{R_2} \longrightarrow (3)$$

4. Adding eqn (1) and (2)

$$\frac{n_2}{v} - \frac{n_1}{u} + \frac{n_1}{v} - \frac{n_2}{v} = \frac{(n_2 - n_1)}{R_1} - \frac{(n_2 - n_1)}{R_2}$$

5. $$\frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

6. $$n_1\left[\frac{1}{v} - \frac{1}{u}\right] = (n_2 - n_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

7. $$\frac{1}{v} - \frac{1}{u} = \frac{(n_2 - n_1)}{n_1}\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

8. $$\frac{1}{v} - \frac{1}{u} = \left[\frac{n_2}{n_1} - \frac{n_1}{n_1}\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

9. $$\frac{1}{v} - \frac{1}{u} = \left[\frac{n_2}{n_1} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

10. For $u = \infty$, $v = f$

$$\frac{1}{f} = \left[\frac{n_2}{n_1} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

11. If $n_1 = 1$ and $n_2 = n$ then

$$\frac{1}{f} = (n - 1)\ \frac{1}{R_1} - \frac{1}{R_2}$$

12 <u>Lens maker's formula :</u>

$$\boxed{\frac{1}{f} = (n - 1)\ \frac{1}{R_1} - \frac{1}{R_2}}$$

13. <u>Significance :</u>

- It tells the lens manufactures what curvature is needed for a material of particular refractive index to make a lens of desired focal length.
- This formula holds good also for any type of lens.

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14. <u>Lens equation :</u>

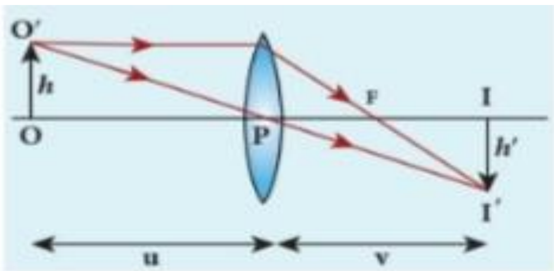
$$\boxed{\frac{1}{f} = \frac{1}{v} - \frac{1}{u}}$$

15. It relates the object distance u and image distance v with the focal length of the lens . This equation holds good for any type of lens.

---

8. Derive the equation for thin lens and for magnification.

<u>Diagram :</u>



<u>Formula :</u>

$$\boxed{m = \frac{f}{f+u} = \frac{f-v}{f}}$$

<u>Theory :</u>

- Object ⟶ $O\ O'$
- Image ⟶ $I\ I'$
- Height ⟶ $h\ ,\ h'$

<u>Lateral Magnification or Transverse magnification :</u>

It is defined as the ratio of the height of the image to height of the object.

Similar triangles $\Delta\ P\,O\,O'$ and $\Delta\ P\,I\,I'$

$$m = \frac{I\,I'}{O\,O'} = \frac{PI}{PO}$$

- On applying sign convention

$$m = -\frac{h'}{h} = \frac{v}{-u}$$

- Magnification :

$$m = \frac{h'}{h} = \frac{v}{u}$$

- Magnification is negative for real image and positive for virtual image.
- Magnification always positive for concave lens and less than one.

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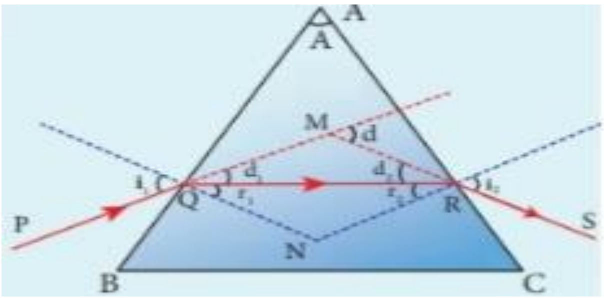
9. Derive the equation for angle of deviation produced by a prism and thus obtain the equation for refractive index of material of the prism.

Angle of deviation :



Formula :

$$n = \frac{\sin \frac{A + D}{2}}{\sin \frac{A}{2}}$$

Theory :

- **Consider a prism A B C.**
- **Polished face → A B , A C**
- **Rough face → B C**
- **Incident Ray → P Q**
- **Emergent Ray → R S**
- **Angle of incidence → i_1 , i_2**
- **Angle of refraction → r_1 , r_2**

Angle of deviation :

The minimum value of angle of deviation is called "angle of deviation."

At surface A B : $\angle RQM = d_1 = i_1 - r_1$

At surface A C : $\angle QRM = d_2 = i_2 - r_2$

Total angle of deviation : $d = d_1 + d_2$

$$d = i_1 - r_1 + i_2 - r_2$$

$$d = i_1 + i_2 - (r_1 + r_2) \quad \text{-------- (1)}$$

Quadrilateral A Q N R : $\angle A + \angle QNR = 180^0$

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Triangle QNR : $r_1 + r_2 + \angle QNR = 180^0$

$$A = r_1 + r_2 \quad \text{----------} (2)$$

sub eqn (2) in (1) : $d = i_1 + i_2 - A$ --------- (3)

At minimum deviation :

$d = D$; $i_1 = i_2 = i$; $r_1 = r_2 = r$

$r_1 + r_2 = A$	$D = i_1 + i_2 - A$
$r + r = A$	$D = i + i - A$
$2r = A$	$D = 2i - A$
$r = \frac{A}{2}$	$i = \frac{A + D}{2}$

Snell's law : $n = \frac{\sin i}{\sin r}$

Refractive Index : $\boxed{n = \frac{\sin\left[\frac{A + D}{2}\right]}{\sin\left[\frac{A}{2}\right]}}$

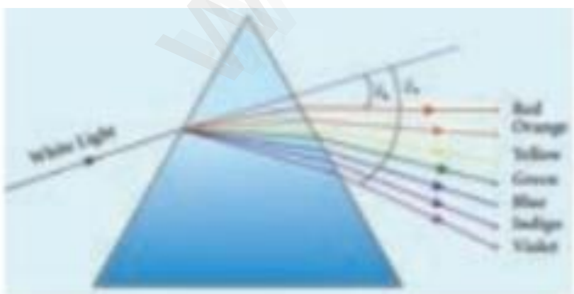
---

10. What is the dispersion ? Obtain the equation for dispersive power of a medium.

Dispersion :

- Splitting of white colour into its constituent colours .
- Band of colours of light is called its spectrum.

Diagram :



Formula :

$$\boxed{\omega = \frac{n_V - n_R}{n - 1}}$$

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Refractive Index :

$$n = \frac{\sin \frac{A + D}{2}}{\sin \frac{A}{2}}$$

- Angle of small angle prism → A
- Angle of minimum deviation → δ

$$n = \frac{\sin \frac{A + \delta}{2}}{\sin \frac{A}{2}}$$

- $\sin \frac{A + \delta}{2} = \frac{A + \delta}{2}$
- $\sin \frac{A}{2} = \frac{A}{2}$
- $n = \frac{\frac{A + \delta}{2}}{\frac{A}{2}} = \frac{A + \delta}{A} = \frac{A}{A} + \frac{\delta}{A}$
- $n = 1 + \frac{\delta}{A}$
- $\frac{\delta}{A} = n - 1$
- $\boxed{\delta = A (n - 1)}$

Colours	Violet	Red
Angle of minimum deviation	δ_V	δ_R
Refractive Index	n_V	n_R

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- For violet colour $\delta_V = (n_V - 1) A$
- For red colour $\delta_R = (n_R - 1) A$
- $\delta_V - \delta_R = (n_V - 1) A - (n_R - 1) A$
- $\delta_V - \delta_R = n_V A - \cancel{A} - n_R A + \cancel{A}$
- $\delta_V - \delta_R = n_V A - n_R A$
- $\delta_V - \delta_R = (n_V - n_R) A$

Angular dispersion :

The angular separation between the two extreme colours violet and red in spectrum is called " angular dispersion "

$$\boxed{\delta_V - \delta_R = (n_V - n_R) A}$$

Dispersive Power :

The angular dispersion for the extreme colours to the deviation for any middle colour is known as " dispersive power "

$$\omega = \frac{\text{Angular Dispersion}}{\text{Middle Deviation}}$$

$$\omega = \frac{\delta_V - \delta_R}{\delta}$$

$$\omega = \frac{(n_V - n_R) A}{(n - 1) A}$$

Dispersive Power :

- It is a dimensionless & unitless quantity.
- It is always positive.
- Depends only on the nature of the prism.
- Independent of the angle of the prism.

$$\boxed{\omega = \frac{n_V - n_R}{n - 1}}$$

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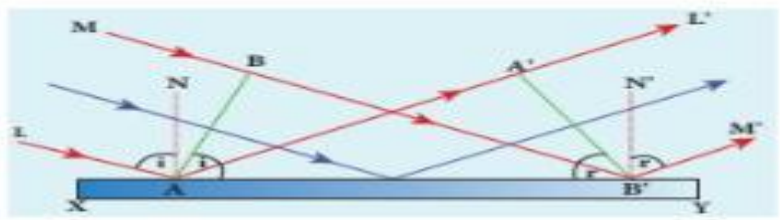
LESSON - 7

1. Prove law of reflection using " Huygen's principle .

Diagram :



Laws of reflection

Theory :

* Let us consider parallel beam of light is incident on a reflecting plane surface.

1. Plane mirror ⟶ X Y
2. Incident wave front ⟶ A B
3. Reflected wavefront ⟶ A' B'
4. Incident rays ⟶ L , M
5. Reflected rays ⟶ L' , M'
6. Two Normals ⟶ N , N'

* By the time of point A of the incident wavefront touches reflecting surface , the point B travel distance BB'.

* By the time of point B of the incident wavefront touches reflecting surface , the point A travel distance AA'.

As the reflection happens in the same medium :

1) Speed of light is same before and after the reflection.
2) Time taken for light to travel from B to B' and A to A' are the same.
3) Distance BB' is equal to the distance AA'.
4) The incident rays , the reflected rays and the normal are lie in the same plane.
5) Angle of incidence , $< i = < NAL = 90^0 - < NBA = < BAB'$
6) Angle of reflection, $< i = < N'B'M' = 90^0 - < N'B'A' = < A'B'A$

For the right angle triangles , $\Delta ABB'$ and $\Delta B'AA'$

➢ Two right angles are $< B$ and $< A'$ are equal . ($< B = < A = 90^0$)

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- Two sides $AA^{/}$ and $BB^{/}$ are equal. ($AA^{/} = BB^{/}$)
- The side $AB^{/}$ is common.
- The two angles $< BAB^{/}$ and $< A^{/}BA$ must be equal.
- Thus , the triangles are congruent.

$\boxed{i = r}$

Hence , the laws of reflection are proved.

---

2. Prove law of refraction using " Huygen's principle .

Diagram :

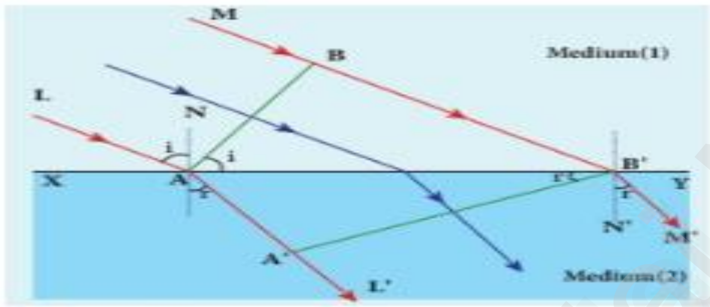

Figure 7.5 Law of refraction

Theory :

* Let us consider parallel beam of light is incident on a refracting plane surface.

1. Plane mirror ⟶ X Y
2. Incident wave front ⟶ A B in rarer medium (1)
3. Reflected wavefront ⟶ $A^{/} B^{/}$ in denser medium (2)
4. Incident rays ⟶ L , M
5. Reflected rays ⟶ $L^{/}$, $M^{/}$
6. Two Normals ⟶ N , $N^{/}$

* By the time of point A of the incident wavefront touches reflecting surface , the point B travel distance $BB^{/}$.

* By the time of point B of the incident wavefront touches reflecting surface , the point A travel distance $AA^{/}$.

As the reflection happens from rarer medium (1) to denser medium (2):

1. Speed of light is v_1 and v_2 before and after the refraction. ($v_1 > v_2$)

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2. Time taken for light to travel from B to B and A to A are the same.

3. $$t = \frac{BB'}{v_1} = \frac{AA'}{v_2}$$

$$\frac{BB'}{AA'} = \frac{v_1}{v_2}$$

4. The incident rays , the refracted rays and the normal are lie in the same plane.

5. Angle of incidence , $\angle i = \angle NAL = 90^0 - \angle NBA = \angle BAB'$

6. Angle of reflection, $\angle i = \angle N'B'M' = 90^0 - \angle N'B'A' = \angle A'B'A$

7. For the right angle triangles , $\Delta ABB'$ and $\Delta AA'B'$

$$\frac{\text{Sin } i}{\text{Sin } r} = \frac{BB'/AB'}{AA'/AB'} = \frac{BB'}{AA'} = \frac{v_1}{v_2} = \frac{c/v_2}{c/v_1}$$

8. Refractive index of the medium

$$n_1 = \frac{c}{v_1} \; ; \; n_2 = \frac{c}{v_2}$$

$$\frac{n_2}{n_1} = \frac{\cancel{c}}{v_2} \frac{v_1}{\cancel{c}}$$

$$\frac{n_2}{n_1} = \frac{v_1}{v_2}$$

9. Snell's law in ratio form

$$\frac{\text{Sin } i}{\text{Sin } r} = \frac{n_2}{n_1}$$

10 . Snell's law in product form

$$n_1 \text{ Sin } i = n_2 \text{ Sin } r$$

Hence , the laws of refraction are proved.

---

3. Obtain the equation for resultant intensity due to interference of light.

<u>Interference :</u>

The phenomenon of superposition of two light waves which produces increases in intensity at some points and decreases in intensity at some points is called " interference of light "

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Theory :

Let us consider two light waves from the two sources S_1 and S_2 meeting at a point P .

1. The wave from S_1 at an instant t at P is ,

$$y_1 = a_1 \sin \omega t$$

2. The wave from S_2 at an instant t at P is ,

$$y_2 = a_2 \sin (\omega t + \phi)$$

3. Amplitudes $\longrightarrow$ a_1 and a_2

Angular frequency $\longrightarrow$ ω

Phase difference $\longrightarrow$ ϕ

Diagram :

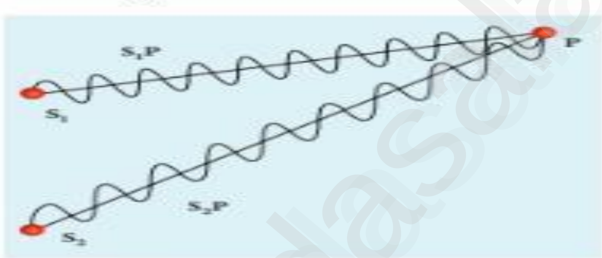

Figure 7.6 Superposition principle

Resultant Displacement :

$$y = y_1 + y_2$$

$$y = a_1 \sin \omega t + a_2 \sin (\omega t + \phi)$$

$$y = a_1 \sin \omega t + a_2 (\sin \omega t \cos \phi + \cos \omega t \sin \phi)$$

$$y = a_1 \sin \omega t + a_2 \sin \omega t \cos \phi + a_2 \cos \omega t \sin \phi$$

$$y = \sin \omega t (a_1 + a_2 \cos \phi) + a_2 \sin \phi \cos \omega t \text{ ---------------------- } (1)$$

Let us consider $a_1 + a_2 \cos \phi = A \cos \theta$ and $a_2 \sin \phi = A \sin \theta$ --------- (2)

Sub eqn (2) in eqn (1)

$$y = A \sin \omega t \cos \theta + A \cos \omega t \sin \theta$$

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$$y = A(\sin\omega t \cos\theta + \cos\omega t \sin\theta)$$

$$\boxed{y = A\sin(\omega t + \theta)} \quad \text{-------------------------------} \quad (3)$$

Resultant Amplitude :

Squaring and adding eqn (2)

$$(a_1 + a_2 \cos\phi)^2 + a_2^2 \sin^2\phi = A^2\cos^2\theta + A^2\sin^2\theta$$

$$a_1^2 + a_2^2\cos^2\phi + 2a_1 a_2\cos\phi + a_2^2\sin^2\phi = A^2(\cos^2\theta + \sin^2\theta)$$

$$a_1^2 + a_2^2\cos^2\phi + a_2^2\sin^2\phi + 2a_1 a_2\cos\phi = A^2$$

$$a_1^2 + a_2^2(\cos^2\phi + \sin^2\phi) + 2a_1 a_2\cos\phi = A^2$$

$$a_1^2 + a_2^2 + 2a_1 a_2\cos\phi = A^2$$

$$A^2 = a_1^2 + a_2^2 + 2a_1 a_2\cos\phi$$

$$\boxed{A = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2\cos\phi}}$$

Max Amplitude : $A_{max} = \sqrt{(a_1^2 + a_2^2)}$ Where $\phi = 0, \pm 2\pi, \pm 4\pi, \ldots\ldots$

Min Amplitude : $A_{min} = \sqrt{(a_1^2 - a_2^2)}$ Where $\phi = \pm\pi, \pm 3\pi, \pm 5\pi \ldots\ldots$

Resultant Intensity :

" Intensity of light is proportional to square of amplitude "

$I \propto A^2$	$I_1 \propto a_1^2$	$I_2 \propto a_2^2$
$A^2 = I$	$a_1^2 = I_1$	$a_2^2 = I_2$
$A = \sqrt{I}$	$a_1 = \sqrt{I_1}$	$a_2 = \sqrt{I_2}$

Resultant Intensity : $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

Max Intensity : $I_{max} = (a_1 + a_2)^2$ Where $\phi = 0, \pm 2\pi, \pm 4\pi, \ldots\ldots$

$$I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$$

Max intensity is called " Constructive interference "

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Min Amplitude : $I_{min} = (a_1 - a_2)^2$ Where $\phi = \pm\pi, \pm 3\pi, \pm 5\pi, \ldots\ldots$

$$I_{max} = I_1 + I_2 - 2\sqrt{I_1 I_2}$$

Min intensity is called " Destructive interference "

---

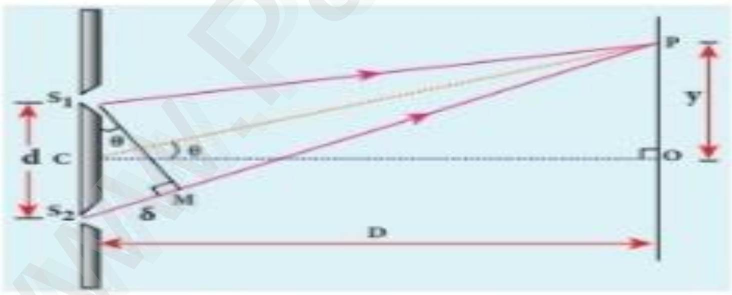
4. Explain the Young's double slit experimental setup and obtain the equation for path difference.

Experimental Setup :

1. Thomas Young used an opaque screen with two openings.
2. This two openings is called double slit S_1 and S_2 .
3. S_1 and S_2 kept equidistance from a source S.
4. The width of each slit is about 0.03 mm.
5. They are separated by a distance of about 0.3 mm.
6. S_1 and S_2 are equidistant from source S

   * Same wavefront * In - phase * Coherent source * Obtain interference pattern.
7. Screen is placed 1 m from the slits , alternate bright and dark fringes appeared.
8. These are called interference fringes and bands.
9. These two waves constructively interfere and bright fringe is observed at O.
10. When one slit is closed , fringes disappear and there is uniform illumination on the screen.

Diagram :



Young's double slit arrangement to find path difference

Theory :

- Let d be the distance between the double slits S_1 and S_2.
- They act as coherent source of wavelength λ .
- A screen is placed parallel to double slit at a distance D.

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- The mid – point of S_1 and S_2 is C .
- The mid – point of the screen is O .
- P is any point at a distance y from O.
- Waves from S_1 and S_2 either in – phase or out – of - phase .

Path difference Derivation :

1. $\delta = S_2 P - S_1 P = S_2 M$ ---------- (1)
2. From right angle triangle $\Delta\ S_1 S_2 M$

$$\sin\theta = \frac{S_2 M}{S_1 S_2}$$

$$S_2 M = d \sin\theta \quad (S_1 S_2 = d)$$

$$\delta = d \sin\theta$$

$$\delta = d\ \theta \text{ ---------- } (2)$$

3. From right angle triangle Δ O C P

$$\tan\theta = \frac{OP}{CO}$$

$$\tan\theta = \frac{y}{D}$$

$$\theta = \frac{y}{D} \text{ --------- } (3)$$

4. Sub eqn (3) in eqn (2)

$$\delta = \frac{d\ y}{D}$$

5. Path Difference :

$$\boxed{\delta = \frac{d\ y}{D}}$$

6. **Condition for bright fringe (or) maxima :**

- Bright Fringe ⟶ Constructive interference
- Path difference $\delta = n\lambda$ where $n = 0, 1, 2, 3$ …….

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- $\delta = \frac{d\,y}{D} = n\lambda$
- $y = \frac{n\lambda D}{d}$

$$\boxed{y_n = \frac{n\lambda D}{d}}$$

7. **Condition for Dark fringe (or) minima :**

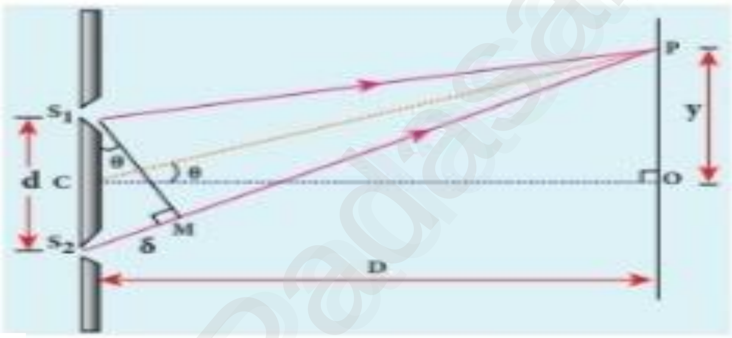
- Dark Fringe $\longrightarrow$ Destructive interference
- Path difference $\delta = (2n - 1)\frac{\lambda}{2}$ where $n = 1, 2, 3 \ldots\ldots$
- $\delta = \frac{d\,y}{D} = (2n - 1)\frac{\lambda}{2}$

$$\boxed{y_n = \frac{(2n-1)}{2}\frac{\lambda D}{d}}$$

---

5. **Obtain the equation for bandwidth in Young's double slit experiment.**

Diagram :



Young's double slit arrangement to find path difference

Theory :

- Let d be the distance between the double slits S_1 and S_2.
- They act as coherent source of wavelength λ .
- A screen is placed parallel to double slit at a distance D.The mid – point of S_1 and S_2 is C .
- The mid – point of the screen is O .
- P is any point at a distance y from O.
- Waves from S_1 and S_2 either in – phase or out – of - phase .

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Equation for bandwidth :

The bandwidth β is defined as the distance between any two consecutive bright (or) dark fringes.

Consecutive Bright Fringes:

$$y_n = \frac{n \lambda D}{d}$$

$$y_{(n+1)} = \frac{(n+1) \lambda D}{d}$$

$$\beta = y_{(n+1)} - y_n$$

$$\beta = \left(\frac{(n+1) \lambda D}{d}\right) - \left(\frac{n \lambda D}{d}\right)$$

$$\beta = \frac{n \lambda D}{d} + \frac{\lambda D}{d} - \frac{n \lambda D}{d}$$

$$\beta = \frac{\lambda D}{d}$$

$$\boxed{\beta \text{ for bright }, \quad \beta = \frac{\lambda D}{d}}$$

Consecutive Dark Fringes:

$$y_n = \frac{(2n-1)}{2} \frac{\lambda D}{d}$$

$$y_{(n+1)} = \frac{(2(n+1) - 1)}{2} \frac{\lambda D}{d}$$

$$\beta = y_{(n+1)} - y_n$$

$$\beta = \left((2n+1) - 1) \frac{\lambda D}{d} \right) - \frac{n \lambda D}{d}$$

$$\beta = \frac{2n \lambda D}{d} + \frac{\lambda D}{d} - \frac{n \lambda D}{d}$$

$$\beta = \frac{\lambda D}{d}$$

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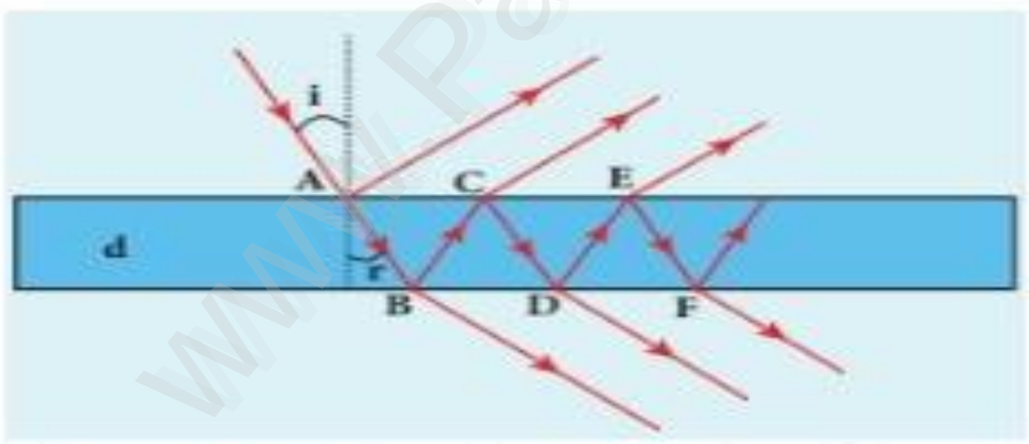
6. Discuss the interference in thin films and obtain the equation for constructive and destructive interference for transmitted and reflected light.

Theory :

1. Let us consider a thin film of transparent material refractive index μ and thickness d.
2. A parallel beam of light is incident on the film at an angle i .
3. The wave is divided into two parts at the point of incidence , as reflected and refracted lights.
4. The refracted part which enters into the film again gets divided at the lower surface into two parts.
   - One is transmitted out of the film .
   - Other is reflected back into the film.
5. The reflected as well as refracted parts are further formed as multiple reflections take place inside the film.
6. The interference occurs in both the reflected and transmitted light.

Diagram :



Interference in thin films

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S.NO	For Transmitted light	For Reflected light
1.	Path difference between B and D.	Path difference between C and A.
2.	The extra path travelled by the wave BC + CD	The additional path travelled by the wave AB + BC
3.	The extra path travelled by the wave is twice thickness of the film.	The extra path travelled by the wave is twice thickness of the film.
4.	For near normal incidence and small thickness then the distance be, $BC + CD = 2d$	For near normal incidence and small thickness then the distance be, $AB + BC = 2d$
5.	As this extra path is traversed inside the refractive index μ, the optical path difference $\delta = 2\mu d$	As this extra path is traversed inside the refractive index μ, the optical path difference $\delta = 2\mu d$
6.	For constructive interference $2\mu d = n\lambda$	For constructive interference $2\mu d + \frac{\lambda}{2} = n\lambda$
7.	For destructive interference $2\mu d = (2n-1)\frac{\lambda}{2}$	For destructive interference $2\mu d + \frac{\lambda}{2} = (2n+\frac{1}{2})\lambda$

---

7. Discuss the diffraction at single slit and obtain the condition for nth minimum.

Theory :

- Let a parallel beam of light fall normally on a single slit AB of width a.
- The diffracted beam falls on a screen kept at a distance D from the slit.
- The centre of the slit is C and straight line through C meets at screen at O.
- Consider any point P on the screen and all the light reaching the point P from different points on the slit make an angle θ with the normal CO.
- The point P is the geometrically shadowed region up to which central maximum spread due to *diffraction.*

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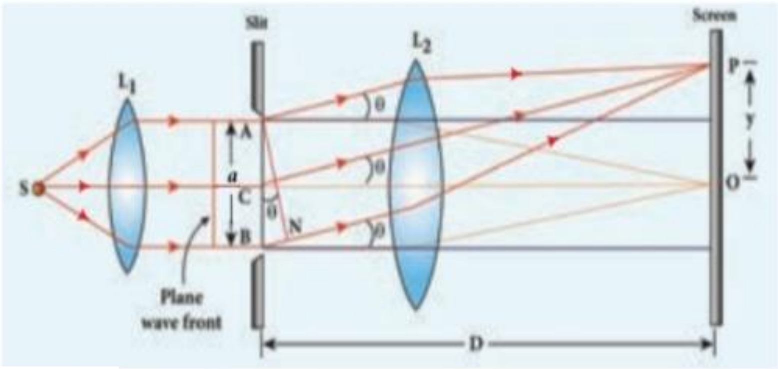
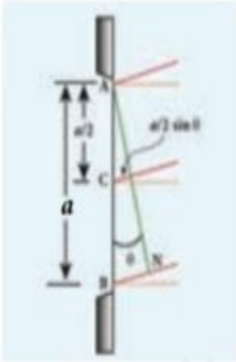
Diagram :



Diffraction at single slit



Corresponding points

Condition for the point P to be Minima :

- The basic idea to divide the slit into *even* number of smaller parts.
- Add their contribution at P with path difference takes place at that point to make it *minimum.*

Condition for P to be first minimum :

- Let us divide the slit AB into *two* halves AC and CB .
- The width of each part is *a / 2.*
- The different points on the slit which are separated by the same width a / 2 called as *corresponding points.*
- The light waves from different points interfere *destructively* to make it a *minimum.*

Path Difference : $\delta = \frac{a}{2} \sin\theta$

$$\frac{a}{2} \sin\theta = \frac{\lambda}{2}$$

$$\boxed{a \sin\theta = \lambda}$$

Condition for P to be second minimum :

- Let us divide the slit AB into *four* equal parts .
- The width of each part is *a / 4.*

Path Difference : $\delta = \frac{a}{4} \sin\theta$

$$\frac{a}{4} \sin\theta = \frac{\lambda}{2}$$

$$\boxed{a \sin\theta = 2\lambda}$$

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Condition for P to be third minimum :

- Let us divide the slit AB into *six equal parts* AC and CB .
- The width of each part is *a / 6.*

Path Difference : $\delta = \frac{a}{6} \sin\theta$

$$\frac{a}{6} \sin\theta = \frac{\lambda}{2}$$

$$\boxed{a \sin\theta = 3\lambda}$$

Condition for P to be n^th minimum :

- Let us divide the slit into 2n number of (even number) equal parts makes as minimum .
- The width of each part is *a / 2n.*

Path Difference : $\delta = \frac{a}{2n} \sin\theta$

$$\frac{a}{2n} \sin\theta = \frac{\lambda}{2}$$

$$\boxed{a \sin\theta = n\lambda}$$

Condition for the point P to be Maxima :

- The basic idea to divide the slit into *odd* number of equal parts.
- One part remains un – cancelled making the point P appear *bright.*

Condition for P to be first maximum :

$$\boxed{\frac{a}{3} \sin\theta = \frac{\lambda}{2} \quad (\text{ or }) \quad a \sin\theta = \frac{3\lambda}{2}}$$

---

8. Discuss the diffraction at a grating and obtain the condition for the m^th maximum.

Diffraction at grating :

- A grating has multiple slits equal widths of comparable size to the wavelengths of diffracting light.
- A grating is a plane sheet of transparent material on which opaque rulings are made.
- Grating contains about 6000 lines per centimetre.
- The transparent space between the rulings act as slit of width a and the rulings

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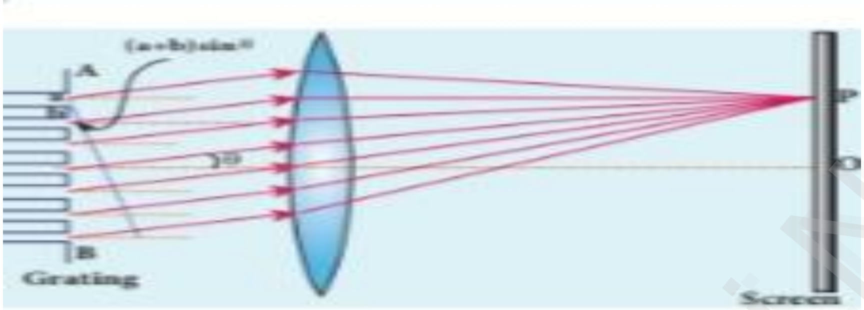
act as obstacles having definite width b.

Grating element :

- The combined width of a ruling and a slit is called grating element e.
- The points on the slit separated by a distance equal to the grating element are called *corresponding points.*

Diagram :



Diffraction grating experiment

Theory :

- A plane transmission grating is represented as AB.
- Let plane wavefront of monochromatic light with wavelength λ be incident on the grating.
- As the width of the slit is comparable to that of wavelength , the incident light undergoes diffraction.
- A diffraction pattern is obtained on the screen when the diffracted waves are focussed on a screen using a convex lens.
- Let us consider a point P at an angle θ .

Path Difference :

$\delta = (a + b) \sin\theta$

Condition for P will be maximum :

$\delta = m\lambda = (a + b) \sin\theta$

$\boxed{(a + b) \sin\theta = m\lambda}$

Condition for P to be zeroth maximum m = 0

$(a + b) \sin\theta = 0$

Condition for P to be first maximum m = 1

$(a + b) \sin\theta_1 = \lambda$

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Condition for P to be second maximum m = 2

$$(a + b) \sin \theta_2 = 2\lambda$$

Condition for P to be m^th maximum

$$(a + b) \sin \theta = m\lambda$$

$$\sin \theta = \frac{1}{a + b} m\lambda$$

N gives the number of grating elements or rulings drawn per unit width of the grating.

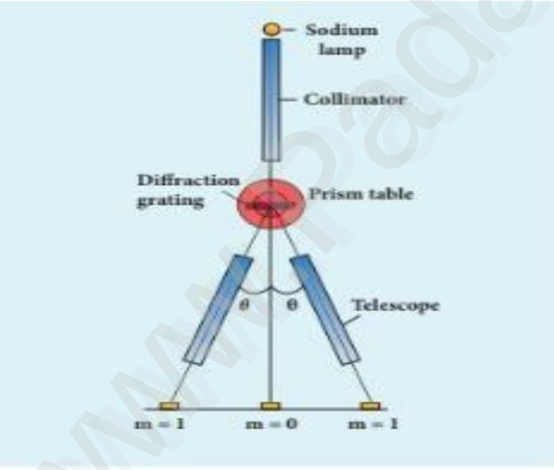
$$\boxed{N = \frac{1}{a + b}}$$

Condition for P to be m^th maximum $\boxed{\sin \theta = N m \lambda}$

---

9. Discuss the experiment to determine the wavelength of monochromatic light using diffraction grating.

Experiment to determine the wavelength :



Theory :

- The wavelength of a spectral line accurately determined with the help of *grating*.
- For that we need to use an instrument called *spectrometer.*
- After preliminary adjustments , the slit of *collimator* is illuminated by monochromatic light.

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- The *telescope* is brought in line with collimator to view the image of the slit.
- The given grating is then mounted on the prism table .
- The telescope is turned to one side until the first order diffraction .
- Reading of the position of the telescope is noted .
- The difference between two readings gives 2θ .
- Half of its valve gives θ.

Wavelength of light :

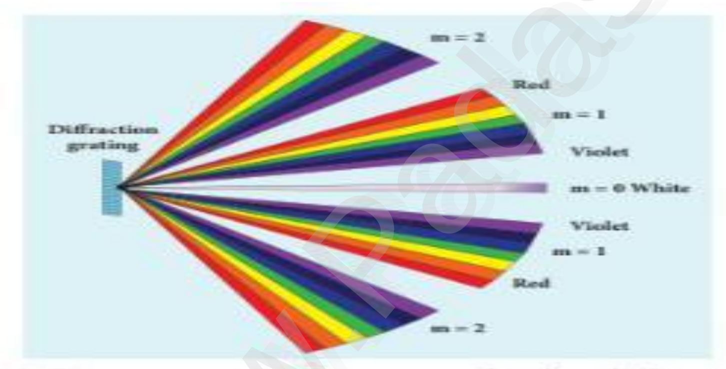
$$\lambda = \frac{\sin\theta}{N\, m}$$

- N is the number of rulings per meter in the grating .
- m is the order of the diffraction image.

---

10 . Discuss the experiment to determine the wavelength of different colours using diffraction grating.

Wavelength of colours using diffraction grating :



Theory :

- The diffraction pattern for white light consists of a white central maximum.
- The continuous coloured diffraction pattern on its both sides.
- The central maximum is white as all the colours constructively meet at centre with no path difference.
- As θ increases , the path differences fulfils the condition for maxima for maxima of different orders for all colours from violet to red.
- It produces a spectrum of diffraction pattern from violet to red on either side of

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central maximum .

- By measuring the angle at which these colours appear for various orders of diffraction , the wavelength of different colours could be calculated.

Wavelength of light :

$$\lambda = \frac{\sin\theta}{N\, m}$$

- N is the number of rulings per meter in the grating .
- m is the order of the diffraction image.

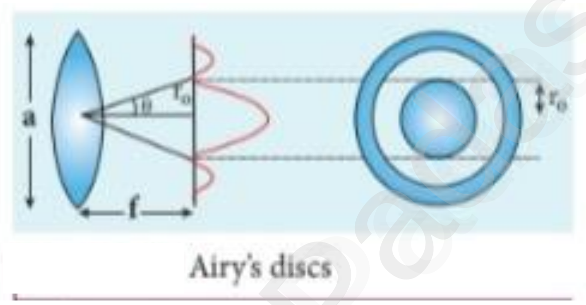
---

11. Obtain the equation for resolving power optical instruments .

Resolving power of optical instrument :

The ability of an optical instrument to distinguish the two closely adjacent objects (or) two points on the same object is said to be " *resolving power* " of the Instrument.

Diagram :



Airy's discs

Theory :

- The effect of diffraction in the sharpness of the image formed.
- There is always spread of central maximum in the image for every point of the object acts as a point source.
- The condition for central maximum produced by rectangular slit is given by

$$a \sin\theta = \lambda$$

- circular slit produces diffraction pattern of concentric circles & kown as *airy disc's*
- Most of the optical instruments form images of objects only through the circular slits .

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Condition for central maximum : $\boxed{a \sin\theta = 1.22\,\lambda}$

- The numerical value 1.22 appears in the expression for central maximum.
- Central maximum or first minimum formed by circular slits.

Derivation :

1. For small angles , $\sin\theta = \theta$
2. $a \sin\theta = 1.22\,\lambda$
3. $a\,\theta = 1.22\,\lambda$
4. $\theta = \dfrac{1.22\,\lambda}{a}$ ------------------ (1)
5. From diagram ,

$$\theta = \frac{r_0}{f}$$

$$r_0 = \theta\, f \quad \text{-------------------- (2)}$$

6. sub eqn (1) in eqn (2)

$$r_0 = \frac{1.22\,\lambda\, f}{a}$$

Rayleigh' criterion :

The two points on an image are said to be just resolved when the central maximum of one diffraction pattern coincides with the first minimum of the other.

Spatial resolution or Angular resolution :

The distance between two central maxima must be at least r_0 .

$$\boxed{r_0 = \frac{1.22\,\lambda\, f}{a}}$$

---

12. Discuss about the simple microscope and obtain the equation for magnification for near point focusing and normal focusing.

Simple Microscope :

- A simple microscope is a single magnifying (convex) lens of small focal length .
- It produce an erect , magnified and virtual image of the object.
- The object be placed within the focal length f on one side of the lens and viewed through the other side of it.
- The nearest point where an eye can clearly see is called *near point* and the farthest

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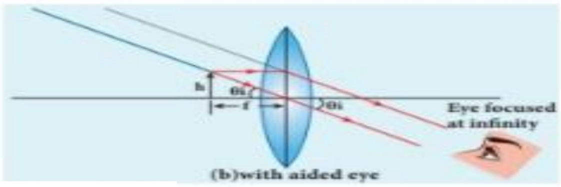
point up to which an eye can clearly see is called the *far point.*

Near point focusing :

- The eye is least strained when image is formed at near point i.e 25 cm.
- The near point is also called as *least distance* of distinct vision .
- Object distance u should be less than f.
- Image distance is the near point D.

Diagram :



Normal focusing

Derivation :

1. Magnification $m = \frac{v}{u}$

Distances are measured to left of the lens . $v = -D$ and $u = -u$

$$m = \frac{-D}{-u}$$

$$\boxed{m = \frac{D}{u}}$$

2. Lens equation

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

Multiple the above eqn by v

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

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

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

$$m = 1 - \frac{(-D)}{f} \quad (v = -D)$$

$$\boxed{m = 1 + \frac{D}{f}}$$

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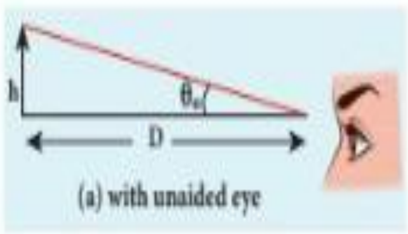
Normal Focusing :

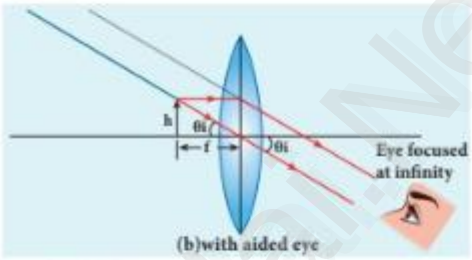
- The eye is most relaxed when the image is formed at infinity .
- The focusing is called normal focusing when the image is formed at infinity.

Angular Magnification :

The ratio of angle θ_i subtended by the image with aided eye to the angle θ_0 subtended by the object with unaided eye.

Diagram :





Derivation :

1. For unaided eye : $\tan \theta_0 = \theta_0 = \dfrac{h}{D}$

2. For aided eye : $\tan \theta_i = \theta_i = \dfrac{h}{f}$

3. Angular magnification : $m = \dfrac{\theta_i}{\theta_0}$

$$m = \frac{h/D}{h/f}$$

$$\boxed{m = \frac{D}{f}}$$

- Magnification of normal focusing is one less than that of near point focusing .
- Viewing is more comfortable in normal focusing than near point focusing.
- For large values of D / f , the difference between the two magnification is negligibly small.

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13. Explain about compound microscope and obtain the equation for the magnification.

Compound Microscope :

- **Compound microscope consists of objective lens and eye piece.**

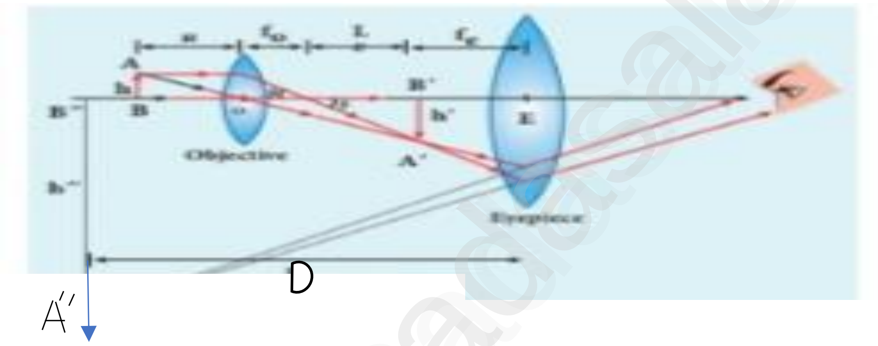
Objective :

- **The lens near the object is called as *objective.***
- **It forms a real , inverted and magnified image of the object.**

Eye Piece :

- **The object for the lens closer to the eye called as *eye piece.***
- **The eye piece serves as a simple microscope that produces finally an enlarged and virtual image.**

Diagram :



Final Image :

- **The final inverted image formed by the objective is to be adjusted within the focus of the eye piece .**
- **So that the final image is formed nearly at infinity (or) at the near point.**
- **The final image is inverted with respect to the object.**

Magnification for objective :

1. $$m = \frac{h'}{h}$$

2. From figure ,

$$\tan\beta = \frac{h}{f_0} = \frac{h'}{L}$$

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3. $$\frac{h'}{h} = \frac{L}{f_0}$$

4. $$\boxed{m_0 = \frac{L}{f_0}}$$

Tube Length:

- Distance L between the focal point of the eye piece to focal point of the objective.
- This is called the tube length of the microscope as f_0 and f_e are smaller than L.

Magnification for eye piece : $$\boxed{m_e = 1 + \frac{D}{f_e}}$$

Total Magnification :

i) Near Point Focusing :

$$m = m_0 \; m_e$$

$$m = \left(\frac{L}{f_0}\right)\left(1 + \frac{D}{f_e}\right)$$

ii) Normal Focusing :

$$m = \left(\frac{L}{f_0}\right)\left(\frac{D}{f_e}\right)$$

---

14. Obtain the equation for resolving power of microscope .

Microscope :

- A microscope is used to see details of the object under observation .
- Good microscope should not only magnify the object.
- Also resolve the two points on an object which are separated by small distance.
- Small distance d_{min} is the resolution and reciprocal is the resolving power.

Diagram :

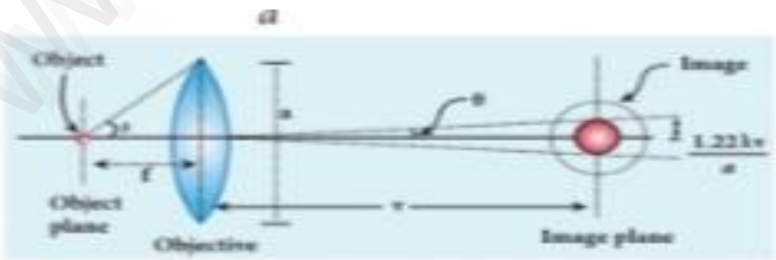

Figure 7.38 Resolving power of microscope

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Spatial Resolution :

Radius of central maximum $r_0 = \frac{1.22\,\lambda f}{a}$

Derivation :

1. Object distance is more than focal length f and image is formed at v. (f = v)

$$r_0 = \frac{1.22\,\lambda f}{a} = \frac{1.22\,\lambda v}{a}$$

2. If the two points on the object to be resolved is d_{min} then magnification ,

$$m = \frac{r_0}{d_{min}}$$

3. $$d_{min} = \frac{r_0}{m}$$

4. $$d_{min} = \frac{1.22\,\lambda v}{a\,m}$$

5. $$d_{min} = \frac{1.22\,\lambda v}{a\,(v/u)}$$

6. $$d_{min} = \frac{1.22\,\lambda u}{a}$$

7. $$d_{min} = \frac{1.22\,\lambda f}{a} \qquad (u = f)$$

8. On the object side ,

$$2\tan\beta = 2\sin\beta = \frac{a}{f}$$

$$a = 2f\sin\beta$$

9. $$d_{min} = \frac{1.22\,\lambda f}{2f\sin\beta}$$

$$d_{min} = \frac{1.22\,\lambda}{2\sin\beta}$$

10. To further reduce the value of d_{min} the optical path of the light is increased by immersing the objective of the microscope into a bath containing oil of refractive index n. Such an objective is called oil immersed objective.

$$d_{min} = \frac{1.22\,\lambda}{2n\sin\beta}$$

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11. The term $n \sin\beta$ is called *numerical aperture N A.*

$$d_{min} = \frac{1.22\ \lambda}{2\ (N A)}$$

12. Resolving power R_M of microscope is ,

$$\boxed{R_M = \frac{1}{d_{min}} = \frac{2\ (N A)}{1.22\ \lambda}}$$

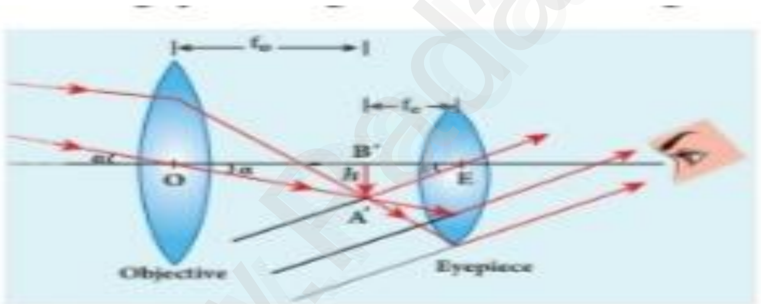
---

15. Discuss about astronomical telescope.

Astronomical Telescope :

1. An astronomical telescope is used to get the magnification of distant astronomical Objects like stars , planets , moon etc.
2. The image formed by astronomical telescope will be inverted.
3. It has an objective of long focal length and much larger aperture than eye piece.
4. Light from a distant object enters the objective and a real image is formed in the tube at its focal point.
5. The eye piece magnifies this image producing final inverted image.

Diagram :



Astronomical telescope

Magnification in astronomical telescope :

It is the ratio of the angle β subtended by the image to the angle α subtended by the object with the principal axis .

$$m = \frac{\beta}{\alpha}$$

- From diagram , $\alpha = \frac{h}{f_0}$ $\beta = \frac{h}{f_e}$

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- $$m = \frac{h}{f_e} \frac{f_0}{h}$$

- $$m = \frac{f_0}{f_e}$$

Length of the telescope : $L = f_0 + f_e$

---

16. Mention different parts of spectrometer and explain the preliminary adjustments.

Spectrometer :

- It is an optical instrument used to analyse the spectra of different sources of light.
- To measure the wavelength of different colours .
- To measure the refractive indices of materials of prisms.

Parts of spectrometer :

1. Collimator 2. Prism Table 3. Telescope

1.Collimator :

- To produce parallel beam of light .
- It is rigidly fixed to the base.
- It has a convex lens and vertical slit.

2. Prism Table :

- Used for mounting the prism , grating .
- It consists of two circular discs with three levelling screws.
- The position can be read from two verniers V_1 and V_2.
- It can be fixed at any desired height.

3. Telescope :

- It is an astronomical type.
- It consists of an eye piece provide with cross wire.
- And consists of objective at other end.
- It is attached to a circular scale.

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Preliminary adjustments of spectrometer

1.Adjustment of the eyepiece :

- The eyepiece is moved to and fro until the cross wire are clearly seen.

2.Adjustment of the telescope :

- The telescope is adjusted to receive parallel rays by focusing it to a distant object to get a clear image on the cross wire.

3.Adjustment of the collimator :

- The collimator is adjusted until a clear image of the slit is seen at the cross wire.

4. Levelling of the prism table :

- By adjusting the levelling screws and is ensured by using sprit level.

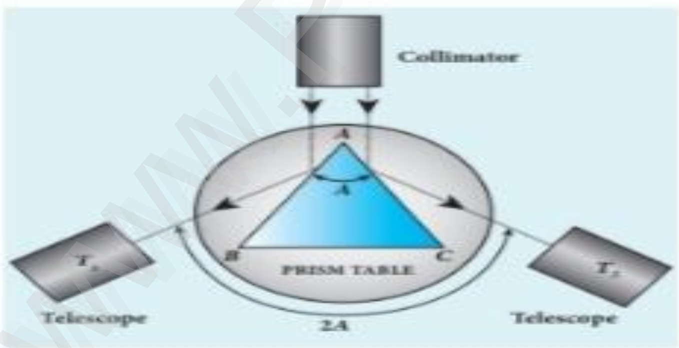
---

17. Explain the experiment determination of refractive index of the material of the prism using spectrometer.

Refractive index of material :

It can be determined by measuring the angle of the prism A and the angle of minimum deviation D.

1. Angle of the prism A :



Angle of prism

- The prism is placed on the prism table with its refracting angle A facing the collimator.
- The slit is illuminated by sodium light (Monochromatic light).
- The parallel rays coming from the collimator fall on the two faces AB and AC

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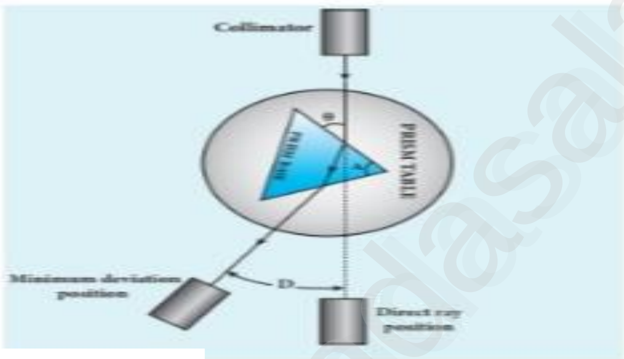
and get reflected.

- The telescope is rotated to the position T_1 and T_2 to capture the reflected rays and the two readings are noted.
- The difference between these two readings gives rotated by the telescope.

  It is twice the angle of the prism and half of this value gives the angle of prism.

2. Angle of minimum deviation D :

- The prism is placed on the prism table so that the light from the collimator falls on a refracting and the refracted image is observed through telescope.
- The prism table alone is now rotated so that the angle of deviation decreases.
- A stage comes when the image stops and returns on further rotation of the prism table.



Angle of minimum deviation

- This is ensured by looking through the telescope simultaneously.
- The reading in this position gives the minimum deviation position.
- The prism is removed and the telescope is turned to receive direct ray and the reading is noted.
- The difference between two readings gives the angle of minimum deviation D .

Refractive Index of the prism :

$$\boxed{n = \frac{\sin\left(\frac{A + D}{2}\right)}{\sin\left(\frac{A}{2}\right)}}$$

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LESSON 8

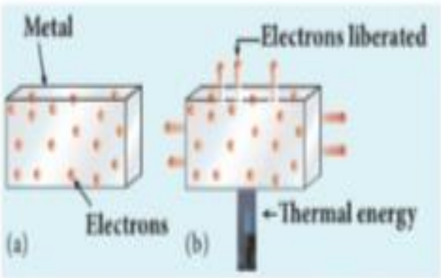
1. What do you mean by electron emission ? Explain briefly various methods of electron emission.

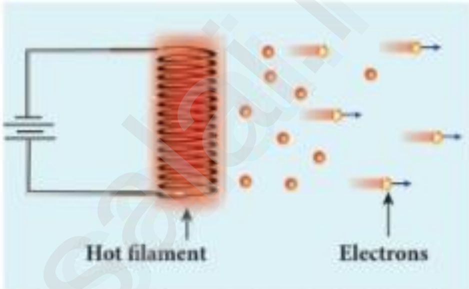
Electron Emission :

The liberation of electrons from any surface of substance .

1. Thermionic Emission :

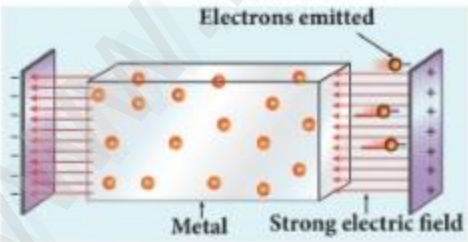
- **When a metal is heated to high temperature free electrons get sufficient energy.**
- **After getting thermal energy , free electrons emitted from the metallic surface.**
- **Example : Cathode ray tube , X ray tube.**





2. Field Emission :

- **When a strong electric field is applied across the metal pulls the free electron.**
- **Free electrons over come the surface barrier of the metal.**
- **Example : Field emission display.**



3.Photo Electric Emission :

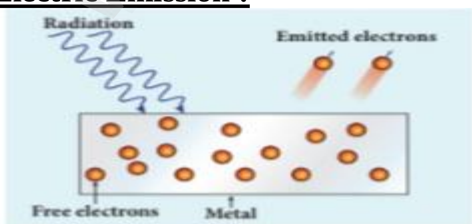


Photo electric emission

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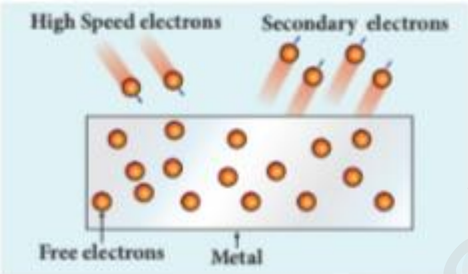
When an em radiation of suitable frequency incident on metal surface.

- After getting sufficient energy , free electrons emitted from the metallic surface.
- Example : Photo Diodes , Photo Electric cells.

4. Secondary Emission :

- When a beam of fast moving electrons strikes on metal surface.
- After getting sufficient energy , secondary emission of electrons occurs.
- Example : Photo multiplier tube.



Secondary emission of electrons

----

2. Briefly discuss the observations of Hertz , Hallwachs and Lenard.

1. Hertz observation :

- Hertz generated and detected electromagnetic wave.
- High voltage applied between two metallic sphere.
- Tiny spark produced and cant observed .
- It was exposed to uv light and noticed by detector.
- Electrons on the outer surface are emitted.

2. Hallwachs Observation :

Hallwachs confirmed that strange behaviour of spark due to uv light.

a) Uncharged Zinc plate :

- Irradiated by uv light from an arc lamp.
- Zinc plate becomes positively charged.

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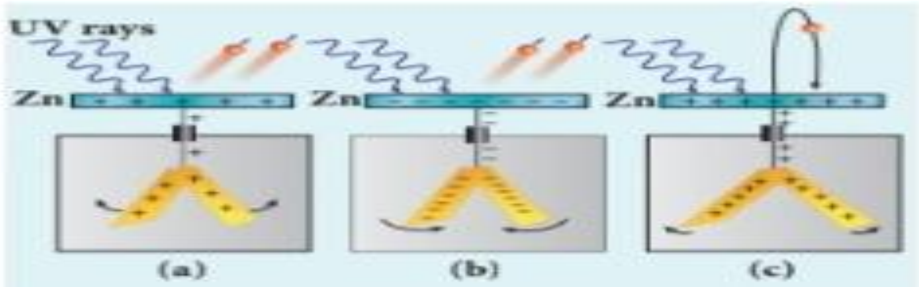
- The gold leaves will open.



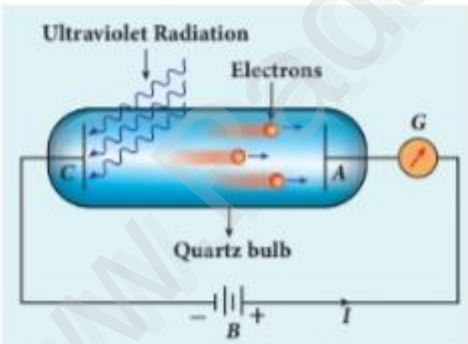
<u>b) Negatively charged Zinc plate :</u>

- **Irradiated by uv light from an arc lamp.**
- **As the charges leaked away quickly.**
- **The gold leaves come closer.**

<u>c) Positively charged Zinc plate :</u>

- **Zinc plate becomes more positive upon uv rays.**
- **The gold leaves will open further.**

3. <u>Lenard's' Observation :</u>



Experimental setup of Lenard

- **Lenard studied the electron emission phenomenon.**
- **Consists of two metallic plates A and C .**
- **They are placed in an evacuated quartz bulb.**
- **Galvanometer and battery are connected.**
- **When uv light is incident on plate C , it causes electron emission.**

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3. Explain the effect of potential difference on photoelectric current.

Experiment :

To study the effect of potential difference

- **Frequency and intensity of incident light are kept constant.**
- **Initially potential A is kept positive w.r.t C .**

Saturation Current :

1. **If the potential of A is increased , photo current also increases.**
2. **At one stage photocurrent reaches saturation current.**
3. **Photo electrons from C collected by A.**

Retarding Potential :

1. **If negative potential is applied to A w.r.t C.**
2. **Current does not immediately drop to zero.**
3. **Photo electrons emitted with different K.E.**

Gradually increasing negative potential :

1. **Photo current starts to decrease.**
2. **At one stage photocurrent becomes zero.**
3. **At particular negative potential V_0.**

Stopping potential :

1. **Value of negative potential given to collecting electrode A.**
2. **It is sufficient to stop most energetic photo electrons emitted.**
3. **And make the photo current zero.**
4. **It is known as " stopping / cut – off potential "**

Graph :

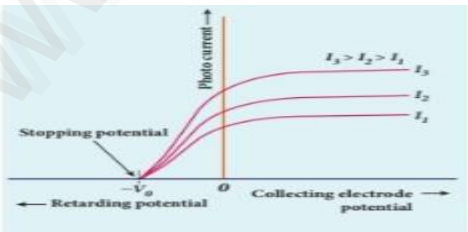

Figure 8.10 Variation of photocurrent with potential difference

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Kinetic Energy :

$$K_{max} = \frac{1}{2} m v^2_{max} = e V_0$$

$$v^2_{max} = \frac{2 e V_0}{m}$$

$$v_{max} = \sqrt{\frac{2 e V_0}{m}} = \sqrt{\frac{2 \times 1.602 \times 10^{-19} \times V_0}{9.1 \times 10^{-31}}}$$

$$v_{max} = 5.93 \times 10^5 \sqrt{V_0}$$

---

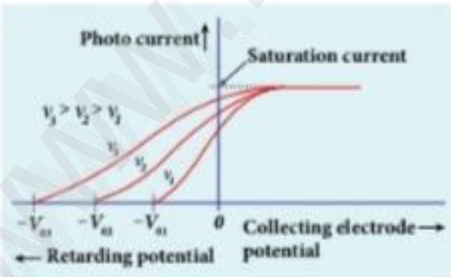
4. Explain how frequency of incident light varies with stopping potential.

Theory :

To study the effect of frequency

- **Intensity of incident light are kept constant.**
- **Photocurrent vary with potential.**
- **Stopping potential vary with frequency.**
- **Greater frequency , larger stopping potential.**
- **If frequency increased , K.E of photo electrons increased.**
- **Retarding potential needed to stop the photo electrons.**

Variation of photo current with potential for different frequency:



Threshold Frequency :

- **Below certain frequency , no electrons emitted.**
- **Hence , stopping potential is zero.**
- **Frequency increases above threshold frequency ,**

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- **Stopping potential varies linearly with frequency.**

<u>Variation of Stopping potential with frequency for two metals:</u>

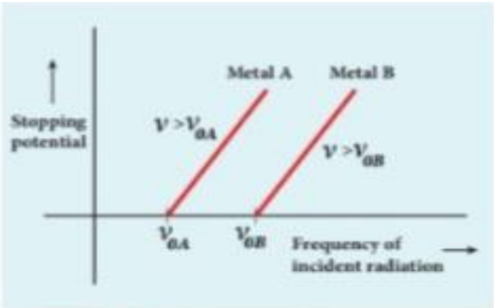

Figure 8.12 Variation of stopping potential with frequency of the incident radiation for two metals

---

5. List out the laws of photo electric effect . (or) 9. Explain experimentally observed facts of photo electric effect with the help of Einstein's explanation.

1. The emission of photo electrons takes place only if the frequency of incident light is greater than a certain minimum frequency is called " Threshold frequency "

2. Number of photo electrons is proportional to intensity of incident light.

3. Saturation current is directly proportional to intensity of incident light.

4. Maximum K. E is directly proportional to frequency of incident light.

5. Maximum K. E is independent of intensity of incident light.

6. There is no time lag between incidence of light and ejection of photo electrons.

---

6. Explain why photoelectric effect cannot be explained on the basis of wave nature of light.

1. Greater the intensity of incident light , Greater the kinetic energy of liberated electrons. But experiment shows that max K.E of photo electrons does not depend on intensity of incident light.

2. If sufficient intense beam of light incident on the surface , electrons liberated from target however low frequency of radiation. It is not possible below certain minimum

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frequency of incident radiation (Threshold frequency).

3. Each electrons need some time to get energy sufficient to overcome the work function. Photo electric emission is almost instantaneous process. The time lag is less than 10^{-9} s after the surface is illuminated.

---

7. Explain the quantum concept of light.

1. Max Planck proposed quantum concept to explain the thermal radiation emitted by black body and shape of radiation curves.
2. Matter is composed of large number of oscillating particles which vibrate with different frequency.
3. Each atomic oscillator which vibrates with its characteristics frequency emits or em radiation of same frequency.
4. If an oscillator vibrates with frequency its energy have only certain discrete values.

$$\boxed{E_n = n h \gamma}$$

5. The oscillator emit or absorb energy in small packet or quanta and energy of each quanta is h γ .This implies that energy of oscillator is quantized so energy is not continuous one. This is called as " quantization of energy ".

8.Obtain Einstein photo electric equation with necessary explanation.

Photo Electric Effect :

The ejection of electrons from a metal surface when illuminated by light or with em radiation of suitable wavelength is called " Photoelectric effect "

Photo electric equation :

$$\boxed{h \gamma = h \gamma_0 + \frac{1}{2} m v^2}$$

Theory

1. When a photon of energy h γ is incident on a metal surface , it is completely absorbed by a single electron and is ejected .

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2. **In this process ,**

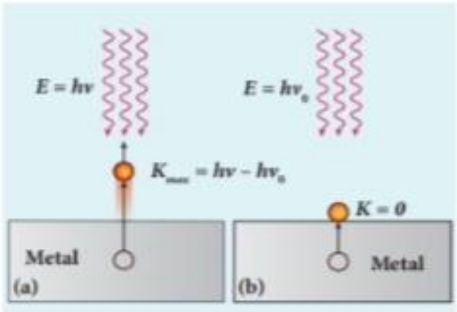
i) Part of energy is used in overcoming the potential barrier of metal surface.

Photo electric work function Φ_0

ii) Remaining energy as kinetic energy of the ejected electron.

$$\text{Kinetic Energy} = \frac{1}{2} m v^2$$

Emission of photo electron :



3. From law of conservation of energy

$$h\gamma = \Phi_0 + \frac{1}{2} m v^2$$

- m → mass of the electron
- v → velocity of the electron

4. If reduce the frequency of incident light , K.E of photo electrons also reduced. The

- photo electrons emitted with zero K.E at frequency γ_0
- γ_0 is Threshold frequency

$$h\gamma_0 = \Phi_0$$

5. **Photo electric equation :**

$$\boxed{h\gamma = h\gamma_0 + \frac{1}{2} m v^2}$$

This is known as " photo electric equation "

6. **Maximum kinetic energy :**

$$K_{max} = \frac{1}{2} m v^2_{max}$$

$$h\gamma = h\gamma_0 + \frac{1}{2} m v^2$$

$$h\gamma = \Phi_0 + K_{max}$$

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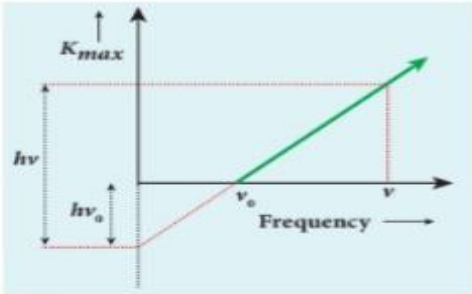
$$\boxed{K_{max} = h\gamma - \Phi_0}$$

7. **K_{max} vs ν graph :**

- **A graph between maximum kinetic energy K_{max} of the photo electron and frequency γ of the incident light is straight line.**



K_{max} vs ν graph

---

10. Give the construction and working of photo emissive cell.

Construction :

1. **Consists of an evacuated glass or quartz bulb.**
2. **Two metallic electrodes are cathode and anode.**
3. **Cathode (C) is semi cylindrical shape.**
4. **It is coated with photo sensitive material.**
5. **Anode (A) is a thin rod or wire.**
6. **Potential difference applied between A and C through galvanometer.**

Working :

1. **Cathode is irradiated with suitable radiation.**
2. **The electrons are emitted from it.**
3. **These electrons are attracted by anode.**
4. **Hence , the current is produced.**
5. **It is measured by the galvanometer.**

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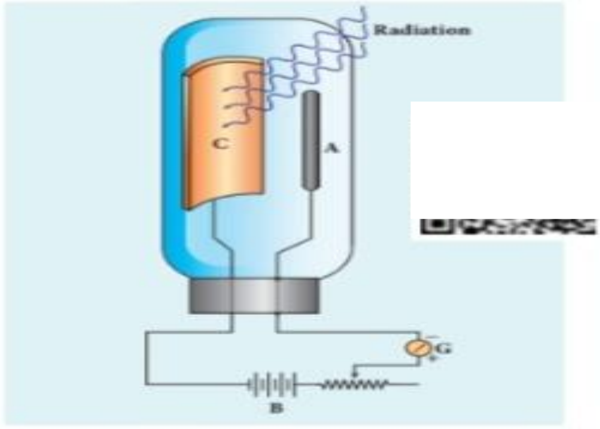
Photo cell



Construction of photo cell

Magnitude of current depends on

1. Intensity of incident radiation.
2. Potential difference between anode and cathode.

Applications of photo cells :

1. Used as switches and sensors.
2. Used to measure intensity of light.
3. Used for reproduction of sound in motion pictures.
4. Used in automatic lights turn on when it gets dark.
5. Used in street lights switch on and switch off according to night or day.
6. Used as timers to measure the speeds of athletes during a race.

---

11. Derive an expression for de Broglie wavelength of electrons.

1. According to de Broglie hypothesis ,

All material particles like electrons , protons and neutrons in motion associated with waves. These waves are called as " de Broglie waves " or " matter waves " .

2. **Momentum of photon :**

$$p = \frac{h\gamma}{c} = \frac{h}{\lambda}$$

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3. **de Broglie wavelength :**

$$\lambda = \frac{h}{m v} = \frac{h}{p}$$

4. Kinetic Energy = Potential Difference

$$\frac{1}{2} m v^2 = e V$$

$$v = \sqrt{\frac{2 e V}{m}}$$

m $\longrightarrow$ mass of the electron

V $\longrightarrow$ Potential difference .

5. $$\lambda = \frac{h}{m v} = \frac{h}{m\sqrt{\frac{2 e V}{m}}} = \frac{h}{\sqrt{2 e m V}}$$

6. $$\lambda = \frac{6.626 \times 10^{-34}}{2 V \times 1.6 \times 10^{-19} \times 9.11 \times 10^{-31}}$$

7. $$\lambda = \frac{12.27 \times 10^{-10}}{\sqrt{V}} = \frac{12.27}{\sqrt{V}} A^0$$

8. $$\boxed{\lambda = \frac{h}{\sqrt{2 e m V}} = \frac{h}{\sqrt{2 m K}}}$$

---

12. Briefly explain the principle and working of electron microscope.

Principle :

1. This is direct application of wave nature of particle.

2. Wave nature of electron is used in electron microscope.

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*** Resolving Power**

1. It is inversely proportional to the wavelength of the radiation.
2. Higher magnification and resolving power obtain for shorter wavelength.

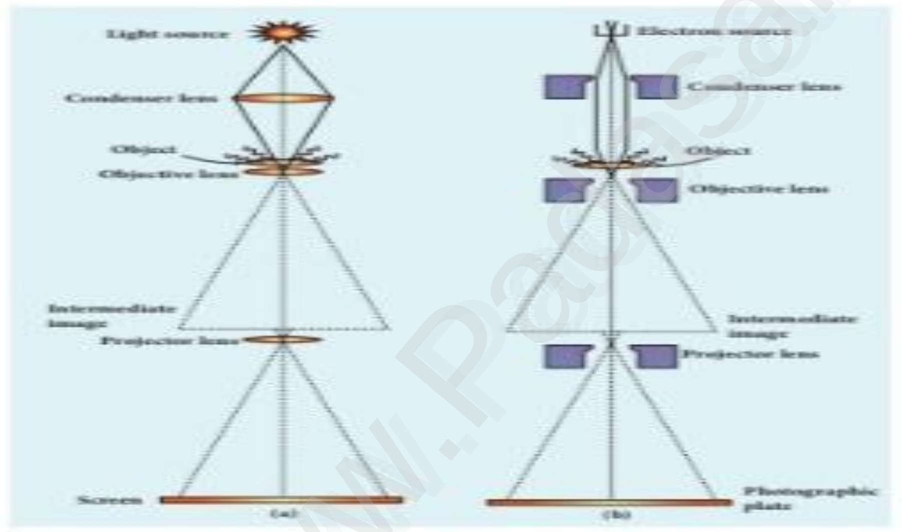
*** Wave length**

1. Louis de Broglie wave length of electron is very much less than that of the visible light used in optical microscope.
2. Louis de Broglie wave length of electron is very much higher resolving power than optical microscope.

*** Magnification**

Electron microscope giving magnification more than 2,00,000 times are common in research laboratories.

Diagram :



Working :

1. Working of an electron microscope is similar to an optical microscope .
2. It focus the electron beam is done by electrostatic or magnetic lens.
3. It is passed through electric or magnetic fields undergoes divergence or convergence.
4. The electrons emitted from source is accelerated by high potential.

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5. The beam is made parallel by magnetic condenser lens.

6. When the beam passes through the sample whose needed magnified image is needed.

7. Magnified image is obtained on the screen by using magnetic objective lens and magnetic projector lens.

8. These electron microscopes are used in all branches of science .

---

13. Describe briefly Davisson - Germer experiment which demonstrated the wave nature of electrons.

Davisson - Germer Experiment :

1. de Broglie hypothesis of matter waves was experimentally confirmed.
2. Davisson – Germer demonstrated that electron beams are diffracted when they fall on crystalline solids.
3. Crystal acts as 3 – D diffraction grating.
4. Electron waves incident on the crystal.
5. It diffracted off in certain specific directions.

Working :

1. The electrons scattered by Ni atoms in different directions.
2. They are received by electron detector .
3. I t measures the intensity of scattered electron beam.
4. The detector is capable of rotation.
5. The angle between incident beam and the scattered beam be changed.
6. The intensity of scattered electron beam is measured as the function of angle Θ.

Variation of intensity of diffracted electron beam with angle θ

1. For the accelerating voltage of 54 V scattered wave shows peak or maximum at an angle 50^0 .
2. From the known value of interplanar spacing of nickel , the wavelength of the electron wave was experimentally calculated as 1.65 A^0 .

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Apparatus for the experiment :

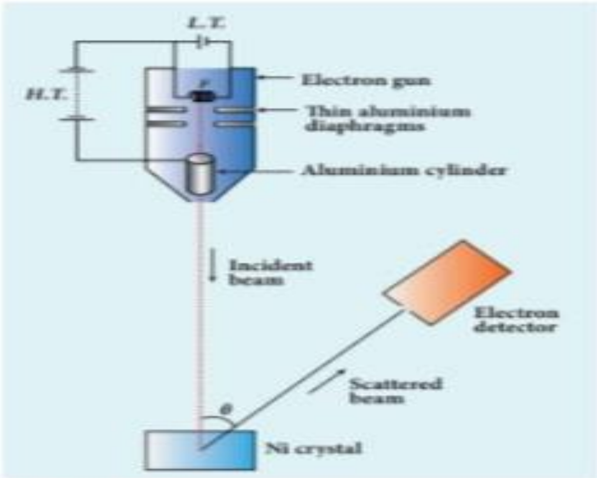

Figure 8.17 Experimental set up of Davisson – Germer experiment

3. de Broglie wavelength

$$\lambda = \frac{12.27}{\sqrt{V}} \ A^0 = \frac{12.27}{\sqrt{54}} \ A^0 = 1.67 \ A^0$$

4. This value agrees with the experimentally observed wavelength of 1.65 A^0 .

5. Thus this experiment directly verifies de Broglie's hypothesis of the nature of moving particles.

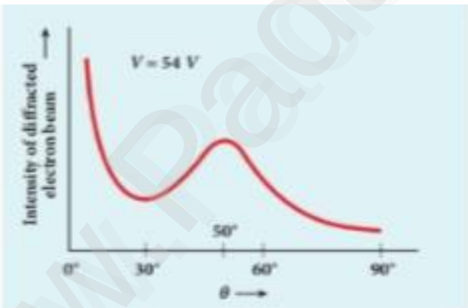

Figure 8.18 Variation of intensity of diffracted electron beam with the angle θ

---

14 . List out the characteristics of photons.

1. The photons of light of frequency γ and wavelength λ will have energy

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

2. The photons travel with speed of light and its momentum.

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$$p = \frac{h}{\lambda} = \frac{h\gamma}{c}$$

3. Photos are electrically neutral they are unaffected by electric and magnetic fields.

4. The energy of a photon is determined by the frequency of the radiation not by intensity. Intensity has no relation with energy of photon.

5. When a photon interacts with matter , the total energy , total linear momentum and angular momentum are conserved. Number of photons may not be conserved.

---

15. Give the applications of photo cells.

Applications of photo cells :

1. Used as switches and sensors.
2. Used to measure intensity of light.
3. Used for reproduction of sound in motion pictures.
4. Used in automatic lights turn on when it gets dark.
5. Used in street lights switch on and switch off according to night or day.
6. Used as timers to measure the speeds of athletes during a race.

---

16. How do we obtain characteristics X – ray spectra?

X – ray spectra :

- X - rays are produced when fast moving electrons strike the metal target.
- The intensity of X – rays when plotted against its wavelength gives a curve .
- It is called as " X – ray spectra "

Characteristics X – ray spectra :

X - ray spectra show some well - defined wavelength when the target is hit by fast electrons. The spectrum showing these peaks is called " characteristics X – ray spectrum". This X – ray spectrum is due to the electronic transition within the atoms.

Process :

1. When an energetic electron penetrates into the target atom.
2. It can remove some of K – shells electron.

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3. Electrons from outer orbits jump to fill up the vacancy in K – shell.

4.During the downward transition , the energy difference between the levels.

5. Such wavelength , Characteristics of the target , constitute line spectrum.

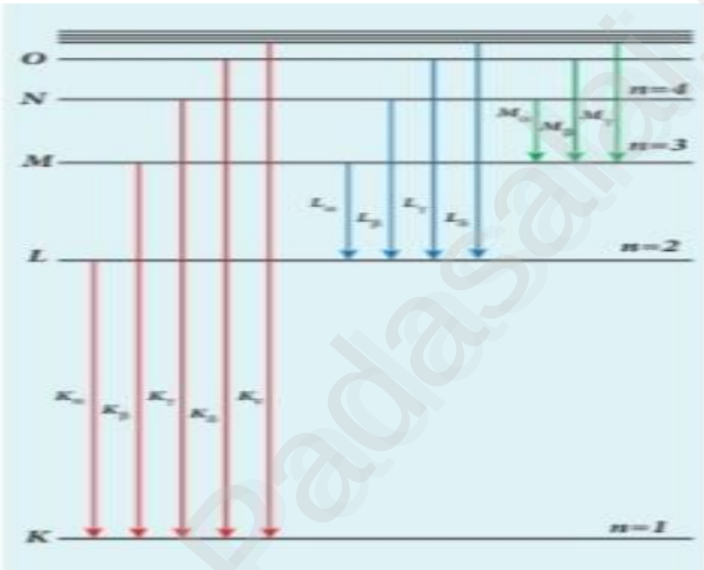
K – series :

K- series of lines in the X – ray spectrum due to electronic transitions from L , M , N levels to K – levels.

L – series :

L – series originates when an L – electron is knocked out the atom and the vacancy is filled by electronic transitions from M , N , O to the L - level and so on.

Origin of characteristic X – ray spectra :



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17. Write the applications of X – ray.

1. **Medical Diagnosis :**

- It pass through flesh more easily than bones.
- It contain deep shadow of bone .
- It contain light shadow of flesh.
- Used to detect fracture , diseased organ.

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2.**Medical Therapy :**

- **Used to kill diseased tissue.**
- **Used to cure skin disease.**
- **Used to cure malignant tumour.**

3. **Industry :**

- **Used to check the flaws in welded joints, motor tyre , tennis ball.**
- **Used to detect contraband goods .**

4. **Scientific Research :**

- **Used to study structure of crystalline structure.**
- **Used to study arrangement of atoms and molecules in crystal.**

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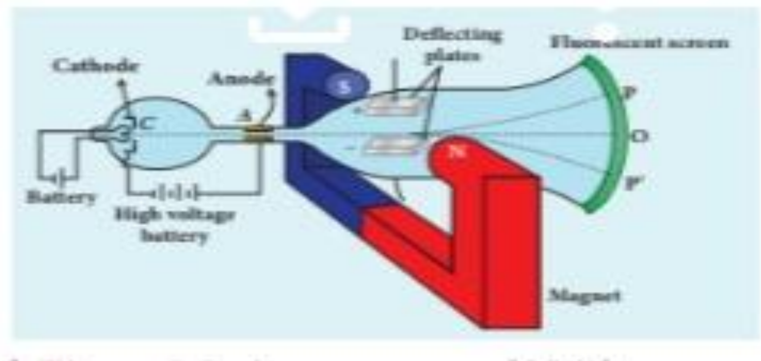
LESSON 9

1. Explain the J.J . Thomson experiment to determine the specific charge of electron.

Diagram :



Principle :

In the presence of electric and magnetic fields , the cathode rays were deflected.

Determination :

Specific charge (charge per unit mass) of the cathode rays is measured.

Arrangement :

1. A highly evacuated discharge tube is used.
2. Cathode rays produced at cathode.
3. Anode disc provided with pin hole.
4. Parallel metal plates at high voltage.
5. Gas discharge tube kept between magnet pole.
6. Both electric & magnetic fields are acts perpendicular to each other.
7. When the cathode rays strike the screen , they produce scintillation & bright spot is observed.
8. This is achieved by coating the screen by zinc sulphide.

i) Velocity of cathode rays :

- Electric field = Magnetic field
- $eE = eBv$

$$\boxed{v = \frac{E}{B}}$$

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ii) <u>Specific Charge :</u>

- Potential Energy = Kinetic Energy
- $eV = \frac{1}{2} m v^2$
- $\frac{e}{m} = \frac{v^2}{2V}$
- $\frac{e}{m} = \frac{1}{2V} \frac{E^2}{B^2}$
- $\frac{e}{m} = 1.7 \times 10^{11} \text{ kg}^{-1}$

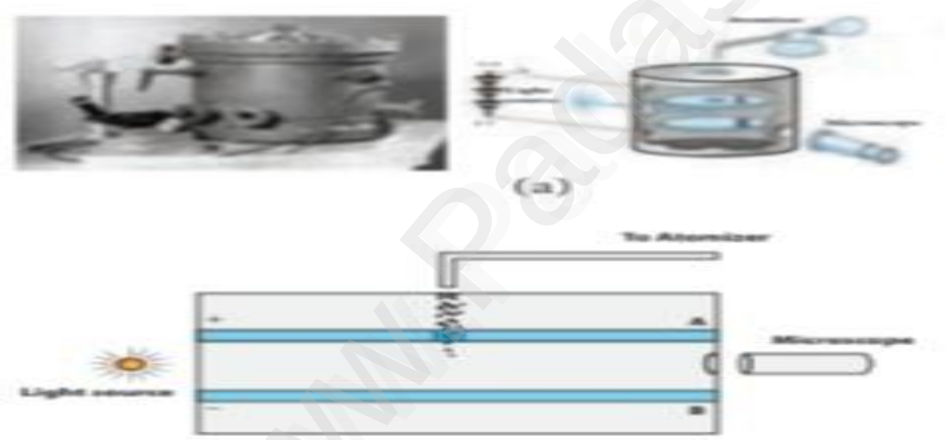
---

2. Discuss the Millikan's oil drop experiment to determine the charge of an electron.

<u>Principle :</u>

By adjusting electric field suitably , the motion of oil drop inside the chamber can be controlled.

<u>Experimental Arrangement :</u>



<u>Construction :</u>

1. Consists of two horizontal circular metal plates A and B.
2. Each with diameter 20 cm are separated by a small distance 1.5 cm.
3. These two parallel plates are enclosed in a chamber with glass walls.
4. Plates A and B are maintained at high potential difference.
5. Such that the electric field acts downward.

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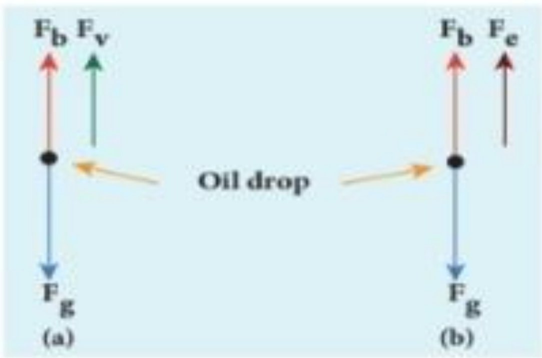
6. A small hole in the upper plate.
7. Atomizer is used to spray the liquid.
8. Highly non volatile liquid (Glycerine) is sprayed.

Free Body Diagram :



Forces acts on oil droplet

1. Gravitational force $F_g = m\,g$
2. Electric force $F_e = q\,E$
3. Buoyant force F_b
4. Viscous force F_v

a) Determination of radius of droplet

i) Without Electric field

1. Density of the oil drop : $\rho = m / v$
2. Volume of the oil drop : $V = \frac{4}{3} \pi r^3$
3. Mass of the oil drop : $m = \frac{4}{3} \pi r^3 \rho$
4. Gravitational force : $F_g = \frac{4}{3} \pi r^3 \rho g$
5. Upthrust force : $F_b = \frac{4}{3} \pi r^3 \sigma g$
6. Viscous force : $F_v = 6 \pi r v \eta$

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Force balancing equation :

$$F_g = F_b + F_v$$

$$\frac{4}{3}\pi r^3 \rho g = \frac{4}{3}\pi r^3 \sigma g + 6\pi r v \eta$$

$$\frac{4}{3}\pi r^3 \rho g - \frac{4}{3}\pi r^3 \sigma g = 6\pi r v \eta$$

$$\frac{4}{3}\pi r^3 (\rho - g)\, g = 6\pi r v \eta$$

$$\frac{2}{3} r^2 (\rho - \sigma) g = 3 v \eta$$

$$r^2 = \frac{9 v \eta}{2(\rho - \sigma) g}$$

$$\boxed{r = \left[\frac{9 v \eta}{2(\rho - \sigma) g}\right]^{1/2}}$$

b) Determination of electric charge with electric field

$$F_e + F_b = F_g$$

$$q E + \frac{4}{3}\pi r^3 \sigma g = \frac{4}{3}\pi r^3 \rho g$$

$$q E = \frac{4}{3}\pi r^3 \rho g - \frac{4}{3}\pi r^3 \sigma g$$

$$q E = \frac{4}{3}\pi r^3 (\rho - \sigma) g$$

$$q E = \frac{4}{3}\pi r\, r^2 (\rho - \sigma) g$$

$$q = \frac{4\pi}{3E}\left(\frac{9 v \eta}{2(\rho - \sigma) g}\right)^{1/2}\left(\frac{9 v \eta}{2(\rho - \sigma) g}\right)(\rho - \sigma) g$$

$$\boxed{q = \frac{18\pi}{E}\left(\frac{\eta^3 v^3}{2(\rho - \sigma) g}\right)^{1/2}}$$

Value of q is -1.6×10^{-19} C

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3.Derive the energy expression for an electron is the hydrogen atom using Bohr atom model.

Potential energy of the n^{th} orbit is

$$U_n = \frac{1}{4\pi\epsilon_0} \frac{(+Ze)(-e)}{r_n}$$

$$U_n = \frac{-1}{4\pi\epsilon_0} \frac{Ze^2}{r_n}$$

$$r_n = \frac{\epsilon_0 h^2}{\pi m e^2} \frac{n^2}{Z}$$

$$U_n = \frac{-1}{4\pi\epsilon_0} \frac{Ze^2}{\epsilon_0 h^2 n^2} \times \pi m e^2 Z$$

$$U_n = -\frac{1}{4\epsilon_0{}^2} \frac{Z^2 m e^4}{h^2 n^2}$$

Kinetic energy of e^- in n^{th} orbit

$$K.E = \frac{1}{2} m v_n^2$$

Angular momentum : $m v_n r_n = l_n = \frac{nh}{2\pi}$

$$v_n = \frac{1}{m r_n} \frac{nh}{2\pi}$$

$$v_n = \frac{\pi m e^2 Z}{m \epsilon_0 h^2 n^2} \frac{nh}{2\pi}$$

$$v_n = \frac{Ze^2}{2\epsilon_0 h n}$$

Sub v_n value in kinetic energy eqn

$$K.E_n = \frac{1}{2} m \left(\frac{Ze^2}{2\epsilon_0 h n}\right)^2$$

$$\boxed{K.E_n = \frac{m e^4 Z^2}{8\epsilon_0{}^2 h^2 n^2}}$$

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Total Energy :

$$E_n = K.E_n + U_n$$

$$E_n = K.E_n - 2K.E_n \quad (U_n = -2K.E_n)$$

$$E_n = -K.E_n$$

$$E_n = \frac{-m e^4 Z^2}{8 \epsilon_0^2 h^2 n^2}$$

For hydrogen atom Z = 1

$$\boxed{E_n = \frac{-m e^4}{8 \epsilon_0^2 h^2 n^2} \text{ joules}}$$

$$E_n = 13.6 \frac{1}{n^2} \text{ eV}$$

- For the first orbit (Ground state) $E_1 = -13.6$ e V
- For the second orbit (First excited state) $E_2 = -3.4$ e V
- For the third orbit (second excited state) $E_3 = -1.51$ e V

4.Discuss the spectral series of hydrogen atom.

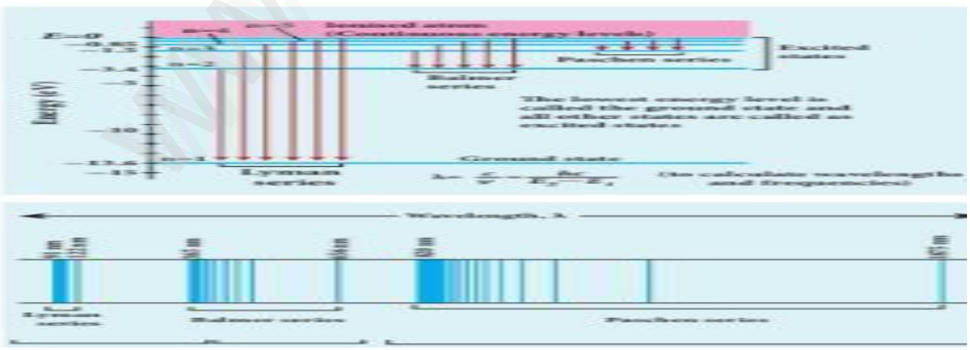
Wavelength of spectral lines

$$\boxed{\frac{1}{m^2} = R\left(\frac{1}{\lambda} - \frac{1}{n^2}\right) = \bar{\gamma}}$$

$\bar{\gamma}$ → Wave number (Inverse of wavelength)

R → Rydberg constant 1.09737 X 10^7 m^{-1}

Spectral series of hydrogen atom



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n	m	Series Name	Region
1	2,3,4.....	Lyman	Ultraviolet
2	3,4,5.....	Balmer	Visible
3	4,5,6.....	Paschen	Infrared
4	5,6,7......	Brackett	Infrared
5	6,7,8.....	Pfund	Infrared

1. Lyman series

- For n = 1 and m = 2, 3, 4
- It lies in ultra violet region.
- Wave number or wavelength

$$\bar{\gamma} = \frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{m^2}\right)$$

2. Balmer series

- For n = 2 and m = 3, 4 ,5
- It lies in visible region.
- Wave number or wavelength

$$\bar{\gamma} = \frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{m^2}\right)$$

3. Paschen series

- For n = 3 and m = 4 , 5 , 6
- It lies in infra red region.
- Wave number or wavelength

$$\bar{\gamma} = \frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{m^2}\right)$$

4. Bracket series

- For n = 4 and m = 5, 6, 7

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- It lies infra red region.
- Wave number or wavelength

$$\bar{\gamma} = \frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{m^2}\right)$$

5. Pfund series

- For n = 5 and m = 6, 7, 8
- It lies in infra red region.
- Wave number or wavelength

$$\bar{\gamma} = \frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{m^2}\right)$$

---

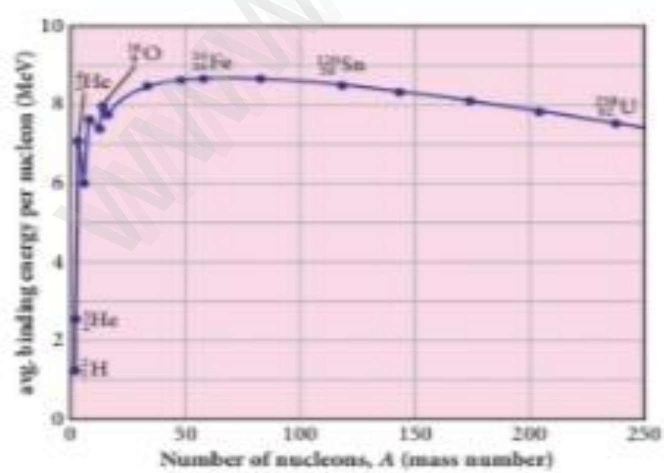
5. Explain the variation of average binding energy with the mass number using graph and discuss about its feature.

Average binding energy per nucleon

$$\boxed{\overline{BE} = \frac{[\, Z m_H + N m_n - M_A \,]\, c^2}{A}}$$

The average binding energy per nucleon is the energy required to separate single nucleon from the particular nucleus.

BE Curve



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Important Features:

1. BE rises as mass number increases , until it reaches maximum value of 8.8 M e V for A = 56 and then it slowly decreases.
2. BE value is about 8.5 M e V for nuclei having mass number lying between A = 40 and 120 . These elements are comparatively more stable and not radioactive.
3. For higher mass numbers , the curve drops slowly and BE for uranium is about 7.6 M e V . Such nuclei are unstable and exhibit radioactive.
   - If two light nuclei with A < 28 combine with nucleus A < 56
   - BE per nucleon is more final nucleus than initial nucleus.
   - Large amount of energy released.
   - It is the basis of nuclear fusion.
   - It is the principle of hydrogen atom.
4. If a nucleus of heavy element is split into two or more nuclei of medium value A , the energy released would again be large.
   - Atom bomb is based on this principle.
   - Huge energy comes from this fission when it is controlled.

---

6. Explain the detail in nuclear force.

Nuclear Force :

- Nucleus of the atoms contains protons and neutrons.
- They are separated by a distance of about few fermi (10^{-15} m) .
- They must exert on each other very strong repulsive force.

Electrostatic repulsive force :

$$F = K \times \frac{q^2}{r^2}$$

$$F = 9 \times 10^9 \times \frac{(1.6 \times 10^{-19})^2}{(10^{-15})^2} = 230 \text{ N}$$

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<u>Acceleration experienced by proton</u>

$$a = \frac{F}{m} = \frac{230\ N}{1.67 \times 10^{-27}} = 1.4 \times 10^{29}\ ms^{-2}$$

- Nearly 10^{28} times greater than acceleration due to gravity.
- If the protons in the nucleus experience only the electrostatic force, then nucleus fly apart in an instant.
- There must be a strong attractive force between protons to overcome the repulsive coulombic force.
- This attractive force which holds the nucleons is called strong nuclear force.

<u>Properties of Nuclear force :</u>

1. * <u>Nuclear force is of very short range.</u>

 * Repulsive coulomb force or attractive force between two protons are weaker than nuclear force.

 * Nuclear force is the strongest force.

2. * <u>Nuclear force is attractive one.</u>

 * Equal strength between proton – proton , proton – neutron , neutron – neutron. * Nuclear force does not act an the electrons.

 * So , it does not alter the chemical properties of the atom.

---

7. Discuss the alpha decay process with example.

<u>Alpha Decay Process :</u>

1. When an unstable nucleus decay by emitting an α - particle $^{4}He_{2}$ nucleus is known as " Alpha decay process "

2. It loses two protons and two neutrons .

3. Atomic number Z decreases by 2.

4. Mass number A decreases by 4.

$$^{A}X_{Z} \longrightarrow {}^{A-4}X_{Z-2} + {}^{4}He_{2}$$

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X → Parent nucleus

Y → Daughter nucleus

6. Example : Decay of Uranium to Thorium with emission of α - particle.

$^{238}U_{92} \longrightarrow {}^{234}Th_{92} + {}^{4}He_{2}$

7. Total mass of daughter nucleus and $^{4}He_{2}$ nucleus is always less than that of parent nucleus.

8. Difference in mass : $\Delta m = m_X - m_Y - m_\alpha$

9. Disintegration Energy : $Q = (m_X - m_Y - m_\alpha)c^2$

10. $Q > 0$, Spontaneous decay occur.

11. $Q < 0$, cannot spontaneous decay.

---

8. Discuss the beta decay process with examples.

Beta Decay :

- A radioactive nucleus emits electron or positron.
- The positron is an anti – particle of an electron.
- Its mass is same as that of electron.
- Its charge is opposite to that of electron.
- Both positron and electron are referred to as beta particles.

β^- Decay :

- If electron is emitted , it is called " β^- Decay "
- Atomic number of nucleus increase by one but its mass number remains same.

Representation of β^- Decay

Element X becomes by Y by giving out an electron and an anti neutrino.

- $^{A}X_{Z} \longrightarrow {}^{A}Y_{Z+1} + e^- + \bar{\gamma}$

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- $^{14}C_6 \longrightarrow {}^{14}N_7 + e^- + \bar{\gamma}$

B$^+$ Decay :

- If positron is emitted , it is called " β^+ Decay "
- Atomic number of nucleus decrease by one but its mass number remains same.

Representation of β^- Decay

Element X becomes by Y by giving out an positron and neutrino.

- $^{A}X_{Z} \longrightarrow {}^{A}Y_{Z-1} + e^+ + \gamma$
- $^{22}Na_{11} \longrightarrow {}^{22}N_{10} + e^+ + \gamma$

9.Discuss the gamma emission process with example.

1. In α and β decay , the daughter nucleus is in the excited state most of the time.

2. Life time of excited state is 10^{-11} s.

3. Excited state nucleus return to the ground state or lower energy state by emits highly energetic photons called " γ rays "

4. Atom is in excited state returns to ground state by emits photons of energy in the order of few e V.

5. If it emits highly energetic photon of energy in the order of M e V.

6. **Representation of gamma emission**

$$^{A}X^{*}_{Z} \longrightarrow {}^{A}X_{Z} + \text{Gamma rays}$$

* asterisk means excited state nucleus.

. There is no change in the mass number or atomic number of nucleus.

Example :

Boron ($^{12}B_5$) has two beta decay mode.

- $^{12}B_5 \longrightarrow {}^{12}C_6 + e^- + \bar{\gamma}$
- $^{12}C^*_6 \longrightarrow {}^{12}C_6 + \gamma$

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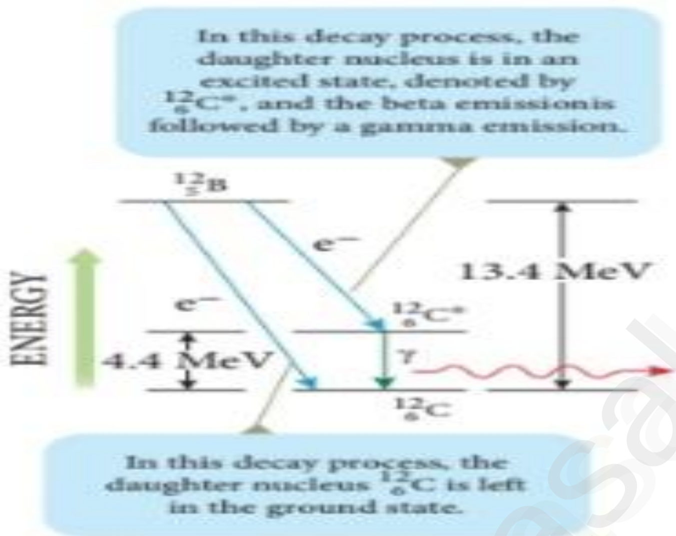
Explanation :

1. It undergoes beta decay directly into ground state carbon ($^{12}C_6$) by emitting an electron of maximum of energy.

2. It undergoes beta ray emission to an excited state of carbon ($^{12}C^*_6$) by emitting an electron of maximum energy 9.0 M e V followed by gamma decay to ground state by emitting photon of energy 4.4 M e V.

Gamma Emission :



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10. Obtain the law of radioactivity.

1. Bulk material of radioactive sample which contains vast number radioactive nuclei.

2. Not all the radioactive nucleus in a sample decay at the same time.

3. It decays over a period of time and this decay is random process.

4. We can calculate approximately how many nuclei in sample are decayed over a period of time.

5. At any instant t , the number of decays per unit time called rate of decay (dN / dt) is proportional to the number of nuclei (N) at the same instant.

Derivation :

1. $\frac{dN}{dt} \propto N$

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2. $\frac{dN}{dt} = -\lambda N$

3. $\lambda \longrightarrow$ Decay constant

4. Negative sign implies that N decrease with time.

5. $\frac{dN}{N} = -\lambda\, dt$

6. $\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_{0}^{t} dt$

7. $[\ln N]_{N_0}^{N} = = -\lambda t$

8. $\frac{N}{N_0} = e^{-\lambda t}$

9. $N = N_0 \; e^{-\lambda t}$

10. This is called as " law of radioactive decay ".

11. Number of atoms decreases exponentially over the time .

12. Infinite time is needed for decay of all the atoms.

---

11. Discuss the properties of neutrino and role in beta decay.

<u>Neutrino role in beta decay:</u>

1. During beta decay , a neutrino in the parent nucleus is converted into the daughter nuclei by emitting only electron.

$$^{A}X_{Z} \longrightarrow {}^{A}Y_{Z+1} + e^{-}$$

2. Kinetic energy of electron coming out of the nucleus did not match with the experimental results.

3. In alpha decay , the alpha particles takes only discrete energies but in beta decay the beta particles has continuous range of energies.

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4. The conservation of energy and momentum gives single value of energy for electron and recoiling nucleus.

5. In 1931 , Pauli explained the particle emitted in beta decay process.

6. Fermi named this particle as " neutrino ".

7. In 1956 , neutrino was detected by Fredrick reins and clyde cowan.

8. In 1995 , Rein received Nobel prize for this discovery.

Properties of neutrino:

1. It has zero charge.

2.It has an anti particle called anti neutrino.

3. It has very small mass.

4. It interacts very weakly with the matter.

5. It is very difficult to detect it.

6. In every second, trillions of neutrinos coming from the sun are passing through our body without causing interaction.

---

12. Explain about carbon dating.

Carbon Dating :

1. Application of beta decay is radioactive dating or carbon dating.

2. The age of an ancient object can be calculated.

3. All living organisms absorb CO_2 from air to synthesize organic molecules.

4.In absorbed CO_2 , major part contains ${}^{12}C_6$.

5. And contains very small fractions 1.3 X 10^{-12} contains radio active ${}^{14}C_6$.

6. ${}^{14}C_6$ whose half life is 5730 years.

7. Carbon -14 in the atmosphere is always decaying.

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8. Cosmic ray from outer space are bombarding the atoms in the atmosphere which produces $^{14}C_6$.

9.The continuous production and decay of $^{14}C_6$ in the atmosphere keep the ratio of $^{14}C_6$ to $^{12}C_6$ always constant.

10. Our human body , tree or any living organism continuously absorb Co_2 from the atmosphere , the ratio of $^{14}C_6$ to $^{12}C_6$ nearly constant.

11. When the organism does , it stops absorbing Co_2 .

12. Since $^{14}C_6$ starts to decay , the ratio of $^{14}C_6$ to $^{12}C_6$ in dead organism or specimen decreases over the years.

13. The ratio $^{14}C_6$ to $^{12}C_6$ in the ancient tree pieces excavated is known , then the age of the tree pieces can be calculated. Example : Keezhadi excavation

---

13. Discuss the process of nuclear fission and its properties.

<u>Nuclear Fission :</u>

1. The process of breaking up of the nucleus of a heavier atom into two smaller nuclei with the release of a large amount of energy is called " nuclear fission "

2. <u>Example :</u>

$$^{235}U_{92} + {}^{1}n_{0} \longrightarrow {}^{235}U^{*}{}_{92} \longrightarrow {}^{141}Ba_{56} + {}^{92}Kr_{36} + 3\ {}^{1}n_{0} + Q$$

$$^{235}U_{92} + {}^{1}n_{0} \longrightarrow {}^{235}U^{*}{}_{92} \longrightarrow {}^{140}Xe_{54} + {}^{94}Sr_{38} + 2\ {}^{1}n_{0} + Q$$

3. When a slow neutron is absorbed by the uranium nucleus , the mass number increases by one and goes to an excited state $^{235}U^{*}{}_{92}$.

4. Excited state does not last longer than 10^{-12} s.

5. It decay into two daughter nuclei along with the release of 2 or 3 neutrons.

6. In each reaction , on an average 2.5 neutrons are emitted.

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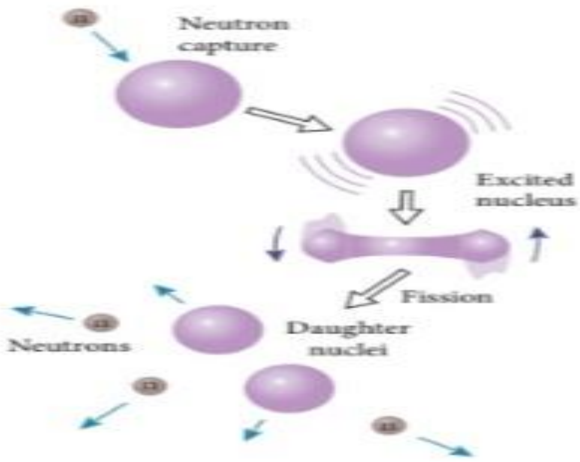
Diagram :



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14. Discuss the process of nuclear fusion and how energy is generated in stars ?

Nuclear Fusion :

1. When two or more light nuclei (A < 20) combine to form a heavier nucleus , then it is called " Nuclear fusion "
2. The mass of the resultant nucleus is less than sum of the masses of original light nuclei.
3. The mass difference appears as energy.
4. The nuclear fusion never occurs at room temperature unlike nuclear fission.
5. It is because when two light nuclei come closer to combine , strongly repelled by the coulomb repulsive force.
6. To over come repulsive force , two light nuclei must have enough K.E to move closer to each other.
7. Nuclear force becomes effective if the temperature greater than 10^7 K.
8. At 10^7 K lighter nuclei start fusing to form heavier nuclei is called thermos nuclear fusion reaction.

Energy generation in stars :

1. In most of the stars including our sun hydrogen atoms fuse into helium and helium fuse into heavier elements.
2. The early stage of a star is in the form of cloud and dust.

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3. Due to own gravitation pull , these clouds fall inward.

4. Gravitational potential energy is converted in to kinetic energy and finally into heat.

5. When the temperature is high enough to initiate the thermos nuclear fusion.

6. They start to release enormous energy which tends to stabilize the star and prevents it from further collapse.

7. Sun's interior temperature is around 1.5 X 10^7 K.

8.In sun ,6 X 10^{11} kg of hydrogen is converted into helium every second.

9. Sun has enough hydrogen such that these fusion reactions for 5 billion years.

10. When hydrogen burn out , sun enter into new phase called red gaint where helium fuse to become carbon.

According to Hans Bethe , the sun is powered by proton – proton cycle of fusion reaction.

$$^1H_1 + {}^1H_1 \longrightarrow {}^2H_1 + e^+ + \gamma$$

$$^1H_1 + {}^2H_1 \longrightarrow {}^3He_2 + \gamma$$

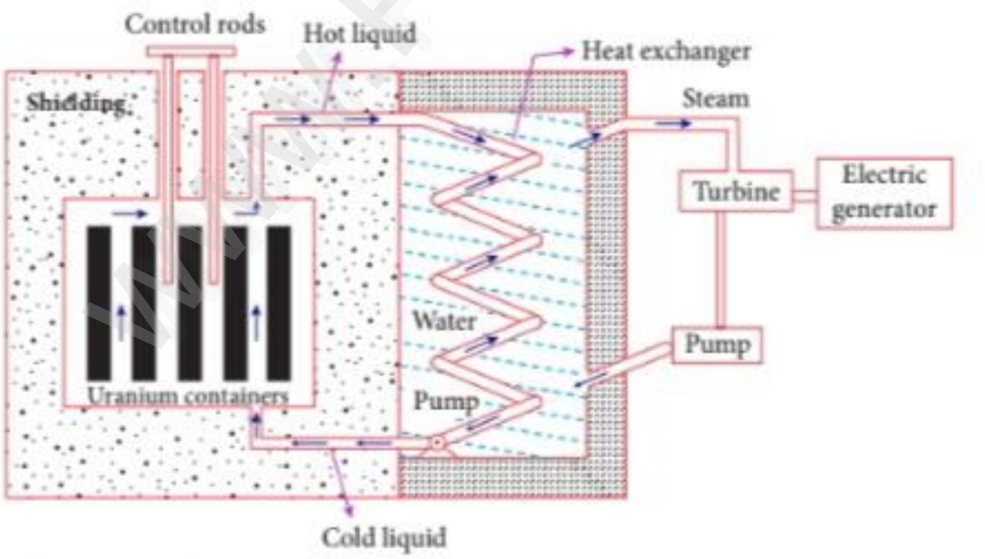
$$^3He_2 + {}^3He_2 \longrightarrow {}^4He_2 + {}^1H_1 + {}^1H_1$$

Over all energy produced is about 27 M e V.

---

15. Describe the working of nuclear reactor with block diagram.

<u>Block diagram of nuclear reactor :</u>



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Nuclear reactor:

- It is a device in which the nuclear fission takes place.
- It is self – sustained controlled manner.
- The energy produced is used for research purpose.
- It is used for power generation.
- First nuclear reactor was built by Enrico Fermi in 1942.

Main parts of nuclear reactor:

1. **Fuel :**

1. It is fissionable material. Ex : Uranium , Plutonium
2. Uranium contains only 0.7 % of $^{235}U_{92}$ and 99.3 % are only $^{238}U_{92}$.
3. $^{238}U_{92}$ contains at least 2 % to 4 % of $^{235}U_{92}$.
4. Neutron source is need for chain reaction . Ex : Beryllium with plutonium.
5. During fission of $^{235}U_{92}$, fast neutrons are emitted.
6. Slow neutrons need for nuclear reactor.

2. **Moderator :**

1. Used to convert fast neutron into slow neutrons.
2. Light nuclei undergo collision with fast neutron and speed of neutron is reduced.
3. This is the reason for using light nuclei used as a moderator.
4. Example : Heavy water (D_2O) , Graphite.

3. Control Rods:

1. They are used to adjust reaction rate.
2. During each fission 2.5 neutrons emitted.
3. To have controlled chain reactions , only one neutron is allowed to cause fission .
4. Remaining neutrons absorbed by control rods.
5. Example : Cadmium , Boron

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4.**Shielding**

Nuclear reactor surrounded by concrete wall of thickness of about 2 to 2.5 m for protection against harmful radiation.

5. **Coolin system :**

1. **It removes heat generator in reactor.**
2. **Ex: Ordinary waver, Heavy water and Liquid sodium.**
3. **Coolant have large boiling point under high pressure.**
4. **It carries away the heat to the steam generator through heat exchanger.**
5. **The steam runs the turbines which produces electricity in power reactor.**

---

16. Explain in detail four fundamental forces in nature.

1. Gravitational Force:

1. **We live on earth because of earth's gravitational attraction on our body.**
2. **Our planets are bound to the sun through gravitational force of sun.**

Ex: Force b\w two masses.

2. Electromagnetic Force:

1. **We are standing on the surface of earth because of electromagnetic force between atoms of surface of the earth and atoms in our foot.**

Ex: Force b\w two charges.

3. Strong Force:

1. **The atoms in our body are stable because of strong nuclear force.**
2. **Strong nuclear force exist b\w two nucleons.**

Ex: Responsible for stability of nucleus.

4. Weak force:

1. **The lives of species on earth depend on the solar energy form the sun and it is due to weak force.**
2. **It plays vital role during nuclear fusion reactions going on in the core of the sun.**
3. **It plays important role in beta decay and energy production in stars.**
4. **During the fusion of hydrogen into helium in sun , neutrons and enormous radiation are produced through weak force.**

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17. Briefly explain the elementary particles present in nature.

Elementary Particles :

1. An atom has a nucleus surrounded by electrons and nucleus is made up of protons and neutrons.

2. Protons and neutrons and electrons are fundamental building blocks of matter.

3. Murray Gellman and George Zweig theoretically proposed that protons and neutrons are not fundamental particles.

Quarks:

- They are made up of quarks.
- These quarks are now considered elementary particles of nature.
- In 1968, Quarks were discovered by Stanford Linear accelerator centre SLAC, USA.

Types of quark:

There are six quarks namely up, down, charm, strange, top and bottom and their antiparticles. All these quarks have fractional charges.

For Examples:

Charge of up quark $+\frac{2}{3}e$

Charge of down quark $-\frac{1}{3}e$

According to Quark model

Proton is made up of two up quarks and one down quark. And neutron is made up of one up quark and two down quarks.

Constituents of Nucleons:

Neutron Proton

The study of elementary particles is called particle physics. It is an active area of research even now more than 20 Nobel prizes awarded for particle physics.

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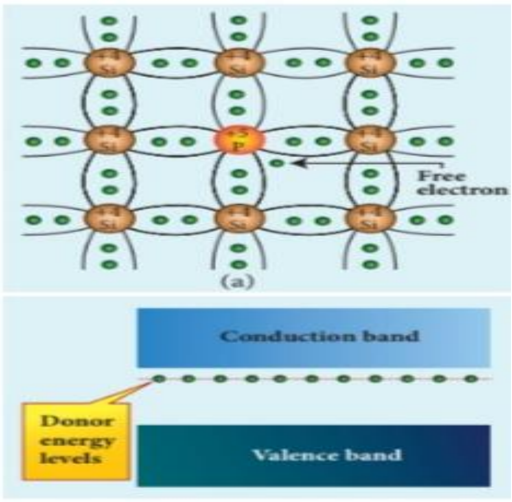
Lesson 10

1.Elucidate the formation of n-type extrinsic semiconductors.

Diagram :



Formation of n- type extrinsic semiconductors:

1. By doping pure silicon crystal with pentavalent impurity atoms.

Ex : phosphorus , arsenic , antimony

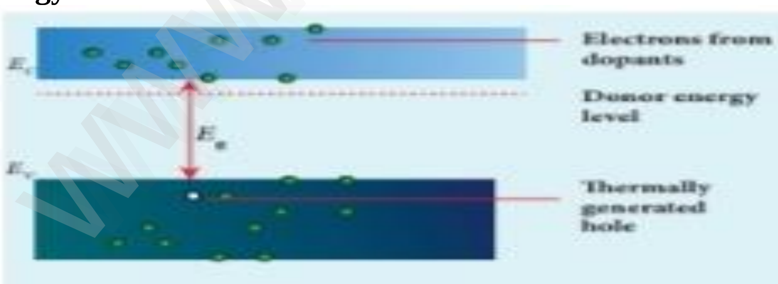
2.The dopant has five valence electron.

3.Silicon atom has four valence electrons.

4.Four of the five valence electron of the impurity atom form covalent bonds with four silicon atoms.

5.Fifth valence electron of the impurity atom is loosely attached with nucleus .

6.Fifth electron from the dopant is found just below the conduction band edge is called donor energy level.



7.At room temperature or by an external electric field loosely bound electrons lead to conduction.

8.Energy required for an electron to jump from valence band to conduction band.

- 0.7 e V for Ge * 1.1 e V for Si

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9. Energy required to set free donor electron.

- 0.01 e V for Ge * 0.05 e V for Si

10. The V group pentavalent impurity atom donates electrons to conduction band and are called " donor impurities "

11. Each impurity atom provides one extra electron to conduction band in addition to thermally generated electrons.

12. These thermally generated electrons leave holes in valence in valence band.

13. Majority Carrier : Electrons Minority Carrier : Holes

---

2. Explain the formation of depletion region and barrier potential in PN junction diode.

Diagram :

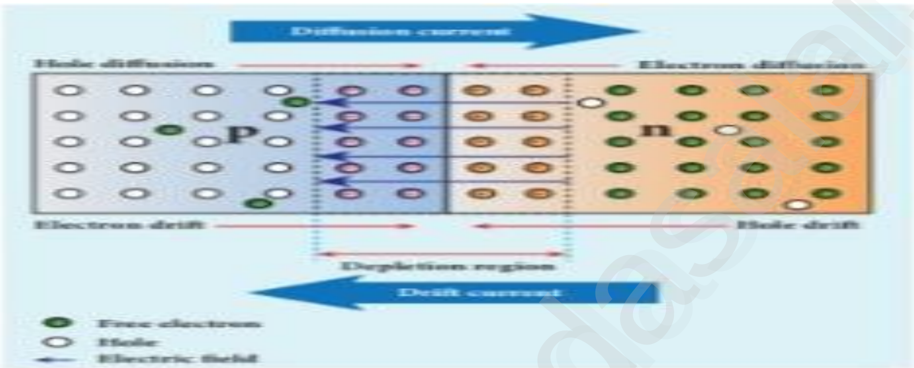

Figure 10.9 Formation of p–n junction

Formation of depletion region:

1. P N Junction :

- Doped semiconductor one side is p – type.
- Doped semiconductor other side is n – type.
- The contact surface between two side is called " p – n junction "

2.Diffusion :

- Free electron diffuse from n- side to p- side.
- Holes diffuse from p – side to n- side.

3.Diffusion Current :

The diffusion of the majority charge carriers across the junction gives rise to an electric current called " diffusion current "

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4. Positive ion :

When an electron leaves n – side , and pentavalent atom in the n- side becomes " positive ion ".

5. Negative ion :

When free electron migrating into p – side , and recombines with a hole then trivalent becomes " negative ion ".

6. Depletion Region :

Thin region near the junction which is free from charge carriers is called " depletion region" .

7.Electric field :

- An electric field is set up between n- side and p-side.
- This electric field makes electrons in the n-side inti p- side.

8.Drift Current :

The electric current produced due to the motion of minority charge carriers by the electric field is known as " Drift velocity "

9.Diffusion & Drift current :

- The diffusion current and drift current flow in opposite directions.
- Drift current is less than diffusion current .
- Diffusion of electron or hole increases electric field and increase drift current.

10. P n junction :

At equilibrium , there is no electric current across the junction . Thus p-n junction is formed.

Junction potential & Barrier potential

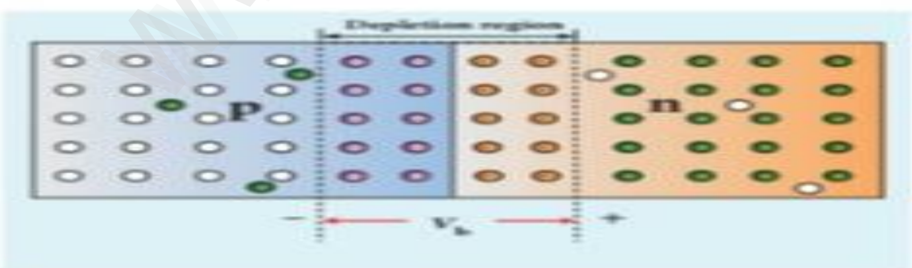

Figure 10.10 Barrier potential formed across the junction

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1. Movement of charge carrier across the junction takes place only to certain point.
2. Beyond which depletion layer acts like barrier to further diffusion of free charges across the junction.
3. Immobile ions on both sides establish an electric potential difference across junction.
4. Electron trying to diffuse into the interior of the depletion region encounters wall of negative ions repelling it backwards.
5. If the free electron has enough energy to break the wall and enter into p-region where it can recombine with hole and create another negative ion.
6. Increasing electric potential difference across depletion region to reach equilibrium.
7. Internal repulsion of depletion layer stops further diffusion of free electrons across the junction.
8. This difference is potential across the depletion layer is called " Barrier potential "
9. At 25^0 c this barrier potential is approximately
   - 0.7 V for silicon
   - 0.3 V for germanium

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3. Draw the circuit diagram of a half wave rectifier and explain its working.

Half wave rectifier circuit :

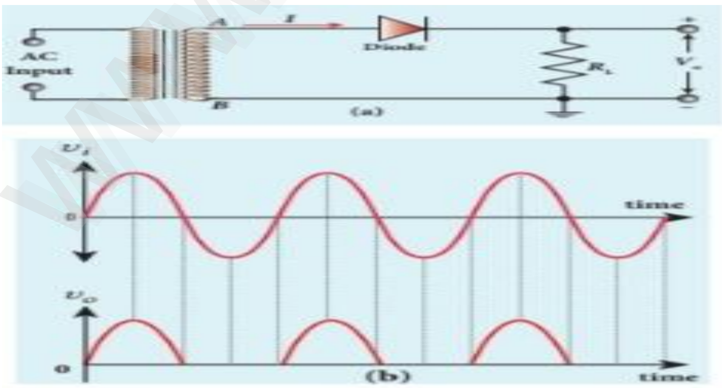

Figure 10.17 (a) Half wave rectifier circuit (b) Input and output waveforms

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Half wave rectifier :

1. It consists of transformer , p-n junction diode and resistor.
2. One half of the input wave is rectified and other half is blocked.
3. p-n junction diode act as a rectifier diode.
4. Not steady DC voltage but pulsating wave.
5. Steady voltage obtained filter circuit & voltage regulator circuit.

Working :

- In a half wave rectifier circuit , either a positive half or the negative of the AC input is passed through by the diode while the other half is blocked.
- There are two types of half cycle in half wave rectifier.

Efficiency :

- Ratio of the output Dc power to the AC input power supplied to the circuit.
- Its value for half wave rectifier is 40.6 %

Types of half cycle :

1. Positive half cycle 2. Negative half cycle

S.NO	During positive half cycle	During negative half cycle
1.	Terminal A becomes positive w.r.t B.	Terminal B becomes positive w.r.t A.
2.	Diode is forward biased.	Diode is reverse biased.
3.	Diode will conduct.	Diode does not conduct.
4.	Current flows through load resistance R_L .	No current passes through load resistance R_L .
5.	Voltage developed across R_L .	No voltage drop across R_L .

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4. Explain the construction and working of a full wave rectifier.

Full wave rectifier :

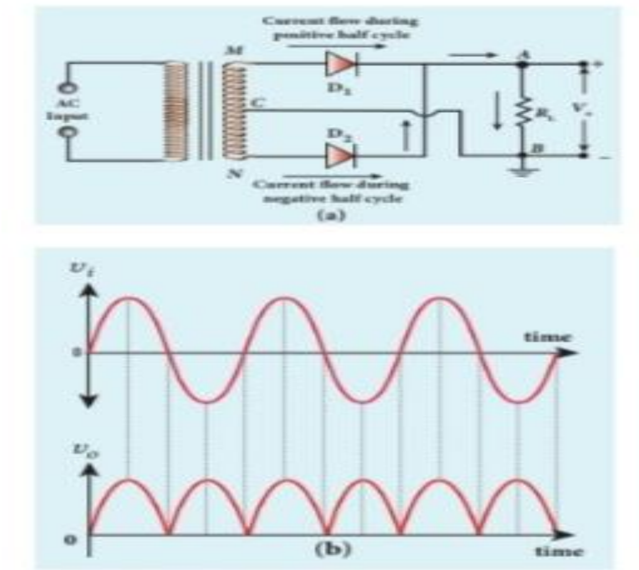

Figure 10.18 (a) Full wave rectifier circuit (b) Input and output waveforms

Theory :

1. It consists of two p-n junction diodes, centre tap transformer and load resistor R_L .

2. The centre is usually taken as the ground or zero voltage reference point.

Types of cycle:

S.NO	i) During positive half cycle :	ii) During negative half cycle :
1.	• Terminal M is positive potential • Terminal N is negative potential ; • C is at zero potential.	• Terminal M is negative potential • Terminal N is positive potential ; • C is at zero potential.
2.	Diode D_1 is forward bias and it conducts.	Diode D_2 is forward bias and it conducts.
3.	Diode D_2 is reverse bias and does not conduct.	Diode D_1 is reverse bias and does not conduct.
4.	Current flows along the path MD_1ABC.	Current flows along the path ND_2ABC.

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Working :

- **During both positive and negative half cycles of the input signal , the current flows through the load in the same direction.**
- **Though both half cycles of AC input are rectified , the output is still pulsating in nature.**

Efficiency :

- **The efficiency of full wave rectifier is twice that of half wave rectifier.**
- **It is found to be 81.2 % efficiency .**
- **It is because of power losses in the winding , the diode and the load resistance.**

---

5. What is an LED ? Give the principle of its operation with a diagram.

Light Emitting Diode :

1. **LED is a p-n junction diode which emits visible or invisible light when it is forward biased.**
2. **Electrical energy is converted into light energy , this process is also called as " electroluminescence ".**

Symbol of LED :

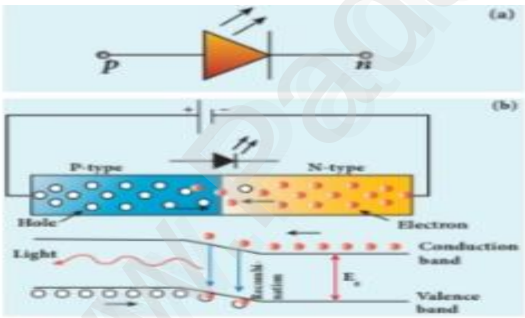

Figure 10.22 (a) Circuit symbol of LED (b) Schematic diagram to explain recombination process

Construction :

1. When p-n junction is forward biased , the conduction band electrons on n-side and valance band holes on p-side diffuse across the junction .

2. When they cross the junction , they become excess minority carriers.

3.These excess minority carrier recombine with oppositely charged majority carriers in the respective regions.

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4. The electrons in the conduction band recombine with the holes in the valence band.

Recombination process :

1. During recombination process , energy is released in the form of light or heat.
2. For radiative recombination , photon energy hγ is emitted.
3. For non – radiative recombination , energy is liberated in the form of heat.
4. Colour of the light is determined by the energy band gap of the material.
5. Example : Si C ⟶ Blue Ga As P ⟶ Red

AL Ga P ⟶ Green Ga In N ⟶ White

Application of LED :

Light emitting diodes are used in ,

1. Seven segment displays
2. Traffic signals
3. Air conditioner
4. Remote control of television
5. Indicator lamps on science lab.

---

6. Write notes on photo diode.

Photo Dide :

1. A p-n junction diode which converts an optical signal into electric signal is known as " photo diode "
2. Operation of photo diode is exactly inverse to that of LED.
3. Photo diode works in reverse bias condition.

Symbol of Photo Diode:

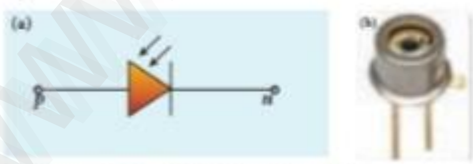

Figure 10.23 (a) Circuit symbol (b) Schematic view of photodiode

Construction :

1. It consists of p-n junction semiconductor made of photosensitive material.
2. It has small transparent window that allows light to be incident on the p-n junction.

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3. Photo diodes can generate current when the p-n junction is exposed to light and hence are called as " light sensors "

Working :

i When light incident on diode :

1. If sufficient energy hγ strikes the depletion region of diode.
2. Valence band electron elevated to the conduction band abd holes are developed.
3. It creates electron – hole pair depends on intensity of incident light.
4. Electric field created by reverse voltage.
5. Hole move towards n- side and electron towards p- side.
6. It constitute photo current.

ii When there is no incident light on diode :

1. There exists a reverse current which is negligible.
2. This reverse current in the absence of any incident light is called " dark current "
3. It is due to thermally generated minority carriers.

Applications :

The photo diodes are used in ,

1. Alarm system
2. Photo conductor
3. Smoke detector
4. Compact disc player
5. Medical applications

---

7. Explain the working principle of a solar cell. Mention its application.

Solar Cell :

1. A solar cell also known as photovoltaic cell.
2. It works on the principle of photo voltaic effect.
3. The p-n junction of solar cell generates emf when solar radiation falls on it.

Construction :

1. Electron – hole pairs are generated due to the absorption of light photons near the junction.
2. The charge carriers are separated due to electric field of depletion region.
3. Electrons move towards n-type Si layer.

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4. **Holes move towards p-type Si layer.**
5. **Electrons and holes are collected by the front and back electrical contact.**
6. **Potential difference is developed across solar cell.**
7. **When an external load is connected to solar cell , photo current flows through the load.**
8. **Many solar cells are connected together series or parallel form " solar panel " .**
9. **Solar panels are connected with each together to form " solar arrays "**

Cross sectional view of a solar cell :

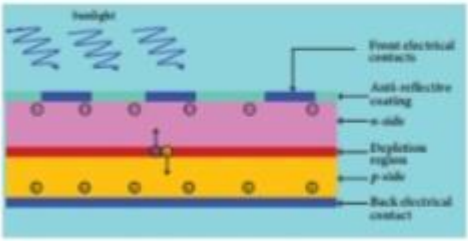

Figure 10.24 Cross-sectional view of a solar cell

Applications Solar cells :

Solar cells are widely used in ,

1. **Calculator , watch , toy**
2. **Satellite and space applications.**
3. **Solar panel used for commercial production of electricity.**

---

8. Sketch the static characteristics of a common emitter transistor and bring out the essential features of input and output characteristics.

Bias supply voltages :

V_{BB} and V_{CC} bias the base - emitter junction and collector – emitter junction respectively.

Junction Potential :

V_{BE} ⟶ Base Emitter voltage

V_{CE} ⟶ Collector Emitter voltage

Current

I_B ⟶ Base current

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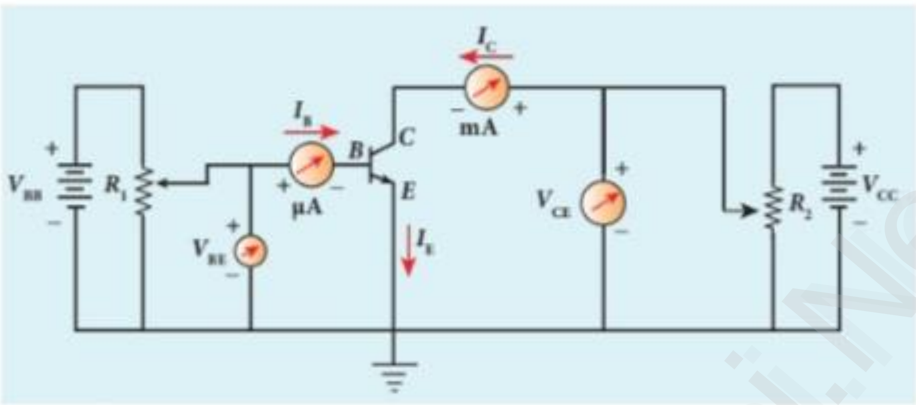
I_E ⟶ Emitter current

I_C ⟶ Collector current

Rheostat R_1 and R_2 vary base and collector current.

Circuit diagram :



| Figure 10.30 NPN transistor in common emitter configuration

Static characteristics of BJT:

i) Input characteristics ii) Output characteristics iii) Transfer characteristics

i) **Input Characteristics :**

- Relationship between I_B and V_{BE} at constant V_{CE}
- For particular V_{CE} increase V_{BE} and note the value of I_B.

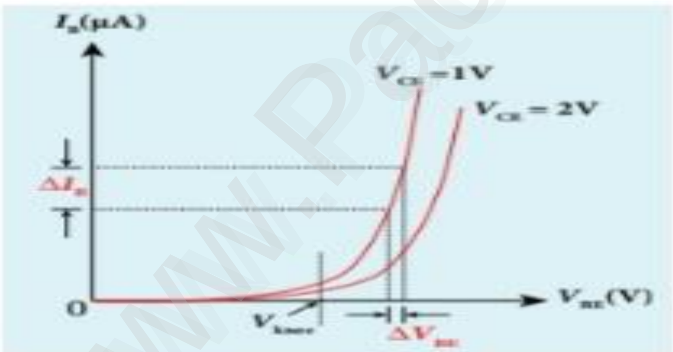


Figure 10.31 Input characteristics

1. Forward characteristics of an ordinary p-n junction diode.

2. Threshold voltage or knee voltage V_{Knee}

- 0.7 V for Silicon * 0.3 V for Germanium

3. Collector – emitter voltage increases

- Decreases base current.

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- **Increases width of depletion region.**
- **Reduces effective base width.**

4. Input Impedance

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$$

Ratio of change in base emitter voltage to change in base current at constant collector emitter voltage.

ii) <u>output Characteristics :</u>

- **Relationship between I_C and V_{CE} at constant I_B.**

<u>i Saturation Region</u>

1. V_{CE} increase above 0 V , I_C increases and reach saturation value at particular value of V_{CE} called " knee voltage ".

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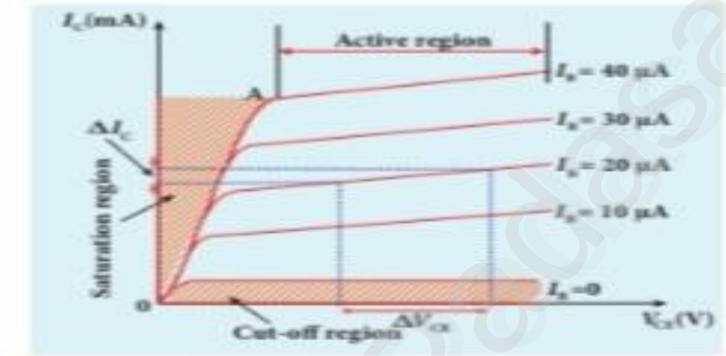

| **Figure 10.32** Output characteristics

2. O A called as saturation region .

3. Transistor always operated above knee voltage.

<u>ii Cut off Region</u>

1. Small collector current exists for I_B = 0 .

2. Region below I_B = 0 called cut – off region.

3. Collector current is cut – off.

<u>iii Active Region</u>

1.Central region of curve is called " Active region ".

2. BE junction is forward bias.

3. CB junction is reverse bias.

4.Used for voltage , current and power amplification.

iv Breakdown Region

1.V_{CE} is increase , I_C increase .

2. It leads to junction breakdown of transistor.

3.Avalanche breakdown damage transistor.

v Output Impedance

$$\boxed{r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}}$$

Ratio of change in collector emitter voltage to change in collector current at constant collector base current.

9.Transistor functions as a switch . Explain.

Circuit Diagram

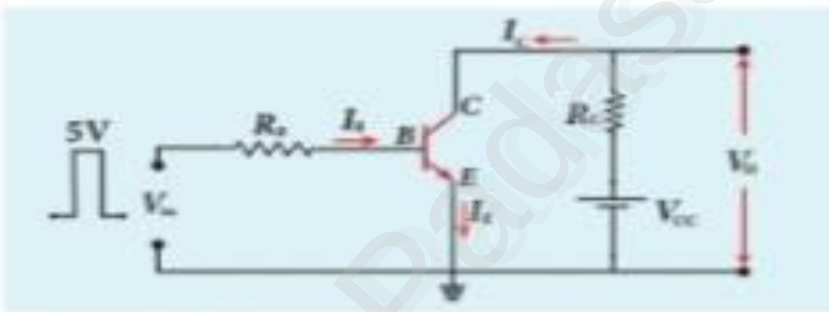

Figure 10.35 Transistor as a switch

Transistor functions as a switch

- Transistor functions like an electronic switch that helps to turn ON or OFF a given circuit by a small control signal.
- A small control signal which keeps the transistor either in saturation region or in cut – off region.
- A transistor in saturation region act as a closed switch.
- A transistor in cut – off region acts an open switch.

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Working :

S.NO	When the input is low : Say 0 V	When the input is high : Say + 5 V
1.	Base Current is zero.	Base Current is increases.
2.	Collector current is zero.	Collector current increases to maximum.
3.	Voltage drop across R_C is zero.	Voltage drop across R_C increases.
4.	No current flows through it.	Maximum current flows through it.
5.	Output voltage is high , equal to V_O.	Lowering voltage close to zero. $V_O = V_{CC} - I_C R_C$
6.	It is in cut – off region.	It is in saturation region.
7.	It is said to be switched off.	It is said to be switched ON.
8.	It acts as an open switch.	It acts as an closed switch.

---

10. Describe the function of a transistor as an amplifier with the neat circuit diagram . Sketch the input and output waveforms.

Amplification :

- Process of increasing the signal strength , increase in amplitude.
- If a large amplification is required , the transistor are cascaded with coupling elements .
- Coupling elements like resistors , capacitors , transformer are called "multistage amplifier .

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Circuit Diagram :

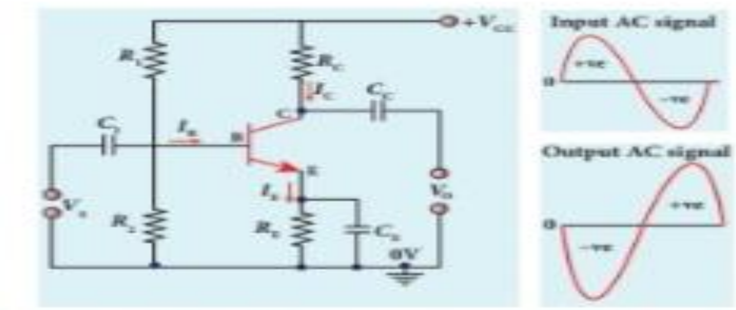

Figure 10.36 (a) Transistor as an amplifier (b) Input and output waveforms showing 180° phase reversal.

Single stage circuit :

- A NPN transistor is connected in the common emitter configuration.
- Q point : Quiescent point which determine the operating point or working point of a transistor.
- Q point is fixed to get maximum signal at the output.

Components :

- R_C ⟶ Load resistance connected in series with collector to measure the output voltage.
- R_1 , R_2, R_3 ⟶ Form the biasing & stabilization circuit.
- C_1 ⟶ Capacitor allows only AC signal.
- C_E ⟶ Bypass capacitor provides low resistance path to amplified AC signal
- V_S ⟶ Sinusoidal input signal

Collector current:

$$\boxed{I_C = \beta\ I_B}$$

Collector Emitter Voltage:

$$\boxed{V_{CE} = V_{CC} - I_C R_C}$$

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Working of the amplifier

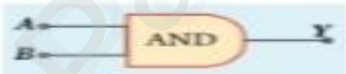
During Positive Half Cycle	During Negative Half Cycle
1. Input signal V_S increases	1. Input signal V_S decreases
2. Base current increases I_B in µA	2. Base current decreases I_C in µA
3. Collector current increases I_C in Ma	3. Collector current decreases I_C in mA
4. Voltage drop across R_C increases	4. Voltage drop decreases across R_C decreases
5. Collector – Emitter voltage V_{CE} decreases	5. Collector – Emitter voltage V_{CE} increases
6. Output signal is reversed by 180°	6. 180° phase reversal is observed.

---

11. Give circuit symbol , logical operation , truth table and Boolean expression of

i) AND gate ii) OR gate iii) NOT gate iv) NAND gate v) NOR gate vi) EX- OR

i) AND gate



(a)

Inputs		Output
A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

(b)

Figure 10.41 (a) Two input AND gate
(b) Truth table

Boolean expression : $\boxed{Y = A . B}$

Logical Operation :

- Output is high only when all the inputs are high.
- Output is low for rest of the cases.

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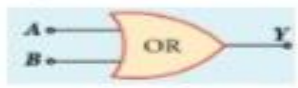
ii) OR gate



(a)

Inputs		Output
A	B	Y= A+B
0	0	0
0	1	1
1	0	1
1	1	1

(b)

Figure 10.42 (a) Two input OR gate (b) Truth table

Boolean expression : $Y = A + B$

Logical Operation :

- Output is high only when either of the inputs or both are high.

iii) NOT gate

(a)

Inputs	Output
A	$Y=\overline{A}$
0	1
1	0

(b)

Figure 10.43 (a) NOT gate (b) Truth table

Boolean expression : $Y = \overline{A}$

Logical Operation :

- Output is complement of input .
- It is represented with an overbar.
- It is also called inverter.

iv) NAND gate

Boolean expression : $Y = \overline{A \cdot B}$

Logical Operation :

- Complement of AND operation.
- AND gate followed by a NOT gate.
- Output is zero when all the inputs are high.

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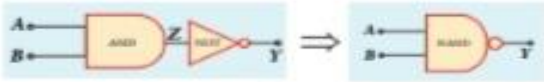

(a)

Inputs		Output (AND)	Output (NAND)
A	B	$Z = A.B$	$Y = \overline{A.B}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

(b)

Figure 10.44 (a)Two input NAND gate (b) Truth table

v) NOR gate

(a)

Inputs		Output (OR)	Output (NOR)
A	B	$Z = A+B$	$Y = \overline{A+B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

(b)

Figure 10.45 (a) NOR gate (b) Truth table

Boolean expression :

$$\boxed{Y = \overline{A + B}}$$

Logical Operation :

- Complement of OR operation.
- OR gate followed by a NOT gate.
- Output is high when all the inputs are low.

vi) EX-OR gate

Boolean expression :

$$Y = A \oplus B$$

$$Y = A.\overline{B} + \overline{A}.B$$

Logical Operation :

- Output is high when either of two input high.
- Exclusive OR gate is known as EX – OR gate.

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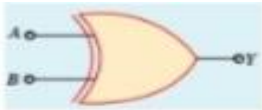

(a)

Inputs		Output (Ex-OR)
A	B	$Y = A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

(b)

Figure 10.46 (a) Ex-OR gate (b) Truth table

---

12. State and prove De Morgon's first and second theorem.

De Morgon's first theorem

Statement :

The first theorem states that the complement of the sum of two logical inputs is equal to the product of its complements.

Proof :

1. **The Boolean equation for NOR gate is** $Y = \overline{A + B}$
2. **The Boolean equation for bubbled AND gate is** $Y = \overline{A} \, . \, \overline{B}$
3. **Both cases generate same outputs for same inputs.**
4. **NOR gate = Bubbled AND gate**
5. $\overline{A + B} = \overline{A} \, . \, \overline{B}$

Symbol

Figure 10.47 NOR gate equals bubbled AND gate

Truth Table :

A	B	$A.B$	$\overline{A.B}$	$\overline{A}$	$\overline{B}$	$\overline{A}+\overline{B}$
0	0	0	1	1	1	1
0	1	0	1	1	0	1
1	0	0	1	0	1	1
1	1	1	0	0	0	0

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De Morgon's second theorem

Statement :

The first theorem states that the complement of the product of two logical inputs is equal to the sum of its complements.

Proof :

1. The Boolean equation for NAND gate is $Y = \overline{A \cdot B}$
2. The Boolean equation for bubbled OR gate is $Y = \overline{A} + \overline{B}$
3. Both cases generate same outputs for same inputs.
4. NAND gate = Bubbled OR gate
5. $\overline{A \cdot B} = \overline{A} + \overline{B}$

Symbol

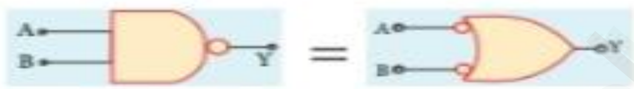

Figure 10.48 NAND gate equals bubbled OR gate

Truth Table :

A	B	$A+B$	$\overline{A+B}$	$\overline{A}$	$\overline{B}$	$\overline{A}.\overline{B}$
0	0	0	1	1	1	1
0	1	1	0	1	0	0
1	0	1	0	0	1	0
1	1	1	0	0	0	0

---

13. Explain the amplitude modulation with necessary diagrams.

Definition :

If the amplitude of the carrier signal is modified in proportion to the instantaneous amplitude of the baseband signal , then it is called amplitude modulation.

- Frequency and phase of the carrier signal remain constant.
- Amplitude modulation is used in radio and TV broadcasting.

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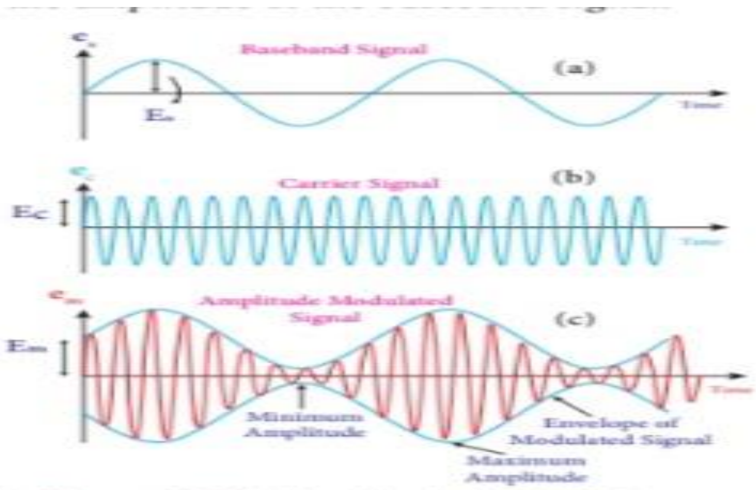

Figure 10.50 Amplitude Modulation
(a) Baseband signal (b) Carrier signal
(c) Modulated signal

Base band signal

- **Low frequency signal is base band signal.**
- **Base band signal carrier information.**

Carrier Signal

- **High frequency signal called carrier signal.**
- **It is used to carry the base band signal.**

Modulated Signal

The amplitude of the carrier wave is modified in proportion to the amplitude of the base band signal.

Advantage of AM

1. Easy transmission and reception. 2. Lesser bandwidth requirement. 3. It is low cost.

Limitations of AM

1. Noise level is high 2. Low efficiency 3. Small operating range.

---

14. Explain the basic elements of communication system with the necessary block diagram.

1. Information

Information is given as input to the input transducer.

Ex : Music , picture , speech

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2. Input Transducer

Transducer converts the information into corresponding electrical signal.

Ex : Microphone

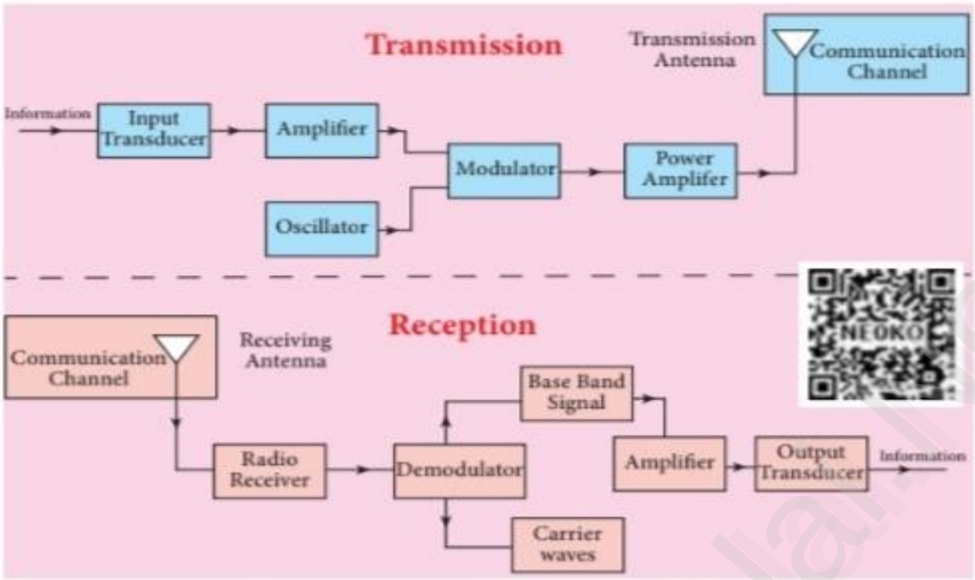

Figure 10.52 Block diagram of transmission and reception of voice signals

3. Transmitter

It feeds the electrical signal from the transducer to the communication channel.

- **Amplifier**
  Transducer weak output is amplified.

- **Oscillator**
  Generates high energy frequency carrier wave.

- **Modulator**
  Generates modulated signal by superimpose baseband to carrier signal.

- **Power Amplifier**
  Increase power level of the electrical signal to cover large distance.

4. Transmitting Antenna

- Radiates radio signal into space in all direction.
- Travels in the form of em waves.

5. Communication Channel

Used to carry the electrical signal from transmitter to receiver with less noise or direction.

Ex : Wire , cable

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6. Receiver

Converts EM waves inti RF signal by receiving antenna.

Ex : Demodulator , amplifier

7. Repeaters

Used to increase the range or distance through which the signal are sent. It is a combination of transmitter and receiver .

Ex : Communication satellite in space

8. Output Transducer

Converts the electrical signal back to its original form such as sound , music , picture.

Ex : Loud speaker , picture tube

---

15. Explain the ground wave propagation and space wave propagation of electromagnetic waves through space.

Ground Wave Propagation

1. If the em waves transmitted by the transmitter glide over the earth surface to reach the receiver , then the propagation is called " Ground wave propagation :

2. The corresponding waves are called as " ground waves " or " surface waves".

3. Both transmitting and receiving antenna's must be close to earth's surface.

Uses :

Used in local broadcasting , radio navigation for ship – ship , ship to shore communication and mobile communication.

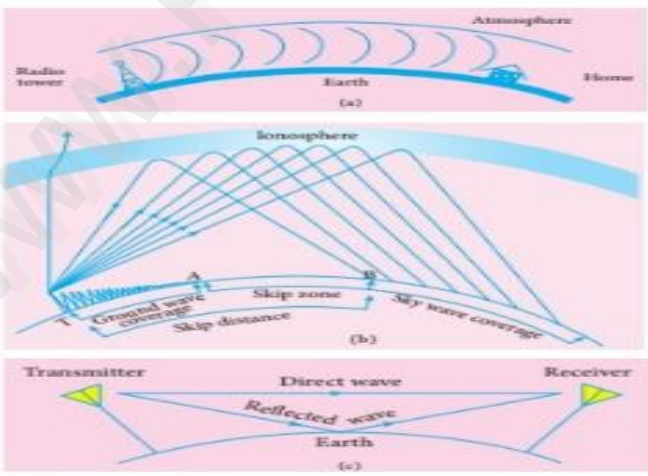

Figure 10.53 Propagation of EM waves (a) Ground wave (b) Sky wave (c) Space wave

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Space Wave Propagation

1. The process of sending and receiving information signal through space is called " Space wave propagation "

2. The em waves of very high frequencies above 30 MHz are called as " Space waves "

3. These waves travel in a straight line from transmitter to receiver.

4.It is used for a line of sight communication [L O S].

5. Like television telecast , satellite communication and RADAR .

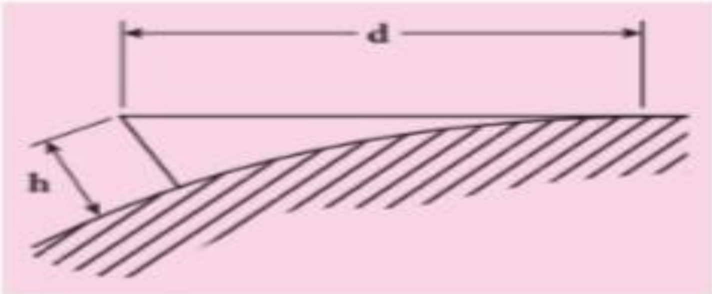

Figure 10.54 Distance of coverage

6. Range or distance (d) of coverage of the propagation depends on the height (h) of the antenna.

$$\boxed{d = \sqrt{2Rh}}$$

R ⟶ Radius of the earth

---

16. Fibre optic communication is gaining popularity among the various transmission media – Justify.

Principle :

It works on the principle of total internal reflection.

Fibre Optic Communication :

The method of transmitting information from one place to another in terms of light pulses through an optical fibre is called " Fibre optic communication "

Applications :

1. International communication.
2. Inter- city communication .
3. Traffic control & defence application .

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Merits :

1. Very thin & weigh less than copper cable.
2. It has much larger band width.
3. Carrying information capacity is larger.
4. immune to electricity interferences.
5. Cheaper than copper cable.

Demerits :

1. It is ab expensive technology.
2. More breakable when compared to copper wires.

---

17. List out the advantages and limitations of frequency modulation.

Advantages of FM :

1. Operating range is quite large.
2. Transmission efficiency is very high.
3. Large decrease in noise.
4. FM bandwidth covers the entire frequency range which humans can hear.

Limitations of FM :

1. FM requires much wider channel.
2. FM transmitters and receivers are more complex and costly.
3. In FM reception , less area is covered compared to AM.

18.What is meant by satellite communication ? Give its applications.

Satellite Communication

1. Mode of transmission of the signal between transmitter and receiver via satellite.
2. The message signal from earth station is transmitted to satellite on board via uplink (frequency band 6 G Hz)
3. Retransmitted to another earth station via downlink. (frequency 4 G Hz)

i) Weather Satellite :

1. Used to monitor the weather and climate of earth.
2. By measuring cloud mass.
3. Satellite enable us to predict rain.
4. Dangerous storms like hurricane cyclone etc.

A . Angelin Femila M.Sc. , M.Phil., PGDCA ., PG ASST (PHY)
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ii) Communication Satellite :

1. **Used to transmit television , radio , internet signal etc.**
2. **Multiple satellites are used for long distance communication.**

iii) Navigation Satellite :

1. **Used to determine the geographic location of ships , air craft or any other object.**

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PSK MATRIC HR. SCL POMMADIMALAI .