Session 2020-21

KENDRIYA VIDYALAYA SANGATHAN

AHMEDABAD-GANDHINAGAR CLUSTER

AHMEDABAD REGION

STUDENT SUPPORT MATERIAL

INSPIRATION

Shri(Dr) Jaydeep Das, Deputy Commissioner, KVS RO Ahmedabad
Smt Shruti Bhargava , Assistant Commissioner, KVS RO Ahmedabad

MENTOR

Shri Avijit Panda, Principal, Kendriya Vidyalaya, Sabarmati

CONTENT DEVELOPEMENT TEAM

Shri Sunil Kumar Devrani, PGT Physics, KV No Sec 30, Gandhinagar
Shri M.P. Dabi, PGT Physics, KV ONGC,Chandkheda
Shri T.C. Agrawal, PGT Physics, KV ONGC,Chandkheda
Shri Bhupesh Nagoda, PGT Physics, KV Cantt, Ahmedabad
Shri Bhur Singh Meena , PGT Physics, KV Cantt, Gandhinagar
Shri Sabbir H., PGT Physics, KV CRPF, Gandhinagar
Shri Vikas Sharma,PGT Physics,KV Sabarmati

PHYSICS

Class-XII

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Session 2020-21
PHYSICS CLASS-XII

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Unit I – Electrostatics

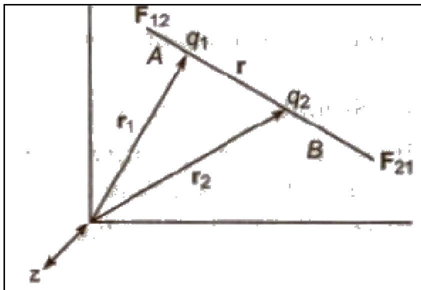
1. Electric Charge and Field

2. Electric Potential and Capacitance

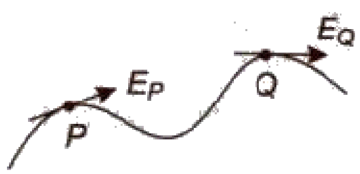
Charge
Charge is that property of an object by virtue of which it apply electrostatic force of interaction on other objects.
Charges are of two types
(i) Positive charge
(ii) Negative charge
Like charges repel and unlike charges attract each other.

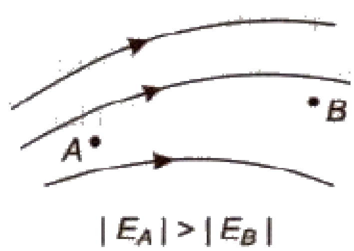
Quantization of Charge
Charge on any object can be an integer multiple of a smallest charge (e).
$Q = \pm ne$
where, n = 1, 2, 3,……. and $e = 1.6 * 10^{-19}$ C.
Conservation of Charge
Charge can neither be created nor be destroyed. but can be transferral from one object to another object.
Recently a new particle has been discovered called 'Quark'. It contains charge $\pm e / 3$, $\pm 2e / 3$.
[The protons and neutrons are combination of other entities called quarks, which have charges 1 / 3 e. However, isolated quarks have not been observed, so, quantum of charge is still e.]
Coulomb's Law of Electrostatics
Electrostatic force of interaction acting between two stationary point charges is given by

where q_1, q_2 are magnitude of point charges, r is the distance between them and ε_o is permittivity of free space.
Here, $1 / 4\pi\varepsilon_o = 9 \times 10^{9}$ N-m^2/C^2
The value of ε_o is 8.85×10^{-12} C^2 / N-mC^2.
If there is another medium between the point charges except air or vacuum, then ε_o is replaced by $\varepsilon_o K$ or $\varepsilon_o\varepsilon_r$ or ε.
where K or ε_r is called dielectric constant or relative permittivity of the medium.
$K = \varepsilon_r = \varepsilon / \varepsilon_o$ where, ε = permittivity of the medium.
For air or vacuum, K = 1 For water, K = 81 For metals, $K = \infty$
Coulomb's Law in Vector Form:

	Force on q_2 due to q_1, $\mathbf{F}_{21} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2} \hat{\mathbf{r}}$ $\mathbf{F}_{21} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^3} \mathbf{r}$ $\mathbf{F}_{21} = \frac{q_1 q_2}{4\pi\varepsilon_0} \cdot \frac{\mathbf{r}_2 - \mathbf{r}_1}{\lvert \mathbf{r}_2 - \mathbf{r}_1 \rvert^3}$

The above equations give the Coulomb's law in vector form.
Force on q_1 due to q_2 = – Force on q_2 due to q_1
$F_{12} = - F_{21}$
The forces due to two point charges are parallel to the line joining point charges; such forces are called central forces and electrostatic forces are conservative forces.
Electric Field
The space in the surrounding of any charge in which its influence can be experienced by other charges is called electric field.
Electric Field Lines
"An electric field line is an imaginary line or curve drawn through a region of space so that its tangent at any point is in the direction of the electric field vector at that point. The relative closeness of the lines at some place give an idea about the intensity of electric field at that point."





Two lines can never intersect.
Electric field lines always begin on a positive charge and end on a negative charge and do not start or stop in mid space.

Electric Field Intensity (E)
The electrostatic force acting per unit positive charge on a point in electric field is called electric field intensity at that point.

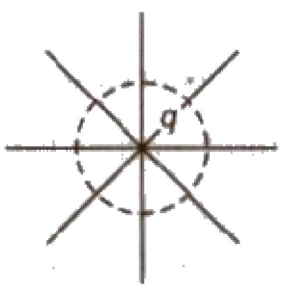
Electric field intensity
Its SI unit is NC^{-1} or V/m and its dimension is $[MLT^{-3} A^{-1}]$.
It is a vector quantity and its direction is in the direction of electrostatic force acting on positive charge.

Electric field intensity due to a point Charge:
due to a point charge q at a distance r is given by
Magnitude -

Electric Potential (V)
Electric potential at any point is equal to the work done per positive charge in carrying it from infinity to that point in electric field.
Electric potential, V = W / q
Its SI unit is J / C or volt and its dimension is $[ML^2T^{-3}A^{-1}]$.
It is a scalar quantity.
Electric potential due to a point charge at a distance r is given by

Potential Gradient:
The rate of change of potential with distance in electric field is called potential gradient.
Potential gradient =
Its unit is V / m.
Relation between potential gradient and electric field intensity is given by

Equipotential Surface
Equipotential surface is an imaginary surface joining the points of same potential in an electric field. So, we can say that the potential difference between any two points on an equipotential surface is zero. The electric lines of force at each point of an equipotential surface are normal to the surface.



(i) Equipotential surface may be planer, solid etc. But equipotential surface can never be point size.
(ii) Electric field is always perpendicular to equipotential surface.
(iii) Equipotential surface due to an isolated point charge is spherical.
(iv) Equipotential surface are planer in an uniform electric field.
(v) Equipotential surface due to a line charge is cylindrical.

Properties of Electric Field Lines:
Electric lines of force are the imaginary lines drawn in electric field at Which a positive test charge will move if it is free to do so.
Electric lines of force start from positive charge and terminate on negative charge.

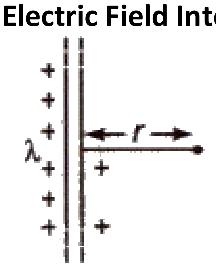
A tangent drawn at any point on electric field represents the direction of electric field at that point.
Two electric lines of force never intersect each other.
Electric lines of force are always perpendicular to an equipotential surface.

Electric Flux (ϕ_E)
Electric flux over an area is equal to the total number of electric field lines crossing this area.
Electric flux through a small area element dS is given by
$\phi_E = E.\ dS$
where E= electric field intensity and dS = area vector.
Its SI unit is Nm^2C^{-1}.

Gauss's Theorem:
The electric flux over any closed surface is $1 / \varepsilon_o$ times the total charge enclosed by that surface, i.e.,
where Qin = Net Charge enclosed in the surface.

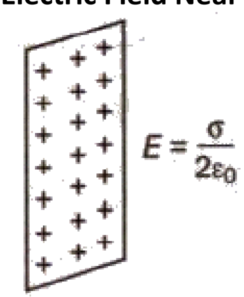
Note: If a charge q is placed at the centre of a cube, then
total electric flux linked with the whole cube = q / ε_o
electric flux linked with one face of the cube = $q / 6\ \varepsilon_o$

Electric Field Intensity due to an Infinite Line Charge



(Direction –Radially outwards for q > 0 and inwards or q<0)
where λ is linear charge density and r is distance from the line charge.

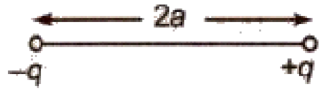
Electric Field Near an Infinite Plane Sheet of Charge:



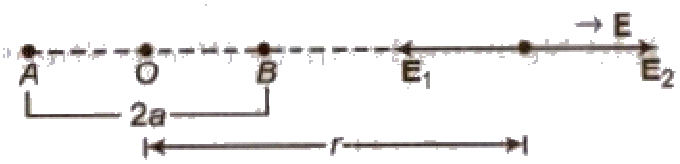
$E = \sigma / 2\ \varepsilon_o$

where σ = surface charge density.
If infinite plane sheet has uniform thickness, then
$E = \sigma / \varepsilon_o$

Electric Dipole:
An electric dipole consists of two point charges of equal magnitude and opposite sign separated by a very small distance. e.g., a molecule of HCL, a molecule of water etc.



Electric Dipole Moment p = q (2a)
Its SI unit is 'coulomb-metre' and its dimension is [LTA).
It is a vector quantity and its direction is from negative charge towards positive charge.
Electric Field Intensity and Potential due to an Electric Dipole
(i) On Axial Line
Electric field intensity
If r > > 2a, then (Short Dipole)
Electric potential



If r > > 2a, then (Short Dipole)

(ii) On Equatorial Line
Electric field intensity

If r > > 2a, then (Short Dipole)

Electric potential V = 0
(iii) At any Point along a Line Making θ Angle with Axis
Electric field intensity

Electric potential

If r > > 2a, then (Short Dipole)

Torque:
Torque acting on an electric dipole placed in uniform electric field is given by
$\tau = pE\sin\theta$ or τ = **p** x **E**
When θ = 90°, then 'τ_{max} = pE (Maximum)
When electric dipole is parallel to electric field, it is in **stable equilibrium** and when it is anti-parallel to electric field, it is in **unstable equilibrium**. (In this Case Torque = 0)

Work Done:
Work done is rotating an electric dipole in a uniform electric field from angle θ_1 to θ_2 is given by $W = pE (\cos \theta_1 - \cos \theta_2)$
If initially it is in the direction of electric field, then work done in rotating through an angle θ, $W = pE (1 - \cos \theta)$.

Potential Energy:
Potential energy of an electric dipole in a uniform electric field is given by
$U = - pE \cos\theta = \mathbf{p}.\mathbf{E}$

Dipole in Non-uniform Electric Field
When an electric dipole is placed in a non-uniform electric field, then a resultant force as well as a torque act on it.
Net force on electric dipole = $(qE_1 - qE_2)$, along the direction of greater electric field intensity.
Therefore electric dipole undergo rotational as well as linear motion.
Electrostatic Potential Energy of Charge System:

(1) Two point charge system, contains charges q_1 and q_2 separated by a distance r is given by
(2) Three point charge system

Important Points
When charge is given to a soap bubble its size gets increased.
In equilibrium for a charged soap bubble, pressure due to surface tension
= electric pressure due to charging
$4T / r = \sigma^2 / 2 \varepsilon_o$
or $4T / r = 1 / 2 \varepsilon_o (q / 4 \pi r^2)^2$
or $q = 8 \pi r \sqrt{2} \varepsilon_o rT$
where, r is radius of soap bubble and T is surface tension of soap bubble.

Behaviour of a Conductor in an Electrostatic Field:
(i) Electric field at any point inside the conductor is zero.
(ii) Electric field at any point on the surface of charged conductor is directly proportional to the surface density of charge at that point, but electric potential does not depend upon the surface density of charge.
(iii) Electric potential at any point inside the conductor is constant and equal to potential.
(iv) Direction of electric field at any point on its surface is always normal to the surface.

Electrostatic Shielding:
The process of protecting certain field from external electric field is called, electrostatic shielding.
Electrostatic shielding is achieved by enclosing that region in a closed metallic chamber.
Dielectric

Dielectrics are of two types **Non-polar Dielectric** The non-polar dielectrics (like N_2, O_2, benzene, methane) etc. are made up of non-polar atoms/molecules, in which the centre of positive charge coincides with the centre of negative charge of the atom/molecule.

Polar Dielectric

The **polar dielectric** (like H_2O, CO_2, NH_3 etc) are made up of polar atoms/molecules, in which the centre of positive charge does not coincide with the centre of negative charge of the atom.

Capacitor

A capacitor is a device which is used to store huge charge over it, without changing its dimensions.

When an earthed conductor is placed near a charged conductor, then it decreases its potential and therefore more charge can be stored over it.

A capacitor is a pair of two conductors of any shape, close to each other and have equal and opposite charges.

Capacitance of a conductor $C = q / V$

Its SI unit is coulomb/volt or farad (F)

Its other units are $1\ \mu F = 10^{-6}$ F

$1\ \mu\mu F = 1\ pF = 10^{-12}$ F

Capacitance of an Isolated Spherical Conductor

$C = 4 \pi \varepsilon_o K R$ For air K = 1

$\therefore C = 4 \pi \varepsilon_o R = R / 9x\ 10^9$

Parallel Plate Capacitor

The parallel plate capacitor consists of two metal plates parallel to each other and separated by a distance d.

Capacitance $C = KA\ \varepsilon_o / d$

For air capacitor $C_o = A\ \varepsilon_o / d$

When a dielectric slab is inserted between the plates partially, then its capacitance.

If a conducting (metal) slab is inserted between the plates, then

Force Between the Plates of the Capacitor:

The plates of a parallel plate capacitor attract each other with a force

$F = Q^2 / 2\ A\ \varepsilon_o$

Charge Induced:

When a dielectric slab is placed between the plates of a capacitor than charge induced on its side due to polarization of dielectric is

$q' = q\ (1 – 1 / K)$

Capacitors Combination:

(i) **In Series:**

Resultant capacitance $= 1 / C = 1 / C_1 + 1 / C_2 + 1 / C_3 + ….$

In series charge is same on each capacitor, which is equal to the charge supplied by the source.
If V_1, V_2, V_3,…. are potential differences across the plates of the capacitors then total voltage applied by the
source
$V = V_1 + V_2 + V_3 + ….$

(ii) **In Parallel:**
Resultant capacitance $C = C_1 + C_2 + C_3 + ….$
In parallel potential differences across the plates of each capacitor is same.
If q_1, q_2, q_3 are charges on the plate of capacitors connected in parallel then total charge given by the source
$q = q_1 + q_2 + q_3 + ….$

Electrostatic Energy Stored in Capacitor:
Electric potential energy of a charged conductor or a capacitor is given by,
Where Q = Charge. V = Potential of Capactor, C = Capacitance

Redistribution of Charge:

When two isolated charged conductors are connected to each other then charge is redistributed in the ratio of their capacitances.
Common potential

Energy loss
This energy is lost in the form of heat in connecting wires.

Very Short Answer Type Questions (1 Mark)

1. Is the force acting between two point electric charges q1 and q2, kept at some distance apart in air, attractive or repulsive, when (i) q1q2 > 0 (ii) q1q2 <0 ?

Ans: (i) The force is repulsive. When $q1q2 > 0$, it means that charges are either both positive or both negative. This implies that the force between them is indeed repulsive.
(ii) The force is attractive. When $q1q2 < 0$, it means that one of the charges is negative and the other is positive. This implies that the force between them is indeed attractive.
2. Which orientation of an electric dipole in a uniform electric field would correspond to stable equilibrium?

Ans: When the electric dipole is in the direction of the electric field ($\theta = 0^o$), it is said to be in stable equilibrium.

3. A hollow metal sphere of radius 10 cm is charged such that the potential on its surface is 5 V. What is the potential at the centre of the sphere?

Solution: $E = -\frac{dv}{dr}$ and for hollow shell electric field at center = 0

$\Rightarrow -\frac{dv}{dr} = 0 \Rightarrow dv = 0$ Hence V_c = 5V

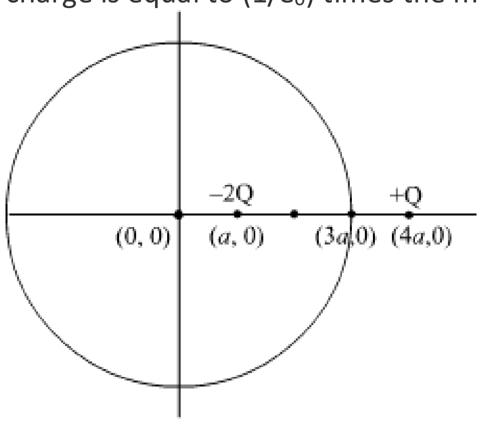
4. Define electric dipole moment. Write its S.I. unit.

Solution: Electric dipole moment is the product of the magnitude of the either charge and the distance between the charges (this distance is also called the displacement vector). SI unit of electric dipole moment is coulomb meter (Cm).

5. A charge 'q' is placed at the centre of a cube of side *l.* What is the electric flux passing through each face of the cube?

Ans : $\phi = \frac{q}{6 \epsilon_0}$

6. Two charges of magnitudes —2Q and +Q are located at points (a, 0) and (4a, 0) respectively. What is the electric flux due to these charges through a sphere of radius '3a' with its centre at the origin?**(1)**
Solution: Gauss' theorem states that the electric flux through a closed surface enclosing a charge is equal to $(1/\varepsilon_0)$ times the magnitude of the charge enclosed.



The sphere encloses a charge of -2Q thus, $\phi = \frac{2Q}{\varepsilon_0}$

7. Two equal balls with equal positive charge 'q' coulombs are suspended by two insulating strings of equal length. What would be the effect on the force when a plastic sheet is inserted between the two?
Solution: Since plastic is an insulator, the electric field lines due to any of the charge will not be able to pass through it. In the absence of an external electric field due to the other charge, both the charges will not experience any force due to each other.

Assertion and Reason Based Questions (1 mark)

For question numbers 1 to 18, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

- **Both A and R are true and R is the correct explanation of A**
- **Both A and R are true but R is NOT the correct explanation of A**
- **A is true but R is false**
- **A is false and R is also false**

1 .**Assertion (A)**: The electrostatics force increases with decrease the distance between the charges.

Reason (R): The electrostatic force of attraction or repulsion between any two stationary point charges is inversely proportional to the square of the distance between them.

Answer: A

2. **Assertion(A):** The Coulomb force between two points charges depend upon the dielectric constant of the intervening medium.

Reason(R): Coulomb's force varies inversely with the dielectric constant of medium.

Answer: A

3. **Assertion(A):** The charge given to a metallic sphere does not depend on whether it is hollow or solid

Reason(R): The charge resides only at the surface of conductor.

Answer: A

4. **Assertion (A):** A comb run through one's dry hair attracts small bits of paper.

Reason(R): Molecules in the paper gets polarized by the charged comb resulting in net force of attraction

Answer: A

5. **Assertion(A):** A proton is placed in a uniform electric field, it tends to move along the direction of electric field.

Reason(R): A proton placed in a uniform electric field experiences a force.

Answer: B

6. **Assertion(A):** Electric field at the surface of a charged conductor is always normal to the surface at every point.

Reason(R): Electric field gives the magnitude & direction of electric force **F** experienced by any charge placed at any point.

Answer: B

7. **Assertion(A):** The potential inside a hollow spherical charged conductor is zero.
Reason (R): Inside the hollow spherical conductor electric field is constant.

Answer: D

8. **Assertion(A):** Electric filed lines not form closed loops.
Reason(R): Electric filed lines are always normal to the surface of a conductor.

Answer: B

9 **Assertion(A):** No work is done in moving a test charge from one point to another over an equipotential surface.
Reason(R): Electric field is always normal to the equipotential surface at every point

Answer: B

10 **Assertion(A):** No work is done in moving a point charge Q around a circular arc of radius $'r'$at the Centre of which another point charge $'q'$ is located.
Reason(R): No work is done in moving a test charge from one point to another over an equipotential surface.

Answer: A

11 **Assertion(A):** A metal plate is introduced between the plates of a charged parallel plate capacitor, its capacitance increased.
Reason(R): A metal plate is introduced between the plates of a charged parallel plate capacitor, the effective separation between the plates is decreased.

Answer: A

12.**Assertion(A):** In the presence of external electric field the net electric field within the conductor becomes zero.
Reason(R): In the presence of external electric field the free charge carriers move and charge distribution in the conductor adjusts itself.

Answer: A

13.**Assertion (A):** Sensitive instruments can protect from outside electrical influence by enclosing them in a hollow conductor.
Reason(R): Potential inside the cavity is zero.

Answer: C

14. **Assertion(A):** Earthing provides a safety measure for electrical circuits and appliances.
Reason(R): When we bring a charged body in contact with the earth, all the excess charge on the body disappears by causing a momentary current to pass to the ground through the connecting conductor.
Answer : A

15. **Assertion(A):** The total amount of charge on a body equal to $4X10^{-19}$ C is not possible.
Reason(R): Experimentally it is established that all free charges are integral multiples of a basic unit of charge denoted by *e*. Thus, charge *q* on a body is always given by $q = ne$.
Answer: A

16. **Assertion(A):** The net force on a dipole in a uniform electric dipole is zero.
Reason(R): Electric dipole moment is a vector directed from –q to +q.
Answer : B

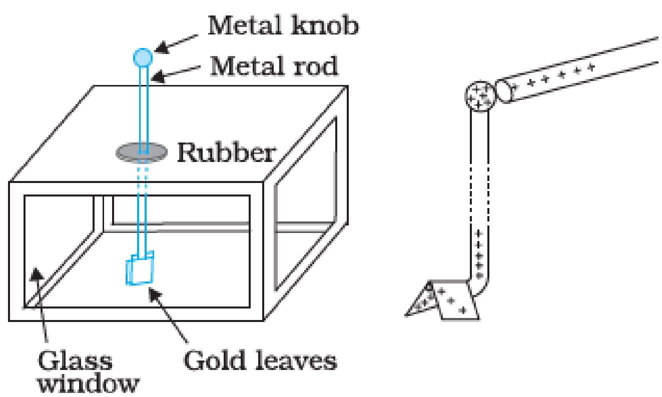
17. **Assertion(A):** Electrostatic forces are conservative in nature.
Reason(R): Work done by electrostatic force is path dependent.
Answer : C

18 **Assertion(A):** The field intensity in between such sheets having equal and opposite uniform surface densities of charge become constant.
Reason(R): The field intensity does not depend upon the distance between the thin sheet. Answer: A

Case Study Based Questions (4 Marks)

1. **Gold Leaf Electroscope:**

Gold leaf electroscope has two gold leafs suspended from a metal(usually brass) stem in a vacuumed glass jar and connected to a metal cap. The glass is grounded with the help of a metal foil to make it uncharged. It can be used to: Detect charge: Body under test is touched with the metal cap.



(i) Neutral atoms contain equal numbers of positive_______and negative__.
(a) Electrons and Protons (b) Protons and Electrons (c) Neutrons and Electrons (d) Protons and Neutrons

(ii) greater the charge on a given body, the divergence in the leaves will be
(a) smaller (b) greater (c) same (d) first smaller then greater

(iii) Magnitude of force between a pair of proton and proton is F and between a proton d electron is F' then
(a) F = F' (b) F > F' (c) F < F' (d) F >> F'

(iv) Earthing means

(a) to perform an experiment on Earth (b) to burry the device in the Earth
(c) To put the device on Earth (d) Process of sharing charges with Earth

(V) If a negatively charged rod touches a conductor, the conductor will be charged by what method?
(a) Friction (b) Conduction (c) Convection (d) Induction

Answers : (b) , (b), (a) , (d), (b)

2. **Concept of Electric Field:**
Electric field is an elegant way of characterizing the electrical environment of a system of charges. Electric field at a point in the space around a system of charges tells you the force a unit positive test charge would experience if placed at that point (without disturbing the system). Electric field is a characteristic of the system of charges and is independent of the test charge that you place at a point to determine the field

(1) Which of the following statement is correct? The electric field at a point is
(a) always continuous. (b) continuous if there is a charge at that point.
(c) discontinuous only if there is a negative charge at that point.
(d) discontinuous if there is a charge at that point

2. The force per unit charge is known as
(a) Electric Field (b) Electric Flux (c) Electric Current (d) Electric potential.

3. The SI unit of electric field is

(a) N/C (b) V/m (c)V m (d) both (a) and (b)

4. A proton of mass 'm'placed in electric field region remains stationary in air then magnitude of electric field is

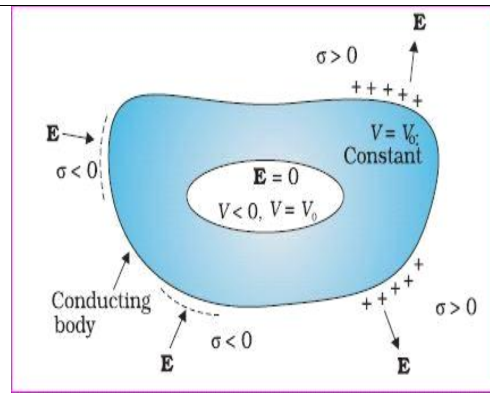
(a) mge (b) mg/e (c) e/mg (d) e^2g/m^2

5. Electric field is

(a) Vector (b)Scalar (c) tensor (d) none of the above

Ans : b , a , d, b, a

3. **Electrostatic Shielding :**

Consider a conductor with a cavity, with no charges inside the cavity. A remarkable result is that the electric field inside the cavity is zero, whatever be the size and shape of the cavity and whatever be the charge on the conductor and the external fields in which it might be placed i.e. any cavity in a conductor remains shielded from outside electric influence: the field inside the cavity is always zero. This is known as electrostatic shielding. Faraday Cages uses this effect to protect sensitive instruments from outside electrical influence.	

1. A metallic shell having inner radius R1 and outer radii R2 has a point charge Q kept inside cavity. Electric field in the region R1 < r < R2 where r is the distance from the centre is given by

(a) depends on the value of r (b) Zero

(c) Constant and nonzero everywhere (d) None of the above

2. The electric field inside the cavity is depend on

- Size of the cavity
- Shape of the cavity
- Charge on the conductor
- None of the above

3. Electrostatic shielding is based

- electric field inside the cavity of a conductor is less than zero
- electric field inside the cavity of a conductor is zero

(c) electric field inside the cavity of a conductor is greater than zero

(d) electric field inside the cavity of a plastic is zero

4. During the lightning thunderstorm, it is advised to stay

- inside the car (b) under trees

(c) in the open ground (c) on the car

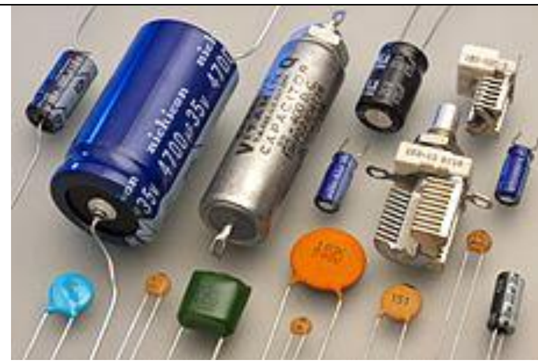
5. Which of the following material can be used to make a Faraday cage (based on electrostatic shielding)

- Plastic
- Glass
- Copper
- Wood

Answer: 1. b 2. d 3. b 4. a 5. C

4. **Capacitor:**

A capacitor is a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals. The effect of a capacitor is known as capacitance. While some capacitance exists between any two electrical conductors in proximity in a circuit, a capacitor is a component designed to add capacitance to a circuit.



1. The energy of a charged capacitor is given by the expression (**q** = charge on the conductor and C = its capacity)

(a) (b) (c) **2qC** (d)

2. The condensers of capacity **C_1** and **C_2** are connected in parallel, then the equivalent capacitance is

(a) $C_1 + C_2$ (b) (c) (d)

3. A parallel plate condenser has a capacitance **50 µ F** in air and **110 µF** when immersed in an oil. The dielectric constant 'k' of the oil is

(a) 0.45 (b) 0.55 (c) 1.10 (d) 2.20

4 The energy of a charged capacitor resides in

(a) The electric field only (b) The magnetic field only

(c) Both the electric and magnetic field (d) Neither in electric nor magnetic field

5. The capacity of a parallel plate capacitor is C. Its capacity when the separation between the plates is halved will be

(a) **4 C** (b) **2C** (c) **C/2** (d) **C/4**

Ans : (a) , (a), (d), (a), (c)

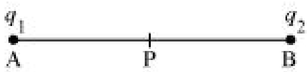
Short Answer Type Questions (2 Marks)

1. A spherical Gaussian surface encloses a charge of 8.85×10^{-10}C.
(i) Calculate the electric flux passing through the surface.
(ii) How would the flux change if the radius of the Gaussian surface is doubled and why?

Solutions: (i) Total flux enclosed $= \frac{q_o}{\varepsilon_0} = \frac{8.85\times10^{-10}}{8.85\times10^{-12}} =$ 100 T m^2

(ii) The flux would not change if the radius of Gaussian surface is double because enclosed charge remains the same.

2. Two point charges $q_1 = 10 \times 10^{-8}$ C and $q_2 = -2 \times 10^{-8}$ C are separated by a distance of 60 cm in air.
(i) Find at what distance from the 1st charge, q_1, would the electric potential be zero.
(ii) Also calculate the electrostatic potential energy of the system.
Solution:



(i) Here, $q_1 = 10 \times 10^{-8}$ C, $q_2 = -2 \times 10^{-8}$ C
And AB = 60 cm = 0.60 = 0.6 m
Let $AP = x$
Then, $PB = 0.6 - x$

Potential P due to charge $q_1 = \frac{kq_1}{AP}$

Potential P due to charge $q_2 = \frac{kq_2}{PB}$

∵ Potential at $P = 0 \Rightarrow \frac{kq_1}{AP} + \frac{kq_2}{PB} = 0$

$$\frac{kq_1}{AP} = -\frac{kq_2}{PB} \Rightarrow \frac{q_1}{AP} = -\frac{q_2}{PB}$$

$$\therefore \frac{10\times10^{-8}}{x} = \frac{-\left(2\times10^{-8}\right)}{0.6-x} \Rightarrow \frac{10}{x} = \frac{2}{0.6-x}$$

$$2x = 6.0 - 10x \Rightarrow 2x + 10x = 6$$

$$\therefore 12x = 6 \Rightarrow x = \frac{6}{12} = 0.5 \text{ m}$$

∴Distance from first charge = 0.5 = 50 cm
(ii) Electrostatic potential energy of the system

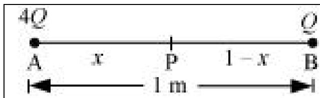
$$U = k\frac{q_1 q_2}{r}$$

$$U = 9\times10^9 \times \frac{10\times10^{-8}\times\left(-2\times10^{-8}\right)}{0.6}$$

$$U = \frac{-18\times10^{-6}}{0.6} \Rightarrow U = -30\times10^{-6} = -3\times10^{-5} \text{ J}$$

3. Two point charges 4*Q*, *Q* are separated by 1 m in air. At what point on the line joining the charges is the electric field intensity zero? Also calculate the electrostatic potential energy of the system of charges, taking the value of charge, $Q = 2 \times 10^{-7}$ C.

Solution



Let the point be at a distance *x* from 4*Q* charge.

Electric field at *P* due to 4*Q* = Electric field at *P* due to *Q*

$$\therefore k = \frac{4Q}{x^2} = k \times \frac{Q}{(1-x)^2}$$

$$\frac{4}{x^2} = \frac{1}{(1-x)^2} \Rightarrow \frac{2}{x} = \pm \frac{1}{1-x}$$

$$\frac{2}{x} = \frac{1}{1-x} \text{ or } \frac{2}{x} = -\frac{1}{1-x}$$

$x = 2 - 2x$ or $-x = 2 - 2x$

$x + 2x = 2$ or $-x + 2x = 2$

$3x = 2$ or $x = 2$

$x = \frac{2}{3}$ or $x = 2$

$\because x = 2$ m is not possible

$\therefore x = \frac{2}{3}$ m

Electrostatic potential energy of the system is

$$U = k\frac{q_1 q_2}{r}$$

$$\Rightarrow U = k \cdot \frac{4Q \cdot Q}{r} = k\frac{4Q^2}{r}$$

$$U = 9 \times 10^9 \times \frac{4 \times (2 \times 10^{-7})^2}{1}$$

$$U = 9 \times 10^9 \times \frac{4 \times 4 \times 10^{-14}}{1}$$

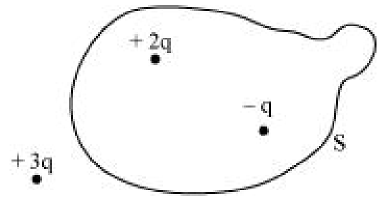
$$U = 144 \times 10^{-5} = 1.44 \times 10^{-3}\text{ J}$$

4. (i) Can two equi-potential surfaces intersect each other? Give reasons.
(ii) Two charges −q and +q are located at points A (0, 0, −a) and B (0, 0, +a) respectively. How much work is done in moving a test charge from point P (7, 0, 0) to Q (−3, 0, 0)?

Solution:

(i) Two equipotential surfaces cannot intersect each other because when they will intersect, the electric field will have two directions, which is impossible.
(ii) Charge P moves on the perpendicular bisector of the line joining +q and −q. Hence, this perpendicular bisector is equidistant from both the charges. Thus, the potential will be same everywhere on this line. Therefore, work done will be zero.

5. Figure shows three point charges +2q, −q and + 3q. Two charges + 2q and −q are enclosed within a surface ‘S’. What is the electric flux due to this configuration through the surface ‘S’?



Solution:

The net electric flux through the surface 'S' is $\frac{q}{\varepsilon_0}$, where ε_0 is the permittivity of free space.

6. **(i)** Net capacitance of three identical capacitors in series is 2 µF. What will be their net capacitance if connected in parallel?
(ii) Find the ratio of energy stored in the two configurations if they are both connected to the same source.

Solution:

(i) When connected in series, the net capacitance is 2 F.

$$\Rightarrow \frac{1}{C}+\frac{1}{C}+\frac{1}{C}=\frac{1}{2}$$

$$\Rightarrow C = 6\ \mu\text{F}$$

When connected in parallel,
$C_{eq} = C_1 + C_2 + C_3$ = 6 µF + 6 µF + 6 µF = 18 µF.
(ii) Energy for series combination

$$E_s = \frac{1}{2}C_{eq,s}V^2 = \frac{1}{2}\times 2\times 10^{-6}\times V \qquad (1)$$

Energy for parallel combination

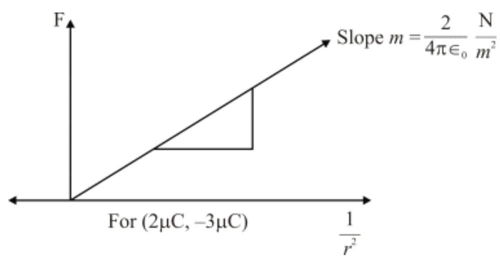
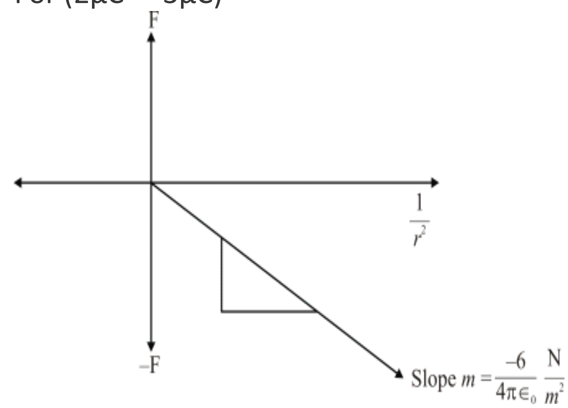
$$E_p = \frac{1}{2}C_{eq,p}V^2 = \frac{1}{2}\times 18\times 10^{-6}\times V \qquad (2)$$

As both are connected to the same source

$$\frac{E_s}{E_p} = \frac{\frac{1}{2}\times 2\times 10^{-6}\times V}{\frac{1}{2}\times 18\times 10^{-6}\times V} = \frac{1}{9}$$

7. Plot a graph showing the variation of coulomb force (F) versus $\left(\frac{1}{r^2}\right)$, where r is the distance between the two charges of each pair of charges: (1 µC, 2 vC) and (2 µC, — 3 µC). Interpret the graphs obtained.

Solution: Graph between *F vs*

For (1μC, 2μC)	For (2μC — 3μC)
	

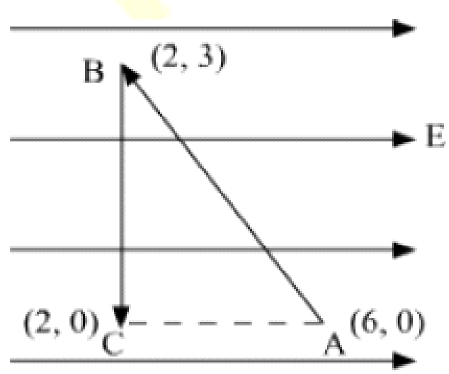
Interpretation

(i) Graphs show that F α $1/r^2$

(ii) Slope gives a constant value and depends only on nature of charges and medium.

(iii) I[st] graph is for repulsive force in I[st] quadrant and II[nd] graph is for attractive force in IV[th] quadrant i.e., $F > 0$ and $F < 0$ respectively.

8. A test charge 'q' is moved without acceleration from A to C along the path from A to B and then from B to C in electric field E as shown in the figure. (i) Calculate the potential difference between A and C. (ii) At which point (of the two) is the electric potential more and why?



Solution:

Since work done is independent of the path therefore we may directly move from A to C. Potential difference between A and C,

$$V_C - V_A = -\int_A^C \vec{E}\cdot\vec{dl}$$

$$= -\int_A^C E dl \cos 180°$$

$$= -E(-1)\int_A^C dl$$

$$= E \times 4$$

$$= 4E$$

So, $V_C - V_A = 4E$

(ii) Electric potential will be more at point C as direction of electric field is in decreasing potential. Hence

$V_C > V_A$

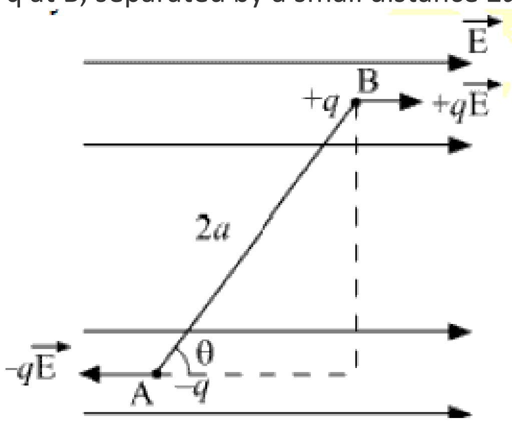
9. An electric dipole is held in a uniform electric field.

(i) Show that the net force acting on it is zero.

(ii) The dipole is aligned parallel to the field. Find the work done in rotating it through the angle of 180°.

Solution:

(i) Consider an electric dipole consisting of two equal and opposite point charges, −q at A and + q at B, separated by a small distance 2*a*.



AB = 2*a*, having dipole moment

$|\vec{p}| = q(2a)$

Let this dipole be held in a uniform external electric field $\vec{E}$ at an angle θ with the direction of $\vec{E}$.

Force on charge −q at A= − q $\vec{E}$, in a direction opposite to $\vec{E}$

Force on charge +q at B = +q $\vec{E}$, along the direction of $\vec{E}$

Net force on the dipole = qE − qE = 0

(ii) Work done on dipole, W = ΔU = pE (cos ϑ_1 − cos θ_2)

W = pE (cos0° − cos180°)

W = 2pE

10 A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness d/2, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor.

Solution: Initially when there is vacuum between the two plates, the capacitance of the two parallel plate is, $C_0 = \frac{\varepsilon_0 A}{d}$

Where, A is the area of parallel plates.

Suppose that the capacitor is connected to a battery, an electric field E_0 is produced.

Now if we insert the dielectric slab of thickness t=d/2 the electric field reduces to E.

Now the gap between plates is divided in two parts, for distance t there is electric field E and for the remaining distance (d-t) the electric field is E_0.

If V be the potential difference between the plates of the capacitor, then $V=Et+E_0(d-t)$

$$V = \frac{Ed}{2} + \frac{E_0 d}{2} = \frac{d}{2}(E + E_0) \qquad (\because t = \frac{d}{2})$$

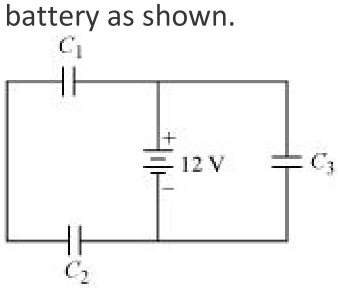
$$\Rightarrow V = \frac{d}{2}(\frac{E_0}{K} + E_0) = \frac{dE_0}{2K}(K+1) \qquad (\text{As, } \frac{E_0}{E} = K)$$

$$\text{Now, } E_0 = \frac{\sigma}{\varepsilon_0} = \frac{q}{\varepsilon_0 A} \Rightarrow V = \frac{d}{2K}\frac{q}{\varepsilon_0 A}(K+1)$$

$$\text{We know, } C = \frac{q}{V} = \frac{2K\varepsilon_0 A}{d(K+1)}$$

Short Answer Type Questions (3 Marks)

1. Three identical capacitors C_1, C_2 and C_3 of capacitance 6 μF each are connected to a 12 V battery as shown.



Find

(i) charge on each capacitor

(ii) equivalent capacitance of the network

(iii) energy stored in the network of capacitors

Solution:

The 12 V battery is in parallel with C_1, C_2, and C_3. C_1 and $C_2$are in series with each other while $C_3$is in parallel with the combination formed by C_1 and C_2.

Total voltage drop across C_3 = 12 V

$q_3 = CV$

Where, q = Charge on the capacitor

C_1, C_2, C_3 = 6 μF (Given in the question)

q_3 = 6 × 12 = 72 μC

Voltage drop across C_1 and C_2 combined will be 12 V.

Let the voltage drop at $C_1 = V_1$
Let the voltage drop at $C_2 = V_2$
Then,
$V = V_1 + V_2$

$$V_1 = \frac{q_1}{C}$$

$$V_2 = \frac{q_2}{C}$$

$$\frac{q_1}{6} + \frac{q_2}{6} = 12$$

As both the capacitors are in series,

$$q_1 = q_2 = q$$

Then,

$$q\left\{\frac{1}{6} + \frac{1}{6}\right\} = 12$$

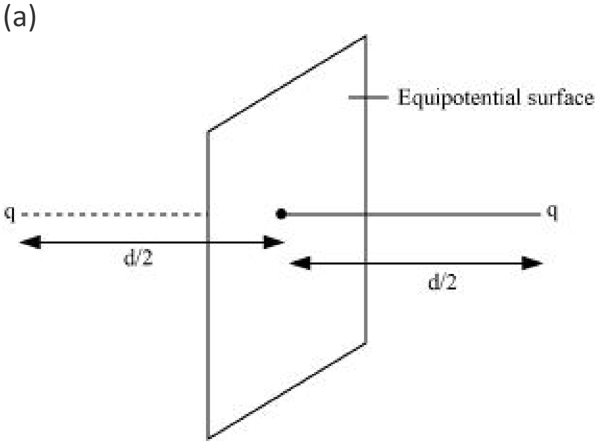
$$q \times \frac{1}{3} = 12$$

Or,
q = 36 micro coulombs
Thus, charge on each of C_1 and C_2 is 36 coulombs.

2. (a) Depict the equipotential surfaces for a system of two identical positive point charges placed a distance 'd' apart.
(b) Deduce the expression for the potential energy of a system of two point charges q_1 and $q_2$brought from infinity to the points $\vec{r_1}$ and $\vec{r_2}$ respectively in the presence of external electric field $\vec{E}$.

Solution:

(a)



(b)
The work done in bringing charge q_1 from infinity to $\vec{r_1}$ is $q_1V(\vec{r_1})$.

Work done on q_2 against external field = $q_2\, V(\vec{r}_2)$

Work done on q_2 against the field due to q_1 $= \frac{q_1 q_2}{4\pi\varepsilon_o r_{12}}$

Where, r_{12} is the distance between q_1 and q_2.

By the superposition principle for fields,

Work done in bringing q_2 to $\vec{r}_2$ is $\left(q_2 V(\vec{r}_2) + \frac{q_1 q_2}{4\pi\varepsilon_o r_{12}}\right)$.

Thus,

Potential energy of system = The total work done in assembling the configuration

$$= q_1 V(\vec{r}_1) + q_2 V(\vec{r}_2) + \frac{q_1 q_2}{4\pi\varepsilon_o r_{12}}$$

3. A parallel-plate capacitor is charged to a potential difference V by a dc source. The capacitor is then disconnected from the source. If the distance between the plates is doubled, state with reason how the following change:

(i) electric field between the plates

(ii) capacitance, and

(iii) energy stored in the capacitor

Solution:

(i) $Q = CV$ $Q = \left(\frac{\varepsilon_0 A}{d}\right)(Ed)$ $Q = \varepsilon_0 AE$ $\therefore E = \frac{Q}{\varepsilon_0 A}$ Therefore, the electric field between the parallel plates depends only on the charge and the plate area. It does not depend on the distance between the plates. Since the charge as well as the area of the plates does not change, the electric field between the plates also does not change.	(ii) Let the initial capacitance be C and the final capacitance be C'. Accordingly, $C = \frac{\varepsilon_0 A}{d}$ $C' = \frac{\varepsilon_0 A}{2d}$ $\frac{C}{C'} = 2$ $C' = \frac{C}{2}$ Hence, the capacitance of the capacitor gets halved when the distance between the plates is doubled.	(iii) Energy of a capacitor, $U = \frac{1}{2}\frac{Q^2}{C}$ Since Q remains the same but the capacitance decreases, $U' = \frac{1}{2}\frac{Q^2}{\left(\frac{C}{2}\right)}$ $\frac{U}{U'} = \frac{1}{2}$ $U' = 2U$ The energy stored in the capacitor gets doubled when the distance between the plates is doubled.

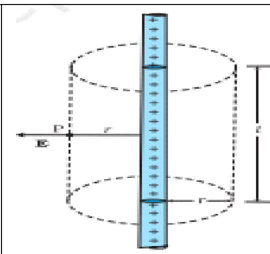
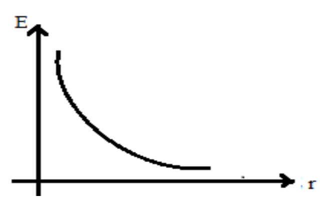
4. Using Gauss's law derive an expression for the electric field intensity at any point 'r' distance away from a uniformly charged wire of infinite length having linear charge density λ C/m. Draw a graph to show the variation of E with perpendicular distance r from the line charge.
Solution:

(a) Direction of Electric Field:

Consider an infinitely long thin straight wire with uniform linear charge density λ. The electric field is everywhere radial in the plane cutting the wire normally, and its magnitude depends only on the radial distance r. (outward if λ > 0, inward if λ < 0).

(b) Magnitude of electric Field:

To calculate the field, imagine a cylindrical Gaussian surface, as shown in the Fig. Since the field is everywhere radial, flux through the two ends of the cylindrical Gaussian surface is zero. At the cylindrical part of the surface, E is normal to the surface at every point, and its magnitude is constant, since it depends only on r. The surface area of the curved part is 2πrl, where l is the length of the cylinder.

Flux through the Gaussian surface = flux through the curved cylindrical part of the surface = E × 2πrl The surface includes charge equal to λ l. Gauss's law then gives $E \times 2\pi rl = \lambda l/\varepsilon_0$ i.e., Vectorially, E at any point is given bywhere **n** is the radial unit vector in the plane normal to the wire passing through the point. E is directed outward if λ is positive and inward if λ is negative.	 

5. State Gauss's law in electrostatic. Use this law to derive an expression for the electric field due to a uniformly charged infinite plane sheet. An infinitely large plane sheet has a uniform charge density +σ. Obtain the expression for the amount of work done in bringing a point charge q from infinity to a point, distance r, in front of the charge sheet.

Solution:

Direction of E:- Let σ be the uniform surface charge density of an infinite plane sheet . We take the x-axis normal to the given plane. By symmetry, the electric field will not depend on y and z coordinates and its direction at every point must be parallel to the x-direction.

Magnitude of E: We take the Gaussian surface to be a rectangular parallelepiped of cross-sectional area A, as shown. (A cylindrical surface will also do.) As seen from the figure, only the two faces 1 and 2 will contribute to the flux; electric field lines are parallel to the other faces and they, therefore, do not contribute to the total flux.

The unit vector normal to surface 1 is in –x direction while the unit vector normal to surface 2 is in the +x direction. Therefore, flux E.ΔS through both the surfaces are equal and add up. Therefore the net flux through the Gaussian surface is 2 EA. The charge enclosed by the closed surface is σA. Therefore by Gauss's law,

$2\,EA = \sigma A/\varepsilon_0$

or, $E = \sigma/2\varepsilon_0$

Vectorically, $\mathbf{E} = \sigma/2\varepsilon_0\,\hat{\mathbf{n}}$ where $\hat{n}$ is a unit vector normal to the plane and going away from it.

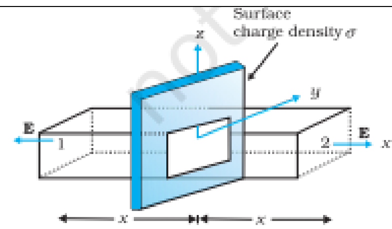
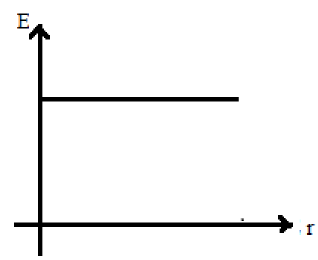


FIGURE Gaussian surface for a uniformly charged infinite plane sheet.



Long Answer Type Questions (5 Marks)

1. Derive the expression for the energy stored in a parallel plate capacitor of capacitance C with air as medium between its plates having charges Q and – Q. Show that this energy can be expressed in terms of electric field as $\frac{1}{2}\varepsilon_0 E^2 A\, d$ where A is the area of each plate and d is the separation between the plates.
How will the energy stored in a fully charged capacitor change when the separation between the plates is doubled and a dielectric medium of dielectric constant 4 is introduced between the plates?

Solution:
Consider a situation when one plate has a charge *Q′* and the other plate will also have charge –*Q′*.

The voltage between the plates will be $\frac{Q'}{C}$. A small charge equal to $\delta Q'$ is transferred from the negative plate to the positive plate. A small work δW is done in this process.

$\delta W = V' \delta Q' = \frac{Q'}{C}\delta Q'$ or

Energy stored = $\frac{1}{2}\frac{Q^2}{C}$ ...(1)

Now,

$Q = \sigma A$ where $\sigma \rightarrow$ Surface charge density

$C = \frac{\varepsilon_0 A}{d}$ where $A \rightarrow$ Area of the plates and $d \rightarrow$ Separation between the plates

Putting these values in equation (1), we obtain

Energy stored = $\frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{\sigma^2 A^2}{\varepsilon_0 A}d = \frac{1}{2}\frac{\sigma^2}{\varepsilon_0}Ad$ ...(2)

Now, we know that,

Electric field, $E = \frac{\sigma}{\varepsilon_0}$

Therefore, energy stored $= \frac{1}{2}\varepsilon_0 E^2 A d$

When distance between the plates is doubled and the dielectric constant is 4, the energy stored in the capacitor will be $= \frac{1}{2}4\varepsilon_0 \frac{\sigma^2}{16\varepsilon_o} A\,2d = \frac{1}{4}\varepsilon_0 \frac{\sigma^2}{\varepsilon_o} A\,d$

Thus, the total energy will become half when the distance between the plates is doubled and the dielectric constant is 4.

2. Define the term dipole moment $\vec{p}$ of an electric dipole indicating its direction. Write its SI unit. An electric dipole is placed in a uniform electric field $\vec{E}$. Deduce the expression for the torque acting on it. In a particular situation, it has its dipole moment aligned with the electric field. Is the equilibrium stable or unstable?

Solution:

Electric dipole moment is defined as the product of any one of the charges and the length of the electric dipole.

$\vec{p} = q(\overrightarrow{2a})$

Where,

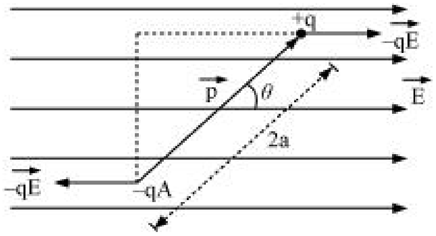
p = Electric dipole moment

q = One of the charges

$2a$ = Length of the electric dipole

Its direction is from negative charge to positive charge.

Its SI unit is coulomb metre.



τ = Either force × Perpendicular distance between the two forces

= $q\,E\,(2a \sin \vartheta)$

⇒ $\tau = p\,E \sin \vartheta$

⇒ $\vec{\tau} = \vec{p} \times \vec{E}$

⇒ $\tau(\vartheta) = p\,E \sin \vartheta$

For equilibrium $\tau(\vartheta) = 0$,

$p\,E \sin \vartheta = 0$

⇒ $\sin \vartheta = 0$

⇒ $\vartheta = 0°$ or $180°$

When the dipole is aligned along the electric field,

$\vartheta = 0°$

Now,

U → Potential energy

$U = -\,p\,E \cos \theta$

$= -\,p\,E \cos 0°$

$= -\,p\,E$

The potential energy is minimum at $\vartheta = 0$.

Hence, the dipole is in stable equilibrium.

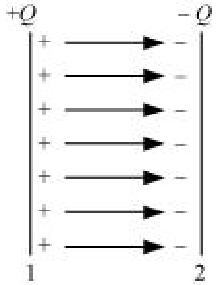
3. Derive an expression for the energy stored in a parallel plate capacitor.

On charging a parallel plate capacitor to a potential V, the spacing between the plates is halved, and a dielectric medium of $\epsilon_r = 10$ is introduced between the plates, without disconnecting the d.c source. Explain, using suitable expressions, how the (i) capacitance, (ii) electric field and (iii) energy density of the capacitor charge.

Solution:

Energy stored in a parallel plate capacitor:

At any intermediate stage, suppose charge on conductor 1 is + q and charge on conductor 2 is − q.



∴Potential difference between conductors 1 and 2 is *q/C,* where C is the capacity of the capacitor.

Suppose the capacitor is charged gradually and at any stage, the charge on the capacitor is *q*.

∴ Potential of capacitor = $\frac{q}{C}$

Small amount of work done giving an additional charge *dq* to the capacitor is

$$dw = \frac{q}{C}dq$$

Total work done in giving a charge *Q* to the capacitor

$$W = \int_{q=0}^{q=Q} \frac{q}{C}dq = \frac{1}{C}\left[\frac{q^2}{2}\right]_{q=0}^{q=Q}$$

$$W = \frac{1}{C}\frac{Q^2}{2}$$

As electrostatic force is conservative, this work is stored in the form of potential energy (*U*) of the capacitor.

$$U = W = \frac{1}{2}\frac{Q^2}{C}$$

Put *Q* = *CV*

$$\therefore U = \frac{1}{2}\frac{(CV)^2}{C} = \frac{1}{2}CV^2$$

$$\therefore \boxed{U = \frac{1}{2}CV^2}$$

(i) Let C' be the charge in capacitance.	(ii) Charge of field: $E' = \frac{V}{d'}$ $E' = \frac{2V}{d} = E_0; E_0 = \frac{V}{d}$ E Charge of energy density: $U_0 = \frac{1}{2}E_0^2\,\varepsilon_0, U = \frac{1}{2}\times\varepsilon_0\times 4E_0^2\times 10$ $\therefore U = 40U_0$

$$C' = \frac{k\varepsilon_a A}{d'}$$

$$\because d' = \frac{d}{2} \text{ and } k = \varepsilon_r = 10$$

$$\therefore C = \frac{E_0 A}{d}$$

$$C'' = \frac{10 \times \varepsilon_0 \times A}{\frac{d}{2}}$$

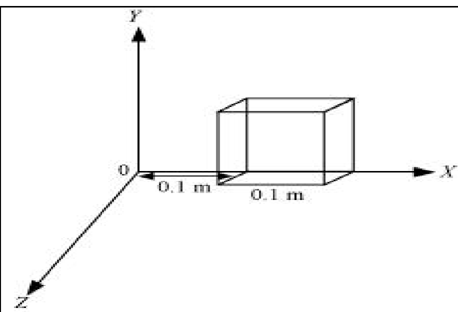
$$C' = \frac{20 \times \epsilon_0 \; A}{d} = 2C_0$$

$$\therefore \boxed{C' = 2C_0}$$

4 (a) Define electric flux. Write its SI unit.

(b) The electric field components due to a charge inside the cube of side 0.1 m are as shown: $E_x = \alpha x$, Where α = 500 N/C – m $E_y = 0$, $E_z = 0$

Calculate (i) the flux through the cube and (ii) the charge inside the cube



(a) Electric flux:

It is the number of electric field lines passing through a surface normally.

S.I unit of flux = $Nm^2 C^{-1}$

(b) Here, $E_x = \alpha x$, $E_y = 0$, $E_z = 0$

α = 500 N/C-m, Side of cube a = 0.1 m

Since the electric field has only x-component,

$\therefore \phi_E = \vec{E} \cdot \overrightarrow{\Delta S} = 0$ for each of four faces of cube ⊥ to y-axis and z-axis.

∴ Electric flux is only for left and right face along x-axis of the cube.

(i) Electric field at the left face, $x = a$, is

$$E_L = \alpha a$$

$$\phi_L = E_L \cdot \overrightarrow{\Delta S} = \alpha a \times a^2 \cos 180° = -\alpha a^3 \qquad [\because E = \alpha x]$$

and electric field at the right face, $x = a + a = 2a$, is

$$\therefore E_R = \alpha(2a)$$

$$\phi_R = \overrightarrow{E_R} \cdot \overrightarrow{\Delta S} = \alpha(2a)a^2 \cos 0° = 2\alpha a^3$$

∴ Net flux through the cube = $\phi_L + \phi_L$

$= -\alpha a^3 + 2\alpha a^3$

$= \alpha a^3$

$= 500 \times (0.1)^3$

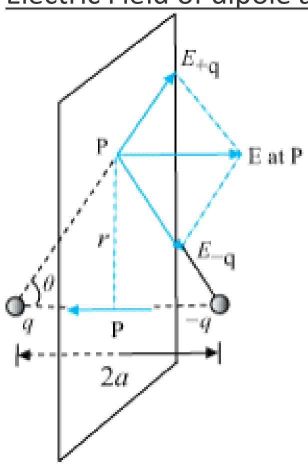
$= 0.5\ \text{Nm}^2\ \text{C}^{-1}$

(ii) By Gauss's law,

$q = \varepsilon_0 \phi$

$= 8.85 \times 10^{-12} \times 0.5 = 4.425 \times 10^{-12}\ \text{C}$

5. (a) Define electric dipole moment. Is it a scalar or a vector? Derive the expression for the electric field of a dipole at a point on the equatorial plane of the dipole.
(b) Draw the equipotential surfaces due to an electric dipole. Locate the points where the potential due to the dipole is zero.
Solution:
(a) Electric dipole moment: The strength of an electric dipole is measured by the quantity electric dipole moment. Its magnitude is equal to the product of the magnitude of either charge and the distance between the two charges.
Electric dipole moment, p = q × d
It is a vector quantity.
In vector form it is written as $\vec{p} = q \times \vec{d}$, where the direction of $\vec{d}$ is from negative charge to positive charge.
Electric Field of dipole at points on the equatorial plane:



The magnitudes of the electric field due to the two charges +*q* and −*q* are given by,

$$E_{+q} = \frac{q}{4\pi\varepsilon_0} \frac{1}{r^2 + a^2} \qquad \text{...(i)}$$

$$E_{-q} = \frac{q}{4\pi\varepsilon_0} \frac{1}{r^2 + a^2} \qquad \text{...(ii)}$$

$\therefore E_{+q} = E_{-q}$

The directions of E_{+q} and E_{-q} are as shown in the figure. The components normal to the dipole axis cancel away. The components along the dipole axis add up.

∴ Total electric field

$E = -(E_{+q} + E_{-q})\cos\theta\,\hat{p}$ [Negative sign shows that field is opposite to $\hat{p}$]

$$E = -\frac{2qa}{4\pi\varepsilon_0 (r^2 + a^2)^{\frac{3}{2}}}\hat{p} \qquad \text{...(iii)}$$

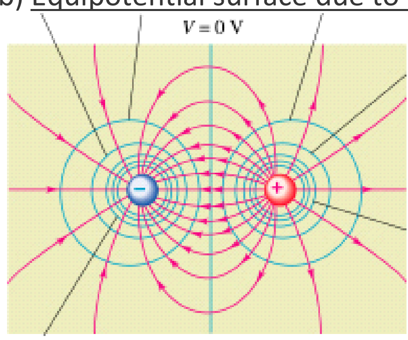
At large distances (*r* >> *a*), this reduces to

$$E = -\frac{2qa}{4\pi\varepsilon_0 r^3}\hat{p} \qquad \text{...(iv)}$$

$\because \vec{p} = q \times \overrightarrow{2a}\hat{p}$

$$\therefore E = \frac{-\vec{p}}{4\pi\varepsilon_0 r^3} \quad (r >> a)$$

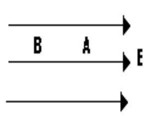
(b) Equipotential surface due to electric dipole:



The potential due to the dipole is zero at the line bisecting the dipole length.

MM 35 Class Test : Electrostatics Time : 90 minutes

- Figure given below shows two points A and B in a uniform electrostatic field. At which point (of the two) the electric potential more and why?(1)



- Why does electric field inside a dielectric decrease when it is placed in an external electric field? (1)
- Which physical quantity has its unit J/C? Is it a scalar or vector quantity? (1)
- Define the term electric flux. Is it a scalar or vector quantity? (1)

For question numbers 6 to 7, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

- Both A and R are true and R is the correct explanation of A
- Both A and R are true but R is NOT the correct explanation of A
- A is true but R is false

- A is false and R is also false

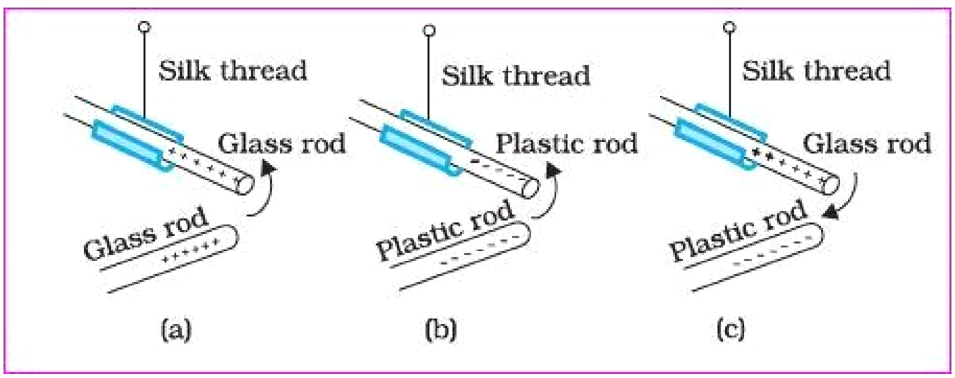
- **Assertion(A):** Work done by the electrostatic force in bringing the unit positive Charge form infinity to the point P is positive.
  Reason(R): The force on a unit positive test charge is attractive, so that the electrostatic force and the displacement (from infinity to P) are in the same direction. (1)

- **Assertion(A):** The interior of a conductor can have no excess charge in the static situation **Reason(R):** Electrostatic potential is constant throughout the volume of the conductor and has the same value (as inside) on its surface. (1)

Case Study Based Question No 7 (answer any four Questions) (4 Marks)

- **Frictional Elecricity:**

When a glass rod is rubbed with silk, the rod acquires one kind of charge and the silk acquires the second kind of charge. This is true for any pair of objects that are rubbed to be electrified. Now if the electrified glass rod is brought in contact with silk, with which it was rubbed, they no longer attract each other. They also do not attract or repel other lightobjects as they did on being electrified.



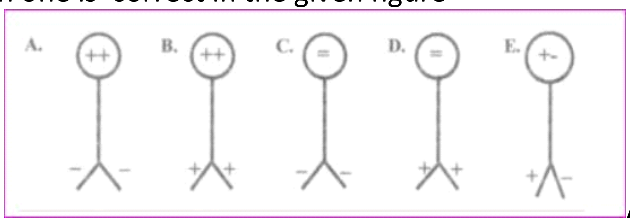
- When you charge a balloon by rubbing it on your hair this is an example ofwhat method of charging?

  (a) Friction (b) Conduction (c) Grouning (d) Induction
- Neutral atoms contain equal numbers of
  and ____.
  (a) Electrons and Protons (b) Protons and Electrons
  (c) Neutrons and Electrons (b) Protons and Neutrons
- Which particle in an atom can you physically manipulate?
  - Protons (b) electrons (c) neutrons
  (d) you can't manipulate any particle in an atom

- The cause of charging of a body is
  (a) transfer of electrons (b) transfert of neutrons
  (c) Transfer of neutrons (d) all of the above.

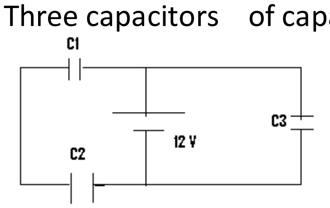
(5) Negatively charged rod is touched to the top of an electroscope,

which one is correct in the given figure



- A
- B
- C
- D

- An electric dipole of length 10 cm having charges ± 6 x 10^{-3}, placed at 30˚ with respect to a uniform electric field, experiences a torque of Nm. Calculate the magnitude of the electric field. (2)
- A charge ‘q’ is placed at the centre of line joining two equal charges Q. Show that the system of the three charges will be in equilibrium if . (2)
- Two point charges 5 x 10^{-8} C and -2 x 10^{-8} C are separated by a distance 20 cm in air. Calculate electrical potential energy of the system taking zero of the potential energy at infinity. (2)
- Three capacitors of capacitance 6 µ F are connected to a 12 V battery as shown.



Find (i) Charge on the each capacitor.
(ii) Equivalent capacitance of the network.
(iii) Energy dtored in the network of the capacitor. (1+1+1)

- Derive an expression for the electric potential due to an electric dipole at a point ‘r’ distance away from the centre of the dipole and making an angle with the electric dipole moment. (3)
- Two point charges 3 µC and -3 µC are located 20 cm apart. Calculate electric field at the mid point O of the line AB joining the two charges? Also calculate the force experienced by a negative test charge of magnitude 1.5 x 10^{-9} C placed at this point. (3)
- Derive an expression for the energy stored in a parallel plate capacitor C charged to a potential difference V. (3)
- State Gauss’s theorem in electrostatics. Using this theorem, derive an expression for the electric field at any point due to a thin, infinitely long wire of uniform charge density λ

C/m. Also draw a graph showing the variation of electric field with distance of the point from the wire. (1+3+1)

UNIT 2
CHAPTER 3, CURRENT ELECTRICITY

Electric current:-The flow of electrically charged particles through a conducting circuit due to the presence of a potential difference is called electric current

The current in a circuit is the amount of charge flowing through any cross sectional area of the conductor in second; its symbol is I.

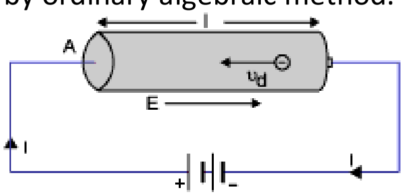
SI unit of current is ampere (coulomb per second). It is a scalar quantity.

$$I = \frac{Charge}{Time} = \frac{q}{t}$$

$If\ \ q = 1\ Coulomb\ \ , t = 1\sec \qquad so\ \ Current\ I = 1\ Coulomb/1\sec = 1\ \ Ampere$

Ampere: - If one coulomb charge is passing through any cross sectional area of a conductor in one second then current in the conductor is called one Ampere.

Direction: - Current flow from higher potential (positive) to lower potential (negative). Current flow along the motion of positive charge or opposite to the motion of electron (negative) because electron move opposite to the motion of positive charge. So, conventional current is opposite to the electronic current. Current is scalar because it can be add or subtract by ordinary algebraic method.



DRIFT VELOCITY: -Conduction in metals is due to motion of free electrons. The free electron moves through the conductor with very high thermal velocity of the order of 0 to 10^6m/sec. It is due to their thermal energy at room temperature. Since electrons are moving randomly in all directions.

So average velocity of electrons is zero i.e. there is no net flow of electrons in any direction. When the two ends of the conductor are connected to the battery a electric field E is set up along the length of the conductor from +ve to ve terminal. Now electron experience a force F= e E - - -(1)

Due to this force the electron get accelerated towards +ve terminal. During their motion they collide with each other and with atoms of the conductor. However an electron acquires an extra velocity but this velocity is destroyed at each collision. The net result is a slow drift of the electrons towards +ve terminal and they acquire a certain average velocity called drift velocity. The average velocity of free electrons with which they get drifted towards the +ve terminal under the influence of external electric field is called drift velocity.

If 'm' is the mass of electron and 'a' is the acceleration produced then, F = m a - - (2)

Comparing equ.1 and eq2. So acceleration acquired by electron qE = ma so a = qE/m - (3)

Average time taken between two successive collisions is called **relaxation time** (). It is characteristic of the given conductor. It is equal to 10^{14}sec.

$$\tau = \frac{t_1 + t_2 + t_3 + t_4 + \text{ - - - - - - - } t_n}{n}$$

The drift velocity $\mathbf{v}_d = \mathbf{u}_{av} + \mathbf{a} = 0 + \mathbf{a}$ Hence $\mathbf{a} = \mathbf{v}_d/$ (4)Comparing eq3 & 4.

$$\frac{v_d}{\tau} = \frac{eE}{m} \qquad v_d = \frac{e\,E\,\tau}{m} \qquad v_d = \frac{eV\tau}{ml}$$

Therefore Hence Since $V = E \times l$

This last result tells us that the electrons move with an average velocity which is independent of time, although electrons are accelerated. This is the phenomenon of drift and the velocity $\mathbf{v}_d$ is called the *drift velocity*.

Current in terms of drift velocity: - Consider a conductor of length 'l'& area of cross section 'A' connected by a battery. Electron density 'n', then drift velocity $v_d = e\,V/ml$

Distance travelled by electron in t sec is $d = v_d\, t$

Volume occupied by the electron in t second is $V = A\, d = A\, (v_d\, t)$

Total no of electron occupied in t sec is $N = n\,V = n\,A\,v_d\,t$

Total charge passing through the cross section in t sec is $q = N\,e = (n\,A\,v_d\,t)\,e$

Electric current $I = q/t = n\,A\,v_d\,t\,e/t$ $\quad I = v_d\,e\,n\,A$.

Current Density: - Current per unit area is define as current density J , it is a vector quantity. Direction of J is along drift velocity i.e. perpendicular to the cross section area. Its unit is A /m^2.

$$J = \frac{I}{A} = \frac{v_d\,e\,n\,A}{A} \qquad \text{Hence} \qquad J = v_d\,e\,n \qquad J = e\tau E\,e\,n/m$$

Mobility:- *mobility is*defined as the magnitude of the drift velocity per unit electric field: $\mu = \frac{v_d}{E} = \frac{e\tau}{m}$

The SI unit of mobility is m^2/Vs and is 10^4 of the mobility in practical units (cm^2/Vs). Mobility is positive.

Derivation of Ohm's Law: - Drift velocity $v_d = e\,V/ml$- - -(1) (n- electron density, A-area of cross section)

But electric current $I = v_d\,e\,n\,A$

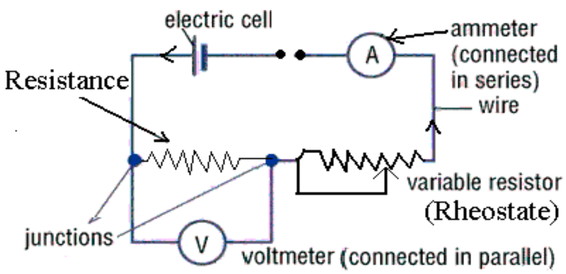
$$I = \frac{e\,V\,\tau}{m\,l} \times e\,n\,A \quad \Rightarrow \quad V = \left(\frac{m\,l}{e^2\,\tau\,n\,A}\right) I$$

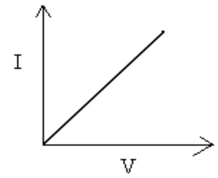
V = R I This is Ohm's law.

$$\text{Where } R \text{ is a constant known as resistance } R = \frac{m\,l}{\tau\,ee\,n\,A}$$

Electric Circuit:-The whole path along which the electric current flow is known as electric current. An unbroken path travelled by current is known as **open circuit**. A broken path of current is known as **closed circuit.**

Ohm's Law:-George Simon Ohm (German) established a relation between current & potential difference in 1826. It state that-"If there is no change in physical conditions such as-temperature, length, density, area of cross section etc then, the current flowing in a metallic conductor is proportional to the potential difference applied across it".





If I current is flowing through the circuit & potential difference developed is V. Then from Ohm's law   I   V   Hence V   I   **V = R I**

This is mathematical form of Ohm's law. If we plot a graph between voltage and current we obtain a straight line.

Where R = V / I is a proportionality constant known as resistance of the conductor.

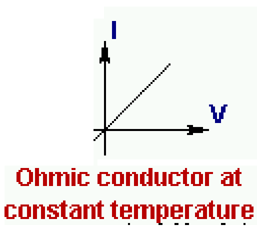
Its value depends on length, area of cross section, temperature & nature of the substance. A conductor having resistance is called **resistor**. The **resistance** R of a conductor is the property due to which it opposes the flow of current through it. The SI unit of resistance is ohm.

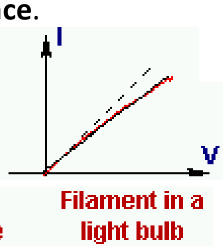
$$R = \frac{V}{I} = \frac{1\ Volt}{1\ Ampere} \quad \Rightarrow \quad R = 1\left(\frac{Volt}{Ampere}\right) \quad \Rightarrow \quad R = 1\ \Omega\ (\ Ohm)$$

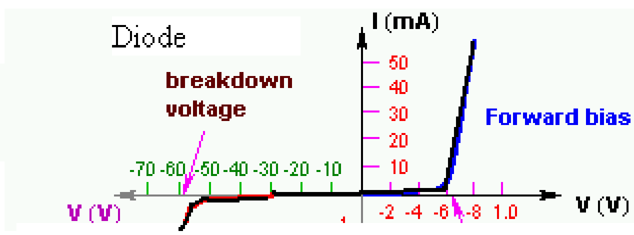
If one-ampere current is flowing through a conductor & p.d. developed across its terminals is 1 Volt then resistance of the conductor is 1 **Ohm**.

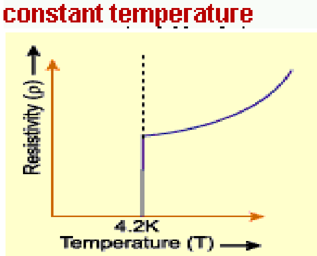
C.G.S. unit of resistance is State Ohm or **e.s.u. of resistance.** 1 State Ohm = 9 10^{11} Ohm

If the metallic conductor obeys the Ohm's law, we call it an **Ohmic conductor** e.g. metals Many devices do not obey Ohm's law i.e. diode, transistor, thermistor, discharge tube, filament in a light. Those substance for which graph between voltage and current is a straight line are called **Nonohmic substance**.









2.10 **Resistivity (Specific Resistance)**: -Resistance of a conductor depends on following factor-

(1)**Length:-**If length of the conductor increases then electron has to travelled longer distance, which increase no of collision hence current decreases. Thus resistance of the conductor is directly proportional to length 'l' of the conductor.   R   *l* - - - - - - - - (1)

(2) **Area of cross section: -** If area of cross section is large then no of free electron available per unit length are more which increases the current hence resistance decreases. thus resistance is inversely proportional to area of cross section 'A' of the conductor.   R   1 /A - - - (2)

(3)**Nature of the material: -** Resistance of any object depends on the nature of the substance of the material of the conductor e.g. resistance of the Cu is less than the resistance of Fe of same length & same area of cross section. Combining eq1 & eq2 R *l* / A

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

$$Where \quad \rho = \frac{R \ A}{l} \quad is \ proportionalty \ constant \ known \ as \ resitivity \ of \ the \ material$$

It is a constant for a material & depends on its temperature only. Resistively does not depend on the length & area of cross section of the conductor. If A = 1m^2 & *l* =1 m then = R

Resistance of a wire of unit length and unit area of cross section is defined as **Resistivity**.

OR - Resistance between two sides of a cube of unit side is defined as **Resistivity**. Its unit is m.

For insulator like amber, glass, wood, mica, Teflon has > 10^{10}. α- **Temperature coefficient of Resistivity**

<u>High Resistivity of alloy</u>: Nichrom is alloy of Ni & Cr. Since size of Ni & Cr have different size, they are arranged

randomly relative to each other, so the free electrons have to travel through a random medium and suffer more collision. Hence alloy has high resistivity. In metals there is systematic & regular arrangement of the atoms so collision of electrons is less hence their less resistivity.

Conductance (G): -The conductance is defined as the reciprocal of resistance. <u>Conductance is the properties of a body due to which it provides easy flow of current through a body</u>.

$$G = \frac{1}{R} = \frac{I}{V}$$

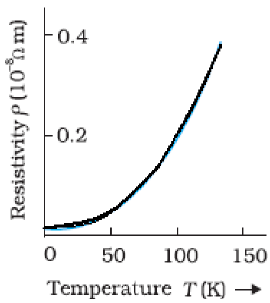
The SI unit of conductance is $^{-1}$ (= Amp / Volt) also known as <u>Mho or Siemen</u>.

Conductivity ( ) : -The conductivity is defined as the reciprocal of resistivity. Conductivity is of a material is its ability to conduct electric current.

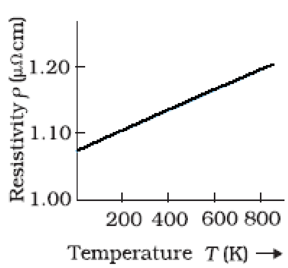
$$Conductivity \ \sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m}$$

The SI unit of conductivity is <u>Mhom^1</u> .

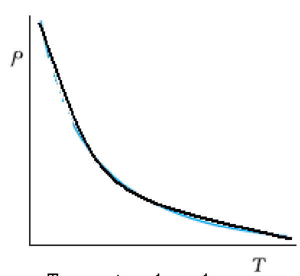
<u>Effect of Temperature to Resistance & Resistivity</u>: -The resistivity of a any object only depends on nature of the substance i.e. free electron density & temperature of the body.



Resistivity ρ of copper as a function of temperature T



Resistivity ρ of nichrome as a function of absolute temperature T.



Temperature dependence of resistivity for a typical semiconductor.

[a] <u>Metals</u>: -As the temperature of metal increases, the effect leads to increase in resistance and decrease in conductivity as shown in the figure. In a normal metal conductor, current flow due to motion of the electrons. The motion of the electrons is impeded by collisions with the atom& ions in the lattice. As the temperature increases, the vibrations amplitude & frequency of the atoms increases. Due to this the thermal velocity of the electron increases so time between two successive collision decreases i.e. relaxation time ( ) decreases. Since $v_d = \frac{e E \tau}{m}$ that the mean drift speed of the charge carrier decreases. Hence Current [$I = v_d e n A$] , decreases. So resistance(R=V/I) & resistivity of the material increase [$R = m l / n e^2 l$].

Resistance at temperature 't' is $R_t = R_o [1 + \alpha t]$

$$\alpha = \frac{R - R_0}{R_0 t}$$

Where is a constant known as temperature coefficient of the resistance. Change in resistance per unit resistance for one-degree rise in temperature is called temperature coefficient of the resistance . Its unit is K^1 or C^1.For metal . Is positive & for insulator and semiconductor is negative.

Alloy like Magnin (alloy of Mn , Ni, Cu and Fe), Constantan, Eureka etc has low value of temperature coefficient due to this there is no significant change in the value of their resistance for a small range of temperature. Hence their resistance is constant. That's why these alloys are used as standard resistance.

Resistivity at temperature t is $\rho_t = \rho_0 [1 + \alpha_r t]$

Where $_r$ - is temperature coefficient of resistivity & - resistivity at zero degree Celsius.

[b] <u>Semiconductor</u>: -Semiconductors has negative value of temperature coefficient i.e. <u>resistance or resistivity of semiconductors decreases with increase in temperature</u>.

Reason-at room temperature they posses less no of free electrons but at high temperature free electron density increases.

[c] <u>Insulator</u>: -<u>Resistance or resistivity of insulator increases exponentially with increase in temperature</u>.

E_g = energy gap, k-Boltzmann constant. Resistivity at temperature t is $\rho_t = \rho_0 e^{E_g/kT}$

Reason-at room temperature they posses less no of free electrons but at high temperature free electron density increases. At T = 0 K , =0

Resistivity of a material is given by $\rho = \frac{m}{ne^2\tau}$. Thus depends inversely both on the number *n* of free electrons per unit volume and on the average time between collisions. As we increase temperature, average speed of the electrons, which act as the carriers of current, increases resulting in more frequent collisions. The average time of collisions , thus decreases with temperature. In a metal, *n* is not dependent on temperature to any appreciable extent and thus the decrease in the value of with rise in temperature causes to increase as we have observed.

For insulators and semiconductors, however, *n* increases with temperature. This increase more than compensates any decrease in in Eq. so that for such materials, decreases with temperature.

[d] **<u>Electrolyte</u>**: - With increase in temperature viscosity of liquid decreases, now the ions have more freedom to move in electrolyte, hence resistivity decreases. <u>The resistivity of electrolyte decreases with increase in temperature & vice versa</u>.

<u>Superconductivity</u>: - As temperature of a substance decreases its resistance decreases. The temperature at which resistance of the substance reduces to zero is known as **transition or critical temperature**.

The resistance of certain metals and their compounds or alloys may reduce to zero at certain low temperatures. This phenomenon is called **superconductivity**. Materials of zero resistance are called **superconductors**.

<u>Note</u>: 1. Superconductor becomes super conducting only below a certain transition temperature.

2. Different metals have different transition temperatures. 3. Usually, transition temperatures are within a few degrees of absolute zero. 4. The benefit of using superconductors is no energy is wasted as heat. 5. The drawback of using superconductors is the energy needed to refrigerate them, but the net energy saving is great. 6. People are still studying new materials for superconductors. The goal is to find high- temperature superconductors that can superconductor even at room temperature.

<u>Applications: -</u> [1] Super conducting strong electromagnets for research in higher energy physics. [2] Electric motors and generators. [3] Long distance power transmission lines without energy loss.[4] For frictionless transport high-speed train without rail, electric cars... etc.[5]For storage memory of computers. [6] Huge saving in energy bills. [7] Medical science [8] In Electronics.

<u>Heating (Joule's) Effect of Current</u>: - When electric current passed through a conductor wire, it becomes hot after some time. <u>The production of heat due to flow of current in a conductor is known as heating effect of current</u>. Joule so also know as Joule's effect or Joule's heating effect first observed this effect. (In 1941)

Cause: - In heating effect, electrical energy converted into heat energy. When a potential difference is applied across the two end of a conductor wire, an electric field is set up. Due to this electric field the large number of electron present in conductor experience a force and they get accelerated opposite to the electric field (i.e. from –ve side to +be side).

Their kinetic energy would increase as they move. We have, however, seen earlier that on the average, charge carriers do not move with acceleration but with a steady drift velocity. This is because of the collisions with ions and atoms during transit. During collisions, the energy gained by the charges thus is shared with the atoms. The atoms vibrate more vigorously, i.e., the conductor heats up.

The electron drifted with very high speed of the order of 10^5 m/sec and suffer collisions with positive metal ions or atoms.

In collisions electron transfer their kinetic energy to the atom and ions. Hence the average kinetic energy of vibration of the atoms and ions increases and consequently the temperature of conductor rises.

<u>Electrical energy</u>: - The total work done by an electrical circuit in given time is called electrical energy.

i.e. total energy consume by the electric circuit.) Its S.I unit is Joule.

If I current passes through the conductor for time 't' through resistor 'R' then,

total charge passes through the resistor Q = I t ---- --- (1)
From definition of potential difference V = W / Q (2)
i.e work done in carrying the test charge 'Q' from A to B is W = V Q = V I t --- ---- ---- (3)
This work done, dissipated as Heat so heat produced by current so, H=W ,from eqn 1) and 3)
Hence H=I R × I t (In Joule) (V = IR)
H = I² R t -- -- -- (4) This is known as **Joule's law** of heating.

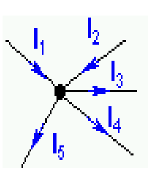
Putting I = V / R, then $H = \frac{V^2 t}{R}$ -- -- -- (5) In calorie **$H = I^2 R t / 4.2$**

<u>Electric Power</u>: - The rates of electric energy consume by the electric circuit is called electric power. **Or** The rate of doing work by an electric current is power. Electric power, P = Electric energy / time

$$P = \frac{W}{t} = \frac{V\ I\ t}{T} \Rightarrow P = V\ I \qquad From\ Ohm's\ law\ V = I R$$

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

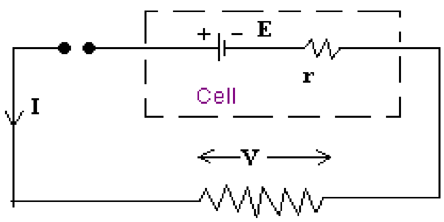
Simillarly
Unit: - SI unit of electric power is <u>watt</u>. If V =1 volt, I =1 amp then power P=1 volt x 1 amp
P= 1 × 1 (Volt x Amp) = 1 Watt When one-ampere current passes through a conductor develops a potential difference of one volt then power of conductor is said to be one **watt**.
Bigger unit of power are Kilowatt, 1 kW = 1000 W and mega watt, 1 MW = 10^6 W.
Engineering unit of power is "**horse power"** 1 H.P. = 746 W.
Unit of electric energy: - SI unit of electric energy is Joule.
W= V I t W = 1 volt × 1 amp x 1 sec = 1 Joule .
If one-ampere current flow for one second through a conductor develops a potential difference of one volt then energy consumes is equal to one **Joule**.
Commercial unit of electric energy is **kilowatt hour** (kWh) also known as **unit** or Board of Trade unit (B.O.T.U).
P= W/t W = P × t P = 1 kW × 1 h = 1 kWh (1 unit).
If an electric device of power one kilowatt is used for one hour then energy consumed is equal to 1 kWh or 1 **unit**.
1 kWh = 1000 W ×3600 sec **1 kWh = 3.6×10⁶ Joule**.



$I_1 + I_2 - I_3 - I_4 - I_5 = 0$

<u>Kirchoff `s law</u>:- Kirchhoff's First Law(**Junction Rule**) (The current Law) <u>It is a consequence of conservation of charge</u>. Charge does not accumulate in a conductor so total charge entering at one end is equal to total charge leaving at another end.
"<u>At any junction, the total current entering the junction is equal to the total current leaving the junction</u>".
Hence, at any junction, <u>the algebraic sum of the currents at any junction is zero</u>. I = 0

In other words, Entering currents = leaving currents
Current approaching the junction is taken as positive & current leaving the junction is negative.
Kirchhoff's Second Law – {The voltage Law}(Loop Rule) It is a consequence of conservation of energy.
"In any closed loop of a circuit, the algebraic sum of the voltage drops across the resistors is equal to the algebraic sum of the e.m.f.s of the cells".
"In any closed loop of a circuit, the algebraic sum of the product of potential difference across the resistors and current through them is equal to the algebraic sum of the e.m.f.s of the cells".
In any closed loop, potential drops = e.m.fs. V I = E
Sign convention- (1) we have to move in a loop in anticlockwise direction. (2) If direction of current is along our movement then product V I is positive. (3) If direction of current is opposite our movement then product V I is negative. (4) As we move through the cell then polarity of the second terminal is the sign of the e.m.f of the cell.



Internal resistance of cell: - The opposition (resistance) offered by an electrolyte against the movement of ions & electrons is called internal resistance of the cell. As current flow in external circuit from positive to negative terminal, current 'I' inside the cell flow from negative to positive terminal. (Positive ions move from cathode to anode) The internal resistance of the cell causes this drop in the voltage. The cell itself has a resistance and acts like a resistor.
Internal resistance depends on the following factors –
[a] Area of the electrode dipping in the electrolyte: -As area of the electrode is more then more ions can reaches to the electrodes which increase current, hence internal resistance decreases & vice-versa.(r 1/A).
[b] Distance between electrodes: -If distance between electrodes is small then ions have to travel small distance so less collision between the ions, so current increases hence internal resistance decreases & vice-versa. (r d)
[c] Conductivity of the electrolyte:-Conductivity of the electrolyte is more , then internal resistance will be less & vice-versa. (r 1 / G)
[d] Internal resistance increases with increase in the amount of current drawn from the cell.
A cell of e.m.f E and an internal resistance r, is connected in series with a resistor of resistance R, if I is current flowing through the circuit and potential difference across resistor is V, then
V = IR - - - -(1)
Potential difference across internal circuit (Inside the cell) W = I r - - - - - (2)
Since e.m.f is the work done in moving 1 coulomb positive charge from one terminal to another terminal along external circuit & inside the cell. E = V + W OR E = V + Ir
From eq1 & 2 E = I r +I R E = I(r + R) - - - - - (3)
Dividing eq3 by 1,

$$\frac{E}{V} = \frac{I\,(r+R)}{I\,R} \quad \Rightarrow \quad \frac{E}{V} = \frac{(r+R)}{R}$$

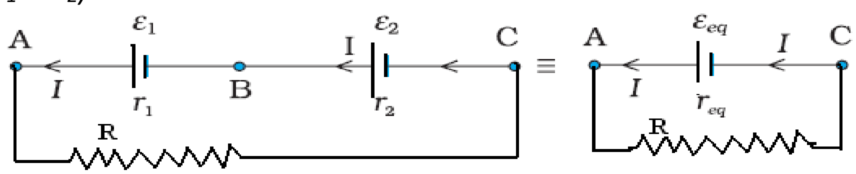
$$\frac{E}{V}=\frac{r}{R}+\frac{R}{R} \quad\Rightarrow\quad \frac{E}{V}-1=\frac{r}{R} \quad\Rightarrow\quad r=\left(\frac{E}{V}-1\right)R$$

Conclusion-Internal resistance is usually considered a nuisance. Not only must it be taken into account in circuit design, but it also limits the maximum current available in a circuit. For this reason, a car battery has a very small internal resistance; consequently, a large current needs to be supplied to the starter motor.

<u>CELLS IN SERIES</u>: Consider first two cells in series, where one terminal of the two cells is joined together leaving the other terminal in either cell free.

ε_1, ε_2 are the emf's of the two cells and r_1, r_2 their internal resistances, respectively. If it is connected by external resistance 'R'.

The potential difference between the terminals A and C of the combination is $\varepsilon_1 + \varepsilon_2 = V + I(r_1 + r_2)$



If we wish to replace the combination by a single cell between A and C of emf ε_{eq} and internal resistance r_{eq}, we would have $\varepsilon_{eq} = V + I\,r_{eq}$

Comparing the last two equations, we get

$\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2 +$ (1) and

$r_{eq} = r_1 + r_2 +$ (2)

If we connect the two negatives or positive electrodes we will get $\varepsilon_{eq} = \varepsilon_1 - \varepsilon_2$ and $r_{eq} = r_1 + r_2$.

The rule for series combination clearly can be extended to any number of cells:

(i) The equivalent emf of a series combination of n cells is just the sum of their individual emf's, and

(ii) The equivalent internal resistance of a series combination of n cells is just the sum of their internal resistances.

Current .

special cases1: If R >> nr. In this case, nr can be neglected as compared to R. Then I = nE/R

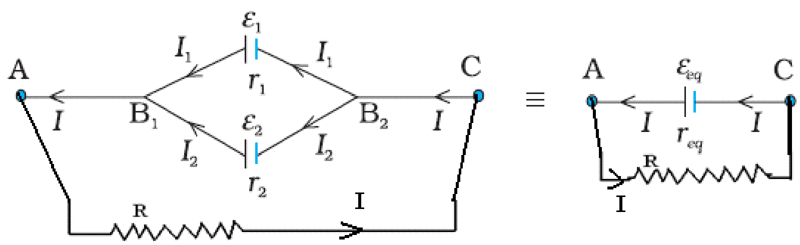
i.e. the current in the external resistance is n times the current due to a single cell.

special cases2: R << nr. In this case, R can be neglected as compared to nr I = nE/nr = E/r

i.e. the current in the external resistance is same as due to a single cell.

Hence the <u>maximum current</u> can be drawn from the series combination of cells if the <u>external resistance is very high</u> as compared to the internal resistance of the cells.

<u>CELLS IN PARALLEL</u>: Next, consider a parallel combination of the cells. I_1 and I_2 are the currents leaving the positive electrodes of the cells. At the point B_1, I_1 and I_2 flow in whereas the current I flows out. Since as much charge flows in as out, we have $I = I_1 + I_2$



Let $V(B_1)$ and $V(B_2)$ be the potentials at B_1 and B_2, respectively. Then, considering the first cell, the potential difference across its terminals is
$V(B_1) - V(B_2)$. Hence, from equation.
V□V□B_1□ↂV□B_2□□□□$_1$–$I_1 r_1$
Points $B1$ and $B2$ are connected exactly similarly to the second cell. Hence considering the second cell, we also have V□$V(B_1) - V(B_2)$ □□□□□– $I_2\, r_2$
Combining the last three equations $I = I_1 + I_2$
I = I = I =
V = (1)
If we want to replace the combination by a single cell, between B_1 and B_2, of emf E_{eq} and internal resistance r_{eq}, we would have $V = E_{eq} - I\, r_{eq}$ (2) Comparing eq1 &2.

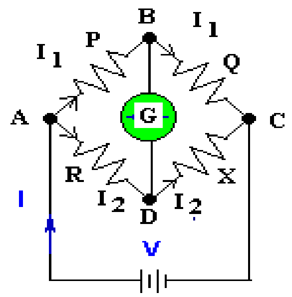
OR

Current in the circuit if m identical cell of emf 'E' connected parallel to a load 'R'. .
Some special cases1: If R << r. In this case, nR can be neglected as compared to r. Then, I = mE/r
i.e. the current in the external resistance is n times the current due to a single cell.
Some special cases2: If r << R. In this case, r can be neglected as compared to nR. Then I = mE/mR= E/R
i.e. the current in the external resistance is same as due to a single cell.
Maximum current can be drawn from the parallel combination of cells if the external resistance is very low as compared to the internal resistance of the cells.

The Wheatstone Bridge Circuit: - This is a very famous circuit for measuring unknown resistance given by Sir Charles Wheatstone in 1883.

Construction: - In this circuit, there are four resistors and a galvanometer connected in a quadrilateral electric network, as shown in the figure. Where X is the resistor with unknown value, R is an adjustable variable resistor with resistance, P and Q are standard resistors with known values, a galvanometer is used to measure small DC currents.

Principle: -We can adjust the adjustable resistor until a zero reading (no deflection) is obtained in the galvanometer. At this point, $\frac{P}{Q} = \frac{R}{X}$. This is known as balance bridge condition.



Proof: - Let I be the current flowing out from the battery. As current is reaching to junction then the current will be divided in to two parts I_1 along AB & I_2 along AD. If potential of B Potential of D (V_b V_d), then current flows through the galvanometer. The value of R is so adjusted that there is no deflection in galvanometer. Because in this case ($V_b = V_d$) potential of B = Potential of D, i.e. potential difference between B & D is zero($V_{bd} = 0$). Applying Kirchoff `s second law in loop ABDA

$I_2 R - 0 G - I_1 P = 0$ $\qquad$ $I_2 R = I_1 P$ - - - -(1)

Applying Kirchoff `s second law in loop BCDB

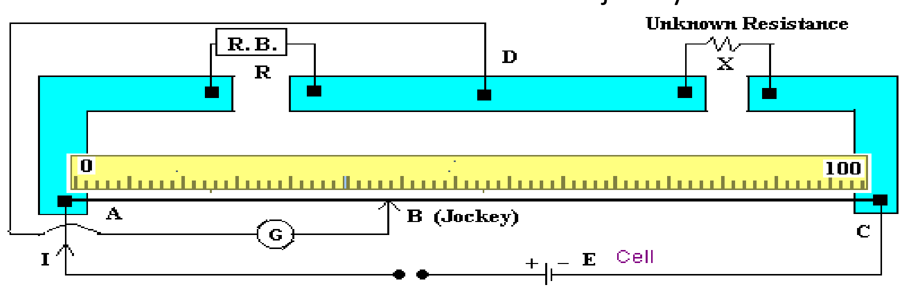
$I_2 X - 0 G - I_1 Q = 0$ $\qquad$ $I_2 X = I_1 Q$ - - - -(2)

Dividing eq1 by eq2 $\frac{I_2 P}{I_2 Q} = \frac{I_1 R}{I_1 X}$ Hence $\frac{P}{Q} = \frac{R}{X}$

Application-Meter-bridge & potentiometer are based on this principle.

__Meter Bridge__: - **Construction: -**It Consist of a Magnin wire AC of one meter length stretched over a wooden board. The ends A and C are soldered to thick copper strips, each of these strips have binding terminals.

Another copper strip is fitted on the wooden board to provide two gaps across which resistances box 'X' are connected by binding screw. A meter scale is fixed on the wooden board along the length of wire .A cell is connected between A and C. One terminal of galvanometer is connected to the terminal D and the other to a jockey 'J' which can slide over the wire AC.



Principle: - Circuit is exactly the same as that of the wheat stone bridge, so its principle is same that of wheat stone bridge. In balance condition

$\frac{P}{Q} = \frac{R}{X}$ ------(1) Where P and Q are the resistance of portion AB and BC.

Method: - Let resistance taken out from resistance box is R and B be the balance point (no deflection position) with balancing length 'l'. If resistance per unit length is ' a' then Resistance of AB is P= a *l* & Resistance of BC is Q = a (100-l) Putting values in eq 1

$$\frac{a\,l}{a\,(100-l)}=\frac{R}{X}$$ Hence $$Unknown\ \ resistance\ X=\left(\frac{100-l}{l}\right)R$$

Since R and l is known hence unknown resistance X can be calculated.

Application: - 1) To measure unknown resistance 2) To compare two resistance

Potentiometer: - It is a device used to measure potential difference between two points.

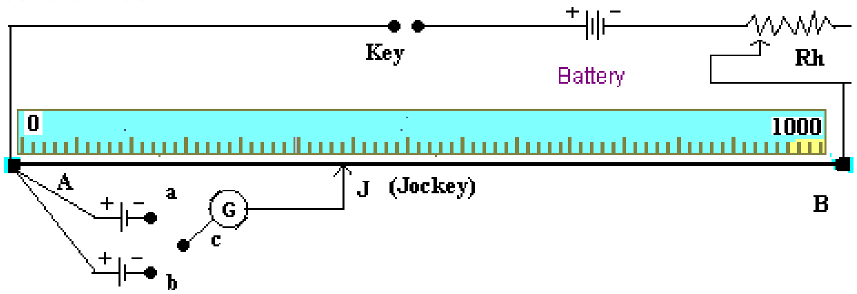
Construction: - It consists of a uniform wire of Magnin or constantan of length usually 10 metres. The wire is arranged on wooden board in the form of parallel wires each of one metre length and their ends are connected in series. A metre scale is fixed parallel to the length of wire. The wires are connected between points 'A' and 'B'. A battery is connected across the wire. There is a jockey 'J' which can move along the length of wire and also perpendicular to it.

Principle: - When a constant current is flowing through the wire of uniform area of cross section , potential difference between any two point of wire is directly proportional to the length of that wire. i.e V *l*

Proof: - Let V be P.D across any portion of wire whose length is '*l*' and resistance is R .If 'I' is current flowing in wire then V = I R --- --- ---- -- --(1) But R = *l* / A where is specific resistance of wire.

Puting values in equ 1) V = *l* (I / A)

If constant current flowing through the wire (I = const) of uniform area so A = const, is already constant so



V = k *l* -----(2) or V *l* .

Where k = I / A is potential gradient

(potential difference developed per unit length) .

Application: - (I) **To compare e.m.f of two cells**: - **Circuit: -** Let E_1 and E_2 be the e.m.f of two cells. The positive terminals of both cells are connected to point 'a' and negative to point 'b' of a two way key. The common terminal C is connected to a jockey 'J' through a galvanometer 'G'. A battery, rheostat and a one-way key K are connected across point A and B.

Method: - A constant current is passed through the wire of potentiometer by battery when plug is put in the gap between 'a ' and 'c' of two way key .The cell of e.m.f E_1 will come the circuit. Let J be the point of no deflection in galvanometer with balancing length l_1 =AJ. So $E_1 = k\,l_1$ --------(1)

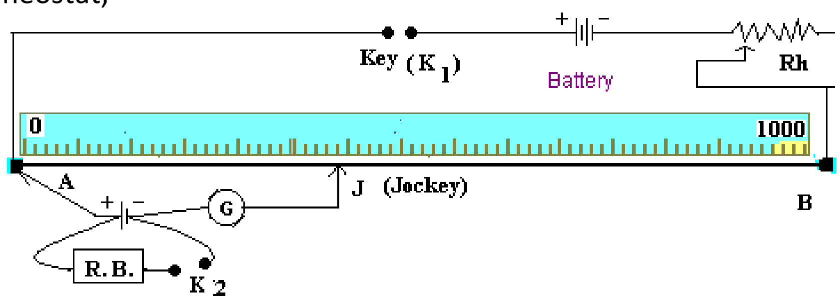
Now key is put between the gaps of 'b' and 'c' the cell of e.m.f E_2 will come in the circuit. Now the balancing length is l_2 . Then $E_2 = k\,l_2$ -- --(2)

Dividing eq (1) by (2) $$\frac{E_1}{E_2}=\frac{k\,l_1}{k\,l_2}$$ Hence $$\frac{E_1}{E_2}=\frac{l_1}{l_2}$$.

By changing current with the help of rheostat in the wire different values of E_1 / E_2 can be find for different value of current. The mean value of E_1 / E_2 can be calculated. If we know the e.m.f of one cell then e.m.f of the other cell can be determined.

Precaution: - In order to obtain balance point on the wire the e.m.f of the battery should always greater than e.m.f of each cell. Ie $E > E_1$ and $E > E_2$.

(II) Determination of Internal Resistance of a cell: - Circuit: - A battery of constant e.m.f E, rheostat,



key k_1 and an ammeter connected between point A and B so that a constant current I flow in the circuit. The positive terminal of the primary cell is connected to point A and its negative terminal is connected to the jockey. A resistance box R is connected parallel to cell.

Method: - (1) When key k_2 is open the balancing length l_1 is determined. So e.m.f of the cell in the circuit

$E = k\, l_1$ ---- --- ---1)

(2) Now close the key k_2 and with the help of resistance box determined the balancing length l_2. Potential difference between the terminals of cells

$V = k\, l_2$ --- --- -- (2) dividing eq 1 by 2

$$\frac{E}{V} = \frac{k\, l_1}{k\, l_2} \Rightarrow \frac{E}{V} = \frac{l_1}{l_2} \quad ---(3)$$

Internal resistance of the cell $r = \left(\frac{E - V}{V}\right) R = \left(\frac{E}{V} - 1\right) R$ From eq3

$$r = \left(\frac{k\, l_1}{k\, l_2} - 1\right) R$$ So $$r = \left(\frac{l_1}{l_2} - 1\right) R$$ OR

$$r = \left(\frac{l_1 - l_2}{l_2}\right) R$$ By knowing the value of L_1 and L_2 and R we can find internal resistance of cell (III) To calibrate the voltmeter.

(IV) To compare unknown resistance

$$\frac{V_1}{V_2} = \frac{l_1}{l_2} \Rightarrow \frac{I\, R_1}{I\, R_2} = \frac{l_1}{l_2}$$ Hence $$\frac{R_1}{R_2} = \frac{l_1}{l_2}$$

<u>Sensitiveness of potentiometer</u>: - It can measure very small resistance so it is most sensitive instrument. Sensitiveness of potentiometer increases with increase in length of its wire because due to increase in length potential gradient $K = v / l$, so decreases balancing length increase.

Q: - Why potentiometer is better than voltmeter?

Ans: - (**1**) Potentiometer does not draw any current from the source of emf. While voltmeter always draw some current to produce deflection. (**2)** During measurement of e.m.f. reading of voltmeter is taken by deflection of pointer so there may be parallax error in the reading while in potentiometer reading is measured by calculation. (**3**) Since no current flow from the cell into the circuit so potentiometer is equivalent to the ideal voltmeter of infinite resistance.

GIST

- Current carriers – The charge particles which flow in a definite direction constitutes the electric current are called current carriers. E.g.: Electrons in conductors, Ions in electrolytes, Electrons and holes in semi-conductors.
- Electric current is defined as the amount of charge flowing through any cross section of the conductor in unit time. $I = Q/t$.
- Current density J = I/A.
- Ohm's law: Current through a conductor is proportional to the potential difference across the ends of the conductor provided the physical conditions such as temperature, pressure etc. Remain constant. $V \alpha I$ i.e. $V = IR$, Where R is the resistance of the conductor. Resistance R is the ratio of V & I
- Resistance is the opposition offered by the conductor to the flow of current.
- Resistance $R = \rho l/A$ where ρ is the resistivity of the material of the conductor- length and A area of cross section of the conductor. If l is increased n times, new resistance becomes n^2R. If A is increased n times, new resistance becomes $\frac{1}{n^2}R$
- Resistivity $\rho = m/ne^2\tau$, Where m, n, e are mass, number density and charge of electron respectively, τ-relaxation time of electrons. ρ is independent of geometric dimensions.
- Relaxation time is the average time interval between two successive collisions
- Conductance of the material G =1/R and conductivity σ=1/ρ
- Drift velocity is the average velocity of all electrons in the conductor under the influence of applied electric field. Drift velocity $V_d = (eE/m)\tau$ also $I = neAv_d$
- Mobility (μ) of a current carrier is the ratio of its drift velocity to the applied field $\mu = \frac{V_d}{E}$
- Effect of temperature on resistance: Resistance of a conductor increase with the increase of temperature of conductor $R_T = R_o(1+\alpha T)$, where α is the temperature coefficient of resistance of the conductor. α is slightly positive for metal and conductor, negative for semiconductors and insulators and highly positive for alloys.
- Cells: E.M.F of a cell is defined as the potential difference between its terminals in an open circuit. Terminal potential difference of a cell is defined as the p.d between its ends in a closed circuit.
- Internal resistance r of a cell is defined as the opposition offered by the cell to the flow of current. r = $\left(\frac{E}{V}-1\right)R$ where R is external resistances.
- Grouping of cells :

i) In series grouping circuit current is given by $I_s = \frac{nE}{R+nr}$,

ii) In parallel grouping circuit current is given by $I_p = \frac{mE}{r+mR}$ where n, m are number of cells in series and parallel connection respectively.

- Kirchhoff's Rule:

  i) Junction Rule:-The algebraic sum of currents meeting at a point is zero. $\sum I = 0$

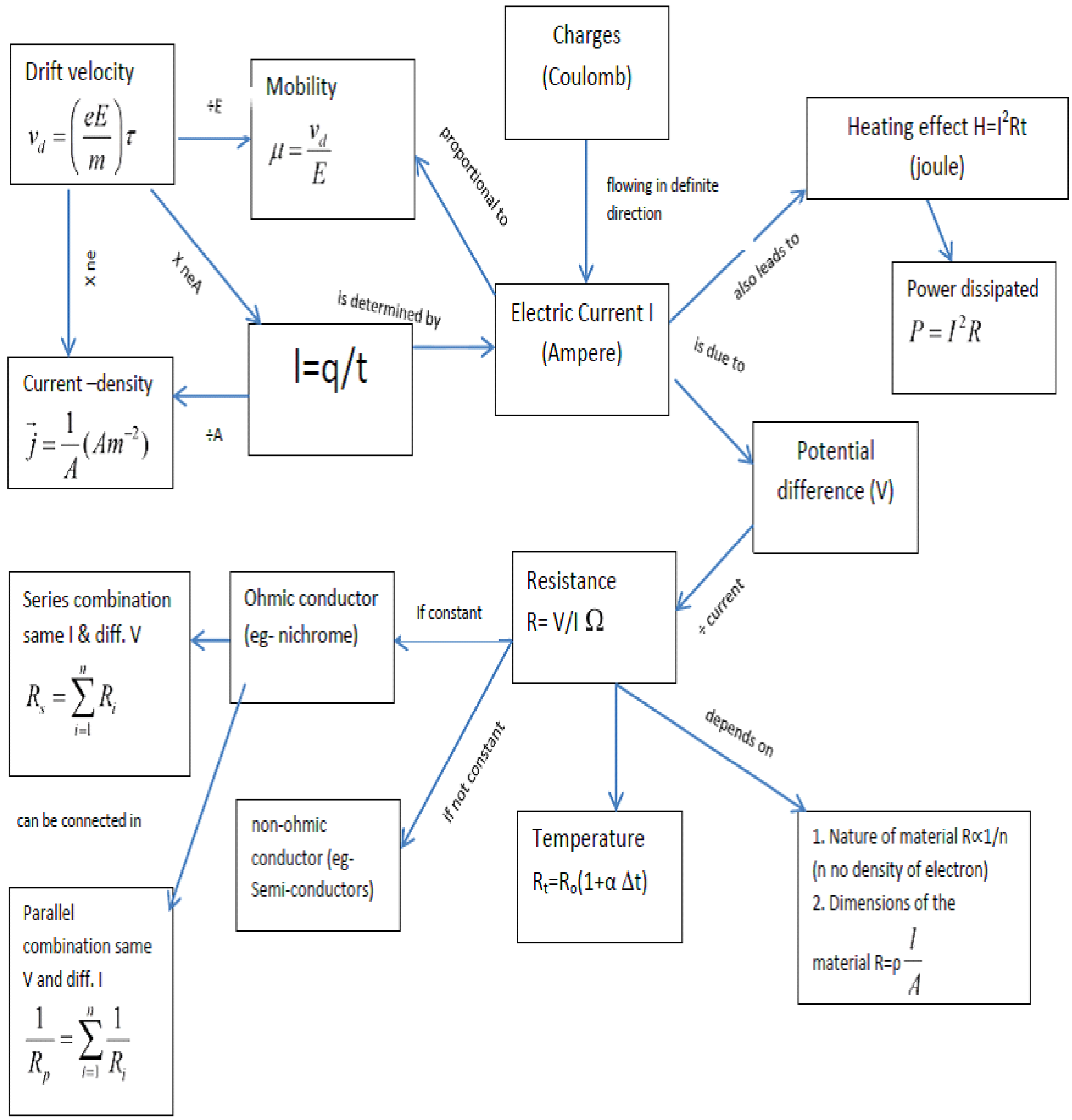
  ii) Loop rule:-The algebraic sum of potential difference around a closed loop is zero $\sum V = o$
- Wheatstone bridge is an arrangement of four resistors arranged in four arms of the bridge and is used to determine the unknown resistance in terms of other three resistances. For balanced Wheatstone Bridge, $\frac{P}{Q} = \frac{R}{S}$
- Slide Wire Bridge or Metre Bridge is based on Wheatstone bridge and is used to measure unknown resistance. If unknown resistance S is in the right gap, $s = \left(\frac{100-l}{l}\right)R$
- Potentiometer is considered as an ideal voltmeter of infinite resistance.
- Principle of potentiometer: The potential drop across any portion of the uniform wire is proportional to the length of that portion of the wire provided steady current is maintained in it i.e. $v \alpha l$
- Potentiometer is used to (i) compare the e.m.f.s of two cells (ii) determine the internal resistance of a cell and (iii) measure small potential differences.
- Expression for comparison of e.m.f of two cells by using potentiometer, $\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$ where l_1, l_2 are the balancing lengths of potentiometer wire for e.m.fs ε_1 and ε_2 of two cells.
- Expression for the determination of internal resistance of a cell I is given by $\left(\frac{l_1 - l_2}{l_2}\right)R$

  Where l_1 is the balancing length of potentiometer wire corresponding to e.m.f of the cell, l_2 that of terminal potential difference of the cell when a resistance R is connected in series with the cell whose internal resistance is to be determined
- Expression for determination of potential difference $V = \varepsilon\left(\frac{\varepsilon}{R+r}\right)\frac{rl}{L}$. where L is the length of the potentiometer wire, l is balancing length, r is the resistance of potentiometer wire, R is the resistance included in the primary circuit.
- Joule's law of heating states that the amount of heat produced in a conductor is proportional to (i) square of the current flowing through the conductor,(ii) resistance of the conductor and (iii) time for which the current is passed. Heat produced is given by the relation $H=I^2Rt$
- Electric power: It is defined `as the rate at which work is done in maintaining the current in electric circuit. $P = VI = I^2R = V^2/R$. Power P is the product of V & I

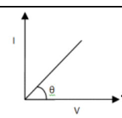
- Electrical energy: The electrical energy consumed in a circuit is defined as the total work done in maintaining the current in an electrical circuit for a given time. Electrical energy = $VIt = I^2Rt = (V^2/R)t = Pt$
- Commercial unit of energy 1KWh= 3.6×10^6J

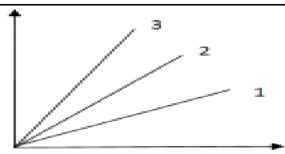
CONCEPT MAP

Flow of Charges

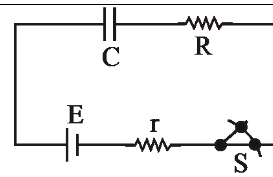


Drift velocity $v_d = \left(\frac{eE}{m}\right)\tau$
÷E
Mobility $\mu = \frac{v_d}{E}$
Charges (Coulomb)
proportional to
flowing in definite direction
Heating effect $H=I^2Rt$ (joule)
also leads to
Power dissipated $P = I^2R$
X ne
X neA
is determined by
I=q/t
Electric Current I (Ampere)
is due to
Current –density $\vec{j} = \frac{1}{A}(Am^{-2})$
÷A
Potential difference (V)
÷ current
Series combination same I & diff. V $R_s = \sum_{i=1}^{n} R_i$
Ohmic conductor (eg- nichrome)
If constant
Resistance R= V/I Ω
depends on
can be connected in
non-ohmic conductor (eg- Semi-conductors)
If not constant
Temperature $R_t=R_o(1+\alpha\,\Delta t)$
1. Nature of material R∝1/n (n no density of electron)
2. Dimensions of the material R=ρ $\frac{l}{A}$
Parallel combination same V and diff. I $\frac{1}{R_p} = \sum_{i=1}^{n} \frac{1}{R_i}$

ONE MARK QUESTIONS	
1	How does the drift velocity of electrons in a metallic conductor vary with increase in temperature? Ans- remains the same
2	Two different wires X and Y of same diameter but of different materials are joined in series and connected across a battery. If the number density of electrons in X is twice that of Y, find the ratio of drift velocity of electrons in the two wires. Ans: $V_{dx}/V_{dy} = n_y/n_x = ½$
3	A 4Ω non insulated wire is bent in the middle by 180^0 and both the halves are twisted with each other. Find its new resistance?) Ans: 1Ω
4	Can the terminal potential difference of a cell exceed its emf? Give reason for your answer. Ans: Yes, during the charging of cell.
5	Two wires of equal length one of copper and the other of manganin have the same resistance. Which wire is thicker? Ans: Manganin.
6	The V-I graph for a conductor makes angle Θ with V- axis, what is the resistance of the conductor? Ans- Ans: R = Cot Θ
7	It is found that 10^{20} electrons pass from point X towards another point Y in 0.1s. How much is the current & what is its direction? Ans: 160A; from Y to X
8	Two square metal plates A and B are of the same thickness and material. The side of B is twice that of side o fA. If the resistance of A and B are denoted by R_A and R_B, find R_A/ R_B. Ans: 1
9	The emf of a cell used in the main circuit of the potentiometer should be more than the potential difference to be measured. Why? Ans- because , If not, then there will be a small potential difference across the potentiometer wire and balancing point will not be obtained

10	 The V-I graph of two resistors in their series combination is shown. Which one of these graphs shows the series combinations of the other two? Give reason for your answer. I V Ans: 1
11	The resistance in the left gap of a metre bridge is 10Ω and the balance point is 45cm from the left end. Calculate the value of the unknown resistance. Ans S = 12.5Ω
12	How can we improve the sensitivity of a potentiometer? Ans- a) By increasing of lenth of wire of the potentiometer b) By reducing the current in the potentiometer
13	Why is potentiometer preferred over a voltmeter? Ans- Because it does not draw any current from the cell.
14	What is the largest voltage you can safely put across a resistor marked 98Ω - 0.5W? Ans- 7 volt ($P= V^2/R$ so, $V^2= PxR= 49$ so, V=7 Volt)
15	. Which lamp has greater resistance (i) 60W and (ii) 100W when connected to the same supply? Ans: $R = V^2/P$, $R \alpha 1/P$, 60 lamp has more resistance
16	Nichrome and Copper wires of the same length and same diameter are connected in series in an electric circuit. In which wire will the heat be produced at a higher rate? Give reason. Ans: $P = I^2R$ $P \alpha R$ Heat produced is higher in Nichrome wire
17	The electron drift velocity is very small (10^{-5} ms^{-1}) and electron charge is also very-very small (1.6 x 10^{-19}C). Even then how can we set up large current in the conductors? Ans. The number density of free electrons (i.e. number of free electrons/volume) is very large ~ 10^{29} m^{-3}. So these large number of electrons cause large current in the conductor.
18	Is the temperature coefficient of resistance always positive? Ans. No. The temperature coefficient of resistance of a semi-conductor is negative.
19	Out of metals and alloys, which has higher value of temperature coefficient of resistance Ans. Metals have higher value of temperature coefficient of resistance than the alloys.

20	Can the potential difference across a battery be greater than its e.m.f.? Ans. Normally not. But during charging when the battery is connected to the external source (charger) terminal voltage V is greater than E i.e. $V_{applied} = E + Ir$
ASSERTION REASON QUESTIONS	
	Some questions (Assertion–Reason type) are given below. Each question contains STATEMENT – 1 (Assertion) and STATEMENT – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which **ONLY ONE** is correct. So select the correct choice : ***Choices are :*** (A) Statement – 1 is True, Statement – 2 is True; Statement – 2 **is** a correct explanation for Statement – 1. (B) Statement – 1 is True, Statement – 2 is True; Statement – 2 **is NOT** a correct explanation for Statement – 1. (C) Statement – 1 is True, Statement – 2 is False. (D) Statement – 1 is False, Statement – 2 is True.
1	**STATEMENT – 1** Voltmeter always gives emf of a cell if it is connected across the terminals of a cell. **STATEMENT – 2** Terminal potential of a cell is given by V = E – ir.
2	**STATEMENT – 1** If there is current in a wire potential drop has to be there. **STATEMENT – 2**If potential drop is zero, the resistance may be zero.
3	**STATEMENT – 1** In a wire of non–uniform cross–section, the current is the same everywhere. **STATEMENT – 2** The current in a wire is due to the drift of electrons along the wire.
4	**STATEMENT – 1** Electric field is present in the vicinity of a current carrying wire. **STATEMENT – 2** The principle of conservation of charge of charge is not followed, when charges are in motion.
5	**STATEMENT – 1** Constant potential difference is applied across a conductor. If temperature of conductor is increases, drift speed of electrons will decrease. **STATEMENT – 2** Resistivity increases with increase in temperature
6	**STATEMENT – 1 :** If potential difference between two points is zero and resistance between those points is zero, current may flow between the points. **STATEMENT – 2 :** Kirchhoff's 1^{st} law is based on conservation of charge
7	**STATEMENT – 1 :** The switch S shown in the figure is closed at t = 0. Initial current flowing

	 through battery is $\frac{E}{R+r}$. **STATEMENT – 2 :** Initially capacitor was uncharged, so resistance offered by capacitor at t = 0 is zero.
8	**STATEMENT – 1 :** Since all the current coming to our house returns to power house. (Since current travels in a closed loop). So there is no need to pay the electricity bill. **STATEMENT – 2 :** The electricity bill is paid for the power used not for the current used.
9	**STATEMENT – 1 :** The e.m.f. of the driver cell in the potentiometer experiment should be greater than the e.m.f. of the cell to be determined. **STATEMENT – 2 :** The fall of potential across the potentiometer wire should not be less than e.m.f. of the cell to be determined.
10	**STATEMENT – 1 :** Direction of current can't be from negative potential. **STATEMENT – 2 :** Direction of current is opposite to flow of electrons.
11	**STATEMENT – 1 :** Internal resistance of battery is drawn parallel to battery in electrical circuit. **STATEMENT – 2 :** Heat generated in battery is due to internal resistance.
12	**STATEMENT – 1 :** When a cell is charged by connecting its positive electrode with positive terminal of the charger battery then potential difference across the electrodes of cell will be smaller to the EMF of cell. **STATEMENT – 2 :** Potential difference across electrodes in a cell providing electric current is E – Ir where E is EMF and r internal resistance.
13	**STATEMENT – 1 :** Potential measured by a voltmeter across a wire is always less than actual potential difference across it. **STATEMENT – 2 :** Finite resistance of voltmeter changes current flowing through the resistance across which potential difference is to be measured.
14	**STATEMENT – 1 :** The drift velocity of electrons in a metallic wire will decrease, if the temperature of the wire is increased. **STATEMENT – 2 :** On increasing temperature, conductivity of metallic wire decreases
15	**STATEMENT – 1** In metre bridge experiment, a high resistance is always connected in series with galvenometer. **STATEMENT – 2** As resistance increases, current through the circuit increases
16	**STATEMENT – 1 :** In a simple battery circuit, the point at the lowest potential is positive

	terminal of the battery. **STATEMENT – 2 :** The current flows towards the point of lowest potential for battery, as it does in a circuit from positive to the negative terminal.
17	**STATEMENT – 1 :** Insulators do not allow flow of current through them. **STATEMENT – 2 :** Insulators have no free charge carrier.
	ANSWERS- 1-D, 2-D, 3-D, 4-BOTH FALSE, 5-B, 6-B, 7-A, 8-D, 9-A, 10-D, 11-D, 12-D, 13-A, 14-B, 15-C, 16-D, 17-A.
	CASE STUDY QUESTIONS-
1.	Ram and Shyam purchased two electric tea cattles A and B of same size, same thickness and the same volume of 0.4 litre. They studied the specifications of kettles as under Kettle A: Specific heat capacity = 1680 J/kgK Mass = 200 g ,Cost = Rs. 400 Kettle B: Specific heat capacity = 2450 J/kgK Mass = 400 g, Cost = Rs. 400 When kettle a is switched on with constant potential source, the tea begins to boil in 6 min. when kettle b is switched on with the same source separately, then tea begins to boil in 8 min. the efficiency of kettle is defined as They made discussion on specification and efficiency of kettles and subsequently prepared a list of questions to draw the conclusions. Some of them are as under (Assume specific heat of tea liquid as 4200 J/kgK and density 1000kg/m^3.) 1-: Efficiency of kettle A is • 63.34% • 83.34% • 93.34% • 73.34% 2-: Efficiency of kettle B is • 82.5% • 72.5% • 92.5% • 62.5% 3- Ratio of efficiency consumed charges for one time boiling of tea in kettle A to that in

kettle B

- 3:5
- 2:3
- 3:4
- 1:1

4-If the resistance of the coil in kettle A and B is Ra and Rb then we can say

- Ra>Rb
- Ra=Rb
- Ra<Rb
- Data insufficient

5- If both the kettles are joined with the same source in series one after another then boiling starts in kettle A and kettle B after

- 4 times of their original time
- Equal to their original time
- 2 times of their original time
- Data insufficient

Answers:
1. b
2. d
3. c
4. d
5. a

2 An ammeter and a voltmeter are connected in series to a battery with an emf of 10V. When a certain resistance is connected in parallel with the voltmeter, the reading of the voltmeter decreases three times, whereas the reading of the ammeter increases two times.

A: Find the voltmeter reading after the connection of the resistance.

1. 1 V
2. 2 V
3. 3 V
4. 4 V

B: If the resistance of the ammeter is 2 ohm, then the resistance of the voltmeter is:-

1. 1 ohm
2. 2 ohm
3. 3 ohm
4. 4 ohm

C: If the resistance of ammeter is 2 ohm ,then resistance of the resistor which is added in parallel to the voltmeter is

1. ⅗ ohm

2. 2/7 ohm

3. 3/7 ohm

4. None of the above

Answers:
A. 2
B. 3
C. 1

3. Electric fuse is a protective device used in series with an electric circuit or an electric appliance to save it from damage due to overheating produced by strong current in the circuit or application. Fuse wire is generally made from an alloy of lead and tin which has high resisatnce and low melting point. It is connected in series in an electric installation. If a circuit gets accidentally short-circuited, a large current flows, then fuse wire melts away which causes a break in the circuit. The power through fuse(F') is equal to heat energy lost per unit area per unit time (h) (neglecting heat loses from ends of the wire).

$P = I^2R$ = h X 2Πrl [R=]

Where r and l are the length and radius of fuse wire, respectively.

A battery is described by its emf € and internal resistance ®. Efficiency of a battery (ἠ) is defined as the ratio of the output power to the input power

ἠ = X 100%

but I = , input power = EI

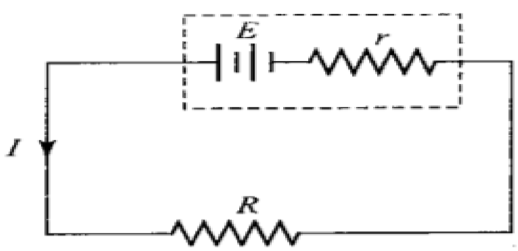
Output power = EI – I^2r

Then ἠ =( )X 100(1 -) X 100

= 1 –(

ἠ =( ) x 100

We know that output power of a source is maximum when the external resistance is equal to internal resistance, i.e., R=r.



A: Two fuse wires of same potential material are having length ratio 1:2 and ratio 4:1 Then respective ratio of their current rating will be

1. 8:1

2. 2:1

3. 1:8

4. 4:1

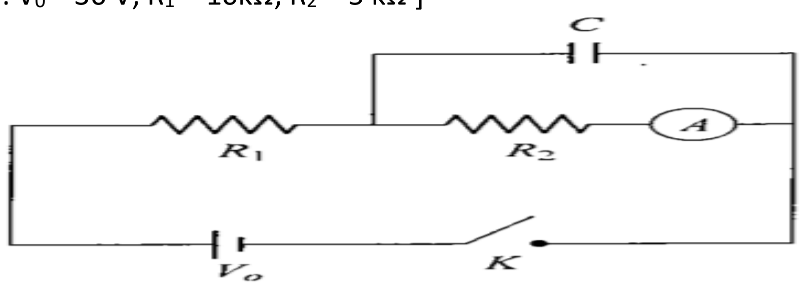
B: The maximum power rating of a 20.0 ohm fuse wire is 2.0 kW,then this fuse wire can

be connected safely to a DC source (negligible internal resistance) of
1. 300 volt
2. 190 volt
3. 250 volt
4. 220 volt

C: Efficiency of a battery when delivering maximum power is
1. 100 %
2. 50 %
3. 90 %
4. 40 %

Answers:
A. 1
B. 2
C. 4

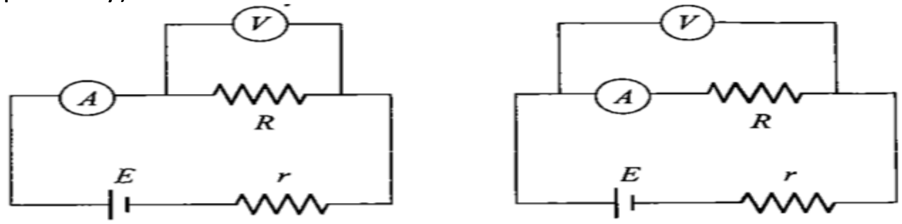
4 In the connection shown in the figure, initially the switck K is open and the capacitor is uncharged. Then the switch is closed and the capacitor is charged up to the steady state and the switch is opened again. Determine the values indicated by the ammeter.
[Given: V_0 = 30 V, R_1 = 10kΩ, R_2 = 5 kΩ]



A: Just after closing the switch
1. 2 mA
2. 3 mA
3. 0 mA
4. None of the above

B: Long time after the switch is closed
1. 2 mA
2. 3 mA
3. 6 mA
4. None of the above

C: Just after reopening the switch

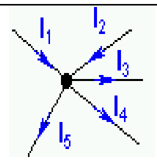
	1. 2 mA 2. 3 mA 3. 6 mA 4. None of the above **Answers:** **A. 3** **B. 1** **C. 1**
5.	Resistance value of an unknown resistor is calculated using the formula R = V/I where V and I are the readings of the voltmeter and the ammeter respectively. Consider the circuits below, the internal resistances of the voltmeter and the ammeter (R_V And R_G respectively) are finite and non-zero.  (a) (b) Let R_A and R_B be the calculated values in the two case A and B, respectively. A: The relation between $RA$and the actual value of R is 1. R > RA 2. R < RA 3. R = RA 4. Dependent on E and r B: The relation between RB and the actual value of R is 1. R < RB 2. R > RB 3. R = RB 4. Dependent upon E and r C: If the resistance of the voltmeter is RV= 1 kilo ohm and that of ammeter is RG = 1 ohm , the magnitude of percentage error in the measurement of R (the value of R is nearly 10 ohm) is 1. Zero in both cases 2. Non-zero but equal in both cases 3. More in circuit A 4. More in circuit B **Answers:** **A. 2**

	B. 2 **C. 4**
6.	When a potential difference V is applied across the two ends of a conductor, the free electrons in the conductor experience a force and are accelerated towards the positive end of conductor. On their way, they suffer frequent collisions with the ions/atoms of the conductor and lose their gained kinetic energy and again get accelerated due to electric field and lose the gained kinetic energy in the next collision and so on. The average velocity with which the free electrons get drifted towards the positive end of the conductor under the effect of applied electric field is called drift velocity. i) The motion of electrons between two successive collisions (with the atoms/ions) in the presence of electric field follows: a) Straight line path b) Circular path c) Elliptical path d) Curved path ii) The drift velocity of the electrons depends on a) Dimensions of the conductor b) Number density of free electrons in the conductor c) Both a and b d) None of these. iii) When potential difference across a given copper wire is increased, drift velocity of free electrons a) Decreases b) Increases c) Remain same d) Get reduced to zero iv) Two wires of same material having radii in the ratio 1:2, carry currents in the ratio 4:1. The ratio of drift velocities of electrons in them is a) 2:1 b) 1:1 c) 1:4 d) 16:1 v) If the temperature of a conductor increases, the drift velocity of free electrons a) Remains same b) Increases c) Decreases d) May increase or decrease.

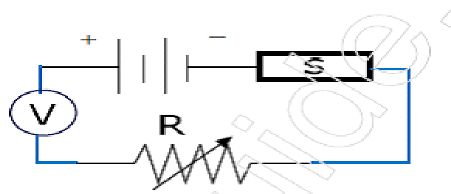
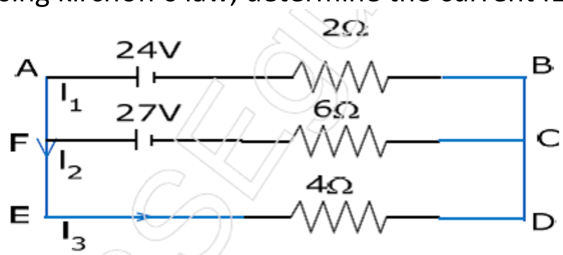
2 MARKS QUESTIONS

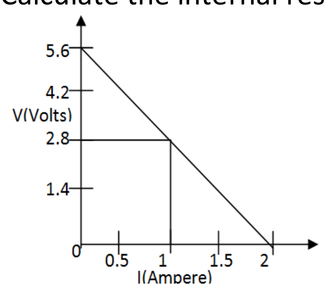
1.	Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time of electrons. Ans- So average velocity of electrons is zero i.e. there is no net flow of electrons in any direction.

	When the two ends of the conductor are connected to the battery a electric field E is set up along the length of the conductor from +ve to ve terminal. Now electron experience a force F= e E - - -(1) If 'm' is the mass of electron and 'a' is the acceleration produced then, F = m a - - - (2) Comparing equ.1 and eq2. So acceleration acquired by electron qE = ma so a = qE/m -(3) Average time taken between two successive collisions is called **relaxation time** (). $\tau = \frac{t_1 + t_2 + t_3 + t_4 + - - - - - - - t_n}{n}$ The drift velocity $\mathbf{v}_d = \mathbf{u}_{av} + \mathbf{a} = 0 + \mathbf{a}$ Hence $\mathbf{a} = \mathbf{v}_d/$ (4)Comparing eq
2.	Deduce the relation between current flowing through a conductor and drift velocity of free electrons Ans- Consider a conductor of length 'l'& area of cross section 'A' connected by a battery. Electron density 'n', then drift velocity v_d = e V/ml Distance travelled by electron in t sec is d = v_d t Volume occupied by the electron in t second is V = A d = A (v_d t) Total no of electron occupied in t sec is N = n V = n A v_d t Total charge passing through the cross section in t sec is q = N e = (n A v_d t) e Electric current I = q / t = n A v_d t e / t I = v_d e n A
3.	Deduce Ohm's law using the concept of drift velocity. **OR** On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. Ans- Drift velocity v_d = e V /ml- - -(1) (n- electron density, A-area of cross sectior But electric current I = v_d e n A $I = \frac{eV\tau}{ml} \times e\,n\,A \Rightarrow V = \left(\frac{m\,l}{e^2 \tau\, n\, A}\right) I$ V=IRThis is Ohm's law. *Where R is a constant known as resistance* $R = \frac{m\,l}{\tau\, e e\, n\, A}$
4.	*State Kirchhoff's rules in electrostatics* *Ans- Kirchhoff's First Law(**Junction Rule**) (The current Law)- <u>At any junction, the total current entering the junction is equal to the total current leaving the junction</u>".* *Hence, at any junction, <u>the algebraic sum of the currents at any junction is zero</u>. I = 0*

	 $I_1 + I_2 - I_3 - I_4 - I_5 = 0$ ***Kirchhoff's Second Law*** *– {The voltage Law}(Loop Rule)- <u>In any closed loop of a circuit, the algebraic sum of the voltage drops across the resistors is equal to the algebraic sum of the e.m.f.s of the cells</u>”.* *<u>“In any closed loop of a circuit, the algebraic sum of the product of potential difference across the resistors and current through them is equal to the algebraic sum of the e.m.f.s of the cells</u>”.* *In any closed loop, potential drops = e.m.fs. V I = E*
5.	*(A) Plot a graph showing the variation of conductivity σ with the temperature T in a metallic conductor.* *(B) Draw a graph to show the variation of resistance R of the metallic wire as a function of its diameter D keeping the other factor constant.* *Ans-* (b) (a) σ R T D
6	Two conducting wires X and Y of same diameter but different materials are joined in series across a battery. If the number density of electrons in X is twice that in Y, find the ratio of drift velocity of electrons in the two wires. Ans: $I \alpha\, nv_d$ i.e. $V_{dx}/V_{dy} = n_y/n_x = ½$
7	A non-conducting ring of radius r has charge q distribute over it. What will be the equivalent current if it rotates with an angular velocity ω? Ans- $I= q/t = q\omega/2\pi$
8	Two cells each of emf E and internal resistances r_1 and r_2 are connected in series to an external resistance R. Can a value of R be selected such that the potential difference of the first cell is 0. Ans: $I = 2\varepsilon/(R + r_1 + r_2)$ Potential diff. for first cell $V_1 = \varepsilon - I r_1 = 0$ $\varepsilon = (2 \varepsilon r_1)/R + r_1 + r_2$ Solving these we get, $R = r_1 - r_2$
9	A piece of silver wire has a resistance of 1Ω. What will be the resistance of the constantan wire of one third of its length and one half of its diameter if the specific resistance of the constantan wire is 30 times than that of the silver? Ans- $R_s = 1\ \Omega$, $l_c=1/3\ l_s$, $r_c=1/2\ r_s$, $\rho_c=30\ \rho_s$ R= $R_c= 40\ \Omega$
10	How does the balancing point of a Wheatstone bridge get affected when • Position of cell and Galvanometer are interchanged? • (3) • Position of the known and unknown resistances is interchanged?

	Ans- 1.There will be no change in the balance point condition of Wheatstone bridge even if galvanometer and cell are interchanged. 2.position of known and unknown resistance is interchanged. 1. There will be no change in the balance point condition of Wheatstone bridge even if galvanometer and cell are interchanged.
11	An electric bulb rated for 500W at 100V is used in circuit having a 200V supply. Calculate the resistance R that must be put in series with the bulb, so that the bulb delivers 500W. Ans: Resistance of bulb=V^2/P = 20Ω, I = 5A, for the same power dissipation, current should be 5A when the bulb is connected to a 200V supply. The safe resistance R' = V'/I = 40Ω. Therefore, 20Ω resistor should be connected in series.
12	Can a 30W, 6V bulb be connected supply of 120V? If not what will have to be done for it? Ans: Resistance of bulb R= V^2/P = 36/30 = 1.2Ω Current capacity of the bulb I = P/V = 5A A resistance R' to be added in series with the bulb to have current of 5 A, I = V'/R + R' =5, R' = 22.8Ω
13	What are ohmic and non-ohmic resistors? Give one example of each? Ans- A resistor which obey ohm's law are called ohmic resistors for eg -> metals A resistor which do not obey ohm's law are called non-ohmic resistors .eg -> semiconductor diode , transistor etc.
14	Three identical cells, each of emf. 2v and unknown internal resistance are connected in parallel .This combination is connected to a 5ohm resister. If the terminal voltage across the cell is 1.5volt. What is the internal resistance of each cell .hence define internal resistance of a cell? Ans- total internal resistance= r/3 Since, r= (- 1)R r/3= (- 1)5 r= 5 ohm.
15	Define emf. of a cell? On what factors does it depend? Ans-It is defined as the potential difference between the two electrodes of the cell in open Circuit (when no current is drawn) It depends on the following factors (i) Nature of Electrodes (ii) Nature and concentration of the Electrolytes (iii) Temperature of the cell.
16	Figure shows a piece of pure semiconductor S in series with a variable resistor Rand a source of constant voltage V. Would you increase and decrease the value of R to keep the reading of ammeter (A) constant, when semiconductor S is heated ? Give reasons.

	 Ans- Resistance of a semi conductor decreases on increasing the temperature, so in order to increase the temperature, s is heated and in order to maintain the ammeter current constant total resistance is the above circuit should remain unchanged, hence value of r has to be increased.
17.	A cylindrical wire is stretched to increase its length by 10% calculate the percentage increase in resistance? Ans- l'= 1.1l, l'A'=lA so, l'/l=A/A'= 1.1 R'= R= 1.21R so,
18	Using kirchoff's law, determine the current I1 , I2 and I3 for the network shown.  Ans- Applying junction rule at point F $I_1 = I_2 + I_3$ -------------- (1) Loop rule for BAFCB 2I1 + 6I2 – 24 + 27 = 0 2I1 + 6I2 + 3 = 0 ------- (2) Loop rule for FCDEF 27 + 6I2 – 4I3 = 0 -------- (3) solving eg . (1) , (2) & (3) we get I1 =3A , I2 = -1.5A , I3 = 4.5A
19	A set of n-identical resistors , each of resistance R ohm when connected in series have an effective resistance of X ohm and when the resistors are connected in parallel the effective resistance is Y ohm. Find the relation between R , X and Y ? Ans- n – resistors connected in series X = nR ----------------1) n – Resistors connected in parallel Y =R/n ----------------2) Multiply eg. (1) & (2) $XY = R^2$ *R* =

20	A potentiometer wire of length 1m has a resistance of 10 Ω. It is connected to a 6V battery in series with a resistance of 5Ω. Determine the emf of a cell which gives a balance point at 40cm. Ans- 1m potentiometer has 10Ω of resistance. ⇒40cm length would have = 110×0.4 [R=PAL⇒RαL] R1=4Ω resistance At balance point, current through both driver circuit and connected cell would be same. (I = constant) Now from onm's Law : V=1R we get, ⇒R1/E=R2//V [E : Emf of primary cell] ⇒4/E=5/6 Gives, ⇒E=4.8V
3 MARKS QUESTIONS	
1.	4 cells of identical emf E_1, internal resistance r are connected in series to a variable resistor. The following graph shows the variation of terminal voltage of the combination with the current output. (i)What is the emf of each cell used? (ii)For what current from the cells, does maximum power dissipation occur in the circuit? Ans: 4E = 5.6 E = 1.4 V When I = 1A, V = 2.8/4 = 0.7V Internal resistance, r= (E – V)/I = 0.7Ω The output power is maximum when internal resistance = external resistance = 4r.I_{max} = 4E/ (4r +4r) = 1A (iii)Calculate the internal resistance of each cell 
2.	Derive the expression of equivalent emf of two cells (, r1) and (, r2) connected in parallel. Where E is emf and r is internal resistance of the cells. Ans- consider a parallel combination of the cells. I_1 and I_2 are the currents leaving the positive electrodes of the cells. At the point B_1, I_1 and I_2 flow in whereas the current I flows out. Since as much charge flows in as out, we have $I = I_1 + I_2$

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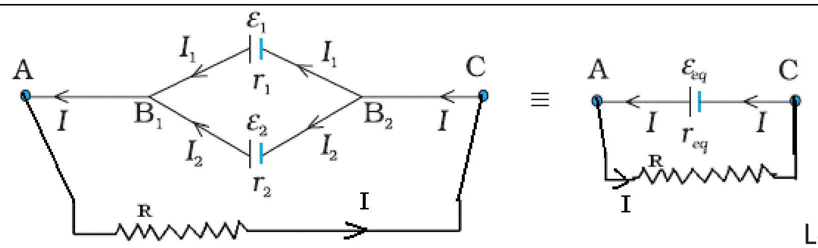

Let $V(B_1)$ and $V(B_2)$ be the potentials at B_1 and B_2, respectively. Then, considering the first cell, the potential difference across its terminals is
$V(B_1) - V(B_2)$. Hence, from equation.
V⍰V⍰B_1⍰ꝿV⍰B_2⍰⍰⍰⍰$_1$–$I_1 r_1$
Points $B1$ and $B2$ are connected exactly similarly to the second cell. Hence considering the second cell, we also have V⍰$V(B_1) - V(B_2)$ ⍰⍰⍰⍰⍰– $I_2 r_2$
Combining the last three equations $I = I_1 + I_2$
I =   I =   I =
V =   (1)
If we want to replace the combination by a single cell, between B_1 and B_2, of emf E_{eq} and internal resistance r_{eq}, we would have $V = E_{eq} - I\, r_{eq}$ (2) Comparing eq1 &2.

OR
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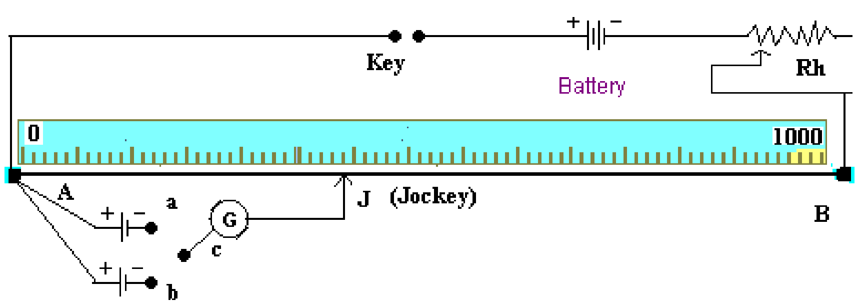
With suitable circuit diagram, show how emfs of a cell can be compared using a potentiometer?
Ans-
Circuit: -


Let E_1 and E_2 be the e.m.f of two cells. The positive terminals of both cells are connected to point ‘a’ and negative to point ‘b’ of a two way key. The common terminal C is connected to a jockey ‘J’ through a galvanometer ‘G’. A battery, rheostat and a one-way key K are connected across point A and B.
Method: - A constant current is passed through the wire of potentiometer by battery when plug is put in the gap between ‘a ‘ and ‘c’ of two way key .The cell of e.m.f E_1 will come the circuit. Let J be the point of no deflection in galvanometer with balancing length l_1 =AJ. So $E_1 = k\, l_1$ --------(1)
Now key is put between the gaps of ‘b’ and ‘c’ the cell of e.m.f E_2 will come in the circuit. Now the balancing length is l_2 . Then $E_2 = k\, l_2$ -- --(2)
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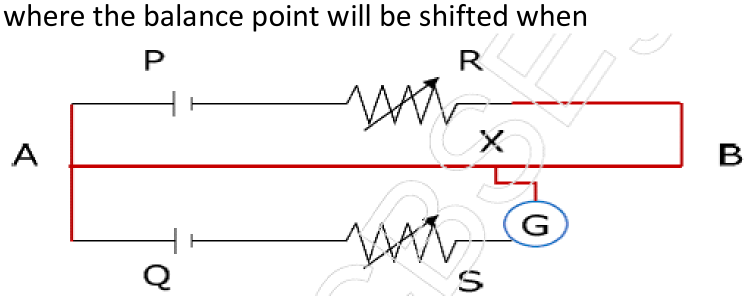
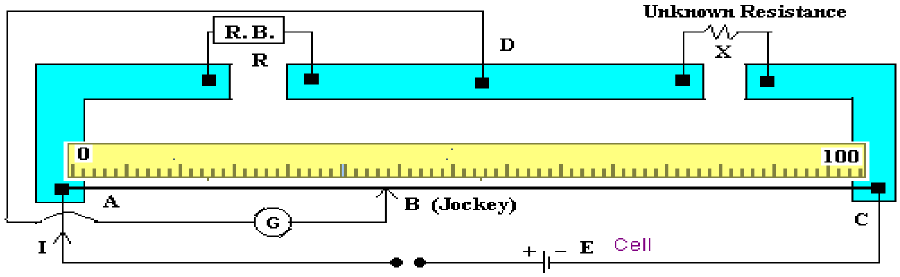
	Dividing eq (1) by (2) $\frac{E_1}{E_2} = \frac{k\ l_1}{k\ l_2}$ Hence $\frac{E_1}{E_2} = \frac{l_1}{l_2}$. By changing current with the help of rheostat in the wire different values of E_1 / E_2 can be find for different value of current. The mean value of E_1 / E_2 can be calculated. If we know the e.m.f of one cell then e.m.f of the other cell can be determined.
4	Potential difference V is applied across the ends of copper wire of length (l) and diameter D. What is the effect on drift velocity of electrons if • V is doubled (2) l is doubled (3) D is doubled Ans- $I=v_d ena$ $v_d=I/enA=V/RenA=V/\rho len$ • If V is doubled, drift velocity gets halved. • If l is doubled, drift velocity gets halved. • Since V of is independent of D, drift velocity remains unchanged.
5	The potentiometer circuit shown, the balance (null) point is at X. State with reason, where the balance point will be shifted when  (1) Resistance R is increased, keeping all parameters unchanged. (2) Resistance S is increased, keeping R constant. (3) Cell P is replaced by another cell whose emf is lower than that of cell Q. Ans- (a) When resistance R is increased, the current through potentiometer wire AB will decrease, hence potential difference across A will decrease, so balance point shifts towards B. (b)When resistance S is increased terminal potential difference of the battery will decrease, so balance point will be obtained at smaller length and hence shifts towards A. (c) When cell P is replaced by another cell whose emf is lower than that of cell Q, the P.D. across AB will be less than that of emfQ so balance point will not be obtained.

6.	(a) State the principle of meter bridge and find the unknown resistance by using the suitable circuit diagram of meter bridge. (b) In a whetstone bridge experiment, a student by mistake, connects key (k) in place of galvanometer and galvanometer (G) in place of Key (K). What will be the change in the deflection of the bridge. Ans-  (**Principle: -** Circuit is exactly the same as that of the wheat stone bridge, so its principle is same that of wheat stone bridge. In balance condition $\frac{P}{Q} = \frac{R}{X}$ ------(1) Where P and Q are the resistance of portion AB and BC. **Method: -** Let resistance taken out from resistance box is R and B be the balance point (no deflection position) with balancing length 'l'. If resistance per unit length is ' a' then Resistance of AB is P= a *l* & Resistance of BC is Q = a (100-l) Putting values in eq 1 $\frac{a\,l}{a\,(100-l)} = \frac{R}{X}$ Hence $Unknown\ resistance\ X = \left(\frac{100-l}{l}\right) R$ Since R and l is known hence unknown resistance X can be calculated. (b) When the bridge is balanced, there will be no current in key, therefore constant current flows through the galvanometer and hence no change in deflection on pressing the key.
7	Two primary cells of emf's E1 and E2 are connected to the potentiometer wire AB as shown in the figure if the balancing length for the two combinations of the cells are 250 cm and 400 cm. find the ratio of E1 and E2 . Ans- E1 – E2 = K×250 ---------- (1) E1 +E2 = K×400 ----------- (2) Adding eg. (1) &(2) 2E1 = 250K+ 400K 2E1 = 650K E1 = 325 K ----- (3) Subtracting eg. (1) & (2) E2 = 75K E1/ E2 = 4.33

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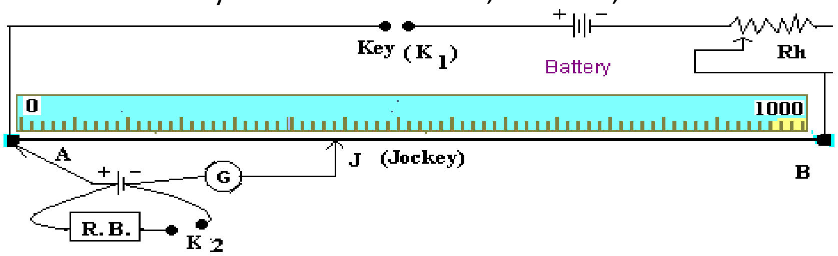
With the help of a circuit diagram, describe the method of finding the internal resistance of the Primary Cell using a potentiometer.
Ans-
Circuit: - A battery of constant e.m.f E, rheostat,


key k_1 and an ammeter connected between point A and B so that a constant current I flow in the circuit. The positive terminal of the primary cell is connected to point A and its negative terminal is connected to the jockey. A resistance box R is connected parallel to cell.
Method: - (1) When key k_2 is open the balancing length l_1 is determined. So e.m.f of the cell in the circuit
E = k l_1 ---- --- ---1)
(2) Now close the key k_2 and with the help of resistance box determined the balancing length l_2. Potential difference between the terminals of cells
V = k l_2 --- --- -- (2) dividing eq 1 by 2
$\frac{E}{V} = \frac{k\, l_1}{k\, l_2} \quad \Rightarrow \frac{E}{V} = \frac{l_1}{l_2} \; - - - (3)$
Internal resistance of the cell $r = \left(\frac{E - V}{V}\right) R = \left(\frac{E}{V} - 1\right) R$ From eq3
$r = \left(\frac{k\, l_1}{k\, l_2} - 1\right) R$ So $r = \left(\frac{l_1}{l_2} - 1\right) R$ OR
$r = \left(\frac{l_1 - l_2}{l_2}\right) R$
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<tr><td>9.</td><td>
A potentiometer wire of length 100cm having a resistance of 10Ω is connected in series with
a resistance and cell of emf 2V of negligible internal resistance. A source emf of 10mV is
balanced against a length of 40cm of potentiometer wire. What is the value of the external
resistance?
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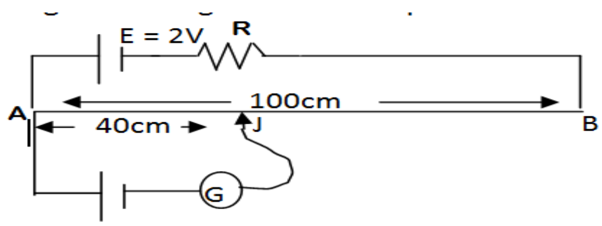
	 Ans: As the source of e.m.f. $E'=10mV=10\times10^{-3}$ V is balanced by a length of 40cm of the potentiometer wire, it follows that 10×10^{-3}=J resistance of 40cm of the potentiometer wire. If I is current through the potentiometer wire then J=E/R+10=2/R+10 Now resistance of 40cm of the potentiometer wire =10/100×40=4Ω $10\times10^{-3}=(2/R+10)\quad)4$ ⇒R=790Ω Hence, resistance is 790Ω
10.	Answer the following: (a) Why are the connections between the resistors in a meter bridge made of thick copper strips? (b) Why is it generally preferred to obtain the balance point in the middle of the meter bridge wire? (c) Which material is used for the meter bridge wire and why? Ans- • The resistivity of copper wire is very low. The connections between the resistors are made of thick wires so as to increase the rate of cross-section. Therefore, the resistance of wires is almost negligible. • The balance point is obtained in the middle of the meter bridge wire so as to increase the sensitivity of the meter bridge and there by no deflection in the galvanometer. so it minimise error in measuring resistance. • Constantan is used for meter bridge wire because its temperature coefficient of resistance is almost negligible due to which the resistance of the wire does not change with increase in temperature of the wire due to flow of current.

KENDRIYA VIDYALAYA SANGATHAN, AHHMEDABAD REGION

SELF ASSISSMENT ON CH-3

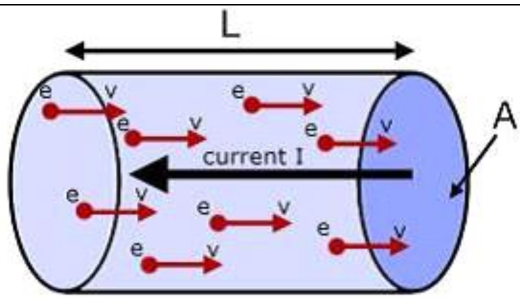
CLASS-XII

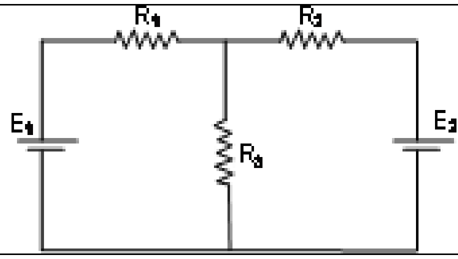
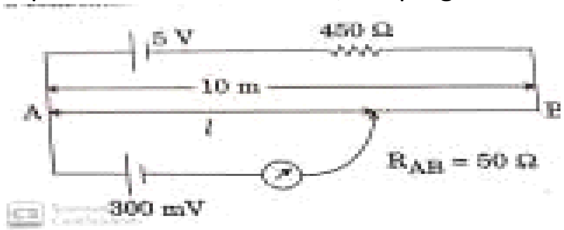
PHYSICS (042)

TIME PERIOD- 60 MINUTES MM-25

Q.NO.	QUESTION	MARK
1	State the Principle of Potentiometer. OR State the principle of Meter Bridge.	1
2	Define mobility of a charge carrier. What is its relation with relaxation time?	1
3	Give reason why a potentiometer is preferred over a voltmeter for the measurement of emf of a cell	1
4	A potential difference V is applied across a conductor of length L and diameter D. How is the drift velocity, v_d, of charge carriers in the conductor	1

	affected when V is halved? Justify your answer in each case.	
	Question No. 5 and 6 (Assertion–Reason type) are given below. Each question contains STATEMENT – 1 (Assertion) and STATEMENT – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which **ONLY ONE** is correct. So select the correct choice : ***Choices are :*** (A)Statement – 1 is True, Statement – 2 is True; Statement – 2 **is** a correct explanation for Statement – 1. (B)Statement – 1 is True, Statement – 2 is True; Statement – 2 **is NOT** a correct explanation for Statement – 1. (C)Statement – 1 is True, Statement – 2 is False. (D)Statement – 1 is False, Statement – 2 is True.	
5	**Statement -1**: The e.m.f. of the driver cell in the potentiometer experiment should be grater then the e.m.f. of the cell to be determined. **Statement-2:** The fall of potential across the potentiometer wire should not be less than the e.m.f. of the cell to be determined.	1
6	**Statement -1**: In a meter bridge experiment, a high resistance ia always connect dib series with the galvanometer. **Statement-2:** As resistance increases, current through the circuit increases.	1
	Question 7 is Case Study based questions and is compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.	
7	A cylindrical copper conductor AB of length 'l' and area of cross section 'A' has a large number of free electrons which at room temperature move at random within the body of the conductor, like the molecules of a gas.The average thermal speed of the free electrons in random motion at room temperature is of the order of 10 5 m/s-1. When a potential difference 'V' is applied across the two ends of a given conductor, the free electrons in the conductor experience a force and are accelerated towards the positive end of the conductor. On their way they suffer frequent Collisions with the ion/atoms of the conductor and lose their gained kinetic energy. After each collision the free electrons are again accelerated due to electric field towards the positive end of the conductor and lose their gained kinetic energy in the next Collision with the Ion/atom of the conductor. The average speed of free electrons with which they drift towards the positive end of the conductor under the effect of applied electric field is called Drift velocity of the electron.	4

	 i) When the potential difference is applied across the two ends of the conductor then electric field exists- (a) outside the conductor (b) inside the conductor (c) both outside and inside the conductor (d) no where. ii) The motion of electrons in between two successive collisions with the atoms/ ion follows a) straight path b) circular path c) elliptical path d) curved path iii) The drift speed of the electrons depend on - a) dimension of conductor b) number density of free electron in the conductor c) both (a) and (b) d) none of these above iv) The current in the conductor is due to- a) Thermal motion of free electrons b) acceleration of the electrons towards the positive end of the conductor c) Drifting of electrons towards positive end of the conductors d) None of the above v) Drift current is due to – a) Applied electric field over a given distance b) Random motion of electrons c) Random motion of holes d) Recombination of holes and electrons	
8	Describe briefly, with the help of a circuit diagram, the method of measuring the internal resistance of a cell.	2
9	Establish the relation between drift velocity of an electron and current in the conductor.	2
10	In the circuit shown in figure E_1 = 7V, E_2 = 7V $R_1 = R_2 = 1\ \Omega$ and $R_3 = 3\ \Omega$ respectively.find current through the resistance R_3 .	2

		
11	Answer the following: (a) Why are the connections between the resistors in a meter bridge made of thick copper strips? (b) Why is it generally preferred to obtain the balance point in the middle of the meter bridge wire? (c) Which material is used for the meter bridge wire and why?	3
12	Show, on a plot, variation of resistivity of (i) a conductor and (ii) a typical semiconductor as a function of temperature. Using the expression for the resistivity in terms of numbers density and relaxation time between the collisions, explain how resistivity in the case of a conductor increases while it decreases in a semiconductor, with the rise of temperature.	3
13	In the potentiometer circuit given below, calculate the balancing length l. Give reason, whether the circuit will work , if the driver cell of emf 5 V is replaced with a cell of 2 V, keeping all other factors constant. 	3

UNITIII Magnetic Effects of Current and Magnetism

Chapter–4: Moving Charges and Magnetism

Chapter–5: Magnetism and Matter

1. **Biot-Savart law:** It states that field strength dB produced due to the current element dl at a point having position vector r relative to the current element is

$dB = \frac{\mu_0 I dl Sin\theta}{4\pi r^2}$ $\mu_0=10^{-7}$ Tm/A

*Direction of dB can be found by using Maxwell's Right hand thumb rule.]

2. **Applications :**
   - (i) Magnetic field at a centre of a current carrying circular coil B= $\mu_0 I/2a$
   - (ii) Magnetic field at a point on the axis of current carrying coil.

   $B = \frac{\mu_0 N i a^2}{2(a^2+x^2)^{3/2}}$ N=no. of turns in the coil

2. **Ampere's circuital law :** it is stated that the line integral of magnetic field B along a closed path is equal to u0 time of the current I passing through the closed path

$$\oint \boldsymbol{B.dl} = \mu_0 I$$

4. **Applications**
   - i) Magnetic field due to straight infinitely long current carrying straight conductor. B= $\mu_0 I/2\pi r$
   - ii) Magnetic field due to a straight solenoid carrying current B= $\mu_0 nI$
     n= no. of turns per unit length
   - iii) Magnetic field due to toroidal solenoid carrying current. B= $\mu_0 NI/2\pi r$
     N= Total no. of turns.

5. **Force on a moving charge**
   - (i) In magnetic field F=q(V x B)
   - (ii) In magnetic and electric field(Lorentz force) F=qxE+(v x B)
   - (ii) Cyclotron frequency or magnetic resonance frequency *v=qB/2πm, T=2πm/Bq*
   - (iii) Maximum velocity and maximum kinetic energy of charged particle. $V_m=Bqr_m/m$

6. **Force on a current carrying conductor in uniform**

   F= (Il x B) **l=length of conductor**

   Direction of force can be found out using Fleming's left hand rule.

7. **Force per unit length between parallel infinitely long current carrying straight conductors.**

   $F/l = \frac{\mu_0 I_1 I_2}{2\pi d}$

   (a) If currents are in same direction the wires will attract each other. (b) If currents are in opposite directions they will repel each other.

8. **Torque experienced by a current loop in a uniform B.**

   τ = NIBA Sinθ τ=MXB Where M=NIA

9. **Motion of a charge in**
   - (a) Perpendicular magnetic field F=q(vxB),F=qvBSin90=qvB (circular path)
   - (b) Parallel or antiparallel field F=qvBSin0 (or) qvBSin180=0(Straight-line path)

10. **(a) Conversion of galvanometer into ammeter**

    A small resistance S is connected in parallel to the galvanometer coil

    $S=I_gG/I-I_g$ $R_A=GS/G+S$

    (b) Conversion of galvanometer into a voltmeter.

    A high resistance R is connected in series with the galvanometer coil.

    $R=V/I_g-G$ $R_V=G+R$

MIND MAP

Moving Charges & Magnetism

Magnetic Field ($\vec{B}$)

- It is a region around a magnet or current carrying conductor or a moving charge in which its magnetic effect can be felt
- SI unit is Tesla(T) = weber/m^2
- 1 Gauss = 10^{-4} Tesla

Magnetic Force on moving charge

$\vec{F} = q\vec{v}\times\vec{B}$

$= qvB \sin\theta$

- For $\theta = 0$, $\vec{F} = 0$ along the magnetic field
- For $\theta = 90°$, i.e. if charge's velocity is perpendicular to field direction, Force is perpendicular to both field & velocity

$F = qvB = \frac{mv^2}{r}$

$r = \frac{mv}{qB}$ = radius of the circle in which charge rotates

Time period (T) $= \frac{2\pi m}{qB}$

v(frequency) $= \frac{1}{T} = \frac{qB}{2\pi m}$

If $\theta \neq 0, 180°, 90°$

Then, $F = qvB \sin\theta$

And the charge particle will follow helix path whose

$r = \frac{m v_{\perp}}{qB}$ and pitch $= V_{\parallel} \times T = V_{\parallel} \times \frac{2\pi m}{qB}$

Oersted Law

In April, 1820, Hans Christian Oersted discovered that flow of current in a wire could deflect a nearby magnetic compass needle

Biot-Savart Law

⊙ ⊗

$d\vec{B} = \frac{1}{4\pi\varepsilon_0 c^2}\frac{i d\vec{l}\times\vec{r}}{r^3}$

$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i d\vec{l}\times\vec{r}}{r^3}$

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

θ = angle between $d\vec{l}$ and $\vec{r}$

Direction of field will be perpendicular to plane containing current element and the point of observation.

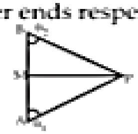
where $\mu_0 = \frac{1}{\varepsilon_0 c^2}$

$= 4\pi \times 10^{-7}$ TmA^{-1}

Magnetic field due to straight wire current

$B = \frac{\mu_0 i}{4\pi d}(\cos\theta_1 - \cos\theta_2)$

where θ_1 and θ_2 are the angle corresponding to the lower and upper ends respectively



Field due to a long straight wire current

i.e $\theta_1 = 0$

$\theta_2 = \pi$

$B = \frac{\mu_0 i}{2\pi d}$

Ampere's Law

$\oint \vec{B}.\vec{dl} = \mu_0 i$

where i = total current crossing the area bounded by closed curve.

Solenoid

- Magnetic filed at a point inside due to a long solenoid $B = \mu_0 ni$
- And at point on one end $B = \frac{\mu_0 ni}{2}$

where n = no. of turns per unit length along the length of solenoid.

Magnetic field due to Toroid

$B = \frac{\mu_0 Ni}{2\pi r}$, N = total no. of turns

i = current in toroid

Force on a current carrying conductor

$d\vec{F} = i\, d\vec{l} \times \vec{B}$, $F = ilB$

Force between parallel currents

$F = \frac{\mu_0 i_1 i_2}{2\pi d}$

Torque experienced by a loop in uniform magnetic field

$\vec{\tau} = MB \sin\theta\, \hat{n} = \vec{M}\times\vec{B}$

Definition of Ampere

If two parallel wire kept 1 m apart, if $F = 2 \times 10^{-7}$, then current = 1A in each.

Sensitivity of moving coil galvanometer is nBA/k

Gal to ammeter

$S = \frac{I_g}{I_T - I_g} G$

Gal to voltameter

$R = \frac{V}{I_g} - G$

Field due to a ⊙ circular current

Field at the centre

$B = \frac{\mu_0 i}{2a}$

⊙ ⊙

Field at an axial point

$B = \frac{\mu_0 i a^2}{2(a^2 + d^2)^{3/2}}$

Field at a point far away from the centre

i.e. for d >> a

$B = \frac{\mu_0 i a^2}{2 d^3}$

VERY SHORT QUESTION (one marks)

Q1. Must every magnetic field configuration have a north pole and a south pole? What about the field due to a toroid?

Ans. No, In toroid, there is no separate N & S pole(poles exists only when the source has some net magnetic moment.)

Q2. What is the effect on the current measuring range of a galvanometer when it is shunted?

Ans. Increased.

Q3 Suggest a method to shield a certain region of space from magnetic fields.

Ans. By putting in a ferromagnetic hollow case

Q4. If the magnetic field is parallel to the positive y-axis and the charged particle is moving along the positive x-axis, which way would the Lorentz force be for an electron (negative charge), (b) a proton (positive charge)

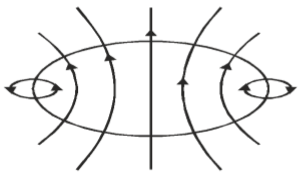
Ans. From fleming's left hand rule
(a) for electron Lorentz force will be along –z axis;
(b) for a positive charge (proton) the force is along +z axis.

Q5. A magnetic dipole of magnetic moment M is kept in a magnetic field B. At what position the minimum and maximum potential energy can be acquired?

Ans. Minimum potential = – MB when $\theta = 0$ (most stable position)
Maximum potential = MB when $\theta = 180°$ (most unstable position).

Q6 Sketch the magnetic field lines for a current carrying circular loop.

Ans



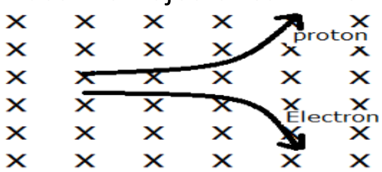
Q7. Imagine that the room in which you are seated is filled with a uniform magnetic field pointing in vertically downward. At the centre of the room, an electron is released with a certain speed in the horizontal direction. Find the nature of the expected path of the electron in the field?

Ans: The electron will keep on revolving clockwise in a circular path.

Q8. In a certain arrangement, a proton does not get deflected while passing through a magnetic field region. State the condition under which it is possible.

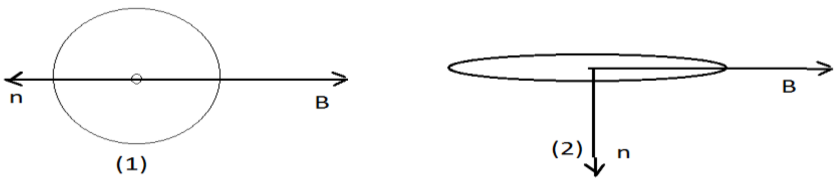
Ans: v is parallel or antiparallel to B

Q9 An electron and proton, moving parallel to each other in the same direction with equal momenta, enter into a uniform magnetic field which is at right angle to their velocities. Trace the trajectories in the magnetic field.



Ans

Q2 A current loop is placed in a uniform magnetic field in the following orientations (1) and (2). Calculate the magnetic moment in each case.



Ans: (1)-mB (2)Zero

<u>Assertion (A) & Reason(R)</u>

Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a). Both A and R are true and R is the correct explanation of A

(b). Both A and R are true but R is not the correct explanation of A

c). A is true but R is false

(d).A is false and R is also false

1.Assertion(A):
The centripetal force on the test charge *qo* is *qo vB*, where v is the velocity of a particle and B is the magnetic field.
Reason (R):
When a charged particle is fired at right angles to the magnetic field, the radius of its circular path is directly proportional to the kinetic energy of the particle.

2.Assertion (A):
Magnetic field due to an infinite straight conductor varies inversely as the distance from it.
Reason (R):
The magnetic field due to a straight conductor is in the form of concentric circles.

3.Assertion (A):
A rectangular current loop is in an arbitrary orientation in an external uniform magnetic field. No work is required to rotate the loop about an axis perpendicular to the plane of loop
Reason (R):
All positions represent the same level of energy.

4.Assertion (A):
The magnitude of magnetic field in a region is equal to the number of magnetic field lines per unit area where area should be normal to the field.
Reason (R):
Magnetic field is tangential to a magnetic field line.

5.Assertion (A):
If a proton and an α-particle enter a uniform magnetic field perpendicularly with the same speed, the time period of revolution of α-particle is double than that of proton.
Reason (R):
In a magnetic field, the period of revolution of a charged particle is directly proportional to the mass of the particle and inversely proportional to the charge of the particle.

6.Assertion (A):
A charged particle is moving in a circular path under the action of a uniform magnetic field. During the motion, kinetic energy of the charged particle is constant.
Reason (R):
During the motion, magnetic force acting on the particle is perpendicular to instantaneous velocity.

7.Assertion (A):
When radius of a circular loop carrying current is doubled, its magnetic moment becomes four times.
Reason (R):
Magnetic moment depends on the area of the loop.

8.Assertion (A):
The magnetic field at the ends of a very long current carrying solenoid is half of that at the centre.
Reason (R):
If the solenoid is sufficiently long, the field within it is uniform.

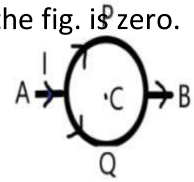
9.Assertion (A):
If an electron and proton enter a magnetic field with equal momentum, then the paths of both of them will be equally curved.
Reason (R):
The magnitude of charge on an electron is same as that on a proton.

10.Assertion (A):
The coils of a spring come close to each other, when current is passed through it.
Reason (R):
It is because, the coils of a spring carry current in the same direction and hence attract each other.

11.Assertion (A):
The range of a voltmeter can be both increased or decreased.
Reason (R):
The required resistance (to be connected in series) can be calculated by using the relation,

12.Assertion (A):
Both A m^2 and J T^{-1} are the units of magnetic dipole moment.
Reason (R):
Both the units are equivalent to each other.
13.Assertion (A):
The true geographic north direction is found by using a compass needle.
Reason (R):
The magnetic meridian of the earth is along the axis of rotation of the earth.
14.Assertion (A):
If a compass needle is kept at magnetic north pole of the earth, the compass needle may stay in any direction.
Reason (R):
Dip needle will stay vertical at the north pole of the earth.

15.Assertion (A):
The magnetic field at the centre of the current carrying circular coil shown in the fig. is zero.



Reason (R):
The magnitudes of magnetic fields are equal and the directions of magnetic fields due to both the semicircles are opposite.

16.Assertion (A):
The voltage sensitivity may not necessarily increase on increasing the current sensitivity.
Reason (R):
Current sensitivity increases on increasing the number of turns of the coil.

17.Assertion (A):
The angle of dip is maximum at the poles of the earth.
Reason (R):
The magnetic field lines are parallel to the surface of the earth at the poles.

18.Assertion (A):
An electron projected parallel to the direction of magnetic force will experience maximum force.
Reason (R):
Magnetic force on a charge particle is given by F = (IL x B).

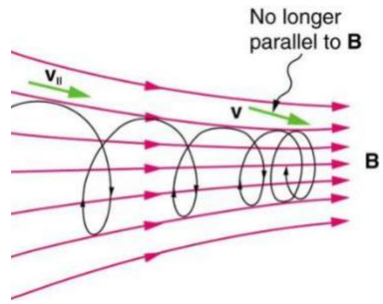
19.Assertion (A):
The torque acting on square and circular current carrying coils having equal areas, placed in uniform magnetic field, will be same.
Reason (R):
Torque acting on a current carrying coil placed in uniform magnetic field does not depend on the shape of the coil, if the areas of the coils are same.
20.Assertion (A):
A phosphor bronze strip is used in a moving coil galvanometer.
Reason (A):
Phosphor bronze strip has the maximum value of torsional constant k.

ANSWER KEY:

1. c	11. a
2. b	12. a
3. a	13. d
4. b	14. b
5. a	15. a
6. a	16. b
7. a	17. c
8. b	18. d
9. a	19. a
10. a	20. c

<u>**CASE BASED QUESTIONS**</u>

Case 1. FORCE ON A CHARGE IN ELECTRIC AND MAGNETIC FIELD



A point charge q (moving with a velocity v and located at r at a given time t) in the presence of both the electric field E and magnetic field B. The force on an electric charge q due to both of them can be written as F = q [E + v x B] = Fel + Fmag It is called the 'Lorentz force'.If the charge q is moving under a field, the force acting on the charge depends on the magnitude of field as well as the velocity of the charge particle,

1.what kind of field is the charge moving in?
(a) Electric field
(b) Magnetic field
(c) Both electric and magnetic field perpendicular to each other
(d) None of these

2.The magnetic force acting on the charge 'q' placed in a magnetic field will vanish if
(a) if v is small
(b) If v is perpendicular to B
(c) If v is parallel to B
(d) None of these

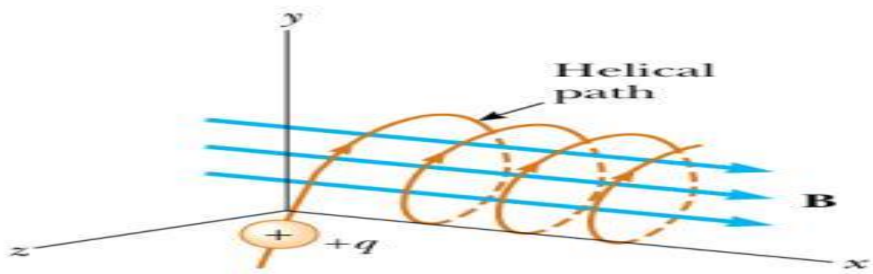
3.If an electron of charge -e is moving along + X direction and magnetic field is along + Z direction, then the magnetic force acting on the electron will be along
(a) + X axis
(b) - X axis
© - Y axis
(c) + Y axis

4.The vectors which are perpendicular to each other in the relation for magnetic force acting on a charge particle are
(a) F and v
(b) F and B
(c) v and B
(d) All of these

5.A particle moves in a region having a uniform magnetic field and a parallel, uniform electric field. At some instant, the velocity of the particle is perpendicular to the field direction. The path of the particle will be
(a) A straight line

(b) A circle
(c) A helix with uniform pitch
(d) A helix with non-uniform pitch

CASE 2: HELICAL MOTION OF A CHARGED PARTICLE IN A MAGNETIC FIELD

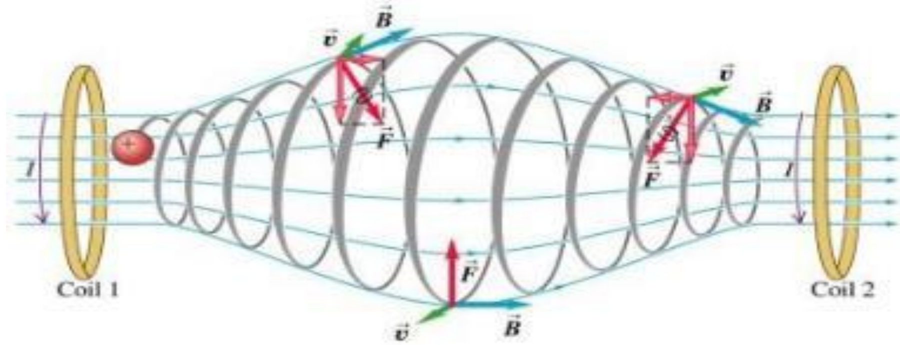


If velocity has a component along B, this component remains unchanged as the motion along the magnetic field will not be affected by the magnetic field. The motion in a plane perpendicular to magnetic field is a circular one, thereby producing a helical motion.

1.The radius of the charge particle, (when v is perpendicular to B) placed in a uniform magnetic field is given by
(a) R = mv/qB
(b) R = qB/mv
(c) R = Bqm/v
(d) R = vq/mB
2.An electron, proton, He^{+} and Li^{++} are projected with the same velocity perpendicular to a uniform magnetic field. Which one will experience maximum magnetic force?
(a) Electron
(b) Proton
(c) He^{+}
(d) Li^{++}
3.The work done by the magnetic field on the charge particle moving perpendicular to a uniform magnetic field is
(a) Zero
(b) q (v x B). S
(c) Maximum
(d) qBS/v

4.The distance moved by a charged particle along the magnetic field in one rotation, when v has a component parallel to B is
(a) 2□v cos□□q Bm
(b) 2□mvcos□□□□qB
(c) qBm/2□v cos□
(d) Bq/2□m

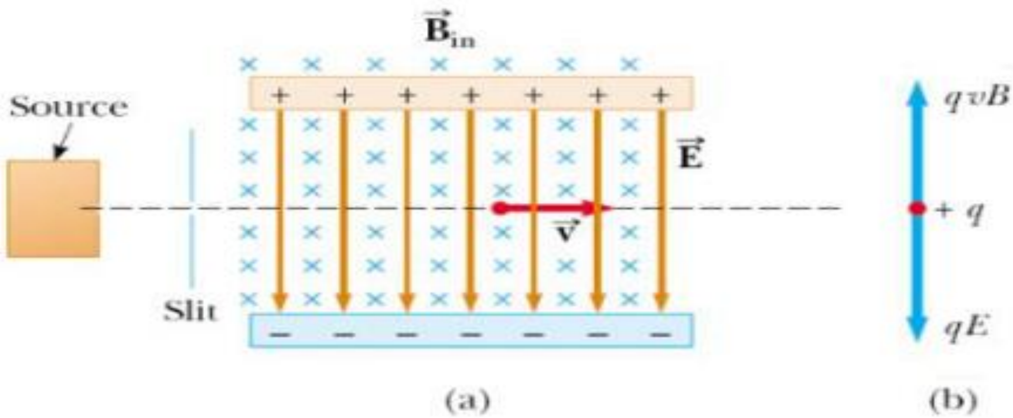
CASE 3: AURORA BOREALIS

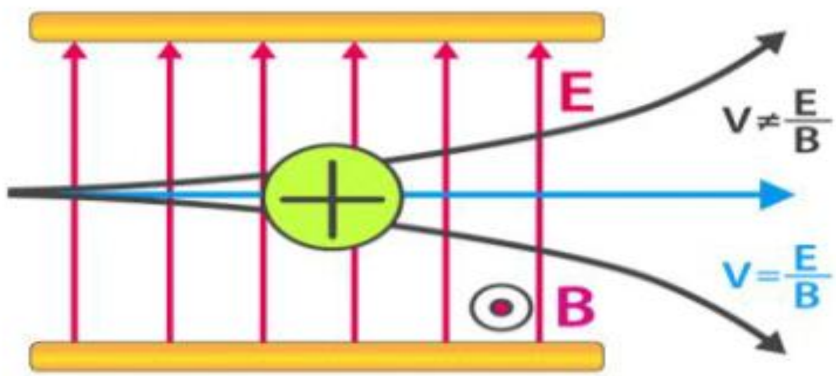


During a solar flare, a large number of electrons and protons are ejected from the sun. Some of them get trapped in the earth's magnetic field and move in helical paths along the field lines. The field lines come closer to each other near the magnetic poles, hence the density of charges increases near the poles. The particles collide with atoms and molecules of the atmosphere. Excited oxygen atoms emit green light and excited nitrogen atoms emit pink light. This phenomenon is called 'Aurora Borealis'.

1.When will the path of the particle be helix, when it is moving in external magnetic field?
(a) When v has a component parallel to B
(b) When v has a component perpendicular to B
(c) When v is parallel to B
(d) None of these
2.When the charged particle travelling in a helical path enters a region where the magnetic field is non-uniform, the pitch of helix of the charge particle will be
(a) Same as in uniform magnetic field
(b) Increases as the charge moves inside the magnetic field
(c) Decreases as the charge moves inside the magnetic field
(d) First increases then decreases as the charge moves inside the magnetic field
3.The colour of Aurora Borealis is due to
(A) Excited ozone, chromium atoms
(B) Excited Oxygen and Nitrogen atoms
© Due to presence of water vapours in the atmosphere
(C) Excited electrons and protons in the atmosphere
4.The density of magnetic field lines is greater________ on the earth
(a) At the poles
(b) Near the equator
(c) Uniform everywhere on the surface
(d) None of these

CASE 4: VELOCITY SELECTOR





A charge q moving with a velocity v in presence of both electric and magnetic fields experience a force F = q [E + v x B]. If electric and magnetic fields are perpendicular to each other and also perpendicular to the velocity of the particle, the electric and magnetic forces are in opposite directions. If we adjust the value of electric and magnetic field such that magnitude of the two forces are equal. The total force on the charge is zero and the charge will move in the fields undeflected.

1.What will be the value of velocity of the charge particle, when it moves undeflected in a region where the electric field is perpendicular to the magnetic field and the charge particle enters at right angles to the fields.
v = E/B
v = B/E
v = EB
v = EB/q

2.Proton, neutron, alpha particle and electron enter a region of uniform magnetic field with same velocities. The magnetic field is perpendicular to the velocity. Which particle will experience maximum force?

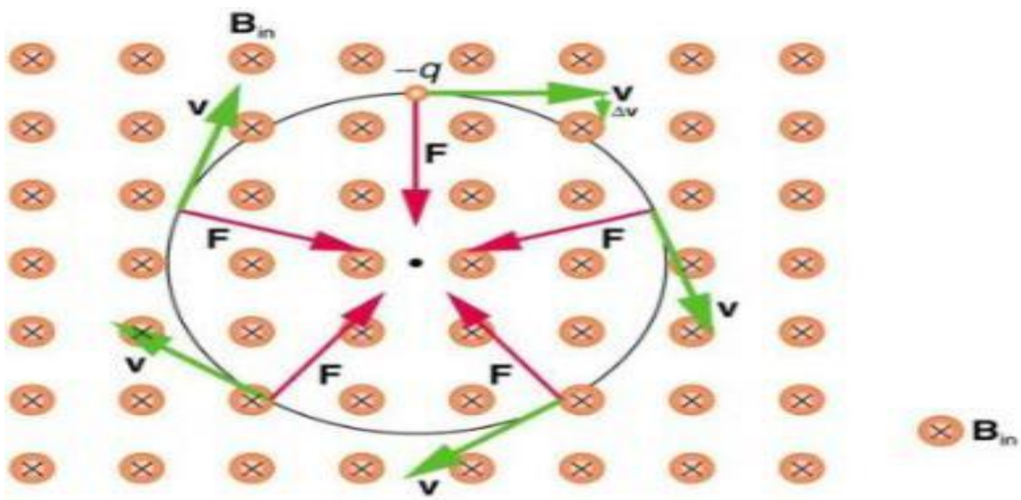
(a) proton
(b) electron
(c) alpha particle
(d) neutron

3.A charge particle moving with a constant velocity passing through a space without any change in the velocity. Which can be true about the region?
(a) E = 0, B = 0
(b) E ≠ 0, B ≠ 0
(c) E = 0, B ≠ 0
(d) All of these

4.Proton, electron and deuteron enter a region of uniform magnetic field with same electric potential-difference at right angles to the field. Which one has a more curved trajectory?

(a) electron
(b) proton
(c) deuteron
(d) all will have same radius of circular path

CASE 5: MOTION OF A CHARGED PARTICLE IN A UNIFORM MAGNETIC FIELD



A charged particle of mass m and charge q moves with a constant velocity along the positive X direction v = ai. It enters a region of magnetic field which is directed towards positive Z direction from x = a which is given by B = bk

1.The initial acceleration of the particle is

(a) a = qab/m i
(b) a =-qam/$\overline{b\ j}$
(c) a = - qa/mb j
(d) none of these

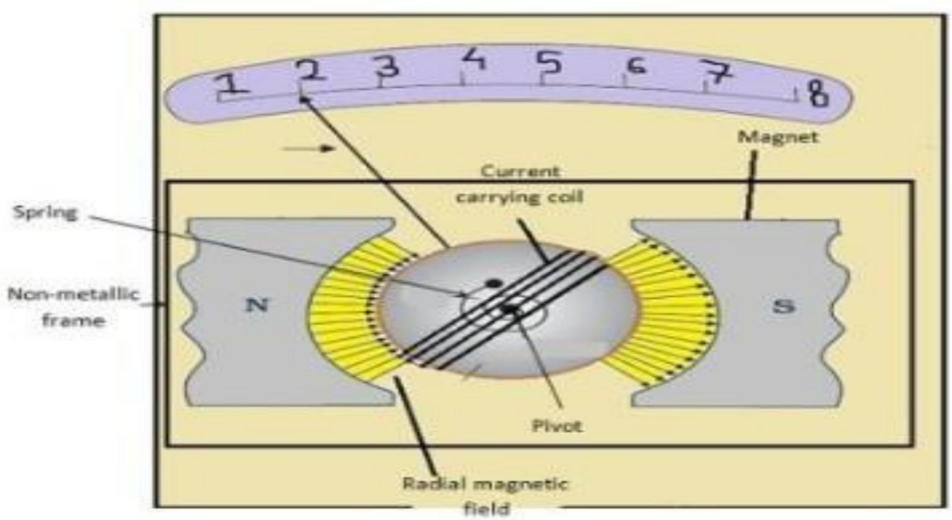
2. The radius of the circular path which the particle moves is

(a) mb/qa
(b) ma/qb
(c) mab/q
(d) None of these

3.Which of the following is true about the motion of the particle in uniform magnetic field, where the charged particle enters at right angles to the field?
(a) Force will always be perpendicular to the velocity.
(b) Kinetic energy of the particle remains constant.
(c) Velocity vector and magnetic field vector remains perpendicular to each other during the motion.
(d) All of these.

4.The frequency of the rotation
(a) depends on the value of a
(b) depends on the value of b
(c) depends on the value of a and b both
(D)does not depend on a and b

CASE 6: MOVING COIL GALVANOMETER



The galvanometer is a device used to detect the current flowing in a circuit or a small potential difference applied to it. It consists of a coil with many turns, free to rotate about a fixed axis, in a uniform radial magnetic field formed by using concave pole pieces of a magnet. When a current flows through the coil, a torque acts on it.

1.What is the principle of moving coil galvanometer?
(a) Torque acting on a current carrying coil placed in a uniform magnetic field.
(b) Torque acting on a current carrying coil placed in a non-uniform magnetic field.
(c) Potential difference developed in the current carrying coil.
(d) None of these.

2.If the field is radial, then the angle between magnetic moment of galvanometer coil and the magnetic field will be

(a) 0°
(b) 30°
(c) 60°
(d)90°

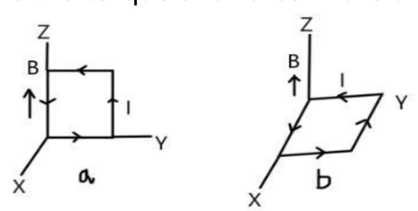
3.Why pole pieces are made concave in the moving coil galvanometer?

(a) to make the magnetic field radial.
(b) to make the magnetic field uniform.
(c) to make the magnetic field non-uniform.
(d) none of these.

4.What is the function of radial field in the moving coil galvanometer?
(a) to make the torque acting on the coil maximum.
(b) to make the magnetic field strong.
(c) to make the current scale linear.
(d) all the above.

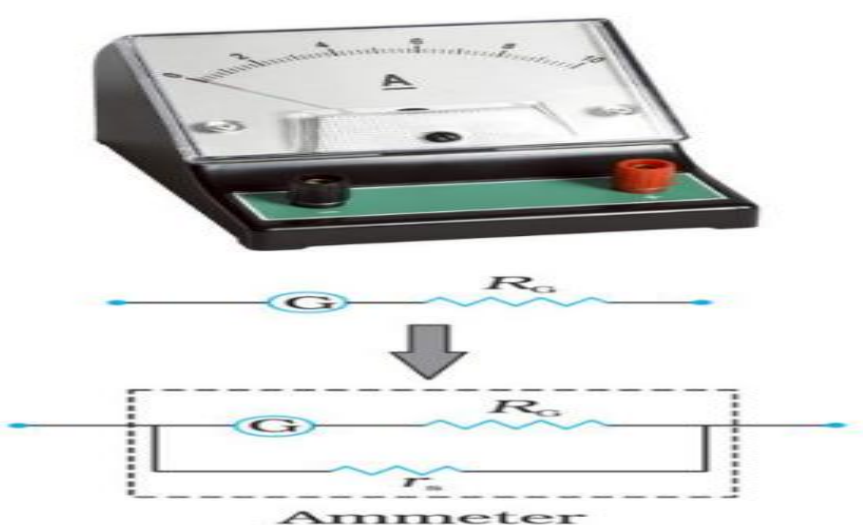
5.If the rectangular coil used in the moving coil galvanometer is made circular, then what will be the effect on the maximum torque acting on the coil in magnetic field for the same area of the coil?
(a) remains the same
(b) becomes less in circular coil
(c) becomes greater in circular coil
(d) depends on the orientation of the coil

6.What is the torque and force in the two cases as shown in the fig.?



(a) $\tau a < \tau b$, $Fa \neq 0$, $Fb \neq 0$
(b) $\tau a > \tau b$, $Fa = Fb = 0$
(c) $\tau a = \tau b = 0$, $Fa = Fb = 0$
(d) $\tau a = \tau b$, $Fa = Fb = 0$

CASE 7: CONVERSION OF MOVING COIL GALVANOMETER INTO AN AMMETER



The galvanometer cannot be used as an ammeter to measure the value of the current directly as it is a very sensitive device. It gives a full-scale deflection for current of the order of μA. For measuring currents, the galvanometer has to be connected in series, and as it has a large resistance, this will change the value of current in the circuit.

1.How is a moving coil galvanometer converted into an ammeter of desired range?
(a)Connecting a shunt resistance in series.
(b)Connecting a shunt resistance in parallel.
(c)Connecting a large resistance in series.
(d)Connecting a large resistance in parallel.

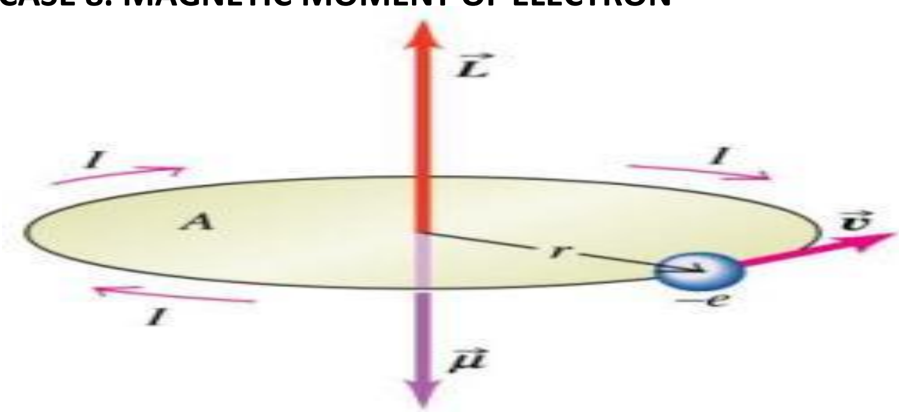
2.A moving coil galvanometer of resistance G gives a full-scale deflection for a current Ig. It is converted into an ammeter of range 0- I ampere. What should be the value of shunt resistance to convert it into an ammeter of desired range?

(a)S = $I/ I - Ig$G
(b)S = $I - Ig/ I$ G
c)S = I/ Ig G
(d)S = Ig / I G

3.Which one will have the greatest resistance – a micro-ammeter, a milli-ammeter, an ammeter?
(a)Micro-ammeter
(b)Milli-ammeter
(c)Ammeter
(d)All will have the same resistance

4.The resistance of the ammeter will be
(a) 1 = 1 + 1 _ _
a) $1/RA = 1/G + 1/S$
(b) RA = G + S
(c)RA = $G+S$ / GS
(d)None of these

CASE 8. MAGNETIC MOMENT OF ELECTRON



In the Bohr model of the Hydrogen atom, the electron revolves around a positively charged nucleus such as a planet revolves around the sun. The force which binds the electron-proton system is the electrostatic force. There will be a magnetic moment associated with this circulating current given by M = I A.

1.What will be the magnetic moment of the electron in the first orbit of H-atom?

(a) $evr/2$

(b) $ev/2r$

(c) $ev/2rm$

(d) $evr/2m$

2.The relation between magnetic moment and angular momentum for an electron revolving in the first orbit of H-atom is

(a) M = $e/2m$ L

(b) L = $e/2m$ M

(c) M = $eB/2m$ L

(d) L = $eB/2m$ M

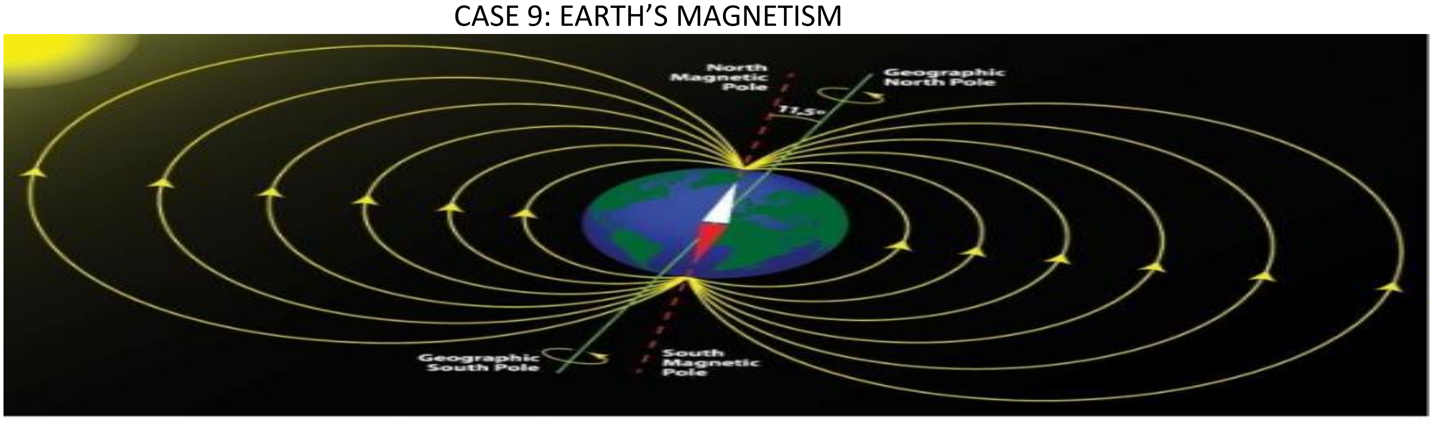
3.The angle between magnetic moment vector and angular momentum vector is

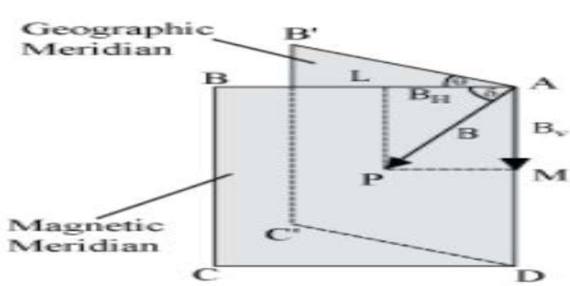
(a) 0° (b)45° (c)90° (d)180°

4.The value of gyroscopic ratio M/L

(b) depends on the value of charge
(c) is a constant quantity
(d) depends on mass of the particle
(e) depends on the axis of rotation.

CASE 9: EARTH'S MAGNETISM





The magnetic field lines of the earth resemble that of a hypothetical magnetic dipole located at the centre of the earth. The axis of the dipole does not coincide with the axis of rotation of the earth but is presently tilted by approximately 11.3° with respect to the later. If the magnetic needle is perfectly balanced about a horizontal axis so that it can swing in a plane of the magnetic meridian, the needle would make an angle with the horizontal. This is known as the angle of dip (also known as inclination).

1.What is the angle of dip at the equator?
0°
45°
60°
90°
2.At the poles, the dip needle will
(a) stay horizontal
(b) stay vertical
(c) stays at 45° angle with the horizontal
(d) does not remain steady in any fixed position
3.The angle of dip where the vertical component of the earth's magnetic field is equal to the horizontal component of the earth's magnetic field will be
(a)0°
(b)45°
(c)60°
(d)90°
Which of the following independent quantities is not used to specify the earth's magnetic field?
(a) Magnetic declination (θ)
(b) Angle of dip (δ)
(c) Horizontal component of earth's magnetic field (BH)
(d) Vertical component of earth's magnetic field (B

ANSWER KEY OF CASE-BASED QUESTIONS

CASE 1	1 (b)	2 (c)	3 (d)	4 (d)	5 (d)
CASE 2	1 (a)	2 (d)	3 (a)	4 (b)	5
CASE 3	1 (a)	2	3 (b)	4 (a)	5
CASE 4	1 (a)	2 (c)	3 (d)	4 (a)	5
CASE 5	1 (a)	2 (b)	3 (d)	4 (b)	5
CASE 6	1 (a)	2 (d)	3 (a)	4 (d)	5 (a) 6 (b)
CASE 7	1 (b)	2 (a)	3 (a)	4 (a)	5
CASE 8	1 (a)	2 (a)	3 (d)	4 (b)	5
CASE 9	1 (a)	2 (b)	3 (b)	4 (d)	5

VERY SHORT QUESTION (two marks) .

Q1 A proton and an alpha particle of the same enter, in turn, a region of uniform magnetic field acting perpendicular to their direction of motion. Deduce the ratio of the radii of the circular paths described by the proton and alpha particle.

Ans $r(n) = \frac{mv}{Bq}$ and $r(\alpha) = \frac{4mv}{B2q} = 2\frac{mv}{Bq}$ →r(α)=2r(n)

Q2 What will be (i) Pole strength (ii) Magnetic moment of each of new piece of bar magnet if the magnet is cut into two equal pieces

(a) normal to its length?

(b)along its length?

Ans (a) Pole strength same; magnetic moment half.

(b) pole strength half; magnetic moment half.

Q3 How will the magnetic filed intensity at the centre of a circular coil carrying current change if the current through the coil is doubled and the radius of the coil is halved.

Ans: $B = \frac{\mu_0 n\, 2I}{2\,(R/2)}$

Q4 A charged particle of mass 5 mg and charge q = 2 μC has velocity **v**= 2**i** – 3**j** + 4**k**. Find out the magnetic force on the charged particle and its acceleration at this instant due to the magnetic field **B** = 3**j** – 2 are in Wb/sq. m and m/s respectively.

Ans. $a = \frac{F}{m} = \frac{q(\vec{v}\, x\, \vec{\boldsymbol{B}})}{m}$ =0.8 (-3**i** +2**j** +3**k**) m/s^2 .

Q 5 Out of Voltmeter and Milli voltmeter, which has the higher resistance?

Ans: We know the resistance connected to galvanometer to convert it into voltmeter is

R = (V / Ig) - G

So if R is higher, range of V will also be higher, so a Voltmeter has the higher resistance.

Q6 Two long straight wires are set parallel to each other. Each carries a current I in the same direction and the separation between them is 2r. What is the intensity of the magnetic field midway between them?

Ans: The fields of the two wires will be in the opposite directions at the midway point.

$B = B_1 - B_2 = \mu_0 I/2\pi r - \mu_0 I/2\pi r = 0$

Q7 A solenoid of length 0.6m has a radius of 1cm and is made up of 600 turns.It carries a current of 5A.What is the magnetic field inside and at ends of solenoid.?

Ans- (i)At the centre

n=1000, $B = \mu_0 nI = 4\pi \times 10^{-7} \times 1000 \times 5 = 6.2 \times 10^{-3}$ T

(ii) At the ends

B = . $\mu 0\, ni = 3.1 \times 10^{-3}$ T

Q8 What is the magnetic field produced at the centre of curvature of an arc of wire of radius r carrying current I subtends an angle π /2radians at its centre.

Ans: $B_1 = B \times \theta / 2\pi = \frac{\mu 0\, I}{2r} \frac{\pi}{2\pi \times 2}$

$B_1 = \mu_0 I/8r$

Q9 Which of the following will experience maximum force, when projected with the same velocity v perpendicular to the field(1)α- particle, and (2)β-particle.

Ans $F = qvb \sin 90^o = qvb$

α- particle=2e F_α=2evB

β - particle=e F_β =evB

SHORT QUESTION (three marks)

Q1 At a place horizontal component of the earths magnetic field is B and angle of dip at the place is 60°. What is the value of horizontal component of the earths magnetic field. (i) at Equator (ii)If horizontal and vertical component of earth's magnetic field are equal at a place, find the angle of dip.

Ans (i)0

(ii)$B_v = B_h$

$\tan\delta = B_v / B_h$

so, $\delta = 45^o$

Q2 (a)state two properties of the material of the wire used for suspension of the coil in a moving coil galvanometer.

(b)The coils, in certain galvanometer have fixed core made of a non-magnetic material. Why does the oscillating coil come to rest so quickly in such core?

Ans (a) i)small torsion constant K

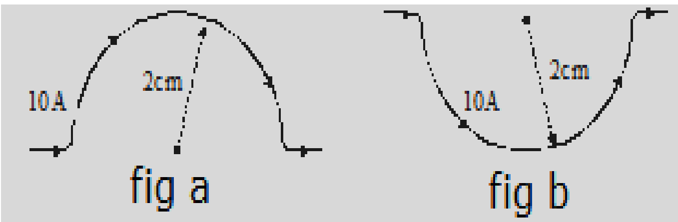
ii)High tensile strength

(b) The eddy current set up in the metallic material oppose the motion

Q3 A galvanometer of resistance 120 gives full scale deflection for a current of 5mA. How can it be converted into an ammeter of range 0 to 5A? Also determine the net resistance of the ammeter

Ans $S = \frac{Ig}{I - Ig} G$ =0.12Ω

Q4 A current of 10A flows through a semicircular wire of radius 2cm as shown in figure (a). What is direction and magnitude of the magnetic field at the centre of semicircle? Would your answer change if the wire were bent as shown in figure (b)?



Ans a) 5×10^{-5} outward

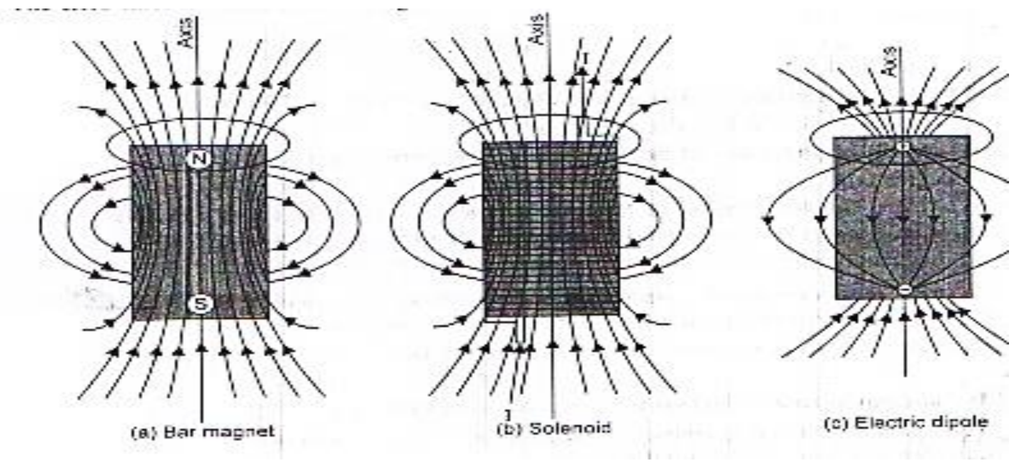
b) a) 5×10^{-5} inward.

Q5 draw field line produce by

(a) a bar magnet.

(b) A solenoid

(c) And a electric dipole



Q6. A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its north tip down at 60° with the horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.4 G. Determine the magnitude of the earth's magnetic field at the place.

Ans $B_h = B\cos\theta$

$B = B_h/\cos 60$

$= 0.8G$

Q7. In a chamber of a uniform magnetic field 6.5G is maintained. An electron is shot into the field with a speed of $4.8 \times 10^6\ ms^{-1}$ normal to the field. Explain why the path of electron is a circle.

(a) Determine the radius of the circular orbit ($e = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg)

(b) Obtain the frequency of resolution of the electron in its circular orbit.

Ans : (a) $r = \frac{m_e v}{eB} = \frac{9.1\times10^{-31}\times4.8\times10^{6}}{1.6\times10^{-19}\times6.5\times10^{-4}} = 4.2\,cm$

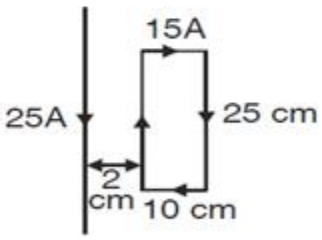
(b) frequency $\nu = \frac{1}{T} = \frac{eB}{2\pi m_e} \frac{1.6\times10^{-19}\times6.510^{-4}}{2\times3.14\times9.1\times10^{-31}} = 1.8\ MH_2$

Q8 A rectangular loop of sides 25 cm and 10 cm carrying current of 15A is placed with its longer side parallel to a long straight conductor 2.0 cm apart carrying a current of 25A. What is the new force on the loop?

Ans : 7.82×10^{-4} N towards the conductor

Ans : $F_2 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r_2}\times\ell = \frac{10^{-7}\times2\times25\times15\times0.25}{0.12} = 1.56\times10^{-4}\,N\,repalsive$

Net $F = F_1 - F_2 = 7.82 \times 10^{-4}$ N



Q9. A long wire is first bent into a circular coil of one turn and then into a circular coil of smaller radius having n turns. If the same current passes in both the cases, find the ratio of the magnetic fields produced at the centres in the two cases.

Ans : When there is only one turn, the magnetic field at the centre,

$B = \frac{\mu_0 I}{2a}$

$2\pi a^1 x n = 2\pi a \Rightarrow a^1 = a/n$

The magnetic field at its centre, $B_1 = \frac{\mu_0 n I}{2a/n} = \frac{\mu_0 n^2 I}{2a} = n^2 B$

The ratio is, $B_1/B = n^2$

Q10 Two moving coil galvanometers, M_1 and M_2 have the following specifications.

$$R_1 = 10\Omega,\ N_1 = 30,\ A_1 = 3.6 \times 10^{-3} m^2,\ B_1 = 0.25T$$

$$R_2 = 14\Omega,\ N_2 = 42,\ A_2 = 1.8 \times 10^{-3} m^2,\ B_2 = 0.50T$$

Given that the spring constants are the same for the two galvano meters, determine the ratio of (a) current sensitivity (b) voltage sensitivity of M_1 & M_2.

Ans (a) Current sensitivity, $\frac{\phi}{I} = \frac{NBA}{K}$

Ratio of current Sensitivity = $\left(\frac{N_1 B_1 A_1}{K}\right) / \left(\frac{N_2 B_2 A_2}{K}\right)$

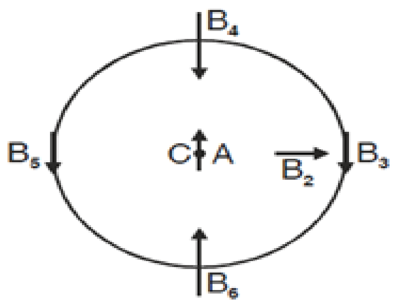
$$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3}}{42 \times 0.50 \times 1.8 \times 10^{-3}} = 5/7$$

(b) Voltage sensitivity, $\frac{\phi}{V} = \frac{NBA}{kR}$

Ratio of voltage sensitivity $= \left(\frac{N_1 B_1 A_1}{kR_1}\right) / \left(\frac{N_2 B_2 A_2}{kR_2}\right)$

$$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3} \times 14}{42 \times 0.50 \times 1.8 \times 10^{-3} \times 10} = 1$$

Q11 In the given diagram, a small magnetised needle is placed at a point O. The arrow shows the direction of its magnetic moment. The other arrows shown different positions and orientations of the magnetic moment of another identical magnetic needs B



(a) In which configuration is the systems not in equilibrium?

(b) In which configuration is the system.

(i) stable and (ii) unstable equilibrium?

Ans (a) For equilibrium, the dipole moment should be parallel or auto parallel to B. Hence, AB_1 and AB_2 are not in equilibrium.

(b) (i) for stable equilibrium, the dipole moments should be parallel, examples : AB_5 and AB_6 (ii) for unstable equilibrium, the dipole moment should be anti parallel examples : AB_3 and AB_4

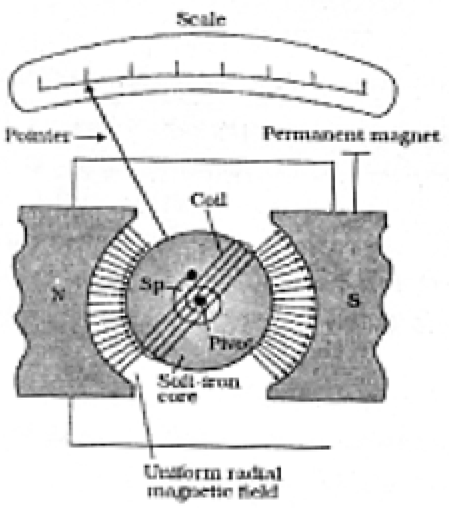
(c) Potential energy is minimum when angle between M and B is 0°, *i.e,* $U = -MB$ Example : AB_6

LONG QUESTION (FIVE marks)

Q1. (a) With the help of a diagram, explain the principle and working of a moving coil galvanometer.

(b) What is the importance of a radial magnetic field and how is it produced ?

(c) Why is it that while using a moving coil galvanometer as a voltmeter a high resistance in series is required whereas in an ammeter a shunt is used ?



1

Principle: Torque acts on the current carrying loop when placed in magnetic field. ($\tau = NIAB\sin\theta$.) 1

Working: The magnetic torque tends to rotate the coil. A spring provides a counter torque that balances the magnetic torque; resulting in a steady angular deflection. The deflection is indicated on the scale by a pointer attached to the spring. 1

Importance and production of radial magnetic field:

In a radial magnetic field magnetic torque remains maximum for all positions of the coils. 1

It is produced due to cylindrical pole pieces and soft iron core.

Reason:

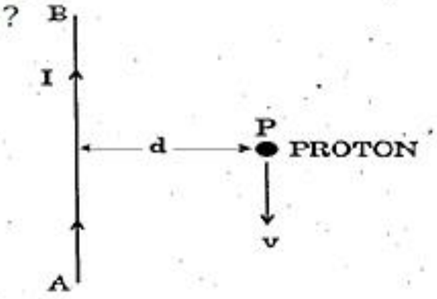
Voltmeter: This ensures that a very low current passes through the voltmeter and hence does not change (much) the original potential difference to be measured. ½

Ammeter: This ensures that the total resistance of the circuit does not change much and the current flowing remains (almost) at its original value. ½

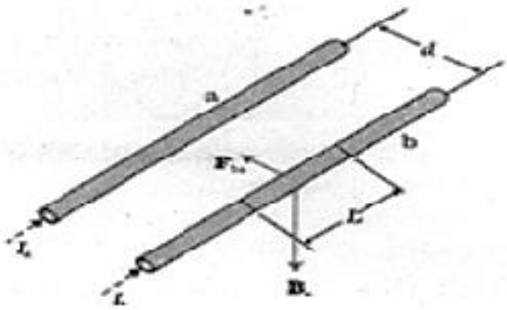
Q2. (a) Derive an expression for the force between two long parallel current carrying conductors.

(b) Use this expression to define S.I. unit of current.

(c) A long straight wire AB carries a current I. A proton P travels with a speed v, parallel to the wire, at a distance d from it in a direction opposite to the current as shown in the figure. What is the force experienced by the proton and what is its direction ?



(a)



½

Two long parallel conductors 'a' and 'b' are separated by a distance d and carry (parallel) currents I_a and I_b, respectively. The conductor 'a' produces, the same magnetic field $\mathbf{B}_a$ at all points along the conductor 'b'. 1

$$B_a = \frac{\mu_0 I_a}{2\pi d}$$

$\mathbf{F}_{ba}$, is the force on a segment L of 'b' due to 'a'. The magnitude of this force is given by ½

$$F_{ba} = I_b L B_a$$ ½

$$= \frac{\mu_0 I_a I_b}{2\pi d} L$$

(b) The ampere is the value of that steady current which, when maintained in each of the two very long, straight, parallel conductors of negligible cross-section, and placed one metre apart in vacuum, would produce on each of these conductors a force equal to 2×10^{-7} newton per metre of length. 1

(c) Magnetic field due to the straight wire AB at a perpendicular distance d from it. ½

$$B = \frac{\mu_0 I}{2\pi d}$$

Therefore, force on proton moving with velocity 'v' perpendicular to B, is

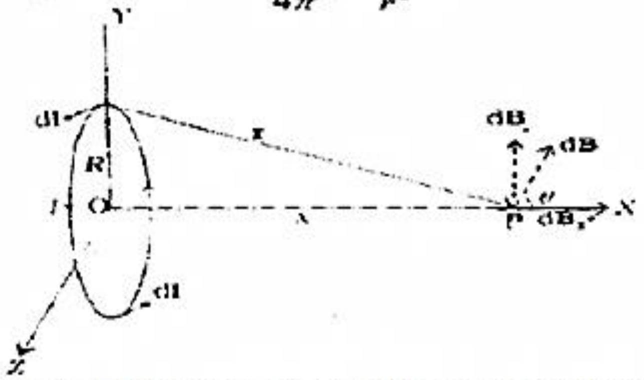
$$F = qvB = \frac{\mu_0 I q v}{2\pi d}$$ 1

Direction : Towards right ½

Q3. State Biot-Savart law, giving the mathematical expression for it.
Use this law to derive the expression for the magnetic field due to a circular coil carrying current at a point along its axis.
How does a circular loop carrying current behave as a magnet ?

Statement of Biot Savart Law : The magnitude of magnetic field $d\vec{B}$ due to current element is directly proportional to the current I, the element length $|dl|$ and inversely proportional to the square of the distance r of the field point. Its direction is perpendicular to the plane containing $d\vec{\ell}$ and $\vec{r}$ ½

$d\vec{B} \; \alpha \; \frac{Id\vec{l} \times \vec{r}}{r^3}$ Or $d\vec{B} = \frac{\mu_o}{4\pi} \frac{Id\vec{l} \times \vec{r}}{r^3}$



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The magnetic field due to dl is given by Biot Savart law as

$$dB = \frac{\mu_0}{4\pi} \frac{I\,|d\vec{l} \times \vec{r}\,|}{r^3}$$

Now $dB_x = dB \text{ Cos}\theta = \frac{\mu_0}{4\pi} \frac{Idl}{(x^2+R^2)} \cos\theta = \frac{\mu_0}{4\pi} \frac{Idl}{(x^2+R^2)} \frac{R}{(x^2+R^2)^{1/2}}$

So $B_x = \int dB_x = \frac{\mu_0}{4\pi} \frac{IR}{(x^2+R^2)^{3/2}} \int_{entireloop} dl$ 1

$= \frac{\mu_0}{4\pi} \frac{IR}{(x^2+R^2)^{3/2}} 2\pi R = \frac{\mu_0 IR^2}{2(x^2+R^2)^{3/2}}$ 1

(The y-components, of the field, add up to zero, due to symmetry)

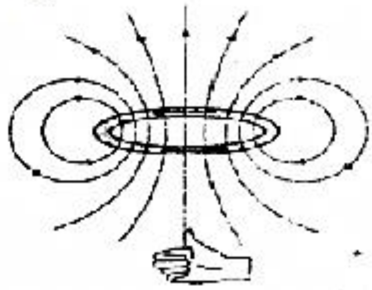
∴ Magnetic field at P due to a circular loop

$= \vec{B} = B_x \,\vec{i} = \frac{\mu_0 IR^2}{2(x^2+R^2)^{3/2}} \vec{i}$

Explanation : A circular current loop produces magnetic field and its magnetic moment is the product of current and its area 1

$\vec{M} = I\vec{A}$

Alternatively

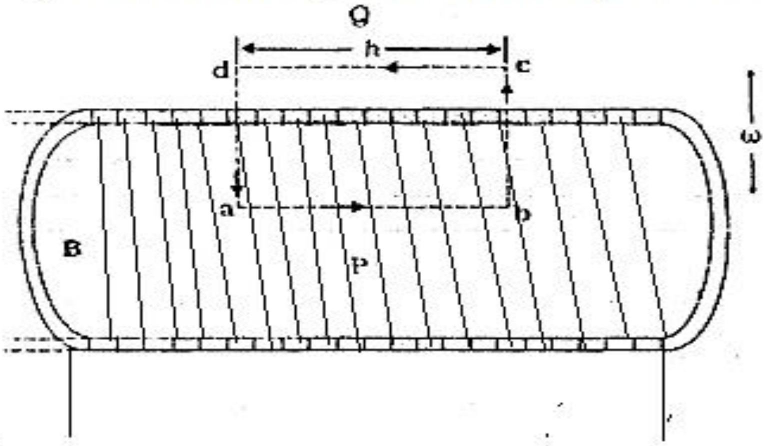


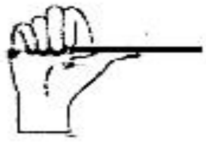
Alternatively : One side of the current carrying coil behaves like the N-Pole and the other side as the S-Pole of a magnet. 1

Q5. a) Using Ampere's circuital law, obtain the expression for the magnetic field due to a long solenoid at a point inside the solenoid on its axis.

(b) In what respect is a toroid different from a solenoid ? Draw and compare the pattern of the magnetic field lines in the two cases.

(c) How is the magnetic field inside a given solenoid made strong ?





1

$$\oint \vec{B}.d\vec{l} = \mu_0 \Sigma i$$

$$\int_a^b \vec{B}.d\vec{l} + \int_b^c \vec{B}.d\vec{l} + \int_c^d \vec{B}.d\vec{l} + \int_d^a \vec{B}.d\vec{l} = \mu_0 I(nh)$$ ½

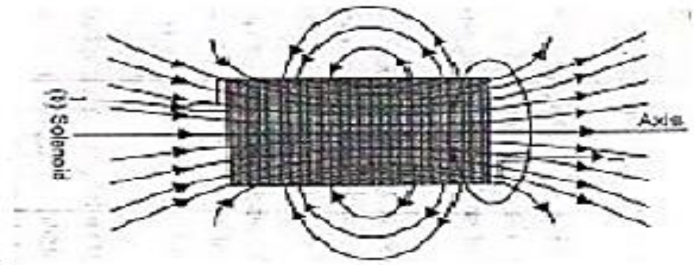
$Bh+0+0+0 = \mu_0 I(nh)$

$B = \mu_0 nI$ ½

b) (Any one difference ~ In a toroid, magnetic lines do not exist outside the body. 1

→ Toroid is closed whereas the solenoid is open on both sides

→ Magnetic field is uniform inside a toroid whereas for 'solenoid, it is different at the two ends and centre.



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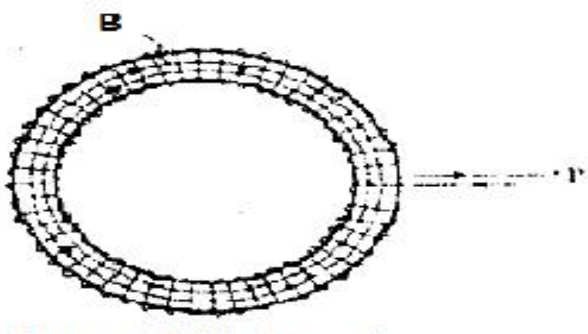


½

Strengthing of magnetic field: (Any one)

- By inserting a ferromagnetic substance inside the solenoid
- By increasing the amount of current through the solenoid 1

SELF-ASSESSMENT TEST

Max. marks: 30 **Time allowed: 1 hour**

1. Choose and write the correct option in the following questions. (3x1=3)

(i) A current loop in a magnetic field
(a) can be in equilibrium in two orientations, both the equilibrium states are unstable.
(b) can be in equilibrium in two orientations, one is stable while other is unstable
(c) experiences a torque whether the field is uniform or non uniform in all orientations.
(d) can be in equilibrium in one orientation.

(ii) two circular coils I and 2 are made of the same wire but the radius of the first coil is twice that of the second coil. What ratio of' the potential deference (in volt) should be applied across then), so that the magnetic field at their centre is the same?

(a) 2
(b) 3
(c) 4
(d) 6

(iii) Current sensitivity of a moving coil galvanometer is 5 div/mA and its voltage sensitivity (angular deflection per unit voltage applied) is 2() div/ V. The resistance of the galvanometer is

(a) 40 Ω
(b) 25 Ω
(c) 250 Ω
(d) 500 Ω

In the following questions a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices. **(2x1=2)**

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
(c) Assertion is correct statement but reason is wrong statement.
(d) Assertion is wrong statement but reason is correct statement.

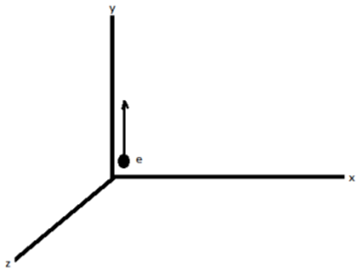
Assertion :Magnetic moment of an atom is due to both the orbital motion and spin motion of every electron.
Reason :A charged particle produces a magnetic field.

Assertion : When radius of circular loop carrying current is doubled, its magnetic moment becomes four times
Reason: Magnetic moment depends on area of the loop.

3. Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current. 1

4.Define one tesla using the expression for the magnetic force acting on a particle of charge 'q' moving with velocity v in a magnetic field B 1

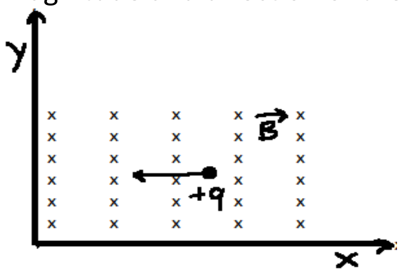
5.A beam of electrons projected along +x-axis, experiences a force due to a magnetic field along the +y-axis.



What is the direction of the magnetic field?

1

6. A point charge is moving with a constant velocity perpendicular to a uniform magnetic field as shown in the figure. What should be the magnitude and direction of the electric field so that the particle moves un



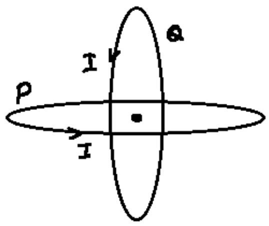
deviated along the same path?

2

7, (a) Obtain the conditions under which an electron does not suffer any deflection while through a magnetic field.

(b)Two proton P and Q moving with the same speed pass through the magnetic fieldsB1 and B2 at right angles to the field directions. If IB21 > IBI l, which of the two the proton will describe circular path of smaller radius? Explain.

8. Two identical coils P and Q each of' radius R are lying in perpendicular planes such that they have a common centre. Find the magnitude and direction of the magnetic field at the common centre when they



carry currents equal (I and1.732 I respectively).

9.(a) Derive the expression the torque on a rectangular current carrying loop suspended in a uniform magnetic field.

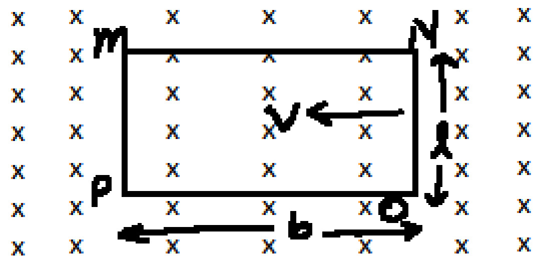
(b) A proton and a deuteron having equal momenta enter in a region of uniform magnetic field at right angle to the direction of the field. Depict their trajectories in the field.

10.A rectangular loop of of size 2 cm x 5 cm carries a steady current of I A. A straight Ion carrying 4 A current is kept near the loop as shown in the figure. If the loop and the wire are coplanar, find (i) the torque acting on the loop and (ii) the magnitude and direction of the force on the loop due to current carrying wire.

11.A proton, a deuteron and an alpha particle, are accelerated through the same potential difference and then subjected to a uniform magnetic field B , perpendicular to the direction of their motions. Compare (i) their kinetic energies, and (ii) if the radius of the circular path described by proton is 5 cm, determine the radii of the paths described by deuteron and alpha particle. 3

12.State the principle of a moving coil galvanometer. Explain its working and obtain the expression the deflection produced due to the current passed through the coil. Define current sensitivity.

13.The figure shows a rectangular conducting frame MNOP of resistance R placed partly in , perpendicular magnetic field B and moved with velocity V as shown in the figure.



Answers

1.(i) a (ii) (c) (iii) (c)

2. (i) c (ii) (b)

10. Torque = O, FI = 1.6 x 10 $^{-5}$ N

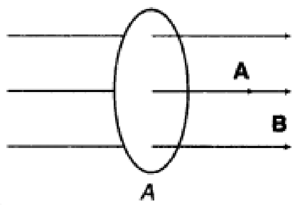
UNIT-IV

6. ELECTROMAGNETIC INDUCTION

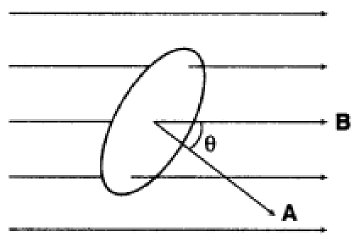
7. ALTERNATING CURRENT

Quick Revision Notes

1. **Magnetic Flux** The magnetic flux linked with any surface is equal to total number of magnetic lines of force passing normally through it. It is a scalar quantity.
   Suppose, we consider small area dA in field B, then $\phi = \int \mathbf{B} \cdot d\mathbf{A}$



Magnetic flux, $\phi = BA$ = Maximum value



Magnetic flux, $\phi = BA$ $\quad \theta = \mathbf{B} \cdot \mathbf{A}$

   SI unit of magnetic flux is Weber (Wb).
   CGS unit of magnetic flux is Maxwell (Mx).

$$1 \text{ Wb} = 10^8 \text{ Mx} = 1 \text{ Tm}^2$$

   Magnetic flux is a scalar quantity and its dimensional formula is $[ML^2T^{-2}A^{-1}]$.

2. **The phenomenon** of generation of current or emf by changing the magnetic flux is known as Electromagnetic Induction EMI).

3. **Faraday's Law of Electromagnetic Induction**
   First Law Whenever magnetic flux linked with the closed loop or circuit changes, an emf induces in the loop or circuit which lasts so long as change in flux continuous.
   Second Law The induced emf in a closed loop or circuit is directly proportional to the rate of change of magnetic flux linked with the closed loop or circuit
   i.e.
$$e \propto \frac{(-)\,\Delta\phi}{\Delta t} \quad \Rightarrow \quad e = -N\,\frac{\Delta\phi}{\Delta t}$$
   where, N = number of turns in loop.
   Negative sign indicates the Lenz's law.

4. **Lenz's Law** The direction of induced emf or induced current is such that it always opposes the cause that produce it.
   NOTE: Lenz's law is a consequence of the law of conservation of energy.

5. If N is the number of turns and R is the resistance of a coil. The magnetic flux linked with its each turn changes by dΦ in short time interval dt, then induced current flowing through the coil is

$$I = \frac{|e|}{R} = -\frac{1}{R}\left(N\frac{\Delta\phi}{\Delta t}\right)$$

6. **If induced current** is produced in a coil rotated in a uniform magnetic field, then

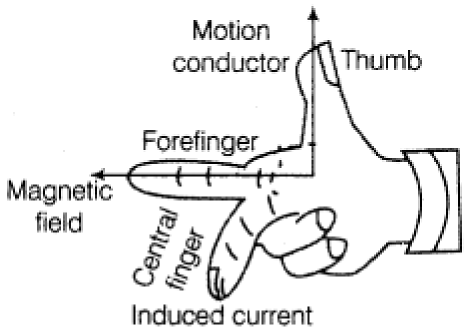
$$I = \frac{NBA\omega \sin \omega t}{R} = I_0 \sin\omega t$$

where, $I_0 = \frac{NBA\omega}{R}$ = Peak value of induced current

7. **Motional Emf** The potential difference induced in a conductor of length l moving with velocity v, in a direction perpendicular to magnetic field B is given by

$$\varepsilon = \int(\mathbf{v}\times\mathbf{B}).d\mathbf{l} = vBl$$

8. **Fleming's Right Hand Rule** If the thumb, forefinger and middle finger of right hand are stretched mutually perpendicular to each other such that the forefinger points the direction of magnetic field, thumb points towards the direction of magnetic force, then middle finger points towards the direction of induced current in the conductor.



9. **The induced emf** developed between two ends of conductor of length l rotating about one end with angular velocity ω in a direction perpendicular to magnetic field is given by,

$$\varepsilon = \frac{B\omega l^2}{2}$$

10. **The induced emf can be produced in a coil by**

(i) putting the coil/loop/circuit in varying magnetic field.

(ii) changing the area A of the coil inside the magnetic field,

(iii) changing the angle 0 between B and A.

11. Rotation of rectangular coil in a uniform magnetic Field:

Magnetic flux linked with coil

$$\phi = BAN \cos\theta$$

$$= BAN \cos\omega t$$

a) Induced emf in the coil

$$E = (d\phi/dt)$$

$$= BANw\ sinwt$$

$$= E_0\ sinwt$$

b) Induced current in the coil.

$$I = \frac{E}{R} = \frac{BAN\omega}{R} \sin \omega t$$

$$= \frac{E_0}{R} \sin \omega t$$

c) Both Emf and current induced in the coil are alternating

12. Self Induction and Self inductance:

a) The phenomenon in which an induced emf is produced by changing the current in a coil is called self in induction.

$$\phi \propto I \quad \text{or} \quad \phi = LI$$

$$\text{or } L = \frac{\phi}{I}$$

$$E = -L \frac{dI}{dt}$$

$$L = \frac{E}{-(dI/dt)}$$

where L is a constant, called self inductance or coefficient of self – induction.

b) Self inductance of a solenoid

$$L = \frac{\mu_0 N^2 A}{l}$$

13. Mutual Induction and Mutual Inductance:

(a) On changing the current in one coil, if the magnetic flux linked with a second coil changes and induced emf is produced in that coil, then this phenomenon is called mutual induction.

$$\phi_2 \propto I_1 \quad \text{or} \quad \phi_2 = MI_1$$

$$\text{Or} \quad M = \frac{\phi_2}{I_1}$$

$$E_2 = -\frac{d\phi_2}{dt} = -M\frac{dI_1}{dt}$$

$$M = \frac{E_2}{-(dI_1/dt)}$$

Therefore, $M_{12} = M_{21} = M$

(b) Mutual inductance two coaxial solenoids

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

(c) If two coils of self- inductance L_1 and L_2 are wound over each other, the mutual inductance is,

$$M = K\sqrt{L_1 L_2}$$

Where K is called coupling constant.

(d) Mutual inductance for two coils wound in same direction and connected in series

$$L = L_1 + L_2 + 2M$$

(e) Mutual inductance for two coils wound in opposite direction and connected in series

$$L = L_1 + L_2 - 2M$$

(f) Mutual inductance for two coils in parallel

$$L = (L_1 L_2 - M^2) / L_1 + L_2 \pm 2M$$

- ## Eddy Current:

When a conductor is moved in a magnetic field, induced currents are generated in the whole volume of the conductor. These currents are called eddy currents.

1. **Alternating Current (AC)** It is the current which varies in both magnitude as well as direction alternatively and periodically.
$I = I_0 \sin \omega t$ or $I = I_0 \cos\omega t$ where, I_0 = peak value or maximum value of AC.

2. **Effective Value or rms Value of AC** It is defined as the value of AC over a complete cycle which would generate same amount of heat in a given resistors that is generated by steady current in the same resistor and in the same time during a complete cycle.

$$I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707 I_0$$

The 70.7% of peak value of current gives effective or rms value of AC.

3. **Average or Mean Value of AC** It is defined as the value of AC which would send same amount of charge through a circuit in half-cycle that is sent by steady current in the same time.

$$I_{av} = \frac{2I_0}{\pi} = 0.637 I_0$$

The 63.7% of peak value of AC gives average or mean value of AC.
NOTE: In a complete cycle of AC, the mean value of AC will be zero

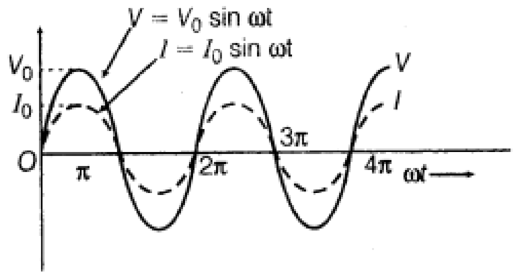
4. .**Alternating emf or Voltage** It is the emf which varies in both magnitude as well as direction alternatively and periodically. The instantaneous alternating emf is given by

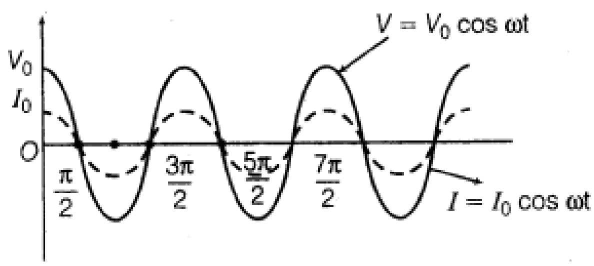
$$V = V_0 \sin \omega t \quad \text{or} \quad V = V_0 \cos \omega t$$

$$V_{rms} = \frac{V_0}{\sqrt{2}} = 0.707 \quad \text{or} \quad V_{rms} = 70.7\% \text{ of } V_0$$

$$V_{av} = \frac{2V_0}{\pi} = 0.637 \quad \text{or} \quad V_{rms} = 63.7\% \text{ of } V_0$$

Both AC voltage and AC current are represented by diagrams as shown below:





5. Inductive Reactance (X_L) The opposing nature of inductor to the flow of current is called Inductive reactance.

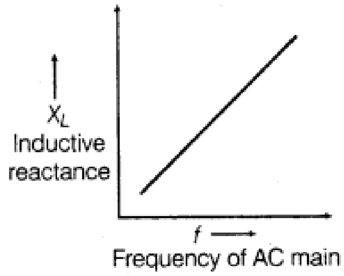
$$X_L = \omega L = 2\pi f L$$

Also for a given inductor, $X_L = (2\pi L)\, f$

$\Rightarrow$ $X_L \propto f$

$\because$ $2\pi L$ = constant

where, L = self-inductance.



6. Capacitive Reactance (X_c) The opposing nature of capacitor to the flow of alternating current is called capacitive reactance.

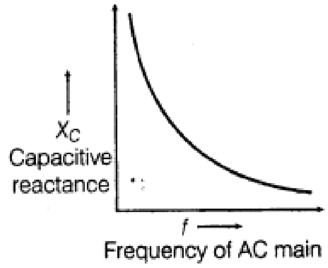
$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

For a given capacitor, $X_C = \left(\frac{1}{2\pi C}\right) \cdot \frac{1}{f}$

$\Rightarrow$ $X_C \propto \frac{1}{f}$

$\because$ $\frac{1}{2\pi C}$ = constant

where, C = capacitance.



a) For L -C-R series circuit:

$$Z_{LCR} = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

And

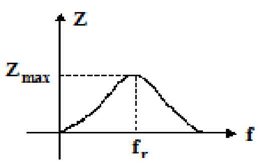
$$\tan\phi = \left(\frac{WL - {}^1/_{WC}}{R}\right)$$

- Series Resonant Circuit

a) When the inductive reactance (XL) becomes equal to the capacitive reactance (XC) in the circuit, the total impedance becomes purely resistive (Z=R).

b) In this state, the voltage and current are in same phase (ϕ = 0), the current and power are maximum and impedance is minimum. This state is called resonance.

c) At resonance, Impedance of the circuit is maximum



7. Conductance:

Reciprocal of resistance is called conductance.

G = 1/R (mho)

8. Power In an AC circuit, both emf and current change continuously w.r.t. time, so in circuit, we have to calculate average power in complete cycle (0 –> T).

$$P_{av} = V_{rms} I_{rms} \cos\phi$$

where, $\cos\phi$ = power factor.

9. Average power consumption in pure inductive and pure capacitive circuit is equal to zero because

$$\text{Phase difference, } \phi = \frac{\pi}{2}$$

$$\Rightarrow \quad \text{Power factor} = \cos\frac{\pi}{2} = 0$$

$$\therefore \quad P_{av} = 0$$

10. Generator or Dynamo:

It is a device by which mechanical energy is converted into electrical energy. It is based on the principle of electromagnetic induction.

- ### Different Types of Generator:

a) AC Generator

It consists of field magnet, armature, slip rings and brushes.

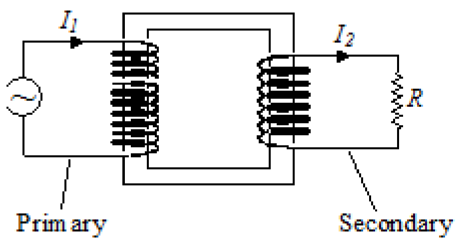
b) DC Generator

It consists of field magnet, armature, commutator and brushes.

11. Transformer:

a) It is a device which changes the magnitude of alternating voltage or current.

Works on principle of Mutual induction



b) For ideal transformer:

$$E_s / E_p = n_s / n_p = I_p / I_s = K$$

c) In an ideal transformer:

$E_p I_p$ □ $E_s I_s$

d) In step – up transformer:

$n_s > n_p$ or $K > 1$

$E_s > E_p$ and $I_s < I_p$

e) In step – down transformer:

$n_s < n_p$ or $K < 1$

$E_s < E_p$ and $I_s > I_p$

f) Efficiency

$$\eta = \frac{E_s I_s}{E_p I_p} x100\%$$

UNIT-IV
6. ELECTROMAGNETIC INDUCTION
7. AND ALTERNATING CURRENT

ASSERTION (A) & REASONING (R) QUESTIONS

Of the following statements, mark the correct Answers as-
A - if both **Assertion** and **Reason --** are true and **Reason --** is correct explanation of the Assertion.
B - if both **Assertion** and **Reason --** are true but **Reason --** is not correct explanation of Assertion.
C - if **Assertion** is true but **Reason --** is false.
D - if both **Assertion** and **Reason --** are false.
E - if **Assertion** is false but **Reason --** is true

1. **Assertion**-- The mutual induction of two coils is doubled, if the self-inductance of the primary or secondary coil is doubled
   Reason -- Mutual induction is proportional to self-inductance of primary and secondary coils.

2. **Assertion**- Making and breaking of current in a coil produce no momentary current in the neighboring coil of another circuit
   Reason -- Momentary current in the neighboring coil of another circuit is an eddy current.

3. **Assertion**- If primary coil is connected by voltmeter and secondary coil by ac source. If large copper sheet is placed between two coils, induced emf in primary coil is reduced
   Reason -- Copper sheet between coils has no effect on induced emf in primary coil

4. **Assertion** - An electric motor will have maximum efficiency when back emf becomes equal to half of applied emf
   Reason -- Efficiency of electric motor depends only on magnitude of back emf.

5. **Assertion**- Armature current in DC motor is maximum when the motor has just started
   Reason -- Armature current is given by I = (E-e)/R where e is back emf, R is resistance of armature

6. **Assertion**- Eddy current is produced in any metallic conductor when magnetic flux is changed around it
   Reason -- Electric potential determine the flow of charge.

7. **Assertion** -- The quantity L/R possesses dimensions of time
   Reason – To reduce the rate of increase of current through a solenoid should increase the time constant L/R

8. **Assertion**- Faraday laws are consequence of conservation of energy
   Reason -- In a purely resistive AC circuit, the current lags behind the emf in phase.

9. **Assertion**- Only a change in magnetic flux through a coil maintain a current in the coil if the current is continues
   Reason -- The presence of large magnetic flux through a coil maintain a current in the coil if the current is continues

10. **Assertion**- magnetic flux can produce induced emf
Reason -- Faraday established induced emf experimentally

11. **Assertion**- Inductance coil are made of copper
Reason -- Induced current is more in wire having less resistance

12. **Assertion**- When two coils are wound on each other, the mutual induction between coil is maximum
Reason -- Mutual induction doesn't depends on the orientation of the coils

13. **Assertion**- an aircraft flies along the meridian, the potential at the ends of its wings will be the same.
Reason -- Whenever there is change in magnetic flux emf induces

14. **Assertion**- A spark occur between the poles of a switch when the switch is opened
Reason -- Current flowing in the conductor produce magnetic field

15. **Assertion** - In the phenomenon of mutual induction self-induction of each of coils persists
Reason -- Self-induction arises when strength of current in same coil change in the mutual induction, current is changing in both the individual

16. **Assertion** - An induced emf is generated when magnet is withdrawn from the solenoid
Reason -- The relative motion between the magnet and solenoid induced emf

17. **Assertion** - A transformer can't work on DC supply
Reason -- DC changes neither in magnitude nor in direction

18. **Assertion** - Soft iron is used as a core of transformer
Reason -- Area of hysteresis is loop for soft iron is small

19. **Assertion** - An AC generator is based on the phenomenon of self-induction
Reason -- in single coil we consider, self-induction only

20. **Assertion** - An electric motor will maximum efficient, when back emf is equal to applied emf
Reason -- Efficiency of electric motor is depends only on magnitude of back emf

21. **Assertion** - An AC doesn't show any magnetic effect
Reason -- AC doesn't vary with time

22. **Assertion** - A variable capacitor is connected in series with a bulb through AC source if the capacitance of variable capacitor is decrease the brightness of bulb is reduced
Reason -- The reactance of capacitor increase if capacitance is reduced

23. **Assertion** - A capacitor of suitable capacitance can be used in AC circuit in the place of choke coil
Reason -- A capacitor blocks DC and allow only AC

24. **Assertion** - An AC doesn't show any magnetic effect
Reason -- AC varies with time

25. **Assertion** - The division are equally marked on the scale of AC ammeter
Reason -- heat produced is directly proportion to current

26. **Assertion** - Average value of AC over a complete cycle is always zero
Reason -- Average value of AC is always defined over half cycle

27. **Assertion** - Eddy current is produced in any metallic conductor when magnetic flux is changed around it
Reason -- electric potential determine the flow of charge

28. **Assertion** - In LCR circuit resonance can take place
Reason -- resonance can take place if inductance and capacitive reactance are equal and opposite

29. **Assertion** - When capacitive reactance is smaller than the inductive reactance in LCR circuit, emf leads the current
Reason -- The phase angle is angle between alternating emf and alternating current of the circuit

30. **Assertion** - The DC and AC both can be measured by a hot wire instrument
Reason -- The hot wire instrument is based on the principle of magnetic effect of current

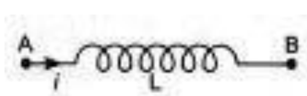
Answers:

1. C	2. D	3. A	4. C	5. B	6. B	7. B	8. C	9. C	10. E
11. A	12. C	13. E	14. B	15. B	16. A	17. A	18. A	19. E	20. D
21. D	22. A	23. B	24. B	25. D	26. B	27. B	28. A	29. B	30. C

CASE STUDY QUESTIONS

Question 1:

An inductor is simply a coil or a solenoid that has a fixed inductance. It is referred to as a choke. The usual circuit notation for an inductor is as shown.



Let a current i flows through the inductor from A to B. Whenever electric current changes through it, a back emf is generated. If the resistance of inductor is assumed to be zero (ideal inductor) then induced emf in it is given by

$$e = V_B - V_A = - L\, di / dt$$

Thus, potential drops across an inductor as we move in the direction of current. But potential also drops across a pure resistor when we move in the direction of the current.

The main difference between a resistor and an inductor is that while a resistor opposes the current through it, an inductor opposes the change in current through it.

Now answer the following questions.

How does inductor behave when

(a) a steady current flow through it?
(b) a steadily increasing, current flows through it?
(c) a steadily decreasing current flows through it?
(d) Name the phenomenon in which change in current in a coil induces EMF in coil itself?

ANS: (i) **(a)** As electric current is steady therefore

di / dt = 0;

:: induced emf = e = 0 and the inductor behaves as short circuit.

(b) in the expression

e = - L di / dt

as di / dt is positive EMF is negative. that is $V_B < V_A$.

That is back EMF is genreted that opposses the increase in current.

(c) di / dt is negative, therefore EMF is positive. that is $V_B > V_A$. Forward EMF is generated that opposses fall in current.

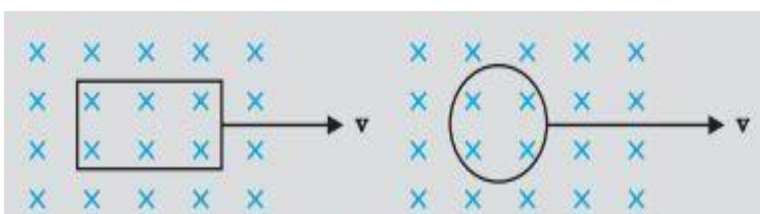
(d) Self induction.

Question 2:

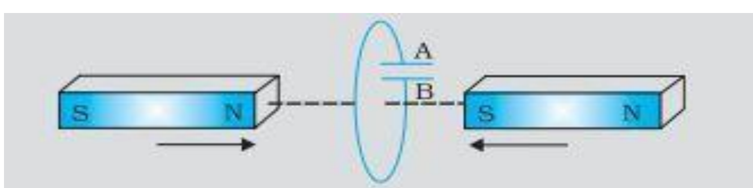
(a) A closed loop is held stationary in the magnetic field between the north and south poles of two permanent magnets held fixed. Can we hope to generate current in the loop by using very strong magnets?

(b) A closed loop moves normal to the constant electric field between the plates of a large capacitor. Is a current induced in the loop
(i) when it is wholly inside the region between the capacitor plates
(ii) when it is partially outside the plates of the capacitor? The electric field is normal to the plane of the loop.

(c) A rectangular loop and a circular loop are moving out of a uniform magnetic field region (Figure) to a field-free region with a constant velocity v. In which loop do you expect the induced emf to be constant during the passage out of the field region? The field is normal to the loops.



(d) Predict the polarity of the capacitor in the situation described by the figure



Solution:

(a) No. However strong the magnet may be current can be induced only by changing the magnetic flux through the loop.

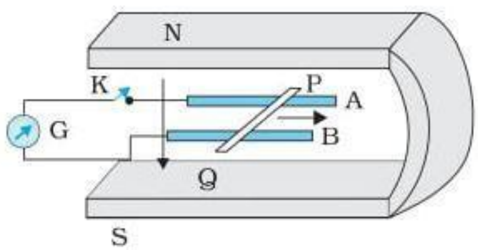
(b) No current is induced in either case. Current can not be induced by changing the electric flux.

(c) The induced emf is expected to be constant only in the case of the rectangular loop. In the case of circular loop, the rate of change of area of the loop during its passage out of the field region is not constant, hence induced emf will vary accordingly,

(d) The polarity of plate 'A' will be positive with respect to plate 'B' in the capacitor.

Question 3:

Given figure shows a metal rod PQ resting on the smooth rails AB and positioned between the poles of a permanent magnet. The rails, the rod, and the magnetic field are in three mutual perpendicular directions. A galvanometer G connects the rails through a switch K. Length of the rod = 15 cm, B = 0.50 T, resistance of the closed loop containing the rod = 9.0 mΩ. Assume the field to be uniform.



(a) Suppose K is open and the rod is moved with a speed of 12 cm s^{-1} in the direction shown. Give the polarity and magnitude of the induced emf.

(b) Is there an excess charge built up at the ends of the rods when K is open? What if K is closed?

(c) With K open and the rod moving uniformly, there is no net force on the electrons in the rod PQ even though they do experience magnetic force due to the motion of the rod. Explain.

(d) What is the retarding force on the rod when K is closed?

(e) How much power is required (by an external agent) to keep the rod moving at the same speed (=12 cm/ sec) when K is closed? How much power is required when K is open?

(f) How much power is dissipated as heat in the closed circuit? What is the source of this power?

(g) What is the induced emf in the moving rod if the magnetic field is parallel to the rails instead of being perpendicular?

Answers:

(a) EMF = vBL = 0.12 0.50 x 0.15 = 9.0 mV;
P positive end and Q negative end.

(b) Yes. When K is closed, the excess charge is maintained by the continuous flow of current.

(c) Magnetic force is cancelled by the electric force set-up due to the excess charge of opposite signs at the ends of the rod.

(d) Retarding force = IBL
= 9 mV / 9 mΩ x 0.5 T x 0.15 m
= 75 x 10^{-3} N

(e) Power expended by an external agent against the above retarding force to keep the rod moving uniformly at 12 cm / s
$= 75 \times 10^{-3} \times 12 \times 10^{-2} = 9.0 \times 10^{-3}$ W
When K is open, no power is expended.

(f) $I^2 R = 1 \times 1 \times 9 \times 10^{-3} = 9.0 \times 10^{-3}$ W
The source of this power is the power provided by the external agent as calculated above.

g) Zero: motion of the rod does not cut across the field lines.
[Note: length of PG has been considered above to be equal to the spacing between the rails.]

Question 4:

A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5Ω per km. The town gets power from the line through a 4000-220 V step-down transformer at a sub-station in the town.

(a) Estimate the line power loss in the form of heat.
(b) How much power must the plant supply, assuming there is negligible power loss due to leakage?
(c) Characterise the step up transformer at the plant.

Answers:

Line resistance = 30 X 0.5 = 15Ω
rms current in the line . 800 x 1000 W / 4000 V = 200 A

(a) Line power loss = $(200\text{ A})^2 \times 15\ \Omega$ = 600 kW.
(b) Power supply by the plant = 800 kW + 600 kW = 1400 kW.
(c) Voltage drop on the line = 200 A 15Ω = 3000 V.
The step-up transformer at the plant is 440 V - 7000 V.

Question 5.

Electromagnetic induction is defined as the production of an electromotive force across an electric conductor in the changing magnetic field. The discovery of induction was done by Michael Faraday in the year 1831. Electromagnetic induction finds many applications such as in electrical components which includes transformers, inductors, and other devices such as electric motors and generators.
Alternating current is defined as an electric current which reverses in direction periodically. In most of the electric power circuits, the waveform of alternating current is the sine wave.

1. How to increase the energy stored in an inductor by four times?
   (a) By doubling the current
   (b) This is not possible
   (c) By doubling the inductance
   (d) By making current $\sqrt{2}$ times
   Answer: (a) By doubling the current

2. Consider an inductor whose linear dimensions are tripled and the total number of turns per unit length is kept constant, what happens to the self-inductance?
   (a) 9 times
   (b) 3 times
   (c) 27 times

(d) 13 times
Answer: (b) 3 times

3. Lenz law is based on which of the following conservation>
(a) Charge
(b) Mass
(c) Momentum
(d) Energy
Answer: (d) Energy

4. What will be the acceleration of the falling bar magnet which passes through the ring such that the ring is held horizontally and the bar magnet is dropped along the axis of the ring?
(a) It depends on the diameter of the ring and the length of the magnet
(b) It is equal due to gravity
(c) It is less than due to gravity
(d) It is more than due to gravity
Answer: (c) It is less than due to gravity

MCQ

Choose the correct option from those given below each question:

1. Two coils are placed closed to each other. The mutual inductance of the pair of coils depends upon
(a) the rate at which currents are changing in the two coils.
(b) relative position and orientation of two coils.
(c) the material of the wires of the coils.
(d) the currents in the two coils.

2. When current in a coil changes from 5 A to 2 A in 0.1 s, average voltage of 50 V is produced. The self-inductance of the coil is
(a) 1.67 H
(b) 6 H
(c) 3 H
(d) 0.67 H

3. A coil having 500 sq. loops of side 10 cm is placed normal to magnetic flux which increases at a rate of 1 T/s. The induced emf is
(a) 0.1 V
(b) 0.5 V
(c) 1 V
(d) 5 V

4. Lenz's law of electromagnetic induction is as per law of conservation of
(a) energy.
(b) momentum angular.
(c) charge.
(d) electromotive force.

5. The current flows from A to B is as shown in the figure. The direction of the induced current in the loop is

(a) clockwise.
(b) anticlockwise.
(c) straight line.
(d) no induced e.m.f. produced

6. The north pole of a long bar magnet was pushed slowly into a short solenoid connected to a short galvanometer. The magnet was held stationary for a few seconds with the north pole in the middle of the solenoid and then withdrawn rapidly. The maximum deflection of the galvanometer was observed when the magnet was
(a) moving towards the solenoid
(b) moving into the solenoid
(c) at rest inside the solenoid
(d) moving out of the solenoid

7. Two identical coaxial coils P and Q carrying equal amount of current in the same direction are brought nearer. The current in
(a) P increases while in Q decreases
(b) Q increases while in P decreases
(c) both P and Q increases
(d) both P and Q decreases

8. A solenoid is connected to a battery so that a steady current flows through it. If an iron core is inserted into the solenoid, the current will
(a) increase
(b) decrease
(c) remain same
(d) first increase then decrease

9. Which of the following statements is not correct?
(a) Whenever the amount of magnetic flux linked with a circuit changes, an emf is induced in circuit.
(b) The induced emf lasts so long as the change in magnetic flux continues.
(c) The direction of induced emf is given by Lenz's law.
(d) Lenz's law is a consequence of the law of conservation of momentum

10. There is a uniform magnetic field directed perpendicular and into the plane of the paper. An irregular shaped conducting loop is slowly changing into a circular loop in the plane of the paper. Then
(a) current is induced in the loop in the anti-clockwise direction.
(b) current is induced in the loop in the clockwise direction.
(c) ac is induced in the loop.
(d) no current is induced in the loop.

11. The north pole of a bar magnet is rapidly introduced into a solenoid at one end (say A). Which of the

following statements correctly depicts the phenomenon taking place?
(a) No induced emf is developed.
(b) The end A of the solenoid behaves like a south pole.
(c) The end A of the solenoid behaves like north pole.
(d) The end A of the solenoid acquires positive potential.

12. Identify the wrong statement.
(a) Eddy currents are produced in a steady magnetic field.
(b) Eddy currents can be minimized by using laminated core.
(c) Induction furnace uses eddy current to produce heat.
(d) Eddy current can be used to produce braking force in moving trains

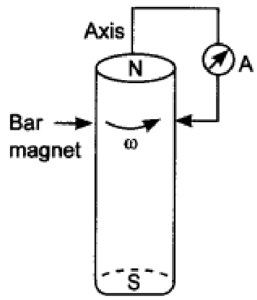
13. Which of the following does not use the application of eddy current?
(a) Electric power meters
(b) Induction furnace
(c) LED lights
(d) Magnetic brakes in trains

14. If number of turns in primary and secondary coils is increased to two times each, the mutual inductance
(a) becomes 4 times
(b) becomes 2 times
(c) becomes A times
(d) remains unchanged

15. Two inductors of inductance L each are connected in series with opposite? magnetic fluxes. The resultant inductance is
(Ignore mutual inductance)
(a) zero
(b) L
(c) 2L
(d) 3L

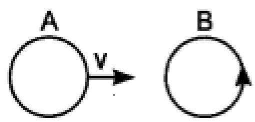
16. A loop, made of straight edges has six comers at A(0, 0, 0), B(L, 0, 0) C(L, L, 0), D(0, L, 0), E(0, L, L) and F(0,0, L). A magnetic field $B = B_o$ (i^+k^)T is present in the region. The flux passing through the loop ABCDEFA (in that order) is
(a) B_oL^2 Wb.
(b) $2B_oL^2$ Wb.
(c) $\surd 2B_oL^2$ Wb.
(d) $4B_oL^2$ Wb.

17. A cylindrical bar magnet is rotated about its axis (Figure). A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then



(a) a direct current flows in the ammeter A.
(b) no current flows through the ammeter A.
(c) an alternating sinusoidal current flows through the ammeter A with a time period $T = 2\pi / \omega$
(d) a time varying non-sinusoidal current flows through the ammeter.

18. There are two coils A and B as shown in Figure. A current start flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counterclockwise. B is kept stationary when A moves. We can infer that



(a) there is a constant current in the clockwise direction in A.
(b) there is a varying current in A.
(c) there is no current in A.
(d) there is a constant current in the counterclockwise direction in A.

19. An e.m.f is produced in a coil, which is not connected to an external voltage source. This is not due to
(a) the coil being in a time varying magnetic field.
(b) the coil moving in a time varying magnetic field.
(c) the coil moving in a constant magnetic field.
(d) the coil is stationary in external spatially varying magnetic field, which does not change with time

20. When the rate of change of current is unity, the induced emf is equal to
(a) thickness of coil
(b) number of turns in coil
(c) coefficient of self-inductance
(d) total flux linked with coil

21. The phase difference between the alternating current and emf is TE/2. Which of the following cannot be the constituent of the circuit?
(a) C alone
(b) L alone
(c) L and C
(d) R and L

22. In an LCR-series ac circuit, the voltage across each of the component L, C and R is 50 V. The voltage across the LC-combination will be
(a) 50 V
(b) $50\sqrt{2}$ V

(c) 100 V
(d) zero

23. In an LCR circuit, capacitance is charged from C to 2C. For resonant frequency to remain unchanged, the inductance should be changed from L to
(a) 4 L
(b) 2 L
(c) L/2
(d) L/4

24. The core of any transformer is laminated so as to
(a) reduce the energy loss due to eddy currents.
(b) make it light weight.
(c) make it robust and strong.
(d) increase the secondary voltage.

25. In an a.c. generator, a coil with N turns, all of the same area A and total resistance R, rotates with frequency ω in a magnetic field B the maximum value of emf generated in the coil is
(a) NABR
(b) NABω
(c) NABRω
(d) NAB

26. If coil is open, then L and R becomes
(a) infinity, zero
(b) zero, infinity
(c) infinity, infinity.
(d) zero, zero

27. If an AC voltage is applied to an L-C-R circuit, which of the following is true?
(a) I and V are out of phase with each other in R.
(b) I and V are in phase in L while in C, they are out of phase.
(c) I and V are out of phase in both C and L.
(d) I and V are out of phase in L and in phase in C.

28. A transformer is used to light a 100 W and 110 V lamp from a 220 V mains. If the main current is 0.5 A, the efficiency of the transformer is approximately
(a) 30%
(b) 50%
(c) 90%
(d) 10%

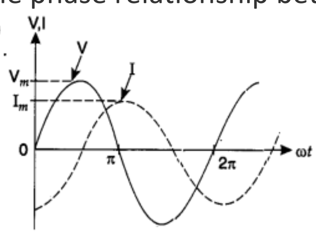
29. Choose the correct statement.
(a) A capacitor can conduct a dc circuit but not an inductor.
(b) In a dc circuit the inductor can conduct but not a capacitor.
(c) In dc circuit both the inductor and capacitor cannot conduct.
(d) The inductor has infinite resistance in a dc circuit.

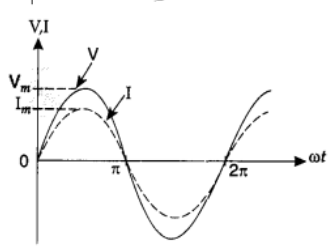
30. A coil of self-inductance L is connected in series with a bulb B and an ac source. Brightness of the bulb decreases when
(a) frequency of the ac source is decreased.
(b) number of turns in the coil is reduced.
(c) a capacitance of reactance $X_C = X_L$ in included.
(d) an iron rod is inserted in the coil.

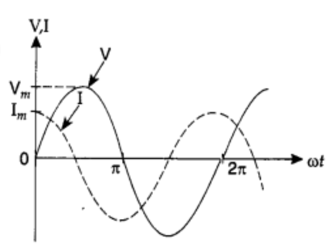
31. In a series LCR circuit the voltage across an inductor, capacitor and resistor are 20 V, 20 V and 40 V respectively. The phase difference between the applied voltage and the current in the circuit is
(a) 30°
(b) 45°
(c) 60°
(d) 0°

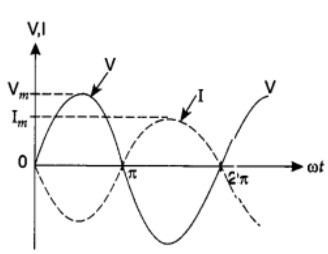
32. Which of the following combinations should be selected for better tuning of an LCR circuit used for communication?
(a) R = 20, L= 1.5 H, C = 35 μF.
(b) R = 25 , L = 2.5 H, C = 45 μF.
(c) R = 15 , L = 3.5 H, C = 30 μF.
(d) R = 25 , L = 1.5 H, C = 45 μF.

33. The phase relationship between current and voltage in a pure resistive circuit is best represented by

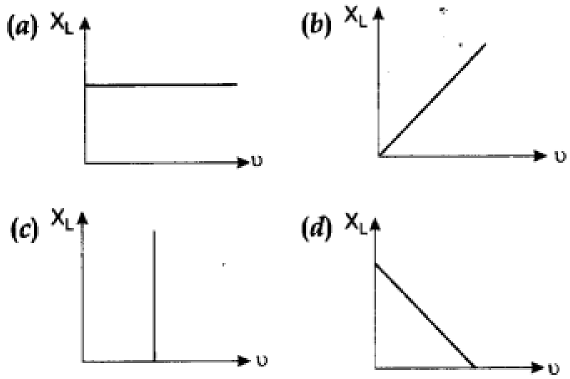
(a)


(b)


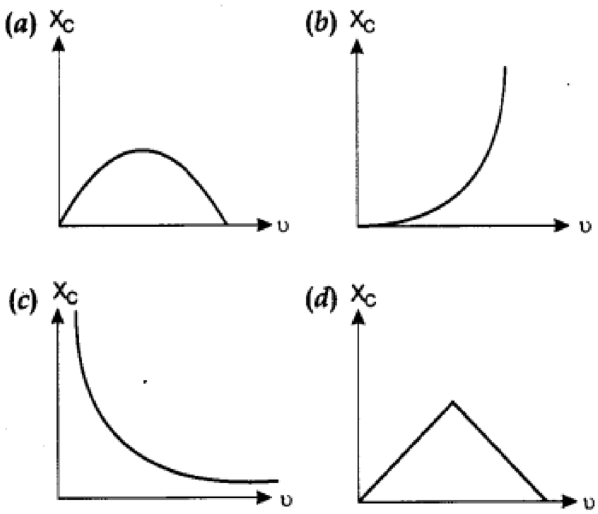
(c)


(d)


34. K Which of the following graphs represents the correct variation of inductive reactance X_L with frequency u?



35. Which of the following graphs represents the correct variation of capacitive reactance Xc with frequency v?



Answer:

1. b	2. a	3. d	4. a	5. a	6. d	7. d	8. b	9. d	10. a
11. c	12. a	13. c	14. b	15. c	16. b	17. a	18. d	19. d	20. c
21. c	22. d	23. c	24. a	25. b	26. b	27. c	28. c	29. b	30. d
31. d	32. c	33. b	34. b	35. c					

Complete the statements :

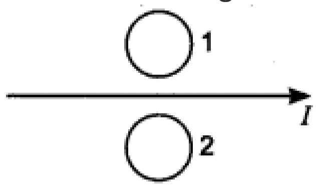
1. Average value of ac over a complete cycle _________ .
2. Inductive reactance increases with _________ in frequency of ac.
3. In ac generator _________ is converted into electrical energy of alternating form.
4. Average or mean value of ac over a half cycle is _________.
5. Capacitive reactance Xc increases with _________ in frequency of ac and current in the capacitive ac circuit _________ the ac voltage.
6. Total number of magnetic lines of force crossing a surface normally is called ________
7. Relation between S.I. unit and C.G.S. unit of magnetic flux is _________
8. Phenomenon of production of induced emf due to change of magnetic flux linked with a closed circuit is known as _________
9. Direction of induced current is such that it _________ the cause which produces it.
10. The electric current flowing in a wire in the direction from B to A is decreasing. The direction of the induced current in the metallic loop kept above the wire ________

Answer:

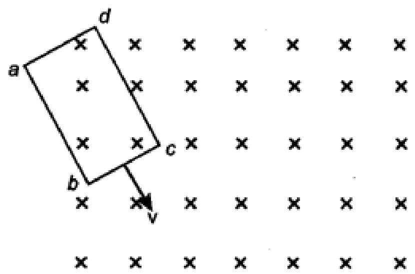
1. Zero
2. Increase
3. Mechanical energy
4. 0.637 I_0
5. Decrease, leading ahead
6. Magnetic flux
7. 1 Weber = 10^8 Maxwell
8. Electromagnetic Induction
9. Opposes
10. Clockwise

Very short answer Questions:

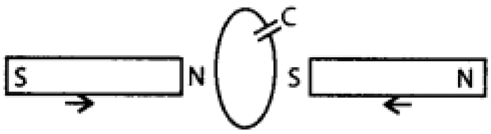
1. What is the direction of induced currents in metal rings 1 and 2 when current I in the wire is increasing steadily?



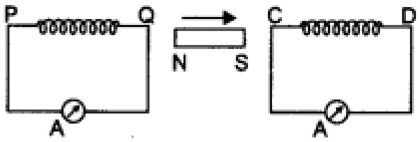
2. Use Lenz's law to determine the direction of the induced current when a rectangular conducting loop abed is moved into a region of magnetic field which is directed normal to the plane of the loop away from the reader.



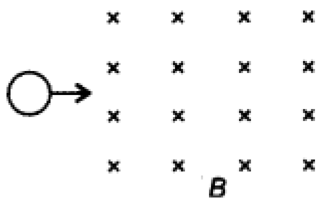
3. Two bar magnets are quickly moved towards a metallic loop connected across a capacitor C as shown in the figure. Predict the polarity of the capacitor.



4. A closed loop is held stationary in the magnetic field between the north and south poles of two permanent magnets held fixed. Can we hope to generate current in the loop by using very strong magnets?
5. A closed loop moves normal to the constant electric field between the plates of a large capacitor. Is a current induced in the loop
(i) when it is wholly inside the region between the capacitor plates, and
(ii) when it is partially outside the plates of the capacitor? The electric field is normal to the plane of the loop.
6. A bar magnet is moved in the direction indicated by the arrow between two coils PQ and CD. Predict the directions of induced current in each coil.

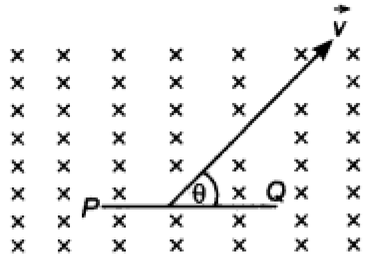


7. Two spherical bobs, one metallic and the other of glass, of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach earlier and why?
8. A circular loop is moved through the region of uniform magnetic field. Find the direction of induced current (clock wise or antic lock wise) when the loop moves (i) into the e field, and (ii) out of the field. [Foreign 2010]

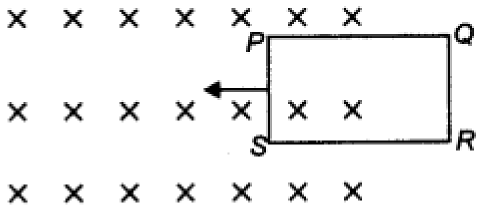


9. When a coil is rotated in a uniform magnetic field at constant angular velocity, will the magnitude of induced emf set up in the coil be constant? Why?
10. How does the mutual inductance of a pair of coils change when
(i) distance between the coils is increased and
(ii) number of turns in the coils is increased?

11. A rod PQ of length 1 is moved in uniform magnetic field $\vec{B}$ as shown. What will be the emf induced in it?

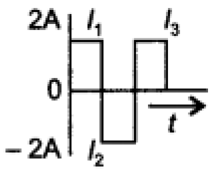


12. The closed loop (PQRS) of wire is moved into a uniform magnetic field at right angles to the plane of the paper as shown in the figure. Predict the direction of the induced current in the loop.

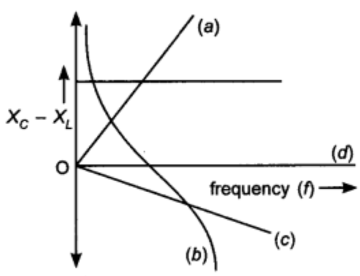


13. Predict the direction of induced current in a metal ring when the ring is moved towards a straight conductor with constant speed v. The conductor is carrying current I in the direction shown in the figure.

14. Which is more dangerous 220 ac or 220 dc and why?
15. The peak value of emf in ac is E_0. Write its
    (i) rms, and (ii) average value over a complete cycle.
16. Calculate the rms value of the alternating current shown in the figure. [HOTS]



17. When an alternating current is passed through a moving coil galvanometer, it shows no deflection. Why?
18. Which of the following curves may represent the reactance of a series LC combination?



19. In a series LCR circuit, the voltages across an inductor, a capacitor and a resistor are 30 V, 30V and 60V respectively. What is the phase difference between the applied voltage and the current in the circuit?
20. Can a capacitor of suitable capacitance replace a inductor coil in an AC circuit?
21. At an airport, a person is made to walk through the doorway of a metal detector, for security reasons. Is she/he is carrying anything made of metal, the metal detector emits a sound. On what principle does this detector work?
22. A capacitor blocks dc and allows ac. Why?
23. A bulb and a capacitor are connected in series to an ac source of variable frequency. How will the brightness of the bulb change on increasing the frequency of the ac source?
24. The instantaneous current and voltage of an ac circuit are given by I = 10 sin314t A and V = 50 sin $(314\ t + \frac{\pi}{2})$ V. What is the power of dissipation m the circuit?
25. Why is the use of ac voltage preferred over dc voltage?
26. Does a step down transformer violate the principle of conservation of energy?
27. Can we measure 110 V, 50 Hz a.c. using moving coil galvanometers? How can we measure it?
28. Why do we prefer carbon brushes than copper in an ac generator?
29. In a series LCR circuit, X_L, X_c and R are the inductive reactance, capacitive reactance and resistance respectively at a certain frequency f If the frequency of ac is doubled, what will be the values of reactance and resistance of the circuit?
30. What is an acceptor circuit and where it is used?

Answer:

1. The direction of induced current is clockwise in metal ring 1 and anticlockwise in metal ring 2.
2. On moving a rectangular conducting loop into the field, the flux increases. According to Lenz's law, the induced current would be anticlockwise.
3. The upper plate is having +ve polarity and the lower plate is having -ve polarity.
4. However strong the magnet may be, current can be induced only by changing the magnetic flux through the loop.
5. No current is induced in either case. Current cannot be induced by changing the electric flux.
6. The direction of induced current clockwise in coil PQ as seen from magnet side. The direction of induced current clockwise in coil CD as seen from magnet side.
7. A glass bob, as in the glass bob, there is no effect of electromagnetic induction due to the presence of earth's magnetic field, unlike in the case of a metallic bob.
8. (i) Anticlockwise, (ii) Clockwise
9. No, the induced emf will vary with time and will be sinusoidal due to the change in orientation of the coil w.r.t. the magnetic field.
10. (i) When the distance between a pair of coils is increased, the magnetic flux linked with the secondary coil decreases and hence, the mutual inductance between them will decrease.
    (ii) Since $M \propto N_1 N_2$, so, when number of turns in the coil is increased, the mutual inductance will also increase.

11. e = Blv sin θ
12. Anticlockwise
13. Clockwise
14. 220 V ac is more dangerous than 220 V dc because its peak value is very high and also ac is in nature.

$$\because\ V_{rms} = \frac{V_m}{\sqrt{2}} \Rightarrow V_m = \sqrt{2} \times 220 \approx 311V$$

$$> 220V\ dc \qquad [\because V_{rms} = 200V\ (ac)]$$

15. (i) $E_{rms} = E0/\sqrt{2}$ (ii) Zero
16.

$$I_{rms} = \sqrt{\frac{I_1^2 + I_2^2 + I_3^2}{3}} = \sqrt{\frac{2^2 + 2^2 + 2^2}{3}} = 2A$$

The rms value of the alternating current shown in the figure is 2 A.

17. A moving coil galvanometer measures an average value of current, which is zero for ac. Hence, no deflection is shown by galvanometer.
18. Curve (b) AS $X_C - X_L = (1 / 2\pi vC) - 2\pi v L$
19. Zero. As $V_L = V_C$, circuit is resistive in nature.
20. Yes, because average power consumed in both is least while controlling an AC.
21. The metal detector works on the principle of resonances in ac circuits.
22. The capacitive reactance is $X_C = 1/2\pi vC$.
    For dc, $v = 0 \Rightarrow X_C = \infty$
    i.e. a capacitor offers infinite resistance to dc and hence blocks it.
    For ac, $v \neq 0, \Rightarrow X_C \neq \infty$, but has some finite value.
    Therefore, an ac can pass through the capacitor.
23. The brightness will increase ($\because X_C \propto 1/v$), and heat produced $H \propto I^2$, where

$$I_{rms} = \frac{V_{rms}}{\sqrt{X_C^2 + R^2}}$$

24. Phase difference between the current and voltage is π/2. So, the power dissipation $P_{av} = P_{rms} \cos \Phi$ is zero.
25. An ac voltage can be stepped up or down using a transformer, but not the dc voltage.
26. No. In a transformer, if a voltage is increased, the current is decreased in the same ratio and the product VI (power) remains the same.
27. No.
    Reason: As average value of a.c. voltage over one complete cycle is zero.
    We can measure the rms value of a.c. voltage using hot wire meters.
28. Corrosion free and small expansion on heating maintains proper contact.
29. Resistance R remains unchanged; X_L will be doubled and X_C will be halved.
30. Series LCR circuit is called acceptor circuit radio or TV sets.

Short Answer Questions: (2 and 3 Marks questions)

1. A bulb is connected in series with a variable capacitor and an a.c. source as shown. How the brightness of bulb changes on reducing the (a) capacitance and (b) frequency ? Justify your answer.

Ans: **(a) Brightness will decreases**

Reason : When capacitance is reduced, reactance (X_c = 1 / wC) increases

⇨ Z = $\sqrt{R^2 + X^2}$ also increases and current decreases

Hence brightness decreases.

(b) Brightness will decreases

Reason : When frequency is reduced, reactance (X_c = 1 / $2\pi f$C) increase.

⇨ Z = $\sqrt{R^2 + X^2}$ also increases and current decreases

Hence brightness I^2Z decreases

2. Define quality factor (Q-factor) and give its significance. What is its S.I. unit ?

Ans. Quality factor: It is defined as the ratio of resonant frequency to the frequency band width of the resonant curve .

Significance : It gives the sharpness of resonance. For larger value of Q, resonance will be sharper and consequently the circuit will be more selective.

Unit : It has no unit

3. Two identical loops, one of copper and the other of aluminium are rotated with the same angular speed in the same magnetic field. Compare
   i) the induced emf and
   ii) the current produced in the two coils. Justify your answer.

Ans: i) The induced emf in both the loops will be same as areas of the loop and time periods are same as they are identical and rotated with same angular speed.

ii) The current induces in Cu coil is more than Al coil as Cu coil has lesser resistance and I ά $^1/_R$(for the same voltage).

4. What are eddy currents? Write their two applications.

Ans: Eddy Current- Eddy currents are the currents induced in the bulk pieces of conductors when the amount of magnetic flux linked with the conductor changes. Eddy currents can be minimized by taking laminated core, consists of thin metallic sheet insulated from each other by varnish instead of a single solid mass. The plane of the sheets should be kept perpendicular to the direction of the currents. The insulation provides high resistance hence, eddy current gets minimized. Applications (i)Electromagnetic damping (ii) Induction furnace.

5. A wheel of 8 metallic spokes each 50cm long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of the Earth's magnetic field. The Earth's magnetic field at the plane is 0.4 G and the angle of dip is 60^0. Calculate the emf induced between the axle and the rim of the wheel. How will be the emf is affected if the number of spokes were increased?

Ans: $\mathcal{E} = \frac{1}{2}B\omega l^2$

$B_H = B \ \cos\delta$

$\mathcal{E} = \frac{1}{2}B\cos\delta\,\omega l^2 = 3.14 \times 10^{-5}$ volt

6. The current flowing in the two coils of self inductance $L_1 = 16mH \; and \; L_2 = 12mH$ are increasing at the same rate. If the power supplied to the two coils are equal, find the ratio of (i) induced voltage, (ii) the currents and (iii) the energies stored in the two coils at a given instant.

Ans: (i) $\mathcal{E} = -L\frac{dI}{dt}$

$$\frac{\mathcal{E}_1}{\mathcal{E}_2} = \frac{L_1}{L_2} = \frac{4}{3}$$

(ii) P= $\mathcal{E}$I$\Longrightarrow \mathcal{E}_1 I_1 = \mathcal{E}_2 I_2$

$$\frac{\mathcal{E}_2}{\mathcal{E}_1} = \frac{I_1}{I_2} = \frac{3}{4}$$

(iii) $U = \frac{1}{2} LI^2$

$$\frac{U_2}{U_1} = \frac{I_2}{I_1} \times \frac{I_2}{I_1} \times \frac{L_2}{L_1} = \frac{4}{3}$$

7. An inductor of reactance X_L is connected in series with a bulb B to an ac source. Explain briefly how does the brightness of the bulb change when (i) number of turns of the inductor is reduced and (ii) a capacitance of reactance $X_C = X_L$ is included in the circuit.

Ans: (i) When number of turns in the inductor is reduced

L decreases, z reduces and I increases so brightness increases.

(ii) Brightness decreases

(iii) Brightness increases

8. A capacitor of unknown capacitance, a resistor of 100Ω and an inductor of self inductance $L = \frac{4}{\pi^2}$ henery are connected in series to an ac source of 200 V and 50 Hz. Calculate the value of the capacitance and impedance of the circuit when the current is in phase with the voltage. Calculate the power dissipated in the circuit.

Ans: $C = \frac{1}{L\omega^2} = 2.5 \times 10^{-5} \, F$

Z = R = 100 Ω and power = 400 watt

9. (i) An ac source is connected to an ideal capacitor show that the average power supplied by the source over a complete cycle is zero.
(ii) A bulb is connected in series with a capacitor and an ac source. What happens to the brightness of the bulb when the key is plugged in and capacitance of capacitor is gradually reduced? Explain.

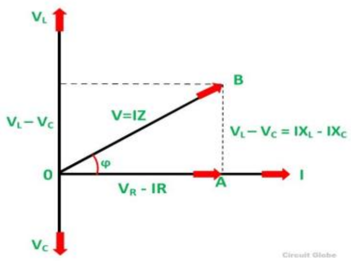
Ans: (i) For capacitive circuit average power is zero.

(ii) Brightness decreases $X_C = \frac{1}{\omega C}$

As C decreases, Z increases so brightness decreases

10. Using phasor diagram for a series LCR circuit connected to an AC source of voltage $v = v_0 \sin \omega\tau$, derive the relation for the current flowing in the circuit and the phase angle between the voltage across the resistor and the net voltage in the circuit.

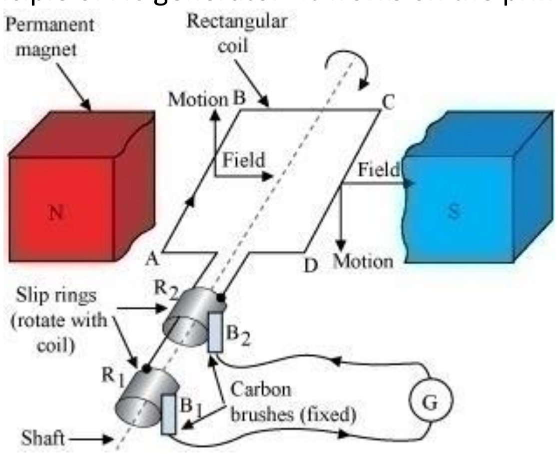
Ans: The phasor diagram of the RLC Series Circuit when the circuit is acting as an inductive circuit
that means (V_L>V_C) is shown below and if (V_L< V_C) the circuit will behave as a capacitive circuit.



Long Answer Questions (5 marks questions)

1. (a) Draw a schematic sketch of an ac generator describing its basic elements. State briefly its working principle. Show a plot of variation of (i) magnetic flux and (ii) alternating emf versus time generated by a loop of wire rotating in a magnetic field
(b) Why is choke coil needed in the use of fluorescent tubes with ac mains?

Ans: (a) Brief explanation.
Principle of AC generator- It works on the principle of electromagnetic induction.



In an A.C. generator, mechanical energy is converted to electrical energy by virtue of Electromagnetic induction.

* Rotation of rectangular coil in a magnetic field causes change in flux (Φ = NBACosωt).

Change in flux induces emf in the coil which is given by

e = - dΦ/dt = NBAωSinωt

$\varepsilon = \varepsilon_0 \sin\omega t$

* Current induced in the coil $I = \varepsilon/R = (\varepsilon_0 \sin\omega t)\,/\,R = I_0 \sin \omega t$

(b) In case of choke coil power dissipation is very negligible.

2. (a) An ac source of voltage $V = V_0 \sin \omega t$ is connected to a series combination of L, C and R. Use the phasor diagram to obtain expressions for impedance of the circuit and phase angle between voltage and current. Find the condition when current will be in phase with the voltage. What is the circuit in this condition called?
(b) In a series LR circuit $X_L = R$ and power factor of the circuit is P_1. When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2. Calculate $\frac{P_1}{P_2}$.

Ans:

(i) Let E and I be the instantaneous values of e.m.f. and current in LCR-circuit, and V_L, V_C and V_R be the instantaneous values of the voltages across inductor L, capacitors C and resistor R respectively.

$V_L = IX_L, V_C = IX_C, V_R = IR, X_L = \omega L, X_C = \frac{1}{\omega C}$

From Phasor Diagram –

$$E = \sqrt{V_R^2 + (V_L - V_C)^2}$$

Substituting values of V_R, V_L and V_C, we have

$E = \sqrt{(IR)^2 + (IX_L - IX_C)^2} = I\sqrt{R^2 + (X_L - X_C)^2}$

$$I = \frac{E}{\sqrt{R^2 + (X_L - X_C)^2}} \quad ...(1)$$

The effective opposition offered by L, C and R to a.c. is called impedance of LCR-circuit. If Z is impedance of circuit,

$$I = \frac{E}{Z} \quad ...(2)$$

Comparing (1) and (2)

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}$$

From Phasor diagram, it follows that in LCR-series circuit, E leads I by phase angle ϕ,

We have

$$\tan \phi = \frac{V_L - V_C}{V_R} = \frac{IX_L - IX_C}{IR} = \frac{X_L - X_C}{R}$$

$$\tan \phi = \frac{\omega L - \frac{1}{\omega C}}{R}$$

When $\omega L = \frac{1}{\omega C}$

It follows that tan ϕ is zero *i.e.* ϕ is zero. In such case, current and emf are in phase with each other. Also Impedance equals to R or due to minimum value of impedance, the current in LCR series circuit will be maximum. This condition is known as Resonance.

(ii) For LR-circuit in series,

$$\tan \phi = \frac{\omega L}{R}$$

$$\text{Power factor } \cos \phi = \frac{R}{\sqrt{R^2 + \omega^2 L^2}} \quad ...(1)$$

As, $X_L = \omega L$,

Here $X_L = R$,

Putting this value in eq.(1)

$$\cos \phi = \frac{R}{\sqrt{R^2 + R^2}} = \frac{R}{\sqrt{2R^2}} = \frac{R}{R\sqrt{2}} = \frac{1}{\sqrt{2}}$$

$\therefore$ Power factor $P_1 = \frac{1}{\sqrt{2}} = \cos \phi$.

Now $X_L = X_C$

Than $\cos\phi = P_2$.

$$P_2 = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{R}{R} = 1 \quad [\because X_L = X_C]$$

$$P_2 = 1$$

So $$\frac{P_1}{P_2} = \frac{\frac{1}{\sqrt{2}}}{1}$$

$$\frac{P_1}{P_2} = \frac{1}{\sqrt{2}}$$

3. (i) What is the function of a transformer. State it principle of working with the help of a diagram. Mention various energy losses in this device.
   (ii) The primary coil of an ideal step up transformer has 100 turns and transformation ratio is also 100. The input voltage and power are respectively 220 V and 1100 W. Calculate
   (a) Number of turns in secondary
   (b) Current in primary
   (c) voltage across secondary
   (d) Current in secondary
   (e) Power in secondary

Ans: (i) Function: Transformer is used for converting low alternating voltage at high current into high voltage at low current and vice-versa.

Principle: It works on the principle of mutual induction.

Various Energy loses in transformer are -

(a) Flux losses.

(b) Copper and Iron losses.

(c) Hysteresis Losses

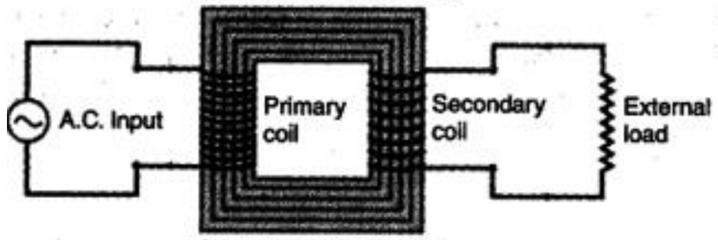
(d) Humming Losses.

Step-Up Transformer:

Converts low voltage A.C. into high voltage A.C. It increase the voltage

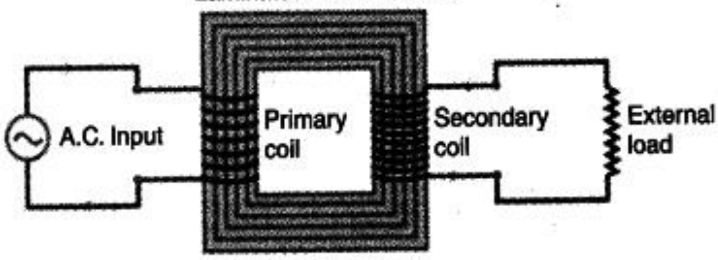
Converts high voltage A.C. into low voltage A.C. It reduces the voltage.

Laminated Soft Iron Core



Step-down Transformer

Laminated Soft Iron Core



Step-up Transformer

Step-Down Transformer :

(ii) Here transformation ratio,

$$k = 100, N_P = 100$$

(a) Number of turns in secondary

$$k = \frac{N_S}{N_P} \Rightarrow$$

$N_S = k \times N_P = 100 \times 100 = 10,000$

(b) Current in primary

Input power, $e_P I_P = 1100$ watt, $e_P = 220$ volt

$$\therefore \quad I_P = \frac{1100}{e_P} = \frac{1100}{220} = 5A$$

(c) Voltage across secondary,

$$k = \frac{e_S}{e_P}$$

$$e_s = ke_p = 100 \times 200 = 22,000 \text{ V}$$

(d) Current in secondary,

$$\frac{e_S}{e_P} = \frac{I_P}{I_S}$$

$$\Rightarrow \quad I_S = \frac{e_P}{e_S} \times I_P = \frac{220}{22000} \times 5$$

$$= 0.05 \text{ A}$$

(e) Since, transformer is an ideal one,

Power in secondary = Power in primary

= 1100 W

MM : 35 **Practice test** **Time : 90 Minutes**

1. When the rate of change of current is unity, the induced emf is equal to (1)
   (a) Thickness of coil
   (b) Number of turns in coil
   (c) Coefficient of self inductance
   (d) Total flux linked with coil
2. Identify the wrong statement. (1)
   (a) Eddy currents are produced in a steady magnetic field
   (b) Eddy currents can be minimized by using laminated core.
   (c) Induction furnace uses eddy current to produce heat.
   (d) Eddy currents can be used to produce braking force in moving trains.
3. A solenoid is connected to a battery so that a steady current flow through it. If an iron core is inserted into the solenoid, the current will (1)
   (a) Increase
   (b) Decrease
   (c) Remain same
   (d) First increase than decrease.
4. What is the frequency of a 5 μF capacitor that a reactance of 1000 Ω? (1)
   (a) 200 cycle / sec
   (b) $100/\pi$ cycle / sec
   (c) 5000 cycle / sec
   (d) $1000/\pi$ cycles/sec
5. What is the peak value of voltage of an electric lamp connected to a 220 V, 50 Hz supply? (1)
   (a) 311 V
   (b) 320 V
   (c) 211 V
   (d) 210 V
6. Case study (4 x 1 = 4)

For many purposes, it is necessary to change (or transform) an alternating voltage from one to another of greater or smaller value. This is done with a device called *transformer* using the principle of mutual induction.

A transformer consists of two sets of coils, insulated from each other. They are wound on a soft-iron core, either one on top of the other as in or on separate limbs of the core. One of the coils called the *primary coil* has *Np* turns. The other coil is called the *secondary coil*; it has *Ns* turns.

Often the primary coil is the input coil and the secondary coil is the output coil of the transformer. When an alternating voltage is applied to the primary, the resulting current produces an alternating magnetic flux which links the secondary and induces an emf in it. The value of this emf depends on the number of turns in the secondary. We consider an ideal transformer in which the primary has negligible resistance and all the flux in the core links both primary and secondary windings

6 (1) if the primary coil of a transformer has 100 turns and the secondary has 200 turns, $N_s/N_p = 2$. Thus, a 220V input at 10A will

a) step-up to 440 V output at 5.0 A.

b) step-up to 660 V output at 5.0 A

c) step-down to 220 V output at 15.0 A

d) step-down to 110 V output at 15.0 A

6 (2) For an Ideal transformer, $E_s / E_p = N_s / N_p$ is valid under the assumptions of

a) the primary resistance and current are small

b) the same flux links both the primary and the secondary as very little flux escapes from the core

c) the secondary current is small

d) All the above

6 (3) If the secondary coil has less turns than the primary ($N_s < N_p$), we will have

a) Step-Up Transformer

b) Step-Down Transformer

c) Neither Step-Up Transformer nor Step-Down Transformer

d) Both Step-Up Transformer and Step-Down Transformer

6 (4) In actual transformers, small energy losses do occur due to the

a) *Flux Leakage*

b) *Resistance of the windings*

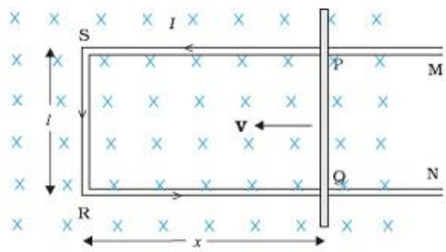
c) *Eddy currents*

d) All the above

7. An L-C-R series circuit connected to a variable frequency 220Vsource with L= 50mH, C = 80 μF and R = 50Ω. Determine (i) the source frequency which drives the circuit in resonance. (ii)Find the impedance of the circuit at resonance (2)

8. What are eddy currents? Write their two applications. (2)

9. Figure shows a rectangular loop conducting PQRS in which the arm PQ is free to move. A uniform magnetic field acts in the direction perpendicular to the plane of the loop. Arm PQ is moved with a velocity v towards the arm RS. Assuming that the arms QR, RS and SP have negligible resistances and the moving arm PQ has the resistance r,obtain the expression for the (i) the current in the loop (ii) the force and (iii) the power required to move the arm PQ with graph. (3)



10. (i) Derive an expression for the mutual inductance of two long coaxial solenoids of same length wound one over the other.
(ii) Write the factors on which the mutual inductance of a pair of solenoids depends. (3)

11. In a series *L-C-R* circuit connected to an a.c. source of variable frequency and voltage $V = V_0 \sin \omega t$, draw a plot showing the variation of amplitude of circuit current with angular frequency of applied voltage for two different values of resistance R_1 and R_2 ($R_1 > R_2$) . Write the condition under which the phenomenon of resonance occurs.
Answer the following using this graph:
(a) In which case the resonance is sharper and why ?
(b) In which case the power dissipation is more and why ?
(c) Which one would be better suited for fine tuning in a receiver set ? (3)

12. Obtain an expression for energy stored in a solenoid of self inductance 'L' when the current through it grows from zero to 'I'. (3)

13. series circuit is connected to an a.c. source having voltage $V = V_0 \sin \omega t$. Using phasor diagram, derive expressions for impedance, instantaneous current and its phase relationship to the applied voltage. Also draw graphs of *V* and *I* versus ωt for the circuit. (5)

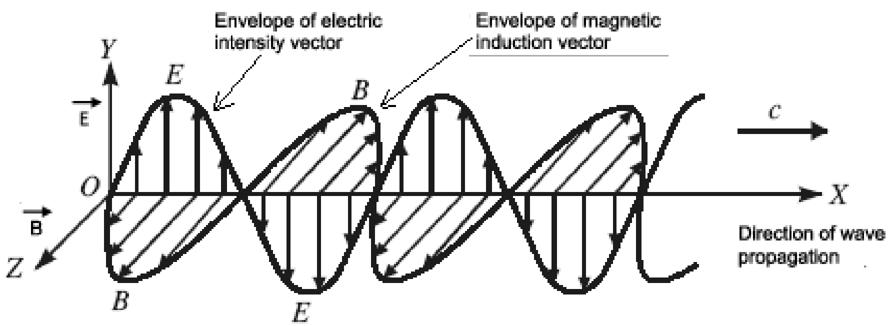
14. Explain with the help of labelled diagram, the principle and working of an AC generator and obtain expression for the emf generated in the coil. Draw a schematic diagram showing the nature of the alternating emf generated by rotating coil in the magnetic field during one cycle. (5)

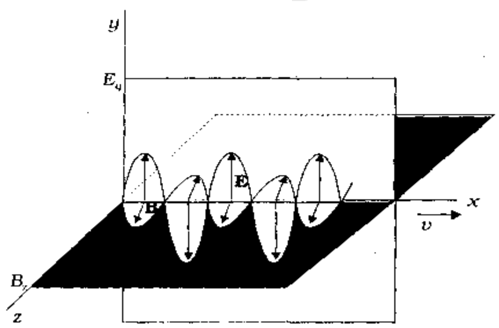
UNIT -5

Chapter – 08 Electromagnetic waves

Electromagnetic wave (E M Waves) : -

The electromagnetic waves are those waves in which there are sinusoidal variations of electric and magnetic field vectors at right angles to each other as well as right angles to the direction of wave propagation. It means electromagnetic waves are transverse in nature.





Properties/Characteristics of electromagnetic waves

(1) E. M. waves are produced by accelerated charged particles. For example an oscillating charge, a charge moving in a circular orbit.

(2) E.M. waves are transverse in nature i,e, Electric & magnetic fields are oscillate perpendicular to each other as well as perpendicular to the direction of propagation of the wave.
(3) The amplitudes of the electric and magnetic fields in free space or vacuum are related with each other

$$\frac{E}{B} = \frac{E_o}{B_o} = c$$

(4) The electromagnetic waves do not require any material medium for their propagation. These waves can propagate in vacuum as well as in a medium.

(5) All electromagnetic waves travel in free space or vacuum with a speed $3X10^8$ m/s and it is given by the relation $c = \frac{1}{\sqrt{\mu_o \in_o}} = 3 \times 10^8 m/s$

(6) The velocity of electromagnetic waves in a material medium is less than c = $3X10^8$ m/s and is given by $c = \frac{1}{\sqrt{\mu \in}}$

v = 1 / √με

= $1 / \sqrt{\mu_0 \mu r \varepsilon_0 \varepsilon r}$

= $1 / \sqrt{\mu r\ \varepsilon r}\sqrt{\mu_0 \varepsilon_0}$

= c / √μr εr = c/μ

(7) The EM waves are not deflected by electric and magnetic fields because these waves are uncharged.

(8) The electric field vector is responsible for optical effects of an EM waves and is called light vector as $E_0 >> B_0$.

(9) In EM waves, the oscillations of electric field and magnetic field are in the same phase.

(10) The cross product **EXB** always tells the direction in which the wave travels i.e. gives the direction of wave propagation.

(11) E.M. waves carry momentum & exert a radiation pressure $P = \frac{F}{A} = \frac{1}{A}\frac{dp}{dt}$ &

$$\text{momentum } p = \frac{U}{c}$$

(12) The EM waves obey principle of superposition.

(13) E.M. waves carry energy, which is shared equally by electric and magnetic fields.

(14) The velocity of electromagnetic waves depends entirely on the electric and magnetic properties the medium in which they travel and is independent of the amplitude of field vectors..

Electromagnetic spectrum :-

It is the orderly distribution/classification of electromagnetic waves according to their wavelength or frequency.

S.No.	Type	Wavelength range(λ)	Visible Spectrum		Decreasing Order of wavelength OR Increasing order of frequency
1	Radiowaves	>0.1m		Red	
2	Microwaves	0.1m to 1mm		Orange	
3	Infra -red rays	1mm to 700nm		Yellow	
4	Visible light	700nm to 400nm		Green	
5	Ultra-Voilet rays	400nm to 1nm		Blue	
6	X-rays	1nm to 10^{-3}nm		Indigo	
7	Gamma(γ) rays	<10^{-3}nm		Violet	

Note : - 1mm = 10^{-3}m and 1nm = 10^{-9}m

For frequency range using following relation c = νλ

- Radiowaves

  Production

  Radiowaves are produced by accelerated motion of charges in conducting wire or oscillating circuits.

  Uses/Applications

  - In radio and television communication systems
  - In radio astronomy.
  - Radiowaves are used by a F.M. radio station for broadcasting

Frequency range/bands	service
530KHz to 1710KHz	AM(Amplitude Modulated) band
1710KHz to 54MHz	Short wave AM band
88MHz to 108MHz	FM(Frequency Modulated) radio
54MHz to 890MHz	TV waves
840MHz to 935MHz	Cellular phones

- Microwaves

  Production

  Microwaves are produced by special vacuum tubes (called Klystron, Magnetrons and Gunn diodes)

  Applications/uses

  - Due to short wavelength, microwaves have high penetrating power with respect to atmosphere and are not diffracted by the obstacle in the path of their propagation.
  - In a microwave oven, frequency of microwaves matches the resonant frequency of water molecules for heating (about 3 GHz), so that the energy from the waves is transferred efficiently to the kinetic energy of the molecules. This raises the temperature of any food containing water.
  - are used in satellite communication/in radar and geostationary satellite.
  - are used for radar systems used in aircraft navigation'
  - microwaves because they go straight and are not absorbed by the atmosphere

- Infrared Rays

  Infrared waves are sometimes referred to as heat waves/radiations because they produces intense heating effect. Snakes can detect IR rays.

  Production-

  IR rays are produced by hot bodies and molecules (vibration of atom or molecules).

  Applications/uses

  (i) Infrared lamps are used in physical therapy i.e. to treat muscular strain

  (ii) used in haze photography i.e. for taking photograph during the conditions of fog, smoke rain etc. because IR rays are less scattered than visible light by atmospheric particles.

  (iii) used in remote control of T.V.& V.C.D.

(iv) used in weather forecasting through IR photography.
(v) used in greenhouse effect
(vi) used in solar cell, solar water heater & solar cooker
(vii) used in checking of purity of chemicals
(viii) used in revealing of secret writings on ancient walls
(ix) used in producing dehydrated fruits

- Visible light
  Uses/Applications
  (i) it produces the sense of vision
  (ii) it provides the information about the world
  (iii) it can cause chemical reactions
  (iv) used in photography to take the picture of objects.
  (v) used in optical instruments

- Ultraviolet rays/UV rays
  Production -The UV rays are produced by Sun, special lamps and very hot bodies. Most of the UV rays coming from the Sun are absorbed by ozone layer.
  UV radiations is absorbed by ordinary glass. Hence, one cannot get tanned or sunburn through glass windows.
  Welders wear special glass googles or face masks with glass windows to protect their eyes from large amount of UV rays produced by welding arcs.
  Uses/Applications
  (i) Infrared lamps are used in physical therapy i.e. to treat muscular strain
  (ii) used in haze photography i.e. for taking photograph during the conditions of fog, smoke rain etc. because IR rays are less scattered than visible light by atmospheric particles.
  (iii) used in remote control of T.V.& V.C.D.
  (iv) used in weather forecasting through IR photography.
  (v) used in greenhouse effect
  (vi) used in solar cell, solar water heater & solar cooker
  (vii) used in checking of purity of chemicals
  (viii) used in revealing of secret writings on ancient walls
  (ix) used in producing dehydrated fruits
- X-Rays
  Production-
  The x-rays are produced when high energy electrons bombard a metal target of high atomic number.
  Applications/Uses
  (i) used as diagnostic tool in medicine like to take the picture of internal organ of human body for the detection fractures in bones because X- rays can pass through flesh but not through bones.
  (ii) used in studying crystal structure because X-rays can be reflected diffracted by crystals.
  (iii) used in radiotherapy to care untraceable diseases and malignant growths.

(iv) structure used in detecting faults, cracks, haws & holes in metal sheets
(v) used in detecting pearls,oysters etc
(vi) used in detecting explosives etc
(vii) used in treatment of certain form of cancer.

- (Gamma) γ -Rays
  Production-
  Radioactive decay of the nucleus i.e. nuclear origin.
  Uses/Applications
  (i) used in treatment of cancer & tumour.
  (ii) used in nuclear reactions.
  (iii) used in study the structure of atomic nuclei.
  (iv) used to preserve food stuffs for a long time because soft γ -rays can kill micro-organisms.
  (v) used in detecting flaws in metal castings.
  (vi) used in manufacturing of polythylene from ethylene.

IDENTIFICATION OF IMPORTANT TOPICS/CONCEPT FOR SLOW LEARNER

ELECTROMAGNETIC SPECTRUM

<table>
<tr><th>Type of radiation</th><th>Properties</th><th>Uses/Applications</th></tr>
<tr><td>Radiowaves
Production-
Radiowaves are produced by accelerated motion of charges in conducting wire or oscillating circuits.</td><td>Obeys laws of refraction & reflection</td><td>(i)In radio and television communication systems
(ii)In radio astronomy.
(iii)Radiowaves are used by a F.M. radio station for broadcasting
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</table></td></tr>
<tr><td>Microwaves
Production-
Microwaves are produced by special vacuum tubes (called Klystron, Magnetrons</td><td>(i) produce heat when absorbed by matter
(ii) obeys laws of reflection & refraction</td><td>(i) used in radar system for aircraft navigation because they have good directional property due to their short wavelength.
(ii) used in long distance communication system via geostationary satellite
(iii) used in cooking (microwave oven). In such ovens, the frequency of the microwaves is selected to match the resonant frequency of</td></tr>
</table>

and Gunn diodes)		water molecules so that energy from waves is transferred efficiently to kinetic energy of the molecules. This rises the temperature of any food containing water. (iv) used in detecting the speed of cricket ball, tennis ball, speed of vehicles etc. (v) used in study of atomic & molecular structure
Infrared Rays Production- IR rays are produced by hot bodies and molecules (vibration of atom or molecules).	(i) produce intensive heating effect (ii) Snakes can detect IR rays. (iii) raise the temperature of the object on which they fall (iv) affect photographic plate (v) absorbed by most of the materials	(i) Infrared lamps are used in physical therapy i.e. to treat muscular strain (ii) used in haze photography i.e. for taking photograph during the conditions of fog, smoke rain etc. because IR rays are less scattered than visible light by atmospheric particles. (iii) used in remote control of T.V.& V.C.D. (iv) used in weather forecasting through IR photography. (v) used in greenhouse effect (vi) used in solar cell, solar water heater & solar cooker (vii) used in checking of purity of chemicals (viii) used in revealing of secret writings on ancient walls (ix) used in producing dehydrated fruits
Visible Light	(i) shows the phenomenon of reflection, refraction (ii)shows the phenomenon of interference, diffraction, polarization etc.	(i) it produces the sense of vision (ii) it provides the information about the world (iii) it can cause chemical reactions (iv) used in photography to take the picture of objects. (v) used in optical instruments
Ultraviolet Rays `Production - The UV rays are produced by Sun, special lamps and very hot bodies.	(i) Most of the UV rays coming from the Sun are absorbed by ozone layer. (ii) Welders wear special glass googles or face masks with glass windows to protect their eyes from large amount of UV rays produced by welding arcs. (iii) cause fluorescence in certain materials (iv) when allowed to fall	(i) UV lamps are used to kill germs in water purifiers. (ii) used in destroying bacteria & sterlizing surgical instruments (iii) used in LASIK (Laser Assisted in Situ Keratomileusis) eye surgery because UV radiations can be focused into very narrow beams for high precision applications. (iv) used in preserving food stuff (v) used in burglar alarm (vi) used in checking mineral samples (vii) used to check forged documents in the forensic labs

	on metal can cause emission of electrons (v) cause skin cancer when exposed to them	(viii) used in studying arrangement of electrons in outermost cell (ix) in study of molecular Structure. (x) can cause ionisation & promote chemical reaction
X-Rays Production- The x-rays are produced when high energy electrons bombard a metal target of high atomic number.	(i) ionize the gas through which they pass (ii) affect photographic plate very intensely (iii) not deflected by electric & magnetic fields (iv) produce injurious effect on human body	(i) used as diagnostic tool in medicine like to take the picture of internal organ of human body for the detection fractures in bones because X- rays can pass through flesh but not through bones. (ii) used in studying crystal structure because X-rays can be reflected diffracted by crystals. (iii) used in radiotherapy to care untraceable diseases and malignant growths. (iv) structure used in detecting faults, cracks, haws & holes in metal sheets (v) used in detecting pearls,oysters etc (vi) used in detecting explosives etc (vii) used in treatment of certain form of cancer.
(Gamma) γ -Rays Production- Radioactive decay of the nucleus i.e.nuclear origin	(i) have highest penetrating power, but very small ionizing power (ii) affect photographic plate (iii) not deflected by electric & magnetic fields (iv) produce heating effect	(i) used in treatment of cancer & tumour. (ii) used in nuclear reactions. (iii) used in study the structure of atomic nuclei. (iv) used to preserve food stuffs for a long time because soft γ -rays can kill micro-organisms. (v) used in detecting flaws in metal castings. (vi) used in manufacturing of polythylene from ethylene.

- **Mark questions**

- What oscillates in electromagnetic waves?
  Ans. Electric and magnetic vectors oscillates in an em wave
- What is the phase relationship between oscillating electric and magnetic fields in an em wave?
  Ans. They are in the same phase
- What is the frequency of em waves produced by oscillating charge of frequency?
  Ans. Frequency of em wave = frequency of oscillating charge =v
- When can a charge acts as a source of em wave?
  Ans. when charge is either accelerated or oscillating
- Write the relation for the speed of electromagnetic waves in terms of the amplitudes of electric and magnetic fields.
  Ans. Speed of em waves is given by the ratio of the amplitudes of electric and magnetic field vectors.

$$\frac{E}{B} = \frac{E_o}{B_o} = c$$

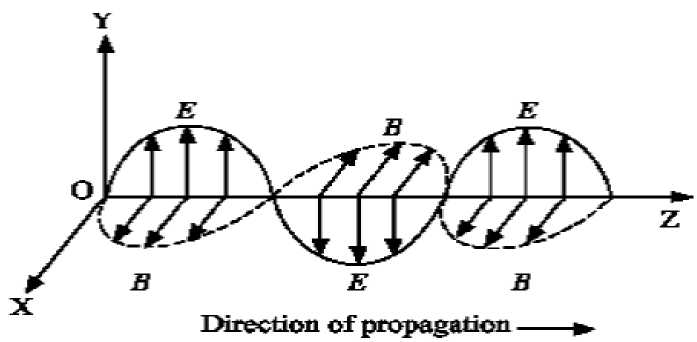
- Write the expression for speed of electromagnetic waves in a medium of electrical permittivity ε and magnetic permeability μ .

  Ans. $c = \frac{1}{\sqrt{\mu \in}}$
- In which directions do the electric and magnetic field vectors oscillate in an electromagnetic wave propagating along the x-axis?

  Ans. Electric field along y-axis and magnetic field along z-axis

  (Alternatively, electric field along z-axis and magnetic field along y-axis.)
- Draw a sketch of linearly polarized em waves propagating in the Z-direction. Indicate the directions of the oscillating electric and magnetic fields.

  Ans.



- Which physical quantity, if any, has the same value for the waves belonging to the different parts of the
  electromagnetic spectrum?

  Ans. Velocity/speed in free space or vacuum.
- Name the physical quantity which remains same for microwaves of wavelength 1mm and UV radiations of 1600 A^0 in vacuum.

  Ans. Velocity/speed in free space or vacuum.
- What is the ratio of speed of infrared and ultraviolet rays in vacuum?

  Ans. 1:1
- Give the ratio of velocities of wavelengths 4000 A^0 and 8000 A^0 in vacuum?

  Ans. 1:1
- Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiations.

  Name the radiations & write the range of their frequency.

  Ans. Ultraviolet radiations, from10^{14} Hz to10^{16} Hz.
- Why are microwaves found useful for the radar systems in aircraft navigation?

  OR

  State the reason why microwaves are best suited for long distance transmission of signals?

  Ans. Due to short wavelength, microwaves have high penetrating power with respect to atmosphere and are not diffracted by the obstacle in the path of their propagation.

- Which of the following electromagnetic radiations has least frequency?
  UV radiations, X-rays, Microwaves
  Ans. Microwaves
- Which of the following has the shortest wavelength?
  Microwaves, Ultraviolet rays, X-rays
  Ans. X-rays
- Arrange the following electromagnetic waves in order of increasing frequency:
  γ-rays, microwaves, infrared rays and Ultraviolet rays
  Ans. Microwaves, infrared rays, Ultraviolet rays, γ-rays

20. Arrange the following electromagnetic waves in order of decreasing frequency:
    x-rays, γ-rays, microwaves, UV rays and infrared rays
    Ans. γ-rays, x-rays, UV rays, infrared rays and Microwaves
21. Arrange the following em waves in order of their increasing wavelength:
    γ-rays, Microwaves, X-rays, U.V. rays and Radio waves
    Ans. γ-rays< X-rays< UV rays < Microwaves < Radio waves
22. Arrange the following electromagnetic waves in decreasing order of wavelength:
    γ-rays, infrared rays, x-rays and microwaves
    Ans. Microwaves, infrared rays, x-rays and γ-rays

ASSERTION (A) AND REASONING (R) QUESTIONS

A. Both assertion and reason are True, *and* reason is the correct explaination .

B. Both assertion and reason are True, *but* reason is not the correct explaination .

C. Assertion is True, but reason is False.

D. Both assertion and reason are False.

- Assertion: Electromagnetic waves do not require medium for their propagation.
  Reason: They can't travel in a medium.
  Answer: C
- Assertion: A changing electric field produces a magnetic field.
  Reason: A changing magnetic field produces an electric field.
  Answer: B
- Assertion: X-rays travel with the speed of light.
  Reason: X-rays are electromagnetic rays.
  Answer: A
- Assertion: Environmental damage has increased amount of Ozone in atmosphere.
  Reason: Increase of ozone increases amount of ultraviolet radiation on earth
  Answer: D
- Assertion: Electromagnetic radiation exert pressure.
  Reason: Electromagnetic waves carry both - Momentum & Energy.
  Answer: B
- Assertion: During discharging, there is magnetic field between plates of capacitor.
  Reason: Time varying electric field produces magnetic field.
  Answer: A
- Assertion: In electromagnetic waves, electric and magnetic Field are perpendicular to

each other.
Reason: E and B are self-sustaining.
Answer: B

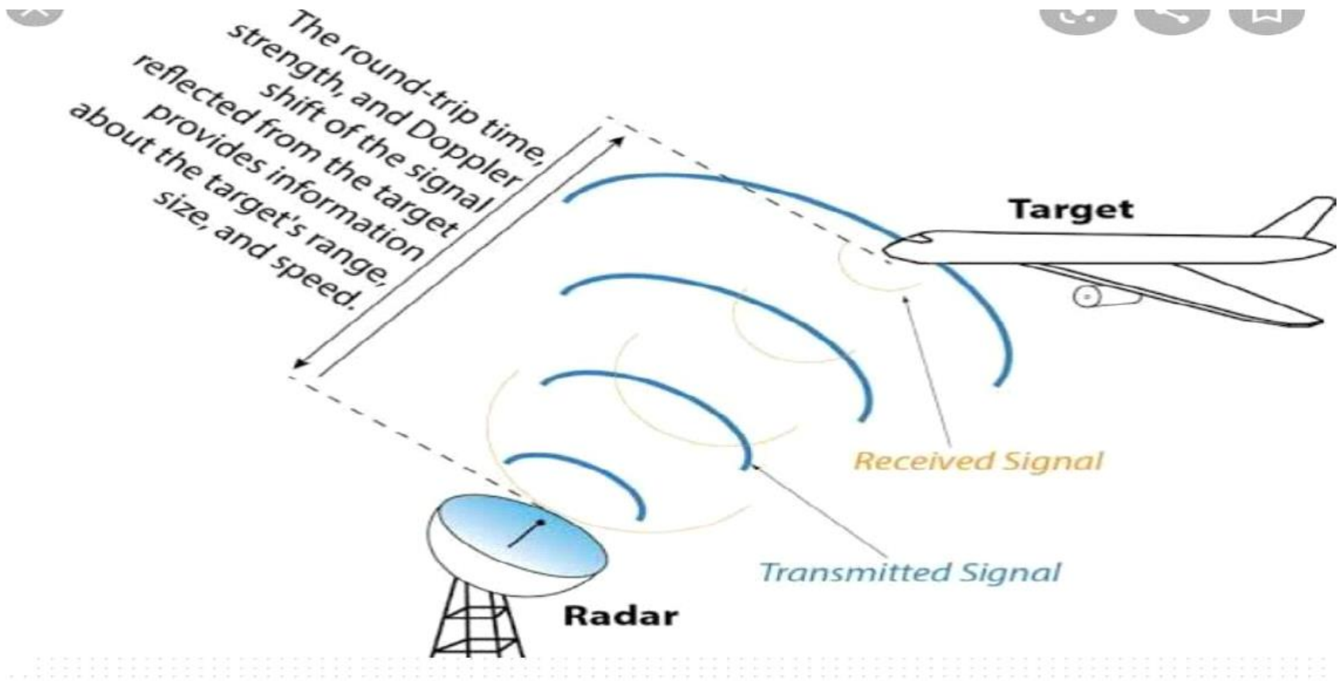
- Assertion: The earth without its atmosphere would be inhospitably Cold.
Reason: All heat would escape in the absence of atmosphere.
Answer: A
- Assertion: The EM waves of shorter wavelength can travel longer distances on earth's surface than those of longer wavelengths.
Reason: Shorter the wavelength, the larger is the Velocity of propagation.
Answer: C
- Assertion: EM waves follow Superposition principle.
Reason: Differential expression of EM wave is linear.
Answer: A
- Assertion: Sound waves cannot travel in vacuum, but light waves can.
Reason: Light is an electromagnetic wave - but sound is a Mechanical wave.
Answer: A
- Assertion: The Microwaves are better carriers of signals than radio waves.
Reason: The electromagnetic waves do not require any medium to propagate.
Answer: B
- Assertion: Transverse waves are not produced in liquids and gases.
Reason: Shorter the wavelength, the larger is the Velocity of propagation.
Answer: B
- Assertion: The energy contained in a small volume through which an em wave is passing, oscillates with the frequency of the wave.
Reason: Energy density of the wave is given by: $\frac{1}{2} \varepsilon_0 E^2$.
Answer: D
- Assertion: Like Light radiation, thermal radiations are also e.m. radiations.
Reason: Thermal radiations require no medium for propagation.
Answer: B
- Assertion: X-rays cannot be deflected by electric or magnetic fields.
Reason: These are electromagnetic waves.
Answer: A
- Assertion: EM waves are transverse in nature.
Reason: Waves of wavelength 10mm are radiowave and microwave.
Answer: C
- Assertion: Dipole oscillations produce em waves.
Reason: Accelerated charge produces em waves.
Answer: A
- Assertion: In an electromagnetic wave, magnitude of magnetic field vector B is much smaller than the magnitude of vector E .
Reason: This is because in an electromagnetic wave $E/B = c = 3 \times 10^8$m/s.
Answer: A
- Assertion: The gyrating electron can be a source of EM wave.
Reason: The electron in circular motion is accelerated motion.

Answer: A

- Assertion: EM waves interacts with matter and set up oscillations.
  Reason: Interaction is independent of em wave's Wavelength.
  Answer: C
- Assertion: When an em wave going through vacuum is described as :
  $E = E0 . \sin (kx-wt)$, then w/k is independent of wavelength.
  Reason: w / k is speed of the wave.
  Answer: A
- Assertion: Ozone layer is essential for sustaining life on earth .
  Reason: Ozone layer absorbs UV radiation, hence preventing it to reach on earth.
  Answer: A
- Assertion: Microwaves are considered suitable for radar, used in navigation
  Reason: Microwaves have wavelength of few millimeters. Due to this reason, they suffer very small diffraction.
  Answer: A
- Assertion: Ratio of speed of uv rays & infrared waves (in vacuum) is 1.
  Reason: Both; infrared and uv rays are electromagnetic waves.
  Answer: A
- Assertion: Welders wear face mask, goggles during welding - on eyes.
  Reason: 'Gamma' rays are produced by welding, is harmful for eyes.
  Answer: C
- Assertion: Infrared radiation are referred as Heat wave.
  Reason: they get readily absorb by molecules in most material.
  Answer: A
- Assertion: Ratio of frequencies of ultraviolet waves to infrared waves - is greater than 1.
  Reason: Frequency of u.v. rays is more than infrared rays.
  Answer: A
- Assertion: Gamma rays are more energetic than X-rays.
  Reason: Gamma rays are of nuclear origin- but X-rays are produced to sudden deceleration of high energy electrons while falling on a metal of high atomic number.
  Answer: B
- Assertion: The velocity of em wave depends on Electric and Magnetic properties of medium.
  Reason: Velocity of em waves in free space is constant.
  Answer: B

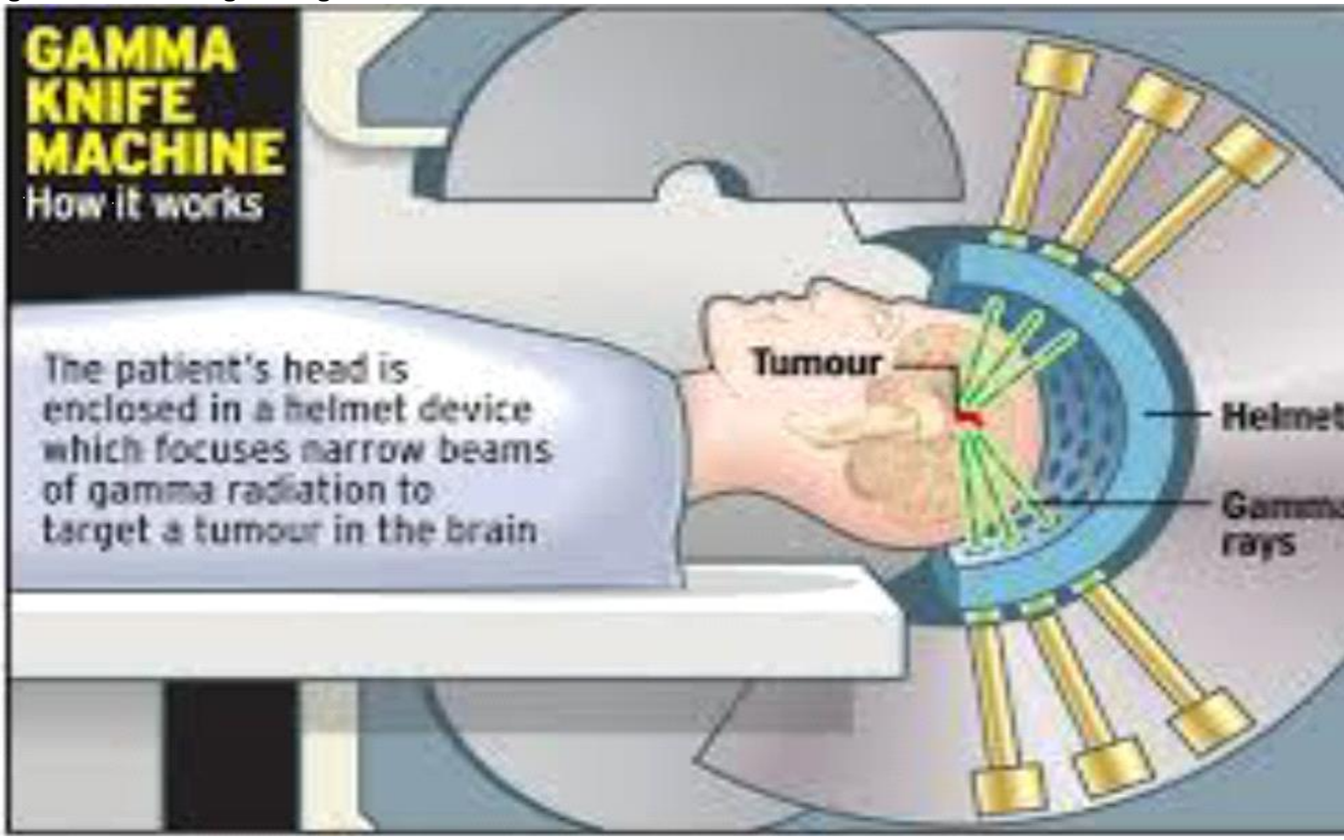
CASE STUDY BASED QUESTIONS

- Microwave in aircraft navigation
  Microwave are used in aircraft navigation. A radar guns out short bursts of microwave and it reflect back from oncoming aircraft and are detected by receiver in gun. The frequency of reflected wave used to compute speed of aircraft



(i) How are microwave produced?
a) klystron and magnetron valve
b) sudden deceleration of electron in x-ray tube
c)accelerated motion of charge in conducting wire
d)hot bodies and molecules
(ii) why microwave use for aircraft navigation?
a) due to high wavelength
b) due to low wavelength
c) due to low frequency
d)due to their frequency modulation power
(iii) which is use of microwave?
a) in treatment of cancer
b) to observe changing blood flow
c)used to kill microbes
d)studying details of atoms and molecule
(iv) where do microwave fall in electromagnetic spectrum?
a) between u.v region and infrared
b) between gamma and u.v
c)between infrared and radio wave
d)between gamma and infrared
Answer
(i) a) klystron and magnetron valve
(ii) b) due to low wavelength
(iii) d) studying details of atoms and molecule
(iv) c) between infrared and radio wave

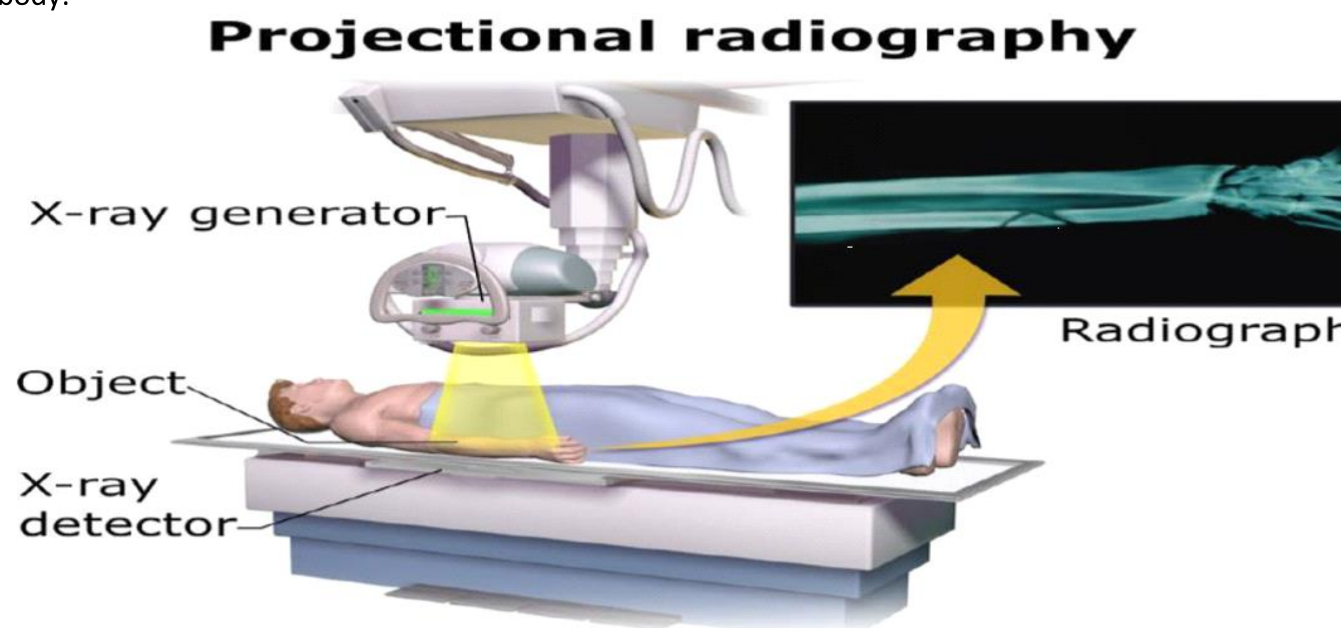
- GAMMA RAYS IN TREATMENT OF CANCER
  Gamma rays are used in radiotherapy to Treat cancer. They are used to spot tumors. they kill the living cells and damage malignant tumour.



(i) what is the source of gamma rays?
a) radioactive decay of nucleus
b) accelerated motion of charges in conducting wire
c) hot bodies and molecule
d) klystron valve
(ii) how is wavelength of gamma rays
a) low
b) high
c) infinite
d) zero
(iii)choose the one with correct radiation order?
a) alpha>beta>gamma
b) beta>alpha>gamma
c) gamma>beta>alpha
d) gamma>alpha>beta
(iv) what is other use of gamma rays?
a) used to change white topaz to blue topaz
b) used in aircraft navigation

c) used in kill microbes
d) checking fractures of bone
Answers

- a) radioactive decay of nucleus
- b) high
- c) gamma>beta>alpha
- a) used to change white topaz to blue topaz
- X- Rays
  X-rays are a form of electromagnetic radiation, similar to visible light. Unlike light, however, x-rays have higher energy and can pass through most objects, including the body. Medical x-rays are used to generate images of tissues and structures inside the body.



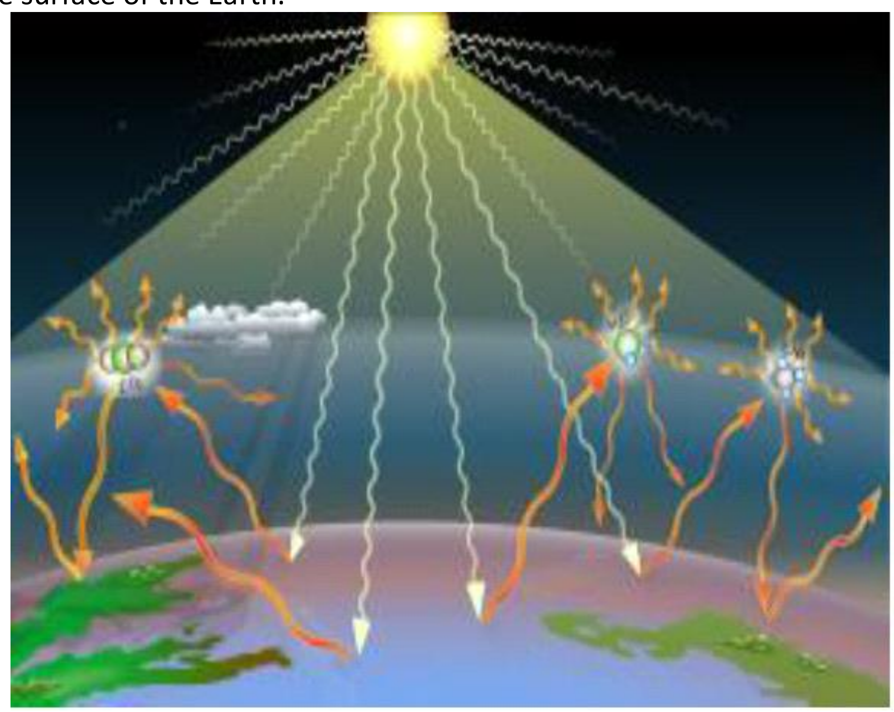
(i). What is the most common method of preparation of X rays ?
a) magnetron valve
b) vibration of atoms and molecules
c) bombardment of metal by high energy electrons
d) radioactive decay of nucleus
(ii). which of the following set of instrument /equipment can detect X- rays
a) Photocells, photographic film
b) Thermopiles, bolometer
c) Photographic film, Geiger tube
d) Geiger tube, human eye
(iii). where do X rays fall on the electromagnetic spectrum?
a) Between UV region and infrared region
b) Between gamma rays and UV region

c) Between infrared and microwaves
d) Between microwaves and radio waves
(iv) what is the use of rays lying beyond X ray region in electromagnetic spectrum
a) used to kill microbes
b) used to detect heat loss in insulated systems
c) used in standard broadcast radio and television
d) used In oncology, to kill cancerous cells.
Answers

- c) bombardment of metal by high energy electrons
- c) Photographic film, Geiger tube
- b) Between gamma rays and UV region
- d) used In oncology, to kill cancerous cells.

- Greenhouse effect

The greenhouse effect is a natural process that warms the Earth's surface. When the Sun's energy reaches the Earth's atmosphere, some of it is reflected back to space and the rest is absorbed and re-radiated by greenhouse gases. The absorbed energy warms the atmosphere and the surface of the Earth.



(i). The one which is not considered as naturally occurring greenhouse gas is
(a) methane
(b) CFCs
(c) carbon dioxide
(d) nitrous oxide
(ii). Which of the following is not a use of infrared waves
a) Used in treatment for certain forms of cancer
b) in military and civilian applications include target acquisition, surveillance, night vision, homing, and tracking.

c) to observe changing blood flow in the skin
d) In imaging cameras, used to detect heat loss in insulated systems
(iii). which of the following is the best method for production of infrared waves
a) bombardment of metal by high energy electrons
b) radioactive decay of nucleus
c) magnetron valve
d) vibration of atoms and molecules
(iv). Wavelength of infrared radiations is
(a) shorter (b) longer (c) infinite (d) zero
Answers

- (b) CFCs
- (a) Used in treatment for certain forms of cancer
- (d) vibration of atoms and molecules
- (b) longer

- ELECTROMAGNETIC (EM) SPECTRUM

The electromagnetic (EM) spectrum is the range of all types of EM radiation. Radiation is energy that travels and spreads out as it goes – the visible light that comes from a lamp in your house and the radio waves that come from a radio station are two types of electromagnetic radiation. The other types of EM radiation that make up the electromagnetic spectrum are microwaves, infrared light, ultraviolet rays, X- rays and gamma rays.
(i). The classification is roughly based on?
a) Wavelength and frequency of waves.
b) Production and detection of waves.
c) The way of travelling of waves.
d) Year discovered.
(ii). Which of the following is NOT an example of EM RAYS.
a) Radiotherapy(medicine).
b) Checking fractures.
c) Sterilisation.
d) Explosives.
(iii). Identify the pair having highest frequency and highest wavelength EM WAVES.
a) UV rays and X- rays
b) Gamma rays and Microwaves.
c) Gamma rays and Radio waves.
d) Radio waves and UV rays.
(iv). What physical quantity is the same for X rays of wavelength 10^{-10}m, red light of wavelength 6800 A^0 and radiowaves of wavelength 500m?
a) Speed in vacuum (c)
b) frequency (f)
c) Scattering
d) Energy (e)
Answers
(i). b) Production and detection of waves.

(ii). d) Explosives.

(iii). c) Gamma rays and Radio waves.

(iv). a) Speed in vacuum (c)

2 Marks questions

- What are electromagnetic waves? Are these waves transverse or longitudinal?
  Ans. The waves produced by accelerated charged particles, in which there are sinusoidal variations of electric and magnetic field vectors at right angles to each other as well as at right angles to the direction of propagation of wave, are called electromagnetic waves.
  em waves are trans verse in nature
- (i) How are electromagnetic waves produced? Explain.
  (ii) What is the source of energy of these waves?
  Ans. **(i) Production of em waves:** em waves are produced by accelerated/ oscillating charges
  A charge oscillating with some frequency, produces an oscillating electric field in space, which produces an oscillating magnetic field perpendicular to the electric field, which in turn is a source of electric field, this process goes on repeating, producing em waves in space perpendicular to both fields.
  (ii) Source of energy of em waves is the energy of accelerated/ oscillating charge
- Name the following constituent radiations of electromagnetic spectrum which-
  (i) are used in satellite communication/in radar and geostationary satellite
  (ii) are used for studying crystal structure of solids
  (iii) are similar to the radiations emitted during decay of radioactive nuclei
  (iv) used for water purification/ are absorbed from sunlight by ozone layer
  Ans. (i) microwaves (ii) x- rays (iii) - rays (iv) UV rays
- Name the following constituent radiations of electromagnetic spectrum which-
  (i) has its wavelength range between 390 nm to 770 nm
  (ii) produce intense heating effect/ used in warfare to look through fog
  (iii) in photographs of internal parts of human body/as a diagnostic tool in medicine
  (iv) are used for radar systems used in aircraft navigation
  Ans. (i) visible light (ii) Infrared rays(iii) X -ray (iv) microwaves
- State any four properties of electromagnetic waves.
  Ans. (i) do not require any material medium for their propagation
  (ii) transverse in nature
  (iii) do not get deflected by electric or magnetic fields
  (iv) same speed in vacuum for all waves
- Identify the electromagnetic waves whose wavelength vary as and also write one use for each.
  (i) $10^{-12}m < \lambda < 10^{-8}m$ (ii) $10^{-3}m < \lambda < 10^{-1}m$
  Ans. (i) X-rays/ γ-rays used for medical purposes/ nuclear reactions (ii) Microwaves used for radar systems

- Identify the electromagnetic waves whose wavelength vary as and also write one use for each.
  (i)10^{-14}m <λ< 10^{-11}m (ii) 10^{-6}m <λ< 10^{-4}m
  Ans. (i) X-rays/γ-rays used for medical purposes/ nuclear reactions
  (ii) Infrared/ visible used for muscular treatment/ vision

3 Marks questions

- Which em waves lie near the high frequency end of visible part of em spectrum? Give its one use. In what way this component of light has harmful effects on humans?
  Ans. Ultraviolet rays used in LASIK eye surgery, UV lamps to kill germs in water (water purification)
  UV rays causes Skin Cancer/Sunburn/ harms eyes when exposed to direct UV rays
- Why is the thin ozone layer on the top of stratosphere is crucial for human survival? Identify to which part of electromagnetic spectrum does this radiation belong and write one important application of the radiation.
  Ans. Because ozone layer absorbs ultraviolet radiation coming from the sun and thus prevent these radiations from reaching the earth which causes Cancer
  Identification: Ultraviolet radiations
  Application: Water purification/ forensics
- How are infrared rays produced? Why are these referred to as "heat waves? Write their three important uses.
  Name the radiations which are next to these radiations in the electromagnetic spectrum having (a) shorter wavelength (b) longer wavelength.
  Ans. Production: Infrared waves are produced by hot bodies due to the vibrations of their atoms/molecules.
  Infrared rays are called heat waves because they produce heat when they fall on any object.
  Uses: (i) in photography during fog (ii) treating muscular strain (iii) in remote controls of electronic devices
  Radiations: (a) Visible light (b) Microwaves
- Electromagnetic waves with wavelengths-
  (i) $\lambda_1$are used to treat muscular strain
  (ii) $\lambda_2$are used by a F.M. radio station for broadcasting
  (iii) $\lambda_3$are used to detect fractures in bones
  (iv) $\lambda_4$are absorbed by ozone layer of the atmosphere
  Identify the name and part of electromagnetic spectrum to which these radiations belong. Arrange these
  wavelengths in order of magnitude.
  Ans. (i) Infrared rays (ii) radio waves (iii) x- rays (iv) UV rays, $\lambda_2 > \lambda_1 > \lambda_4 > \lambda_3$
- Which constituent radiations of electromagnetic spectrum is used -
  (i) in Radar
  (ii) in photographs of internal parts of human body/as a diagnostic tool in medicine
  (iii) for taking photographs of sky, during night and fog conditions.
  (iv) has the largest penetrating power

Give reason for your answer in each case.

Ans. (i) microwaves because they go straight and are not absorbed by the atmosphere
(ii) x- rays because they can penetrate light elements (flesh)
(iii) Infrared rays, because they penetrate fog and are not absorbed by the atmosphere
(iv) γ-rays as they have the highest frequency and hence highest energy

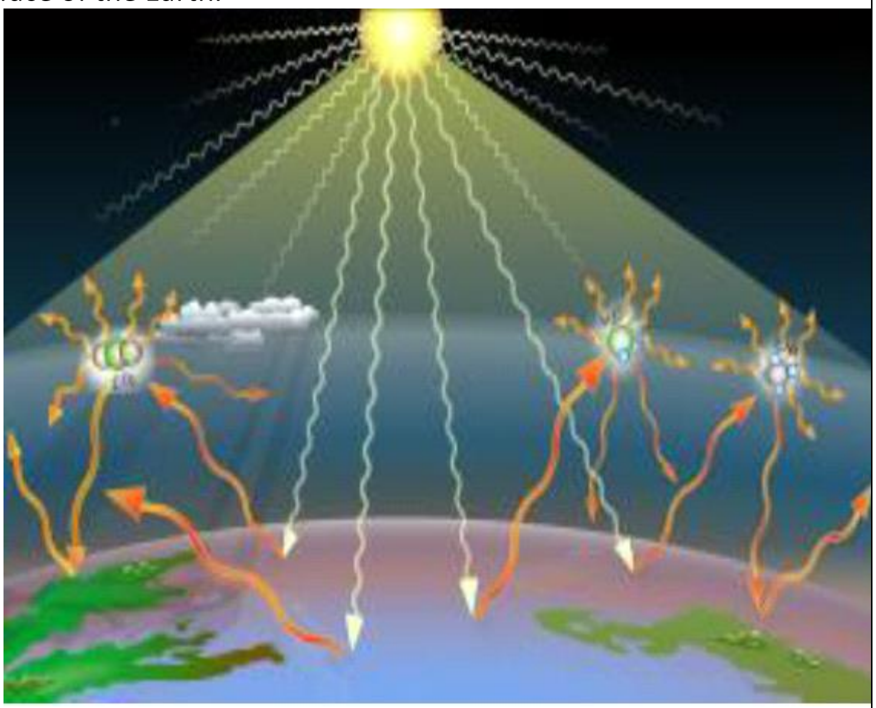
Worksheet

S.No.	Questions	Marks
1	Microwaves are used in RADAR. Why?	1
2	Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiations. Name the radiations and write the range of their frequency	½ + ½
3	Arrange the following electromagnetic waves in order of increasing frequency: γ-rays, microwaves, infrared rays and Ultraviolet rays	1
4	Write the relation for the speed of electromagnetic waves in terms of the amplitudes of electric and magnetic fields.	1
5	Give the ratio of velocities of wavelengths 4000 A^0 and 8000 A^0 in vacuum?	1
	ASSERTION (A) AND REASONING (R) QUESTIONS **For question numbers 6 and 7, two statements are given-one labeled Assertion (A) and the other labeled Reason (R). Select the correct answer to these questions from the codes (A), (B), (C) and (D) as given below**. **A. Both assertion and reason are True, *and* reason is the correct explaination .** **B. Both assertion and reason are True, *but* reason is not the correct explaination .** **C. Assertion is True, but reason is False.** **D. Both assertion and reason are False.**	
6	Assertion: Ozone layer is essential for sustaining life on earth. Reason: Ozone layer absorbs UV radiation, hence preventing it to reach on earth.	1
7	Assertion: Dipole oscillations produce em waves. Reason: Accelerated charge produces em waves.	1
8	**Question number 8 is Case Study based questions and are compulsory.**	4

Attempt any 4 sub parts from each question. Each question carries 1 mark.

Greenhouse effect

The greenhouse effect is a natural process that warms the Earth's surface. When the Sun's energy reaches the Earth's atmosphere, some of it is reflected back to space and the rest is absorbed and re-radiated by greenhouse gases. The absorbed energy warms the atmosphere and the surface of the Earth.



(i). The one which is not considered as naturally occurring greenhouse gas is

(a) methane

(b) CFCs

(c) carbon dioxide

(d) nitrous oxide

(ii). Which of the following is not a use of infrared waves

a) Used in treatment for certain forms of cancer

b) in military and civilian applications include target acquisition, surveillance, night vision, homing, and tracking.

c) to observe changing blood flow in the skin

d) In imaging cameras, used to detect heat loss in insulated systems

(iii). which of the following is the best method for production of infrared waves

a) bombardment of metal by high energy electrons

b) radioactive decay of nucleus

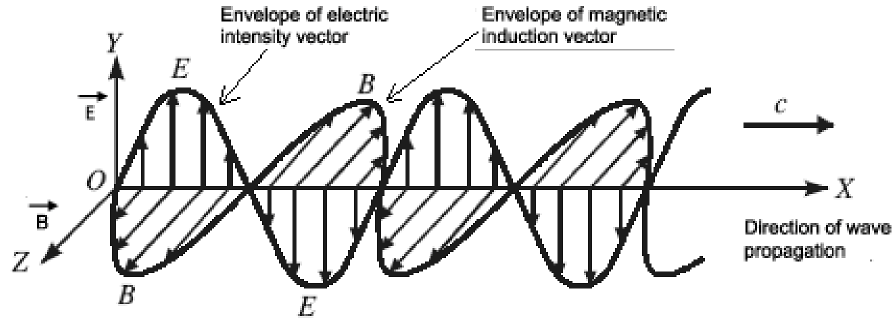
c) magnetron valve

	d) vibration of atoms and molecules (iv). Wavelength of infrared radiations is (a) shorter (b) longer (c) infinite (d) zero (v) If the amplitude of the electric field in a plane electromagnetic wave is 100V/m then the amplitude of the magnetic field is: (a) 0.27T (b) 6.7×10^{-7} T (c) 3.3×10^{-7} T (d) 8.0 $\times 10^{7}$ T	
9	Name the following constituent radiations of electromagnetic spectrum which- (i) are used in satellite communication/in radar and geostationary satellite (ii) are used for studying crystal structure of solids (iii) are similar to the radiations emitted during decay of radioactive nuclei (iv) used for water purification/ are absorbed from sunlight by ozone layer	2
10	Write any four characteristics of EM waves.	2
11	Which constituent radiations of electromagnetic spectrum is used - (i) for taking photographs of sky, during night and fog conditions. (ii) has the largest penetrating power Give reason for your answer in each case.	2
12	Electromagnetic waves with wavelengths- (i) $\lambda_1$are used to treat muscular strain (ii) $\lambda_2$are used by a F.M. radio station for broadcasting (iii) $\lambda_3$are used to detect fractures in bones (iv) $\lambda_4$are absorbed by ozone layer of the atmosphere Identify the name and part of electromagnetic spectrum to which these radiations belong. Arrange these wavelengths in order of magnitude.	3
13	What is meant by transverse nature of electromagnetic wave? Draw a diagram showing the propagation of an electromagnetic wave along the X-direction, indicating clearly the directions of the oscillating electric and magnetic fields associated with it.	3
14	Identify the following electromagnetic radiation as per the wavelength given below. Write one application of each. a)10^{-12}m b)10^{-4}m c)10^{6}m	3

Answers

S.No.	Answers	Marks

1	As microwaves are of smaller wavelengths, hence they can be transmitted as a beam signal in a particular direction much better than radiowaves because microwaves do not bend around the corner of any obstacle coming their path.	1
2	Ultraviolet radiations. Frequency range: $5x10^{16}$ to $8x10^{14}$ Hz	1
3	Microwaves, infrared rays, Ultraviolet rays, γ-rays	1
4	Speed of em waves is given by the ratio of the amplitudes of electric and magnetic field vectors. $\frac{E}{B} = \frac{E_o}{B_o} = c$	1
5	1:1	1
6	A	1
7	A	1
8	• (b) CFCs • (a) Used in treatment for certain forms of cancer • (d) vibration of atoms and molecules • (b) longer • (c) 3.3×10^{-7} T	4
9	(i) microwaves (ii) x- rays (iii) - rays (iv) UV rays	½X4=2
10	(i) E. M. waves are produced by accelerated charged particles. (ii) E.M. waves do not require any medium for their propagation. These waves can propagate in vacuum as well as in a medium. (iii) Velocity of em waves in a free space is given by, v = c = m/s (iv)They are deflected by electric and magnetic field.	½X4=2
11	(i) Infrared rays, because they penetrate fog and are not absorbed by the atmosphere (ii) γ-rays as they have the highest frequency and hence highest energy	½+½ ½+½
12	(i) Infrared rays (ii) radio waves (iii) x- rays (iv) UV rays, $\lambda_2 > \lambda_1 > \lambda_4 > \lambda_3$	½X4=2 1
13	E.M. waves are transverse in nature i.e., E & B are perpendicular to each other as well as perpendicular to the direction of propagation of the wave.	1 2

		
14	Identification: - a) gamma rays use- radiotherapy b) Infrared rays use – haze photography c) long radio wave use in radio communication	½+½ ½+½ ½+½

Unit-6, Chapter–9, Ray Optics

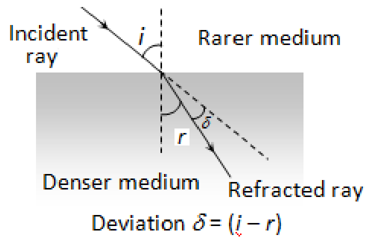
Ray Optics:-It is the branch of physics in which we study about the phenomenon of light without taking into the account the nature of light. In ray optics we use the concept of the geometry so it is also known as geometric optics. The straight Lines that show the direction of the propagation of wave of light is called **ray** of light.
If the size of object is sufficiently greater than the wavelength of the light then we can ignore interference and diffraction. Hence ray optics is limiting case of wave optics.

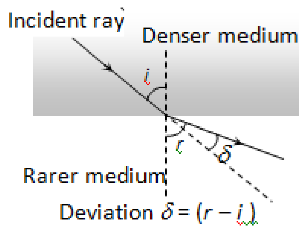
Light: - Light is a form of energy, which gives us sense of sight.Light is a very small portion of electromagnetic waves. It has all the properties of a transverse wave and can travel through a vacuum.
Different colours light has different wavelength.

Image: -After reflection (or refraction) the light rays actually meet at a point or appear to meet at a point then the point is called image. **OR** After reflection (or refraction) the light rays converge at a point or appear to diverge from a point then the point is called image.

Real Image: -A real image is the image which can be obtained on a screen. A real image is the image in which the light rays actually (really) pass (meet) at some points. e.g. Image formed by concave mirror & convex lens.

Virtual Image: - A virtual image is the image which can not be obtained on a screen. A virtual image is the image in which after reflection (or refraction) the light rays appear to meet at some points or light rays appear to diverge from a point.[light rays are not actually (really) pass (meet) at some points] .e.g. The images appearing behind a plane mirror (concave lens) are virtual images, because in this case light rays never pass through the image.





Refraction: - When a light rays passes from one medium to another, the direction of light changes, this bending of light rays when light rays pass from one medium to another is called refraction.

Cause: -Light travel with a different speed in different materials, which causes change in direction of light.

Optically Denser and Rarer Medium: -Light travels at different speeds through different types of medium. The one in which light travels slower is called an optically denser medium; otherwise, it is an optically rarer medium.

From Optically Denser Medium to Rarer One: -Consider a light ray that enters from an optically denser medium to an optically rarer one then light rays moves away from normal. The angle of refraction is larger than the angle of incidence. When angle of incidence gradually increases, the angle of refraction increases more, and the refracted ray becomes closer and closer to the boundary surface.

From Optically Rarer Medium to Denser One: -Leta light ray that enters from an optically rarer medium to optically denser one then light rays moves towards the normal. The angle of refraction is smaller than the angle of incidence.

Snell's Law: -The ratio of the sine of the incident angle to the sine of the refracted angle is a constant.

$$\frac{\sin i}{\sin r} = \mu_{12} \qquad (\text{Or} \quad {}_1\mu_2 \quad \text{Or} \quad {}^1\mu_2) \text{ (Constant)}$$

Refractive Index: -The refractive index of a transparent medium is a measure of the degree to which the medium refracts (bends) a ray of light passing through it. The refractive index of a material indicates the extent to which light is refracted when it passes from a vacuum to that material.

Dependence of Refractive index:–

(i)Nature of the media of incidence and refraction. (ii) Colour of light or wavelength of light. It does not depend on the frequency of the light because frequency remains constant when light passes from one medium to another.

(iii)Temperature of the media : Refractive index decreases with the increase in temperature.
The refractive index determines the angles at which light rays are refracted into and out of the medium.

Refractive Index is defined as the ratio of the speed of light in a vacuum to the speed of light in the material. The higher the refractive index of a material, the more slowly light travels through it. Glass, for example, has a refractive index of about 1.5, water has 1.3, ice has 1.31, and Quartz has 1.55 & ruby 1.71. This indicates that light travels more slowly through glass than it does through water. Refractive index of the 2nd medium with respect to 1st medium

Speeds of light and indices of refraction of some medi

Medium	Speed of light (10^8 m/s)	Index of refraction
vacuum	3.0	1.0000
air	3.0	1.0003
water	2.25	1.33
flint	1.61	1.86
diamond	1.24	2.42

$$\mu_{12} = \frac{v_1}{v_2} = \frac{\text{Velocity of light in first medium}}{\text{Velocity of light in second medium}}$$

Also ${}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{\lambda_1}{\lambda_2}$

If first medium is air then refractive index of the medium with respect to air is called absolute refractive index

$$\mu = \frac{c}{v} = \frac{\text{Velocity of light in air}}{\text{Velocity of light in medium}}.$$

The refractive index of a transparent medium is a measure of the degree to which the medium refracts (bends) a ray of light passing through it, and reflects light from its surface. The refractive index of a material indicates the extent to which light is refracted when it passes from a vacuum to that material. The refractive index determines the angles at which light rays are refracted into and out of the medium.

Example of Refraction: - Refraction also occurs with sound and with other types of waves, including the seismic waves produced by earthquakes.

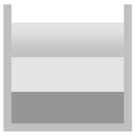
1) **Deep Water appear shallow** : -Consider an object 'O' placed in side of water so OB is incident ray with angle of incident 'i' , light moving from denser to rare medium so refracted light ray BC move away from the normal with angle of refraction 'r'. Another light ray incident normally at i = 0 so it will move straight. The two refracted rays are diverging rays and we extend the refracted rays then they appear to meet at point 'I' forming virtual image.

From Snell's law of refraction $\frac{\sin i}{\sin r} = \mu_{wa}$ - - - (1)

$\angle i = \angle x$ (Alternate interior angle) & $\angle r = \angle y$ (Corresponding angle)

$$\frac{\sin x}{\sin y} = \frac{1}{\mu_{aw}} \Rightarrow \frac{AB/OB}{AB/IB} = \frac{1}{\mu_{aw}} \Rightarrow \frac{IB}{OB} = \frac{1}{\mu_{aw}} \Rightarrow \mu_{aw} = \frac{OB}{IB}$$

If point P is close to A then OB ≈ OA- real depth, IB ≈ IA- apparent depth



$$\boxed{\mu_{aw} = \frac{OA}{IA} = \frac{Real\ depth}{Apparent\ depth}}$$

Since μ is always greater then 1 so object always seems to be raised up.
This explain why a coin inside water appear to be slightly raised OR water appear to be shallow in a tank while it is not so.

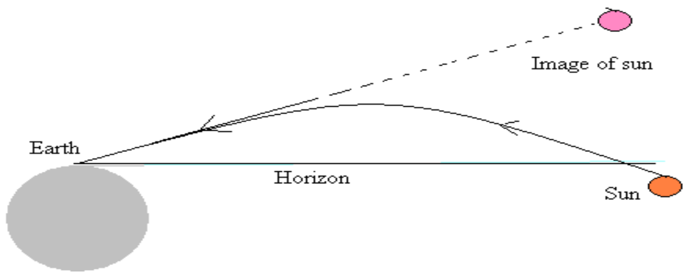
***If a beaker contains various immiscible liquids as shown then apparent depth of bottom $= \frac{d_1}{\mu_1} + \frac{d_2}{\mu_2} + \frac{d_3}{\mu_3} + ...$

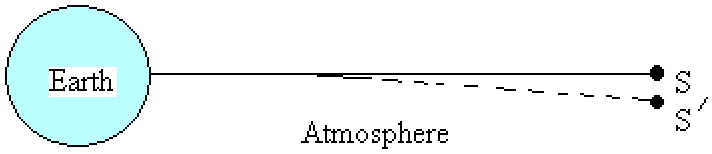
$\mu_{\text{combination}} = \frac{d_{AC}}{d_{App.}} = \frac{d_1 + d_2 + ...}{\frac{d_1}{\mu_1} + \frac{d_2}{\mu_2} + ...}$ (In case of two liquids if $d_1 = d_2$ than $\mu = \frac{2\mu_1\mu_2}{\mu_1 + \mu_2}$)

2) **Early rising & late setting of sun**: -Atmosphere extends up to a distance about 500 km above the surface of the earth. The density and hence refractive index of the air decreases as we moves up. Light rays from sun enters in the atmosphere from rarer to denser medium due to refraction bent towards normal and reaches to the observer on earth. If we extend these refracted rays then they appear to meet at point $S^/$ i.e. the rays appear to come from $S^/$ and form a virtual image of sun which is above the horizon while the sun is still below horizon.

When the sun is near the horizon the thickness of the atmosphere is maximum so the size of the sun is larger than at noon, when light has to travel minimum thickness of air.

c) **A stick in water appear to be bent**: - The light rays from the stick C move from water to air due to refraction light rays move away from the normal. The refracted rays appears to start from some another point D. the position BC appear at position BD i.e. the stick appear bent at B.



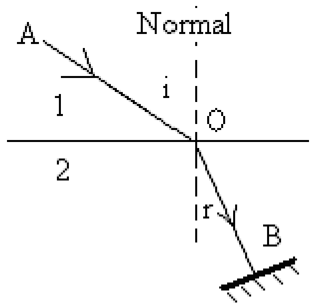


d) **Twinkling of the stars**:-The density of the atmosphere continuously changes due to this reason the rays of light from stars undergoes reflection at different layers and apparent image of the star S appears to be at $S^{/}$. The position of the $S^{/}$ also changes continuously so the stars appear to be twinkling.

<u>Principle of Reversibility</u>: -**Statement**: -" If light after suffering any number of reflection & refraction, has its final path reversed then the light rays (retraces) travels back along the same path".

Proof: -Consider AO is incident ray with angle of incident 'i'. OB is refracted ray with angle of refraction 'r'.

From Snell's law of refraction $\frac{\sin i}{\sin r} = \mu_{12}$ - - - - (1)

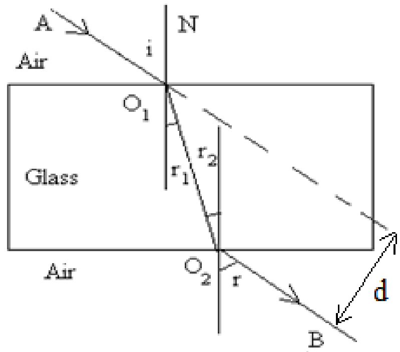


If the plane mirror is placed perpendicular to the refracted ray since i = o so r = 0 therefore the light ray retraces its path. Now BO is incident ray with angle of incident 'r' & OA is refracted ray with angle of refraction 'i'.

From Snell's law of refraction $\frac{\sin r}{\sin i} = \mu_{21}$ - - - (1) Multiplying eq1 &eq2

$\frac{\sin i}{\sin r} \times \frac{\sin r}{\sin i} = \mu_{12} \times \mu_{21}$ Hence $\boxed{\mu_{12} \times \mu_{21} = 1}$ OR $\boxed{\mu_{12} = \frac{1}{\mu_{21}}}$

<u>Refraction through glass slab</u>: - Let AO_1 is incident ray in air with angle of incident 'i'. O_1B is refracted ray in glass with angle of refraction 'r_1'.



From Snell's law of refraction $\frac{\sin i}{\sin r_1} = \mu_{ag}$ - - - - (1)

Now light is travelling from glass to air. O_1O_2 is incident ray with angle of incident 'r_2', O_2B is refracted ray with angle of refraction 'e' also called angle of emergent.From Snell's law of refraction

$\frac{\sin r_2}{\sin e} = \mu_{ga}$ - - - (2) Multiplying eq1 & eq2 $\frac{\sin i}{\sin r_1} \times \frac{\sin r_2}{\sin e} = \mu_{ag} \times \mu_{ga}$

But $r_1 = r_2$ alternate interior angle & $\boxed{\mu_{12} \times \mu_{21} = 1}$ $\frac{\sin i}{\sin r_2} \times \frac{\sin r_2}{\sin e} = 1$ $\Rightarrow$ $\sin i = \sin e$ Hence $\boxed{e = i}$. Henceincident ray & emergent rays are parallel to each other in a glass slab however the emergent get laterally displaced.

Lateral shift of the ray is the perpendicular distance between the incident and the emergent ray, and it is given by

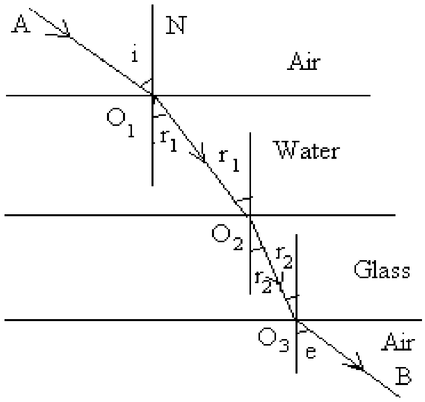
$\boldsymbol{d = t \sec r \sin (i - r)}$

<u>Refraction through several medium:</u> -Consider three medium air, water & glass separated by parallel surfaces. Consider light travelling from air to water. AO_1 is incident ray with angle of incident 'i'O_1B is refracted ray with angle of refraction 'r_1'.

From Snell's law of refraction $\frac{\sin\ i}{\sin\ r_1} = \mu_{aw}$ - - - - (1)

Now light is travelling from water to glass. O_1O_2 is incident ray with angle of incident 'r_1', O_2O_3 is refracted ray with angle of refraction 'r_2'. From Snell's law of refraction $\frac{\sin\ r_1}{\sin\ r_2} = \mu_{wg}$ - - - - (2)

Now light is travelling from glass to air. $O_2\ O_3$ is incident ray with angle of incident 'r_2', O_3B is refracted ray with angle of emergent 'e'.

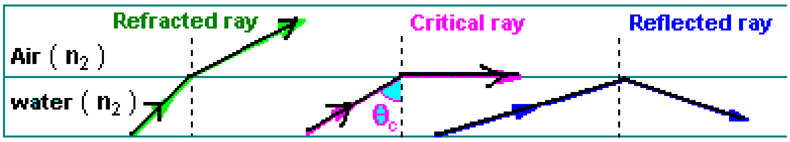


From Snell's law of refraction $\frac{\sin\ r_2}{\sin\ e} = \mu_{ga}$ - - - - (3)

Multiplying eq1 eq2 & eq3 $\frac{\sin\ i}{\sin\ r_1} \times \frac{\sin\ r_1}{\sin\ i_2} \times \frac{\sin\ r_2}{\sin\ e} = \mu_{aw} \times \mu_{wg} \times \mu_{ga}$

But $\mu_{ga} = \frac{1}{\mu_{ag}}$ & i = e so

$\frac{\sin\ e}{\sin\ e} = \mu_{aw} \times \mu_{wg} \times \frac{1}{\mu_{ag}} = 1$ Hence $\boxed{\frac{\mu_{ag}}{\mu_{aw}} = \mu_{wg}}$



Total Internal Reflection(TIR): -If light is travelling from denser to rarer medium it move away from normal. As we increase the angle of incident the angle of refraction increases. At a particular angle of incident the angle of refraction become 90°& the light is refracted along the boundary between the materials this angle of incident is called **critical angle** (i_c).

$\frac{\sin\ i}{\sin\ r} = \mu_{ga} \Rightarrow \frac{\sin\ i_c}{\sin\ 90^\circ} = \frac{1}{\mu_{ag}}$ Hence $\boxed{\sin\ i_c = \frac{1}{\mu}}$

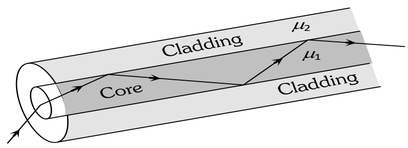
If we increase the angle of incident beyond critical angle the light ray in place of refraction, reflected back from the boundary in the same medium with no loss of intensity the surface of the separation behaves as mirror. This phenomenon is called total internal reflection.

Condition for total internal reflection: -

1) light should travel from denser to rarer medium.

2) Angle of incident should be greater then critical angle. Then there's no refract ray at all, all the light is reflected.

Uses of Total Internal Reflection: -Total internal reflection is extremely useful because there is no loss of intensity due to the reflection process itself. This is unlike normal reflection, where only around 96 percent of the light is reflected. The property of conserving the intensity of reflected light makes total internal reflection very useful in many applications where light levels must be maintained throughout a system of optics.



1) Fibre-optic: -Fine fiber of glass or quartz in which light enter from one end and comes out from another end du to total internal reflection is called optical fiber**.** Each fiber is made of glass of high refractive index surround by layer of glass of lower refractive index, so that light entering the fibre at a suitable angle (greater than critical angle) due to it undergo repeated total internal reflection until it reaches the other end. Light finally comes out from the other end of the fiber even the fiber is bent or twisted in any form. The reflection process involves no loss of intensity. The signal can only be weakened by absorption or scattering of the light, but the development of extremely pure glasses has overcome this problem.

a) In addition to sending laser signals over long distances and inside the body for surgery and cancer therapy.

b) Total internal reflection is the principle behind the **endoscope**, a flexible tube used for internal medical examinations. For example, an endoscope can be inserted through your mouth and pushed down your throat.

Light is sent down it and then reflected back within optical fibres in the tube to show a picture of the inside of your stomach on a small TV screen.**c)** To produce shadow free image.

d) In fiber optics. **e)** Used in telephone and other transmission cables. Each cable can carry nearly 2000 telephone signal without much loss of intensity.

2) Total internal reflection prisms (Porro prism), designed to bounce light through a set angle, are widely used. In binoculars, two matched prisms in each tube reflect the light through right angles. This means the tube length can be very short, enabling binoculars to be both compact and precise. In this prism one angle is 90° so angle of incident is 45° which is greater than the i_c = 42° (critical angle for glass) so due to total internal reflection the light rays can bent through 90°& 180°.An isosceles right angled prism can be used to reflect the light at 90° and 180°. These prisms are also called porro prisms.

(i) deviate a light ray through 90^0, (ii) deviate a light ray through180°/ to obtain the inverted image

(iii) to invert an image without the deviation of the rays

Advantages:- 1) Light is totally (100 %) reflected. 2) The reflecting properties are permanent.3) **Optical Illusions**: -Optical illusions are false images of objects – things we see that are not really there.

Mirages are examples of optical illusions. The word mirage is applied to a variety of optical phenomena.

All of them are due to unusual kinds of reflection and refraction of light by the atmosphere.

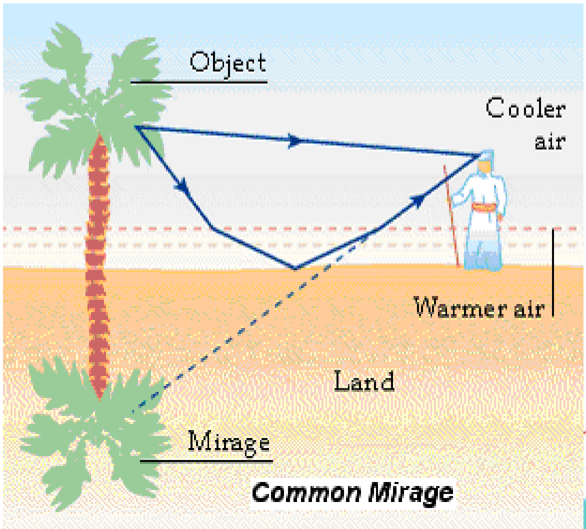
<u>Mirages</u>: - In desert region hot & low density air lies over sand, but higher up the air is cooler i.e. high density air. These regions have different refractive indices: they refract (bend) the light from distant objects to different degrees.

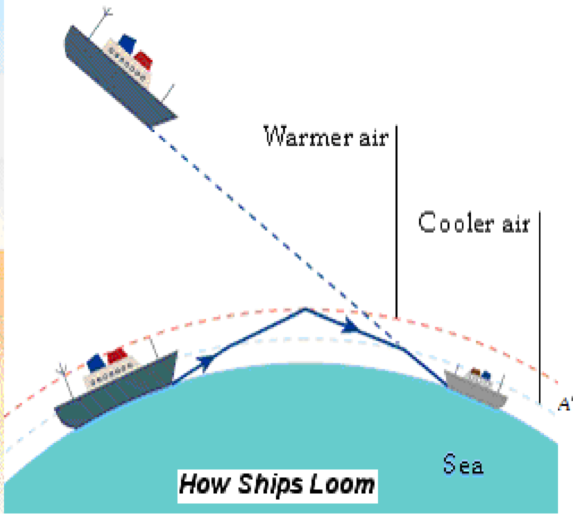
1) Light travelling from denser to rarer medium. 2) If Angle of incident is greater then critical angle. It satisfied the condition for total internal reflection so the incident light rays from any object in place of refraction, reflected back from the boundary between the two layers in the same medium with no loss of intensity. This reflected ray appears to meet at some point form inverted image of the object. So a reflected inverted image of the sky may be seen superimposed over the sand near the horizon, its shimmering appearance making it look like water.

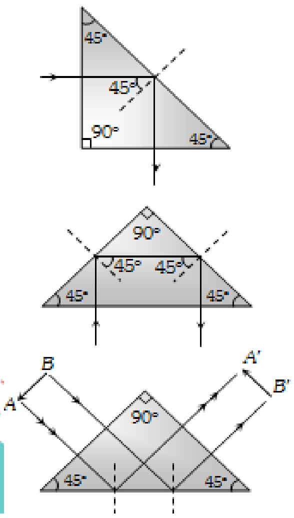
Even in temperate regions, mirages may form above hot road surfaces during the summer.

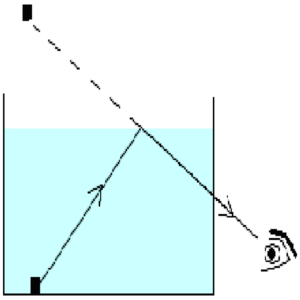
Looming: - In cold country at lower region air is cooler i.e. high density air lies over the see, but higher up the air is hot & has low density. In this case light travelling from denser to rarer medium & If Angle of incident is greater then critical angle then due to total internal reflection light rays appear to come from different point in the sky forming virtual image. This can make objects such as ships over the horizon at sea "loom," appearing nearer and larger than they normally would.

4) Sparkling of the diamond: - Refractive index of diamond is 2.43 and the critical angle is 24.4° for air. The faces of diamond are cut suitably so that the light rays entering the diamond from any face fall at an angle greater than 24.4° due to multiple total internal reflections at various faces the light rays remain within the diamond for long time and it sparkles. 5) **Fountain of fire**

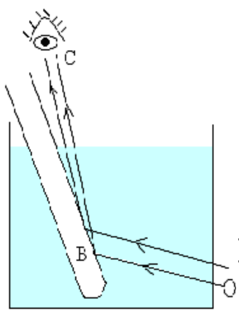




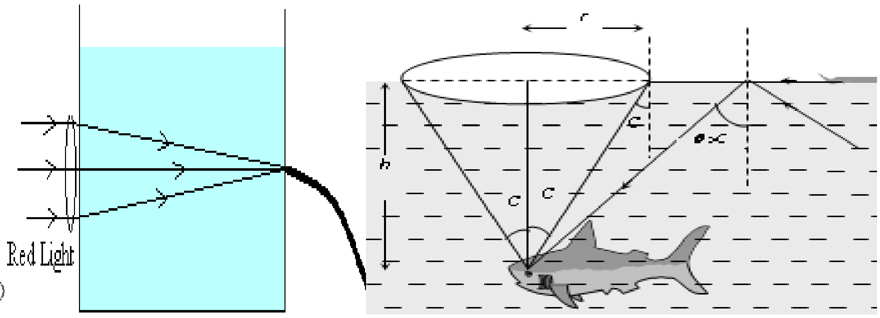




(i)



(ii)



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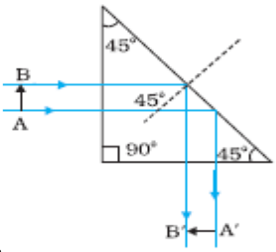
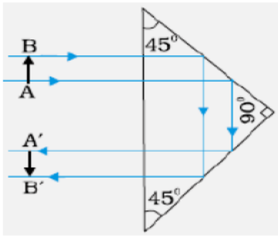
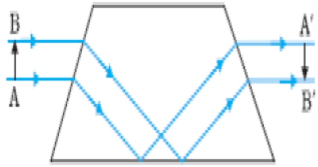






6) An empty test tube is in a sloping position in a beaker contain water; if we look from the top of the tube appear to be silvery like mirror. OB is light moving in water to glass suffer total internal reflection and the light falling on the tube will be totally reflect back and tube will glitter. **7) Coin hanging**: -A coin in a beaker filled with water and a coin at bottom viewed at suitable angle (i > 48°), the coin appears to float in air. OA is incident ray in water (denser) to air (rare), due to total internal reflection light appear to come from 'I' in air ands coin appear at 'I'.

8. Field of vision of swimmer (or fish) : A fish (diver) inside the water can see the whole world through a cone with.(a) Apex angle = 2C = 98°

(b) Radius of base $r = h\tan C = \dfrac{h}{\sqrt{\mu^2 - 1}}$; for water $r = \dfrac{3h}{\sqrt{7}}$ (c) Area of base $A = \dfrac{\pi h^2}{(\mu^2 - 1)}$; for water $a = \dfrac{9\pi}{7}h^2$

<u>Spherical refracting Surface</u>: -A part of a sphere of transparent refracting material is called Spherical refracting Surface.

1) If refracting surface is convex toward rare medium is called convex refracting surface.

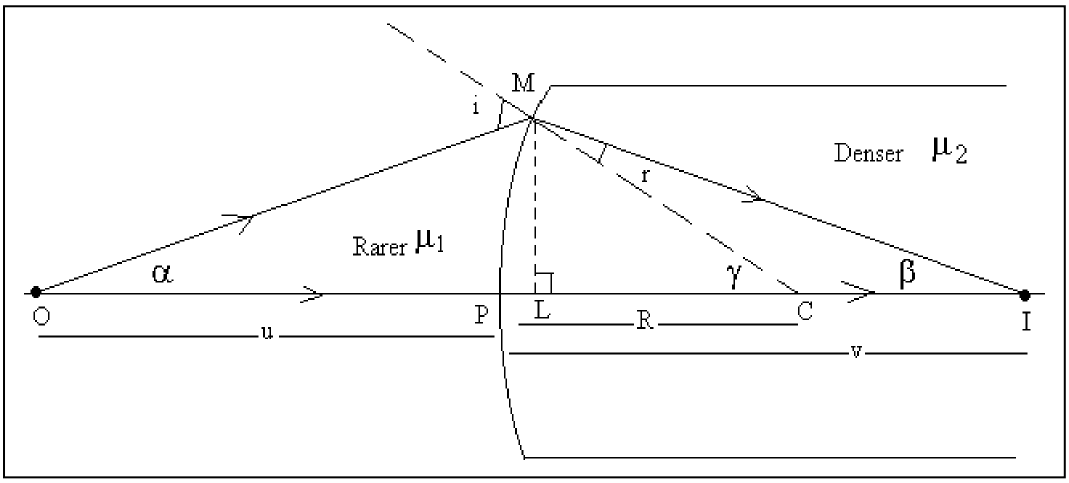
2) If refracting surface is concave toward rare medium is called concave refracting surface.

The centre (radius) of that sphere of which the refracting surface forms a part is called **centre (radius) of curvature** of the refracting surface.

Centre of the refracting surface is called **pole** of the surface.

The **principal axis** of the refracting surface is the straight line that passes through the centres of curvature & pole.

<u>Refraction through Convex Spherical surface</u>: -Let O is a point object on principle axis. OM is incident ray with angle of incident 'i', MI is refracted ray with angle of refraction 'r'. Two rays meet at I and form an image.



Angle form by incident ray OM, refracted ray MI and normal MC with principle axis is α, β&γ respectively. From laws of refraction

$\dfrac{\sin i}{\sin r} = \dfrac{\mu_2}{\mu_1}$ For small angle θ→ 0 Then sin θ = θ ,

so $\dfrac{i}{r} = \dfrac{\mu_2}{\mu_1}$ Hence

$i\ \mu_1 = r\ \mu_2$ - - -(1)

In Δ MCI , exterior angle is

equal to sum of two interior opposite angle. $\gamma = r + \beta$ OR $r = \gamma - \beta$ - - - (2)

In Δ MOC $i = \gamma + \alpha$ - - - (3) From eq1,2 & 3

$(\gamma + \alpha)\ \mu_1 = (\gamma - \beta)\ \mu_2 \quad \Rightarrow \gamma\ \mu_1 + \alpha\ \mu_1 = \gamma\ \mu_2 - \beta\ \mu_2$

$\alpha\ \mu_1 + \beta\ \mu_2 = \gamma\ \mu_2 - \gamma\ \mu_1 \quad \Rightarrow \alpha\ \mu_1 + \beta\ \mu_2 = \gamma(\mu_2 - \mu_1)$ If $\theta \to 0$ Then $\tan\theta = \theta$.

$\tan\alpha\ \mu_1 + \tan\beta\ \mu_2 = \tan\gamma(\mu_2 - \mu_1)$ Putting values from Δ MLO, Δ MLI, Δ MLC.

$\frac{ML}{LO}\mu_1 + \frac{ML}{LI}\mu_2 = \frac{ML}{LC}(\mu_2 - \mu_1)$ If M is close to P then P → L i.e. LC = PC = R radius of curvature.

$ML\left(\frac{1}{LO}\mu_1 + \frac{1}{LI}\mu_2\right) = \frac{ML}{LC}(\mu_2 - \mu_1)$. PO = LI = - u distance of object, PI = LI = v distance of image.

$\frac{\mu_1}{-u} + \frac{\mu_2}{v} = \frac{(\mu_2 - \mu_1)}{R} \quad \Rightarrow \boxed{\frac{(\mu_2 - \mu_1)}{R} = \frac{\mu_2}{v} - \frac{\mu_1}{u}}$

If first medium is air then $\mu_1 = 1$ & $\mu_2 = \mu$ is absolute refractive index $\boxed{\frac{(\mu - 1)}{R} = \frac{\mu}{v} - \frac{1}{u}}$

For refraction from denser to rarer medium $\boxed{\frac{(\mu_1 - \mu_2)}{R} = \frac{\mu_1}{v} - \frac{\mu_2}{u}}$

<u>Refraction through Concave Spherical surface</u>: -Let O is a point object on principle axis. OM is incident ray with angle of incident 'i', MI is refracted ray with angle of refraction 'r'. Two rays appear to meet at I and form an image. Angle form by incident ray OM, refracted ray MI and normal MC with principle axis is α, β &γ respectively. From laws of refraction

$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$ For small angle $\theta \to 0$ Then $\sin\theta = \theta$, so $\frac{i}{r} = \frac{\mu_2}{\mu_1}$ Hence $i\ \mu_1 = r\ \mu_2$ - - - (1)

In Δ MCI , exterior angle is equal to sum of two interior opposite angle.

$\gamma = r + \beta$ OR $r = \gamma - \beta$ - - - (2)

In Δ IMO $\gamma = i + \alpha$

$i = \gamma - \alpha$ - - - (3) From eq1,2 & 3

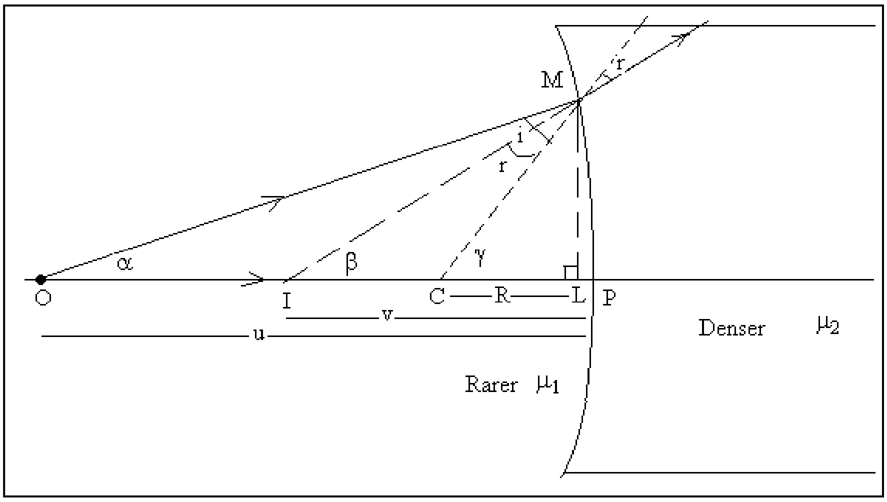
$(\gamma - \alpha)\ \mu_1 = (\gamma - \beta)\ \mu_2 \quad \gamma\ \mu_1 - \alpha\ \mu_1 = \gamma\ \mu_2 - \beta\ \mu_2$

$-\alpha\ \mu_1 + \beta\ \mu_2 = \gamma\ \mu_2 - \gamma\ \mu_1 \quad \beta\ \mu_2 - \alpha\ \mu_1 = \gamma(\mu_2 - \mu_1)$ If $\theta \to 0$ Then $\tan\theta = \theta$.

$\tan\beta\ \mu_2 - \tan\alpha\ \mu_1 = \tan\gamma(\mu_2 - \mu_1)$ Putting values from Δ MLO, Δ MLI, Δ MLC.

$\frac{ML}{LI}\mu_2 - \frac{ML}{LO}\mu_1 = \frac{ML}{LC}(\mu_2 - \mu_1)$ If M is close to P then P → L i.e. LC = PC = R radius of curvature.

$ML\left(\frac{1}{LI}\mu_2 - \frac{1}{LO}\mu_1\right) = \frac{ML}{LC}(\mu_2 - \mu_1)$.



PO = LI = – u distance of object,

PI = LI = v distance of image.

$\frac{\mu_2}{-v} - \frac{\mu_1}{-u} = \frac{(\mu_2 - \mu_1)}{-R}$

$\boxed{\frac{(\mu_2 - \mu_1)}{R} = \frac{\mu_2}{v} - \frac{\mu_1}{u}}$

If first medium is air then $\mu_1 = 1$ & $\mu_2 = \mu$ is absolute refractive index

$\boxed{\frac{(\mu - 1)}{R} = \frac{\mu}{v} - \frac{1}{u}}$

For refraction from denser to rarer medium $\boxed{\frac{(\mu_1 - \mu_2)}{R} = \frac{\mu_1}{v} - \frac{\mu_2}{u}}$

Lateral magnification : The lateral magnification *m* is the ratio of the image height to the object height.

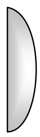
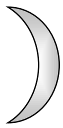
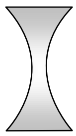
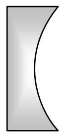
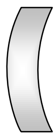
$$m=\left(\frac{h_i}{h_0}\right)=\left(\frac{\mu_1}{\mu_2}\right)\left(\frac{v}{u}\right)$$

Lens: -A **lens** is a transparent medium bounded by two non parallel surfaces in which at least one is spherical.

Types of Lenses: -There are two main types of lenses.

Convex lenses–The lens which are thicker at the centre than at the edges are called convex (.converging) lenses. They bring light rays to a focus at a single point. The lens of the human eye is convex It can change its focal length by increasing or decreasing its thickness.

Concave lenses–The lens which are thinner at the centre than at the edges known as Concave (diverging) lenses. They spread light rays out from a single point. Each type of lenses are of three types.

Convex lens (Converges the light rays)			**Concave lens (Diverges the light rays)**		
					
Double convex	Plano convex	Concavo convex	double concave	Plane concave	Convexo concave
Thick at middle. It forms real and virtual images both			Thin at middle. It forms only virtual images		

The point on the principle axis in the lens where the light rays passes through un deviated is called **optical centre**.

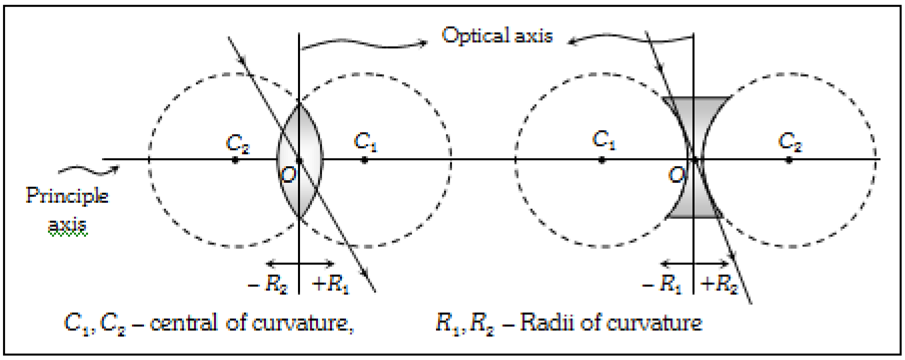
In thin lens there is no lateral displacement. In thick lens there may be small lateral displacement.

The **principal axis** of the lens is the straight line that passes through the centres of the two surfaces, optical centre & focus of the lens.

The straight line other then the principle axis passes through the optical centre is called **secondary axis**.

Distance between optical centre & focus is called **focal length** (f).

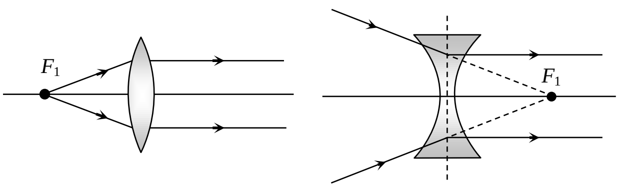
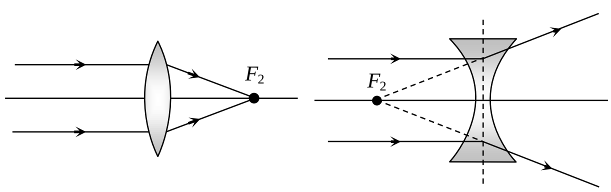
The parallel rays of light after refraction through **convex lens** converge to (actually meet at) a point, F, called the principle **focus** of the lens. Focal length is **positive**.



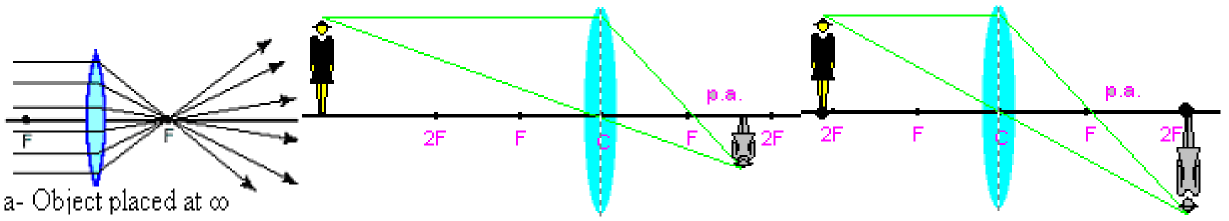
The parallel rays of light after refraction through **concave lens** appear to diverge from (appear to meet at) a point, F, called the principle **focus** of the concave lens. The parallel rays leave the lens as if they come from the focal point on the other side of the lens. Focal length is **negative**.

The focal length f of a lens depends on its refractive index and geometrical shape.

First principal focus : An object point for which image is formed at infinity. **Second principal focus:** An image point for an object at infinity. Second principle focus is the principle focus of the lens

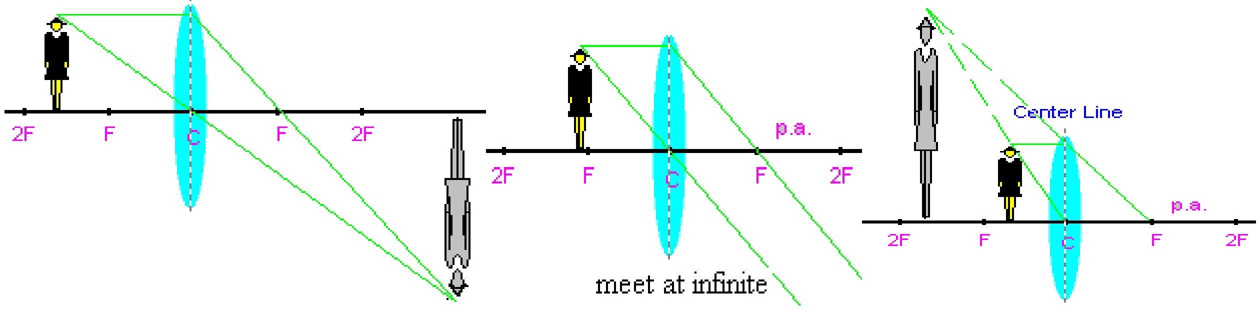
First principle focus	**Second principle focus**
	

How Lenses Work: -Light is refracted – in other words, it changes direction – when it passes from air to glass, or from glass to air. It follows that refraction of light takes place at both surfaces of a lens, which can be shaped to alter the directions of the incident (incoming) light rays in such a way that whole groups of rays pass onward to a single point, or in directions away from a single point.**Image Formed by Convex & Concave Lens**: -



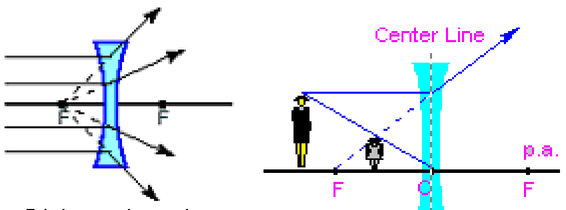
a- Object placed at ∞ b- Object at u > 2 f c- Object at u = 2 f

Real, inverted, point image at v = f. Real, inverted, small image at f <v < 2f. Real, inverted equal image at v = 2f



d- Object at f < u < 2 f e- Object at u = f f- Object at u < f

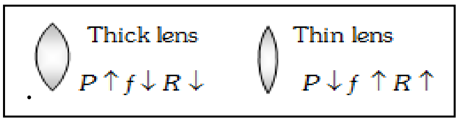
Real, inverted, large image at v > 2f. Real, inverted very large image at v = f. Virtual erect magnified image.



a- Object placed at ∞

Virtual, erect point image. At v = f . Virtual, erect small image. at v < f

The power of a lens: -It is its ability to refract or bend light. The degree up to which a lens converge or diverge light rays is called power of lens.OR-The ability of lens to converge or diverge light rays is called power of lens. It is equal to reciprocal of focal length in metre.



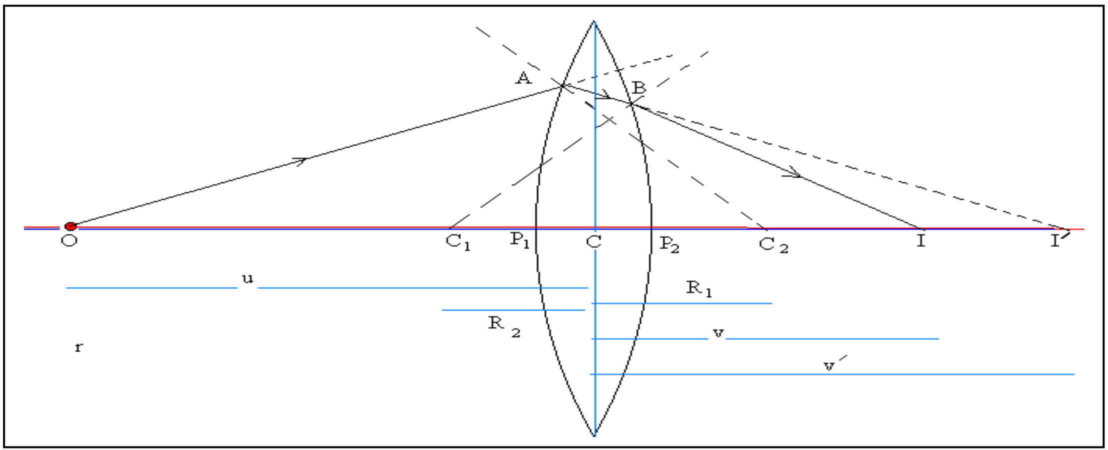
Power of lens $P = \frac{1}{f}$ Dioptre (Focal length in metre). $P = \frac{100}{f}$ Dioptre (Focal length in centimetre).

If f =1 m then P = 1 D. If focal length of a lens is 1m then its power is called one Dioptre.

For convex lens focal length is positive so its power is positive. Smaller the focal length, greater the power of lens (more ability to converge) and vice-versa. $P_{convex} \rightarrow$ positive, $P_{concave} \rightarrow$ negative, $P_{plane} \rightarrow$ zero

For concave lens focal length is negative so its power is negative. Greater the focal length, less light rays diverge so greater the power of lens (more ability to converge) and vice-versa.

Lens maker's Formula: -The lens maker's (or thin lens) formula specifies what size of lens is needed to achieve particular object and image distances (that is, a particular magnification) with glass of a known refractive index. The relation between radius of curvature of the surfaces



of the lens & focal length is known as focal length.
Consider a thin lens of refractive index μ_2 whose thickness is negligible compared to its radius of curvature. An object *O* is placed in a medium of refractive index μ_1 at a distance *u* from the lens. C_1& C_2 are centre of curvature; C_1& C_2 are radius of curvature of the surface of lens. OA is incident ray for first surface P_1A light ray refract along AB which will form an image I at a distance $v^{/}$.

Refraction from spherical surface $\frac{(\mu_2 - \mu_1)}{R_1} = \frac{\mu_2}{v^{/}} - \frac{\mu_1}{u}$ - - - (1) In this case $v \rightarrow v^{/}, u \rightarrow u$

But for second surface BP_2, $I^{/}$ act as object & its image formed at I. The light ray refract AB suffer further refraction & move along BI which will form an image I at a distance *v*. Now $I^{/}$ act as object and I is image.

$\frac{(\mu_1 - \mu_2)}{R_2} = \frac{\mu_1}{v} - \frac{\mu_2}{v^{/}}$ - - - (2) In this case $u \rightarrow v^{/}, v \rightarrow v$.

Adding eq1 &2. $\frac{(\mu_2 - \mu_1)}{R_1} + \frac{(\mu_2 - \mu_1)}{R_2} = \frac{\mu_2}{v^{/}} - \frac{\mu_1}{u} + \frac{\mu_1}{v} - \frac{\mu_2}{v^{/}}$

$\frac{(\mu_2 - \mu_1)}{R_1} - \frac{(\mu_2 - \mu_1)}{R_2} = -\frac{\mu_1}{u} + \frac{\mu_1}{v} \Rightarrow (\mu_2 - \mu_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \mu_1\left(\frac{1}{v} - \frac{1}{u}\right)$

$\left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{v} - \frac{1}{u}$ Hence $\boxed{(\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{v} - \frac{1}{u}}$ - - - (3)

If object is placed at infinite i.e. u = ∞ then image is formed at focus v = f.

$(\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f} - \frac{1}{\infty} = \frac{1}{f} - 0$ Hence $\boxed{\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$

This is known as lens maker's formula. Comparing eq3 & 4. $\boxed{\frac{1}{f} = \frac{1}{v} - \frac{1}{u}}$ This is called lens formula.

Combination of thin lenses in contact: -Consider two lenses L_1& L_2 of focal length f_1& f_2 placed in contact. O is a pointobject, OA is incident rays of light for first lens L_1 and it refract along AB which will form an image $I^{/}$ at a distance $v^{/}$. From lens formula $\frac{1}{f_1} = \frac{1}{v^{/}} - \frac{1}{u}$ - - - (1) In this case $v \rightarrow v^{/}, u \rightarrow u$

But for second lens L_2, $I^{/}$ act as object with incident ray AB. The light ray refract AB suffer further refraction & move along BI which will form an image I at a distance *v*. Now $I^{/}$ act as object and I is image.

$\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v^{/}}$ - - -(2) In this case $u \rightarrow v^{/}, v \rightarrow v$. Adding eq1 &2.

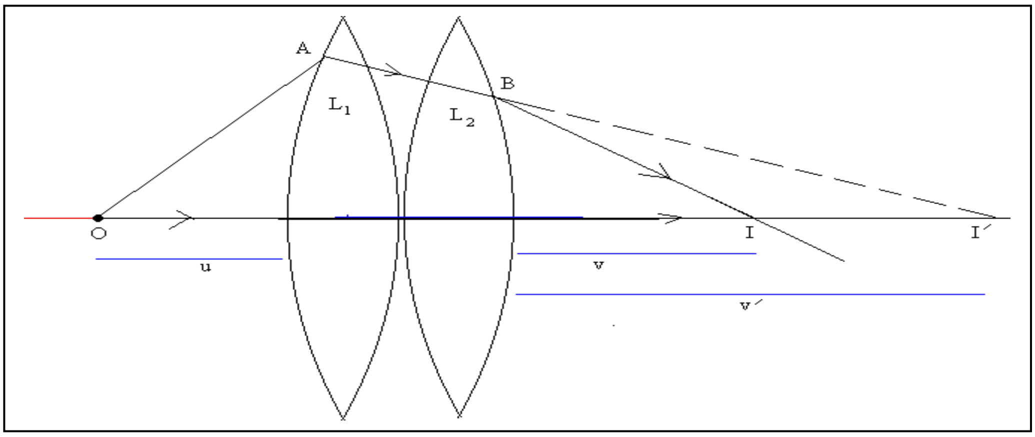
$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{v^{/}} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v^{/}}$ $\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{v} - \frac{1}{u}$ But From lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ so

$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f}$ In general focal length of combination

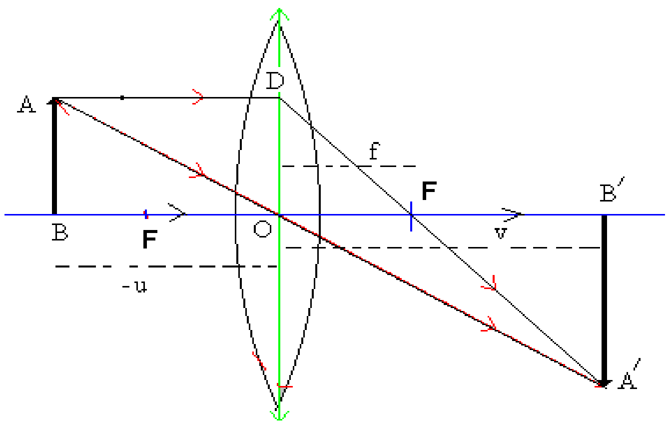
$\boxed{\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + - -}$

Hence power of this combination P = P_1 + P_2 + P_3 + - - - - -

Magnification of the combination m = $m_1 \times m_2 \times m_3 \times m_4$ - - - - -



Lens Formula (Convex Lens):- Consider a convex lens of focal length ‘f’. AD is incident ray parallel to the principle axis after refraction passes through focus along DF. AO is another incident ray incident on optical centre O so it will move un deviated along same path. The two refracted rays intersect each other at $A^/$ & a real inverted image $A^/B^/$ formed at $B^/$.



Since Δ ABO ~ Δ $A^/$ $B^/$ O (Because all the angles are equal) . Ratio of corresponding sides of the similar triangles are equal so

$$\frac{\text{Perpendicular of } \Delta ABO}{\text{Perpendicular of } \Delta A^/B^/O} = \frac{\text{Base of } \Delta ABO}{\text{Base of } \Delta A^/B^/O}$$

Hence $\frac{AB}{A^/B^/} = \frac{BO}{B^/O}$ OR $\frac{AB}{A^/B^/} = \frac{-u}{v}$ - - - (1)

Since Δ DOF ~ Δ $A^/$ $B^/$ F (Because all the angles are equal) Ratio of corresponding sides of the similar triangle s are equal so $\frac{DO}{A^/B^/} = \frac{OF}{FB^/}$ But OF = f. &AD || BO so AB = DO ,

$\frac{AB}{A^/B^/} = \frac{OF}{OB^/ - OF}$ $\Rightarrow \frac{AB}{A^/B^/} = \frac{f}{v - f}$ - - - (2)Comparing eq1 & 2 $\frac{-u}{v} = \frac{f}{v - f}$

$-uv + uf = fv$ $\Rightarrow$ $uv = uf - fv$ Dividing eq by uvf.

$\frac{uv}{uvf} = \frac{uf}{uvf} - \frac{fv}{uvf}$ Hence $\boxed{\frac{1}{f} = \frac{1}{v} - \frac{1}{u}}$ This is lens formula.

Linear Magnification: -the ratio of the size of the image formed by mirror to the size of object is called magnification (m). m is positive for real image & m is negative for real image.

$m = \frac{\text{Size of the image}}{\text{Size of the object}}$ $\Rightarrow \boxed{m = \frac{I}{O} = -\frac{v}{u}}$

Lens Formula (Concave Lens):- Consider a concave lens of focal length ‘f’. AD is incident ray parallel to the principle axis after refraction along DE. If we extend this light ray it appears to diverge from focus. AO is another incident ray incident on optical centre O so it will move un deviated along same path. The two refracted rays appear to intersect each other at $A^/$ & a virtual erect image $A^/B^/$ formed at $B^/$.Since Δ ABO ~ Δ $A^/$ $B^/$ O (Because all the angles are equal) so Ratio of corresponding sides of the similar triangles are equal

$\frac{\text{Perpendicular of } \Delta ABO}{\text{Perpendicular of } \Delta A^/B^/O} = \frac{\text{Base of } \Delta ABO}{\text{Base of } \Delta A^/B^/O}$ Hence $\frac{AB}{A^/B^/} = \frac{BO}{B^/O}$ OR $\frac{AB}{A^/B^/} = \frac{-u}{-v}$ - - (1)

Since Δ DOF ~ Δ $A^/$ $B^/$ F (Because all the angles are equal) Ratio of corresponding sides of the similar triangles

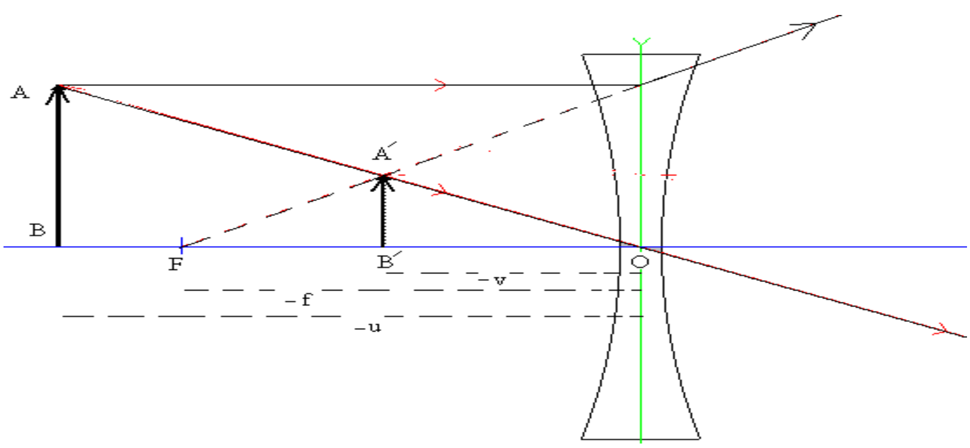
are equal so $\frac{DO}{A^/B^/} = \frac{OF}{FB^/}$ But OF = f &AD || BO so AB = DO , $\frac{AB}{A^/B^/} = \frac{OF}{OF - OB^/}$ $\frac{AB}{A^/B^/} = \frac{-f}{-f - (-v)}$

- - - (2)Comparing eq1 & 2 $\frac{u}{v} = \frac{f}{f - v}$

$uf - uv = fv$ $\Rightarrow$

$uf - fv = uv$

Dividing eq by uvf.



$$\frac{uv}{uvf} = \frac{uf}{uvf} - \frac{fv}{uvf}$$ Hence $\boxed{\frac{1}{f} = \frac{1}{v} - \frac{1}{u}}$ This is mirror formula.

Magnification:–The ratio of the size of the image to the size of object is called magnification

(a) Transverse magnification: $m = \frac{I}{O} = \frac{v}{u} = \frac{f}{f+u} = \frac{f-v}{f}$ (use sign convention while solving the problem)

(2) Longitudinal magnification: $m = \frac{I}{O} = \frac{v_2 - v_1}{u_2 - u_1}$. For very small object $m = \frac{dv}{du} = \left(\frac{v}{u}\right)^2 = \left(\frac{f}{f+u}\right)^2 = \left(\frac{f-v}{f}\right)^2$

(3) Areal magnification: $m_s = \frac{A_i}{A_o} = m^2 = \left(\frac{f}{f+u}\right)^2$, ($A_i$ = Area of image, A_o = Area of object)

(4) **Relation between object and image speed:** If an object moves with constant speed (V_o) towards a convex lens from infinity to focus, the image will move slower in the beginning and then faster. Also $V_i = \left(\frac{f}{f+u}\right)^2 . V_o$

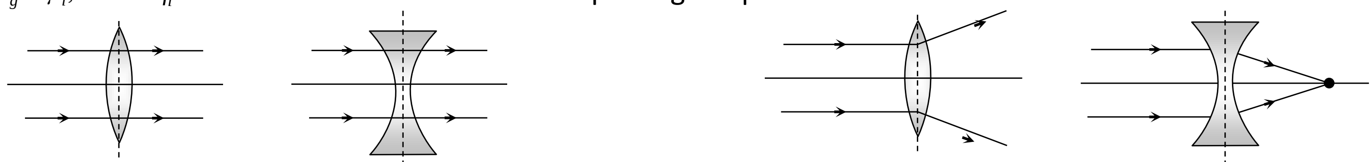
(6) Lens Immersed in a Liquid:–If a lens (made of glass) of refractive index μ_g is immersed in a liquid of refractive index μ_l, then its focal length in liquid, f_l is given by $\frac{1}{f_l} = ({}_l\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ ......(i)

If f_a is the focal length of lens in air, then $\frac{1}{f_a} = ({}_a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$......(ii) $\Rightarrow \frac{f_l}{f_a} = \frac{({}_a\mu_g - 1)}{({}_l\mu_g - 1)}$

(a) If $\mu_g > \mu_l$, then f_l and f_a are of same sign and $f_l > f_a$.

That is the nature of lens remains unchanged, but it's focal length increases and hence power of lens decreases.

(b) If $\mu_g = \mu_l$, then $f_l = \infty$. It means lens behaves as a plane glass plate and becomes invisible in the medium.



(3) If $\mu_g < \mu_l$, then f_l and f_a have opposite signs and the nature of lens changes *i.e.* a convex lens diverges the light rays and concave lens converges the light rays.

Aberrations of Lenses

Aberrations of Lenses: - a simple lens will not focus every ray of light from a point on an object to a single point on the image so the image is sometimes not an exactly correct depiction of the object.. Any deviations from a completely accurate depiction are called aberrations.

1) **Chromatic Aberration of a Lens: -**The power of a lens (its ability to refract or bend light) depends on its refractive index. But the index itself decreases as the light wavelength increases. So a single, simple lens (singlet) will focus shorter-wavelength blue rays closer than longer-wavelength red light rays so a coloured image is formed this defect in image is called chromatic aberration. It produces colured fringes around an image.

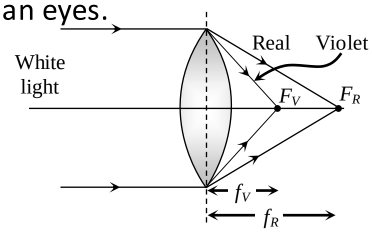
Image of a white object is coloured and blurred because μ(hence f) of lens is different for different colours. This defect is called chromatic aberration.

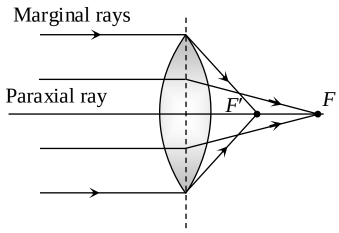
From Cauchy's formula $\mu \propto 1/\lambda$ and $f \propto \lambda$ Since $\lambda_r > \lambda_v$ so $f_r > f_v$. Hence focal length of red is maximum & focal length of violet is minimum while the remaining colour lies in between the two.

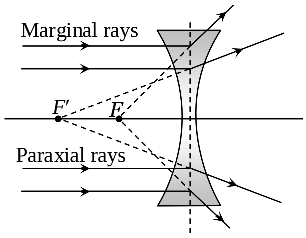
The effect can be countered by using an achromatic doublet (a double lens). This is a combination of two lenses, one convex, the other concave, whose combined power is the same as that of the single lens. However, their refractive indices are different, and produce chromatic aberrations that cancel each other out almost completely.

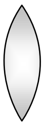
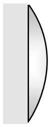
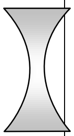
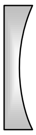
2) **Spherical Aberrations: -**Radius of curvature at the edges of lens is smaller as compare to the other part of lens.Due to this rays passing through a lens near the centre focus at a different distance to rays passing through near the edge due to this multiple images are formed This defect is called spherical aberration. The effect can be reduced by using a lens ground to the shape of a parabola, rather than the shape of a sphere.

Application of Lenses: -1) As magnifying glass (Simple microscope). 2) In photographic camera. 3) Spectacles. 4) In microscope, telescope & Binoculars. 5) In Cinema projectors. 6) In human eyes.







Lens	**Focal length**	**For $\mu = 1.5$**
Biconvex lens  $R_1 = R$ $R_2 = -R$	$f = \frac{R}{2(\mu - 1)}$	$f = R$
Plano-convex lens  $R_1 = \infty$ $R_2 = -R$	$f = \frac{R}{(\mu - 1)}$	$f = 2R$
Biconcave  $R_1 = -R$ $R_2 = +R$	$f = -\frac{R}{2(\mu - 1)}$	$f = -R$
Plano-concave  $R_1 = \infty$ $R_2 = R$	$f = \frac{-R}{(\mu - 1)}$	$f = -2R$

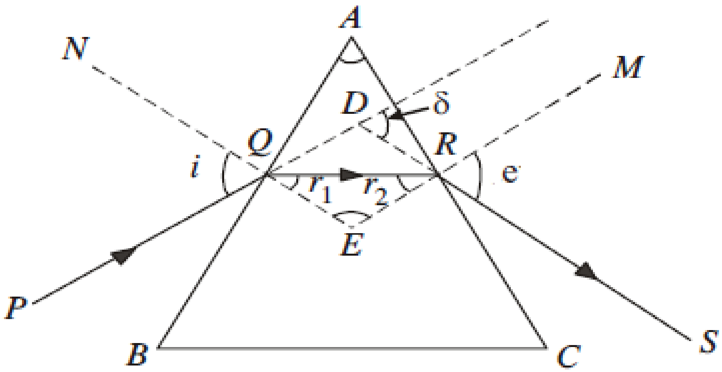
Prism: - A prism is a transparent medium bounded by three rectangular plane-refracting surfaces inclined to each other at some angle

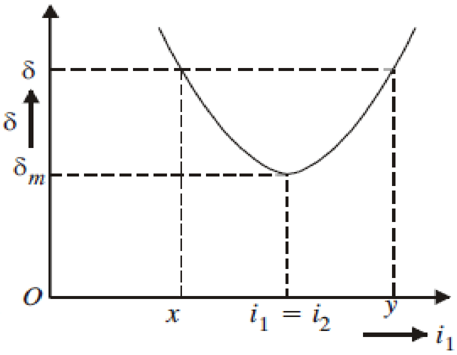
The line along which the two refracting faces of a prism meet is called the refracting **edge** of the prism.

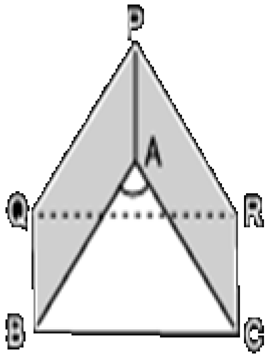
The angle between the two refracting faces is called the **angle of the prism**. In above figure, a glass prism has three rectangular faces meeting along the edges BQ, AP and CR. The end faces ABC and PQR are equilateral triangles. In the diagram, ABQP and ACRP are the refracting surfaces and AP is the refracting edge. Angle A between them is the refracting angle called the angle of prism.On passing through a prism, a ray of light undergoes two refractions and hence deviates through a certain angle from its original path called **Angle of deviation.**

Angle between incident ray and emergent ray is called**Angle of deviation.**

Refraction of light due to a prism:- Fig. shows the phenomenon of refraction of light through a prism *ABC* with an angle of prism = *A*. A ray *PQ* of monochromatic light is incident on face *AB* of the prism at an angle *i*. This ray is refracted towards the normal *NQE* and travels in the prism along *QR*; the angle of refraction r_1 is less than *i*. The refracted ray *QR* is incident at angle r_2 on the face *AC* of the prism. The ray *QR* again suffers refraction and emerges out of face *AC* at an angle *e* (angle of emergence). The angle δ (*i.e*. angle between the direction of the incident ray and the emergent ray) is called the angle of deviation.







(*i*) Angle of deviation (δ):In triangle *QDR* , exterior angle is equal to sum of interior opposite angle.

$\delta = \angle DQR + \angle DRQ \quad \Rightarrow \delta = (i - r_1) + (e - r_2) \Rightarrow \delta = (i + e) - (r_1 + r_2)$-------(1)

This is the expression for the angle of deviation in a prism.

(*ii*) To prove that A = $r_1 + r_2$:In the triangle, $\angle A + \angle AQR + \angle ARQ = 180$.

$\angle A + (90 - r_1) + (90 - r_2) = 180$. Hence $\angle A = r_1 + r_2$ -------------(2) From equation (1) and (2)

$\delta = (i + e) - \angle A$ Or $\delta + \angle A = i + e$ -------------(3)

(*iii*) MINIMUM DEVIATION:-The deviation produced by a prism depends upon (I) the angle of incidence (II) the angle of prism and (III) therefractive index of the prism material w.r.t. the surrounding.It is found experimentally that as the angle of incidence changes,the angle of deviation also changes. If we plot a graph between anglesof incidence (*i*) and the corresponding angle of deviation (δ), we getthe curve shown in Fig.

(*a*) As the angle of incidence (*i*) increases, the angle of deviation first decreases, becomes minimum for a particular angle of incidence and then again increases.

(*b*) The angle of incidence for which the deviation produced by the prism is minimum is called *the angle of minimumdeviation* (δ_m). In the position of minimum deviation, a ray of light passes symmetrically through the prism *i.e.*

the refracted ray *QR* (Fig.2) is parallel to the base of the prism. In this position, $i = e$ and $r_1 = r_2 = r$ (let)

So from eq2 $\angle A = r + r$ Hence $r = \angle A/2$--------(4)

So from eq3 $\delta_m + \angle A = i + i$ Hence $i = (\delta_m + \angle A)/2$--------(5)

(*c*) Note that a prism can deviate incident ray through the same angle δ for two different angles of incidence *x* and *y* (Fig. 2). *However, for one and only one particular angle of incidence, theprism produces minimum deviation*.

(iv) REFRACTIVE INDEX OF PRISM MATERIAL from Snell's law $\mu = \frac{\sin i}{\sin r}$. From equation 4 & 5.

$$\boxed{\mu = \frac{\sin(\delta m + \angle A)/2}{\sin \angle A/2}}$$

<u>Optical Instruments</u>:- Optical instruments are those devices, which are designed to assist, extend or amplify the abilities of the human eye. By these devices, one can observe highly magnified images of small objects and very far–off objects e.g. eye, camera, microscope & telescope and prism binocular etc.

<u>Angular magnification</u>:-The angular magnification (or magnifying power) of an optical instrument is defined as the ratio of the angle subtended at the eye by the image to that subtended at the unaided eye by the object, i.e. Angular magnification, $M = \beta/\alpha$

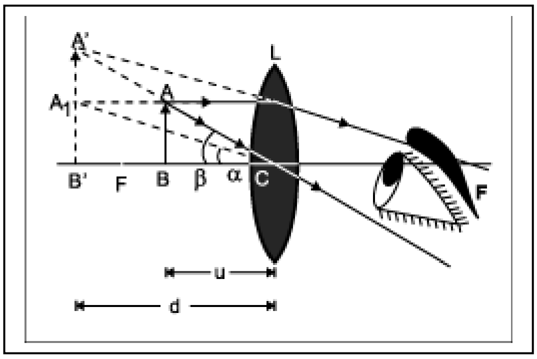
Where β = angle subtended at the eye by the image & α = angle subtended at the unaided eye by the object.

<u>MICROSCOPE</u>:-A microscope is an instrument which forms an enlarged image of a small object placed close to the eye. With naked eye, the object subtends a small angle at the eye. However, when the object is viewed through the microscope, the image of the object subtends a large angle at the eye. The eye uses this enlarged image as the object. The retinal image (i.e. image formed at the retina) will be much larger than it would be if the actual small object were being viewed with the naked eye.

<u>SIMPLE MICROSCOPE (MAGNIFYING GLASS)</u>:- A simple microscope or magnifying glass is a single convex (converging) lens of very small focal length.

Principle:-When the object is inside (or at) the focallength of the lens, a virtual, erect w.r.t. object and enlarged image of the object is formed. The position of the imagedepends upon the position of the object relative to that of the lens. The image formed is very bright and sharpbecause object is held very close to the lens.

Working :-(i) When image is formed at the near point v = D: an object AB is placed between C and F such that a magnified erect image $A^/B^/$ is formed behind the object. The lens is adjusted so that the image is at the near point. The image is seen most clearly when it is at the near point. This is the normal use of the microscope. If the observer's eye is close to the lens; then the distance $CB^/$ is equal to the least distance of distinct vision. Magnifying power (M) of a simple microscope is the ratio of the angles subtended by the image and the object on the eye, when both are at the least distance of distinct vision from the eye. If the angle subtended by the object and the image on the eye is and β, respectively, then according to definition of Magnifying power $M = \frac{\beta}{\alpha}$



where β = angle subtended at the eye by the image at the near point

α = angle subtended at the unaided eye by the object at the near point

Since the angles are very small, θ→0 then tanθ= θ Therefore for small angle, tanβ≈β& tanα≈α, so $M = \frac{tan\beta}{tan\alpha}$

From Triangle $A_1B^/C$ & ABC , $M = \frac{AB/CB}{AB/CB^/}$

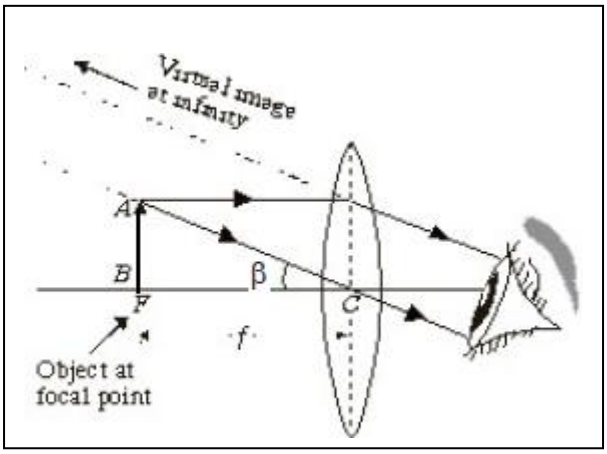
Therefore, $M = \frac{CB^/}{CB}$ Hence $M = \frac{-v}{-u}$

Since CB = –u, distance of the object from the lens' $CB^/$= –v, distance of the image from the lens. Now, using lens formula

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ OR $\frac{1}{f} = \frac{1}{-v} - \frac{1}{-u}$ or $\frac{1}{f} + \frac{1}{v} = \frac{1}{u}$

Now, magnifying power of the microscope, $M = v\left(\frac{1}{f} + \frac{1}{v}\right)$

Hence $M = 1 + \frac{v}{f}$..(v)



From the concept of visual angle, the image would appear tallest, if it is nearest to the eye. For the eye, the nearest an object can be brought so that vision remains distinct is called the least distance of distinct vision D and the image is adjusted to be formed at D (= 15 cm)so that the magnifying power becomes the largest.

Since, v = – D Therefore $\boxed{M = 1 + \frac{D}{f}}$...(vi)

(ii) **When image is formed at infinity**: This situation is shown in Fig. In this case, the object is placed at the focus of the lens. This is not the normal use of microscope. The advantage of this is that the eye is relaxed (unaccommodated).

Magnifying power:-β= angle subtended at the eye by the image, α= angle subtended at the unaided eye by the object when it is at the near point. Magnifying power,

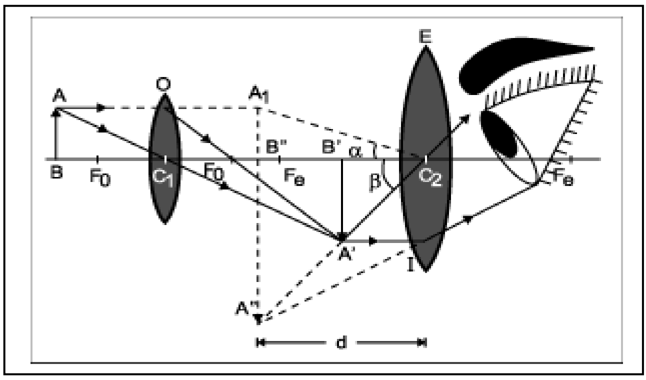
$M = \frac{\beta}{\alpha} = \frac{AB}{f} \times \frac{D}{AB} = \frac{D}{f}$ or $M = \frac{D}{f}$

Note: The maximum angular magnification is produced when the image is at the near point and minimum angular magnification is produced when the image is at infinity.

Application:- (a) Jewellers and watch markers use the magnifying glass to obtain a magnified view of tiny parts of jewellery and watch parts. (b).A simple microscope can be used for magnifying tiny parts of watch and in taking vernier scale readings etc.

Limitation: -Since magnification M ∝ 1/f so for larger magnification focal length must be small. A simple microscope can produce magnification only within a limit since lens defects become considerable for magnifications greater than 5. A compound microscope is used when larger magnifications are required and for images free from aberrations.

COMPOUND MICROSCOPE:-A compound microscope makes use of two converging lenses. Therefore, its magnifying power is muchgreater than that of the simple microscope or magnifying glass.
Principle:A compound microscope is based on the principle that a converging lens can form magnified images in the following two ways : (**i**) With the object is inside the focal length of the lens, the image formed is virtual, erect w.r.t. object and magnified as in a simple microscope. (**ii**) When the object is between the focal length f and $2f$ from the lens, the image formed is real, inverted w.r.t. object and magnified.
As we shall see, a compound microscope combines both these effects to achieve greater magnification.
Construction:- It consists of a system of two coaxially, converging lenses. The lens nearer to the object is called the**objective lens**. The lens through which the final image is viewed is near eyes called the **eyepiece**. Theeyepiece behaves as a magnifying glass and produces enlarged virtual image of it.
The objective lens & the eyepiece aremounted at the outer ends of two metal tubes which can be made to slide into one another with thehelp of thumb screw. The focal length of each lensshould be small in order to achieve a high overall magnification. Eyepiece has a normal (or moderate) focal length while the objective lens has a very short focal length.
(a) When image is formed at near point:- (i) Ray diagram The ray diagram of a compound microscope is given in the figure below. The object AB is placed at a distance slightly greater than the focal length of the objective 'O' (between F_o and $2F_o$ where F_o is the focus of the objective lens.). A real and inverted image $A'B'$ is formed at A'. It will act as an object for the eye lens. The eyepiece is adjusted so that the distance of A' from it is less than its focal length. As the eyepiece acts as a simple magnifying glass, the final image $A''B''$ is formed at A'' which is magnified and virtual. The adjustments are so made that $A''B''$ is at the least distance of distinct vision 'D' from the eye. Thus,$C_2B'' = D$
(ii) Magnifying power (m):-It is the ratio of the angle subtended at the eye by final image to the angle subtended at the eye by the object, when both the final image and the object are situated at the least distance of the distant vision from the eye. In other words, it is the product of magnifications produced by the objective and the eyepiece separately.



Assume that the object AB is to be shifted to A_1B'' such that it is at a distance D from the eye. By the definition of magnifying power, $M = \frac{\beta}{\alpha}$
Where $\angle A''C_2B'' = \beta$ = angle subtended at the eye by the image at the near point and $\angle A_1C_2B'' = \alpha$ = angle subtended at the unaided eye by the object at the near point
Since the angles are very small, $\theta \to 0$ then $\tan\theta = \theta$ Therefore for small angle, $\tan\beta \approx \beta$ & $\tan\alpha \approx \alpha$, so $M = \frac{\tan\beta}{\tan\alpha}$

From $\Delta A''B''C_2$ and $\Delta A_1B''C_2$ $\tan\beta = \frac{A''B''}{C_2B''}$ In $\Delta A_1B''C_2$,

$\tan\alpha = \frac{A_1B''}{C_2B''}$ Substituting the values

$$m = \frac{A''B''}{C_2B''} \times \frac{C_2B''}{AB} = \frac{A''B''}{AB} = \frac{A''B''}{A'B'} \times \frac{A'B'}{AB}$$ Hence $m = m_e \times m_0$ ...(iii)

$m_0 = \frac{A'B'}{AB}$

,$m_o = \frac{A'B'}{AB}$ = Magnification produced by objective lens,

$$= \frac{\text{distance of image } A'B' \text{ from } C_1}{\text{distance of object } AB \text{ from } C_1} = \frac{C_1B'}{C_1B} = \frac{v_0}{-u_0}$$

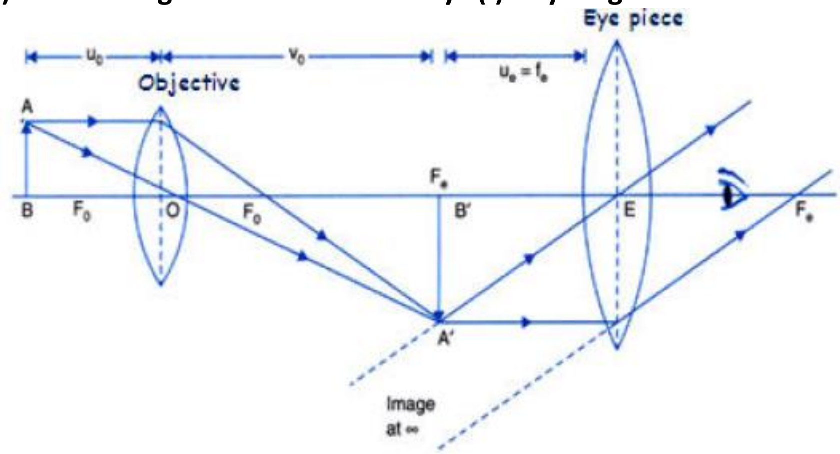
Where $m_e = \frac{A''B''}{A'B'}$ = Magnification produced by eye lens,

$m_e = 1 + \frac{D}{f_e}$; D (C_2B'' = D, least distance of distinct vision Substituting in equation

$$\boxed{M = \frac{v_o}{-u_o}\left(1 + \frac{D}{f_e}\right)}\text{------(iv)}$$

Since object AB lies very close to F_o, the focus of lens O, therefore, $u_o = f_o$ focal length of objective lens.
Also $A^{/} B^{/}$ is formed very close to eye lens. Therefore, $u_o = C_1B^{/} \approx L \approx C_1C_2$= length of microscope tube
Substituting in equation (iv), $M_e = -\frac{L}{f_O}(1 + \frac{D}{f_e})$...(v)
In compound microscope, objective lens & eye lens are fixed. Moving it, either towards object or away from the object, focuses it.

(b) When image is formed at infinity:-(i) Ray diagram



(ii) Magnifying power $M = m_o m_e = -\frac{L}{f_O}(1 + \frac{D}{f_e})ORM = \frac{v_O}{-u_O}\frac{D}{f_e}$Hence $M = \frac{-L}{f_O}\frac{D}{f_e}$

(c) General remarks:-(*i*) To focus over an object, the distance of the objective lens from the object is adjusted with the help of rack and pinion arrangement. (*ii*) Since the apertures of both the lenses are small, *spherical aberration* (*i.e.* distortion of image) is minimised. (*iii*) In order to minimise *chromatic aberration,* both objective lens and eyepiece are formed by a number of lenses.

Telescope:-A telescope is an optical instrument to observe distant stars. It increases the angular size of the final image many times the angular size of the object, which is far away. When a distant object is viewed through a telescope, it appears closer and, therefore, larger. A telescope increases the visual angle; it does not make the image bigger than the object. Jan Lippershy invented the first telescope in 1608. But in 1602, Galileo was the first man who made a telescope.

The most commonly used refracting telescopes are:

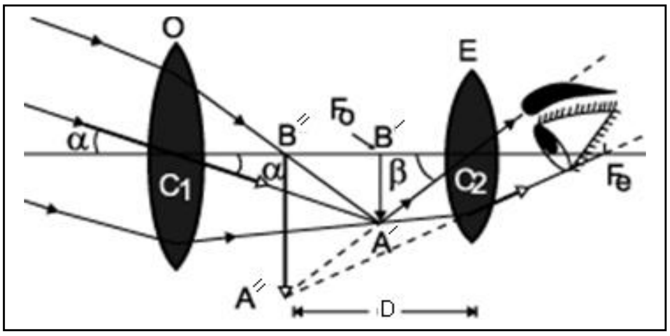
(A) Refracting telescope: - It is an optical instrument used for observing distinct images of heavenly bodies (like stars, planets, etc.) These telescopes consist of two lenses, one objective of long focal length, which forms a real image of the distant object and the other eyepiece of small focal length. (*i*) Astronomical telescope, (***ii***) Terrestrial telescope (not in syllabus).

ASTRONOMICAL (REFRACTING) TELESCOPE:- An astronomical telescope is used for seeing heavenly astronomical bodies such as sun and stars.

Principal:-The objective lens produces a real image of the object beingviewed. This (intermediate) image at as an object for the eyepiece lens which behaving as a magnifyingglass produces a virtual image of it.

Construction:- It consists of a system of two coaxially, converging lenses. The lens of **large focal length** (f_o) nearer to the object is called the **objective lens**. The lens of short focallength (f_e) through which the final image is viewed is near eyes called the **eyepiece**. Theeyepiece behaves as a magnifying glass.

The objective lens and the eyepiece aremounted at the outer ends of two metal tubes which can be made to slide into one another with thehelp of thumb screw.



Construction:- It consists of a system of two coaxially, converging lenses. The lens nearer to the object is called the **objective lens**. The lens through which the final image is viewed is near eyes called the **eyepiece**. Theeyepiece behaves as a magnifying glass & produces enlarged virtual image of it. The objective lens and the eyepiece aremounted at the outer ends of two metal tubes which can be made to slide into one another with thehelp of thumb screw. The focal length of each lensshould be small in order to achieve a high overall magnification. The eyepiece has a normal (or moderate) focal length while the objective lens has a very short focal length.

(i) Final image at the near point: The final can be formed at the near point. A parallel beam of light from an astronomical object (which is at infinity) is made to fall on the objective lens O of the telescope. This forms an inverted image $A'B'$ of the object near its focus F_o. The eyepiece is so adjusted that $A'B'$ lies between the focus of the eyepiece F_e and its optical centre. The telescope is adjusted so that the final image $A''B''$is at the near point.

Magnifying power:- Since it is the ratio of the angle subtended at the eye by the final image to the angle subtended at eye by the object, when the final image and the object both lie at infinity. Suppose the object is at a large distance and the angle subtended by the object at eye lens is almost the same as the angle subtended by the object at objective lens.

Suppose the object is very far–off, and the angle subtended by the object on the eye is almost the same as the angle subtended by it at the objective lens If it is α. The magnifying power $M = \frac{\beta}{\alpha}$

Where $\angle C_2 A'B' = \beta$ = angle subtended at the eye by the image at the near point and $\angle A'_1C_1B' = \alpha$ = angle subtended at the unaided eye by the object at the near point

Since the angles are very small, $\theta \to 0$ then $\tan\theta = \theta$ Therefore for small angle, $\tan\beta \approx \beta$& $\tan\alpha \approx \alpha$, so $M = \frac{tan\beta}{tan\alpha}$

Now from $\Delta A'B'C_2$, $\tan\beta = \frac{A'B'}{C_2B'}$ and $\Delta A'B'C_1$, $\tan\alpha = \frac{A'B'}{C_1B'}$ Therefore, $m = \frac{A'B'}{C_2B'} \times \frac{C_1B'}{A'B'} = \frac{C_1B'}{C_2B'} = \frac{f_o}{-u_e}$

Where, $C_1B' = f_o$ = focal length of objective lens, $C_2B' = -u_e$ = distance of $A'B'$ from eye lens.

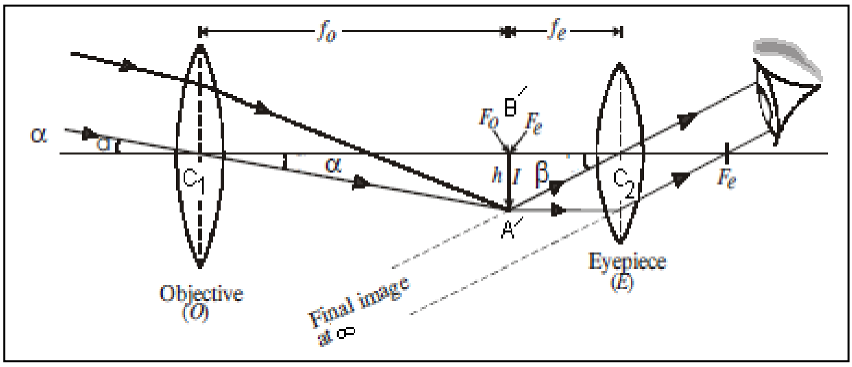
Since $v_e = -D$, $u = -u_e$ and $f = +f_e$, Now using lens formula for eye lens we will get,

This shows that magnifying power is negative. It means that the final image of an astronomical telescope is inverted.

Now, using lens formula $\frac{1}{f_e} = \frac{1}{-D} - \frac{1}{-u_e}$ OR $\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D}$ OR $\frac{1}{u_e} = \frac{1}{f_e}\left[1 + \frac{f_e}{D}\right]$

Now, magnifying power of the microscope, $\boxed{M = \frac{-f_o}{f_e}\left[1 + \frac{f_e}{D}\right]}$

(*ii*) Final image at infinity (*i.e.* normal adjustment): The telescope is said to be in normal adjustment when the final image is formed at infinity. The eye is then relaxed when viewing the image so the image is not seen distinctly. Fig. shows the situation when the astronomical telescope is in normal adjustment. The objective lens *O* collects parallel rays from the distant object and forms an intermediate image *I* at its focus F_o. The separation of the lenses is so adjusted that F_o(focus of objective) and F_e(focus of eyepiece) coincide.



Since the intermediate image Iis at F_e, the eyepiece lens acting as a magnifying glass produces a final image at infinity. It may be seen that when the telescope is in normal adjustment, the separation of the lenses = $f_o + f_e$.

Magnifying power:- The magnifying power $M = \frac{\beta}{\alpha}$

Where $\angle A'_1C_1B' = \alpha$ and $\angle A' C_2 B' = \beta$are angle subtended at the unaided eye by the object and angle subtended at the eye by the final image.

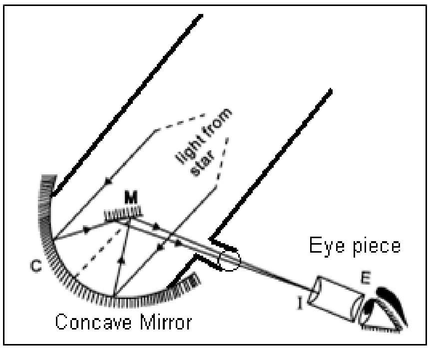
Since the angles are very small, $\theta \to 0$ then $\tan\theta = \theta$ Therefore for small angle, $\tan\beta \approx \beta$& $\tan\alpha \approx \alpha$, so $M = \frac{tan\beta}{tan\alpha}$

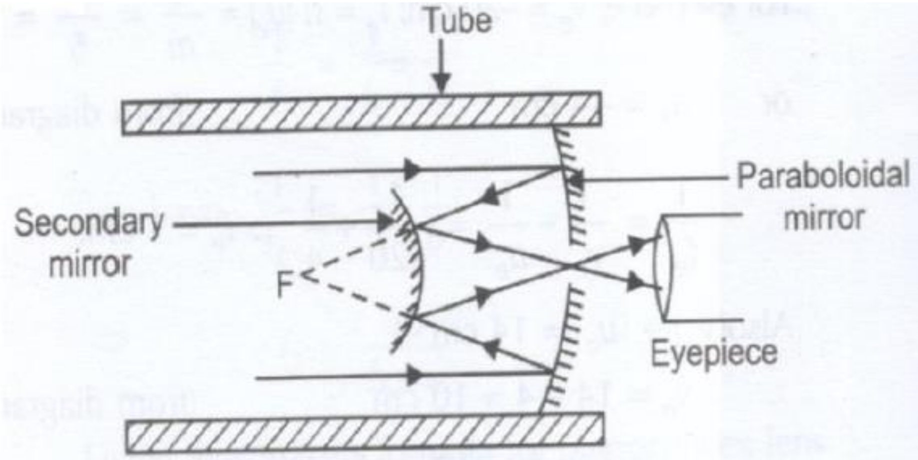
Now, considering $\Delta A'B'C_2,\ \tan\beta = \frac{A'B'}{C_2B'}$ and considering $\Delta A'B'C_1, \tan\alpha = \frac{A'B'}{C_1B'}$

Therefore, $m = \frac{A'B'}{C_2B'} \times \frac{C_1B'}{A'B'} = \frac{C_1B'}{C_2B'}$ Hence $M = \frac{-f_o}{f_e}$

Since, from the figure, $C_1B' = f_o$ = focal length of objective lens $C_2B' = -f_e$ = focal length of eye lens
Here, negative sign indicates that final image is inverted.
Thus, (a) magnifying power of an astronomical telescope can be increased by keeping focal length of objective lens larger and that of eye lens smaller. (b) The aperture of objective lens is made large to increase magnifying power and resolving power ofthe telescope and to produce bright image.

(B) Reflecting type telescope: -In such type of telescope, objective lens is replaced by a concave parabolic mirror of large aperture, which is free from chromatic and spherical aberrations. The resolving power of reflecting type telescope is higher than the refracting type telescope. Reflecting type telescope was designed by Newton for observing distant stars. The following figure shows a cassegrain type telescope. It has parabolic concave reflector C. Rays from distant star entering the telescope in a direction parallel to principal axis of the mirror tend to collect at focus F of the mirror. However, these reflected rays encounter a convex mirror B before meeting at F. They are reflected by convex mirror. These pass through the hole in the C, and form an image at I, at the back of C, and it is observed through the eyepiece E. R being the radius of curvature of concave reflector.
Newtonian (reflecting type) telescope: - In this type of telescope, a concave mirror of large aperture is used as objective instead of a convex lens.





In normal adjustment, magnifying power of a reflecting type telescope is $M = \frac{f_o}{f_e} = \frac{R/2}{f_e}$;

Advantages:-The purpose of the objective lens of a refracting telescope is to produce an image which can be examined by the eyepiece. In the reflecting telescope, a concave mirror is used for the same purpose.
Mirrors have a number of advantages over lenses *viz*.
(*i*) Mirros are easier to manufacture and cheaper than lenses. (*ii*) Mirrors are less liable to flaws or imperfections. (*iii*) A mirror is lighter than an equivalent lens. (*iv*) A mirror has only one surface to be ground and can be supported along its entire surface. A large lens, supported at its edges, would sag under its own weight.
(*v*) Since mirrors are used instead of lenses, a reflecting telescope is free from spherical and chromatic aberrations.
(*vi*) The light gathering power of a reflecting type telescope is large so that the final image formed is brighter.
(*vii*) A reflecting telescope has a high resolving power than that of a refracting telescope.
(*viii*) Since the aperture of objective is large, high resolution is achieved in a reflecting telescope.
(ix) As the mirror is an objective mirror, there is no chromatic aberration. (x) Spherical aberration is reduced using mirror objective in the form of a paraboloid.
Disadvantages:(*i*) It is inconvenient to use because of frequent adjustments. (*ii*) It cannot be used for general purposes.

1Mark questions

1.How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced with red light?
Ans.
$\delta_{violet} > \delta_{red}$
Thus, when incident violet light is replaced with red light, the angle of minimum deviation of a glass decreases.
2. You are given following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope?

Lens	Power (P)	Aperture (A)
L_1	3D	8 cm
L_2	6D	1 cm
L_3	10D	1 cm

Solution:

For constructing an astronomical telescope, the objective should have the maximum diameter. Of the three lenses given, L_1 has the maximum diameter.
The eyepiece should have the highest power for better magnification. Therefore, we use lens L_3.

3. Calculate the speed of light in a medium whose critical angle is 30°.
Solution:

Speed of light in the medium $= \dfrac{\text{Speed of light in air}}{\text{Refractive index of the medium with respect to air}}$

$$= \frac{3\times10^8 \text{ m/s}}{\left(\frac{1}{\sin 30^\circ}\right)}$$

$$= \frac{3\times10^8 \text{ m/s}}{2}$$

$$= 1.5\times10^8 \text{ m/s}$$

4. A glass lens of refractive index 1.45 disappears when immersed in a liquid. What is the value of refractive index of the liquid?

Solution:

The refractive index of the liquid is 1.45.
5. For the same value of angle of incidence, the angles of refraction in three media A, B and C are 15°, 25° and 35° respectively. In which medium would the velocity of light be minimum?

Solution:

As light travels from a rarer to denser medium it bends towards the normal as its speed decreases. So, if the bending is more, the speed of the light would be less in that medium, compared to other media. As the angle of refraction is measured with respect to the normal, the ray making the least angle of refraction would bend more and the speed of light would be minimum in that case. So, the correct option is medium A where refracting angle is 15°.

6. A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason.
Solution:

A biconvex lens acts as a diverging lens in air because the refractive index of air is less than that of the material of the lens. The refractive index of water (1.33) is more than the refractive index of the material of the lens (1.25). So, it will behave as a converging lens.

ASSERTION REASONING QUESTIONS

For following questions two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.
a) Both A and R are true and R is the correct explanation of A
b) Both A and R are true but R is NOT the correct explanation of A
c) A is true but R is false
d) A is false and R is also false

1. Assertion(A):
A convex lens of focal length 30 cm can't be used as a simple microscope in normal setting.
Reason (R):
For normal setting, the angular magnification of simple microscope is M=D/f
Ans. **b) Both A and R are true but R is NOT the correct explanation of A**

2. Assertion (A) Within a glass slab , a double convex air bubble is formed. This air bubble behaves like aconverging lens.
Reason –Refractive index of air is more than the refractive index of glass.
Ans. d) A is false and R is also false

3. **Assertion(A) :**
A total reflecting prism is used to erect the inverted image without deviation
Reason(R):
Rays of light incident parallel to base of prism emerge out as parallel rays
Ans. (a) Both A and R are true and R is the correct explanation of A

4. Assertion : If objective and eye lenses of a microscope are interchanged then it can work as telescope.
Reason : The objective of telescope has small focal length.
Correct Answer: D
Solution : We cannot interchange the objective and eye lens of a microscope to make a telescope. The reason is that the focal length of lenses in microscope are very small, of the order of mm or a few cm and the difference (fo & fe) is very small, while the telescope objective have a very large focal length as compared to eye lens of microscope.

5. Assertion : Although the surfaces of a goggle lens are curved, it does not have any power.
Reason : In case of goggles, both the curved surfaces have equal radii of curvature.
Correct Answer: A
Solution : The focal length of a lens is given by $1/f=(\mu-1)(1/R1-1/R2)$ For, goggle, R1 = R2 $1/f=(\mu-1)(1/R1-1/R2) = 0$. Therefore, P = 1/f = 0.

6. Assertion : If the angles of the base of the prism are equal, then in the position of minimum deviation, the refracted ray will pass parallel to the base of prism.
Reason : In the case of minimum deviation, the angle of incidence is equal to the angle of emergence.
Correct Answer: A
Solution : In case of minimum deviation of a prism $\angle i=\angle e$. so, $\angle r_1=\angle r_2$

7. Assertion : An empty test tube dipped into water in a beaker appears silver, when viewed from a suitable direction.
Reason : Due to refraction of light, the substance in water appears silvery.
Correct Answer: C

Solution : The ray of light incident on the water air interface suffers total internal reflections, in that case the angle of incidence is greater than the critical angle. Therefore, if the tube is viewed from suitable direction (so that the angle of incidence is greater than the critical angle), the rays of light incident on the tube undergoes total internal reflection. As a result, the test tube appears as highly polished i.e. silvery.
8. Assertion : Spherical aberration occur in lenses of larger aperture.
Reason : The two rays, paraxial and marginal rays focus at different points.
Correct Answer: A
Solution : In wide beam of light, the light rays of light which travel close to the principal axis are called paraxial rays, while the rays which travel quite away from the principal axis

is called marginal rays. In case of lens having large aperture, the behaviour of the paraxial and marginal rays are markedly different from each other. The two types of rays come to focus at different points on the principal axis of the lens, thus the spherical aberration occur. However in case of a lens with small aperture, the two types of rays come to focus quite close to each other.

9. Assertion : The frequencies of incident, reflected and refracted beam of monochromatic light incident from one medium to another are same

Reason : The incident, reflected and refracted rays are coplanar.

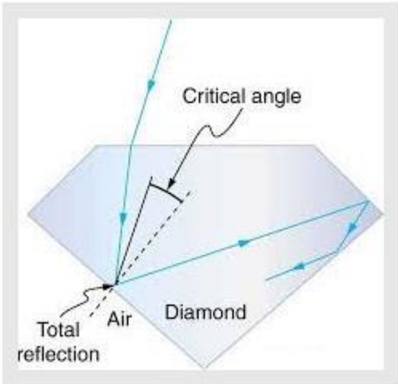
Correct Answer: B

Solution : If both assertion and reason are true but reason is not the correct explanation of the assertion.

CASE STUDY BASED QUESTIONS

Following questions are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

1.



total internal reflection of the light is used in polishing diamonds to create a sparking brilliance. By polishing the diamond with specific cuts, it is adjusted the most of the light rays approaching the surface are incident with an angle of incidence more than critical angle. Hence, they suffer multiple reflections and ultimately come out of diamond from the top. This gives the diamond a sparking brilliance.

(i). Light cannot easily escape a diamond without multiple internal reflections. This is because:

a) Its critical angle with reference to air is too large

b) Its critical angle with reference to air is too small

c) The diamond is transparent

d) Rays always enter at angle greater than critical angle

(ii). The critical angle for a diamond is 24.4^0. Then its refractive index is-

a) 2.42

b) 0.413

c) 1

d) 1.413

(iii). The basic reason for the extraordinary sparkle of **suitably cut** diamond is that

a) It has low refractive index

b) It has high transparency

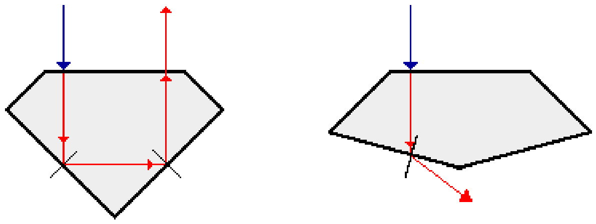
c) It has high refractive index

d) It is very hard

(iv). A diamond is immersed in a liquid with a refractive index greater than water. Then the critical angle for total internal reflection will

a) will depend on the nature of the liquid
b) decrease
c) remains the same
d) increase

(v). The following diagram shows same diamond cut in two different shapes.



The brilliance of diamond in the second diamond will be:
a) less than the first
b) greater than first
c) same as first
d) will depend on the intensity of light

Ans.

(i) (b) Its critical angle with reference to air is too small
(ii) (a) 2.42
(iii) (c) It has high refractive index
(iv) (d) increase
(v) (a) less than the first

2. Optical fibre

Optical fibre are long, thin strands of carefully drawn glass about the diameter of human hair. These strands are arranged in bundles called optical cables. We rely on them to transmit light signals over long distances.

Light travels down fibre optic cables by bouncing off the walls of the cable repeatedly. Each light particle bounces down the pipe with internal reflection. The light beam travels down the core of the cable. The core is the middle of the cable and the glass structure .The cladding is another layer of glass wrapped around the core. Cladding is there to keep the light signals inside the core.

(i). Optic fibers are used in
a)Medical industry
b) Communication
c) lighting and decorations
d) all of the above

(ii). The refractive index of diamond is 2.42. Then its critical angle is
a) 24.4^0
b) 44.5^0
c) 42.4^0
d) 54.4^0

(iii). For total internal reflection in optical fibers
a)Core has low refractiveindex than cladding
b)Both core and cladding have same refractive index
c)Core has high refractiveindex than cladding
d)None of the above

(iv). A glass slab is immersed in water. Then the critical angle for total internal reflection of glass will be
a)Increases
b) Decreases
c) Remains the same
d) May be increase or decrease

(v). What is the principle of fibre optical communication?
(a) reflection
(b) total internal reflection
(c) Interference
(d) diffraction

Ans.

(i) .(d) all of the above

(ii).(a) 24.4^0

(iii).(c) Core has high refractiveindex than cladding

(iv) .(a) Increases

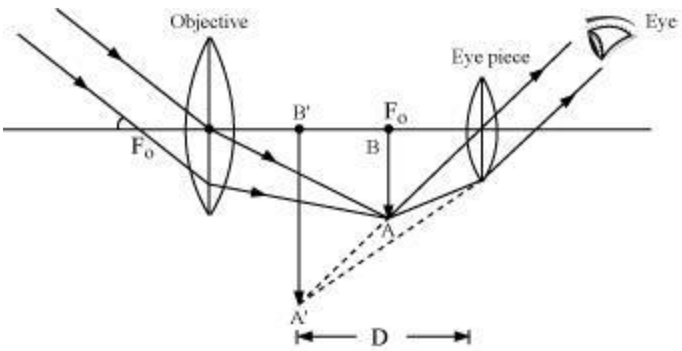
(v). (b) total internal reflection

2Mark questions

1.Draw a labelled ray diagram of an astronomical telescope in the near point position. Write the expression for its magnifying power.

Solution:

Astronomical telescope in the near point position:



Magnifying power,

$$m = \frac{F_0}{F_e}\left(1 + \frac{F_e}{D}\right)$$

2. Find the radius of curvature of the convex surface of a plano-convex lens, whose focal length is 0.3 m and the refractive index of the material of the lens is 1.5.

Solution:

The focal length of a combined lens can be determined by the formula

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Here, $R_2 = \infty$ and $f = 0.3$ m

$$\frac{1}{0.3} = (\mu - 1) \times \frac{1}{R_1}$$

$$\begin{aligned} R_1 &= 0.3(\mu - 1) \\ &= 0.3(1.5 - 1) \\ &= 0.3 \times 0.5 \\ &= 0.15 \text{ m} \\ &= 15 \text{ cm} \end{aligned}$$

3. (i) Out of blue and red light which is deviated more by a prism? Give reason.
(ii) Give the formula that can be used to determine refractive index of materials of a prism in minimum deviation condition.

Solution:

(i) Between blue and red light, blue light is deviated more by a prism. This is because the wavelength of blue light is smaller than that of red light. Therefore, the speed of blue light is lower than that of red light in a medium.
(ii) The formula used for determining the refractive index of materials of a prism in minimum deviation condition,

$$n_{21} = \frac{\sin\left[(A + D_m)/2\right]}{\sin\left[\frac{A}{2}\right]}$$

Where, n_{21} $\longrightarrow$ Refractive index of prism material with respect to the surrounding medium

A $\longrightarrow$ Angle of the prism

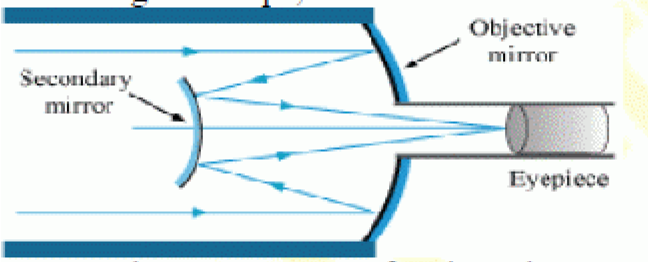
D_m $\longrightarrow$ Angle of minimum deviation

4. Draw a labeled ray diagram of a reflecting telescope. Mention its two advantages over the refracting telescope.

Solution:

Reflecting Telescope,

Reflecting Telescope,



Its two advantages over Refracting telescope:

Its two advantages over Refracting telescope:

1. It reduces the spherical aberration and forms a clear focused image.
2. It doesn't require a lens of very large aperture as refracting type requires that cannot be manufactured easily.

5. A convex lens of focal length f_1 is kept in contact with a concave lens of focal length f_2. Find the focal length of the combination.

Solution:

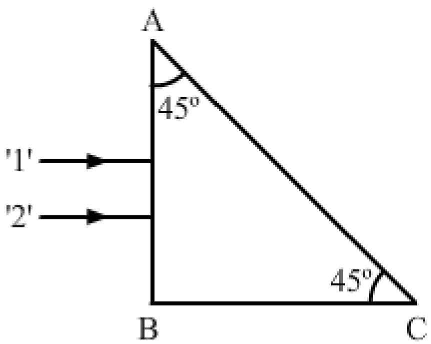
For convex lens, focal length, $f = f_1$ and for concave lens, the focal length, $f = -f_2$

The equivalent focal length of a combination of convex lens and concave lens is given as:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{-f_2}$$

$$\Rightarrow F = \frac{f_1 f_2}{f_2 - f_1}$$

6. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.35 and 1.45. Trace the path of these rays after entering the prism.



Solution:

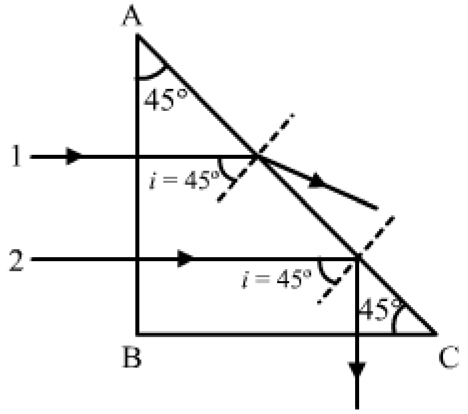
Critical angle of ray 1:

$\sin(c1)=1\mu1=11.35\Rightarrow c1=\sin-1(11.35)=47.73°$

Similarly, critical angle of ray 2:

$\sin(c2)=1\mu2=11.45\Rightarrow c2=\sin-1(11.45)=43.6°$

Both the rays will fall on the side AC with angle of incidence *(i)* equal to 45°. Critical angle of ray 1 is greater than that of *i*. Hence, it will emerge from the prism, as shown in the figure. Critical angle of ray 2 is less than that of *i*. Hence, it will be internally reflected, as shown in the figure.



3Mark questions

1.How does the frequency of a beam of ultraviolet light get affected when it goes from air into glass?
A ray of light incident on an equilateral glass prism shows minimum deviation of 30°.
Calculate the speed of light through the glass prism.

Solution:

The frequency of the ultraviolet beam of light does not change when it goes from air to glass. This is because frequency is the property of source and does not change with medium.

$$\mu = \frac{\frac{\sin(A+\delta_m)}{2}}{\frac{\sin A}{2}}$$

$$\mu = \frac{\sin\left(\frac{60+30}{2}\right)}{\sin\left(\frac{60}{2}\right)}$$

$$\mu = \frac{\sin 45^\circ}{\sin 30^\circ} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in glass}}$$

Speed of light in glass

$= 3 \times 10^8 \times \sin 30 \times \frac{1}{\sin 45^\circ}$

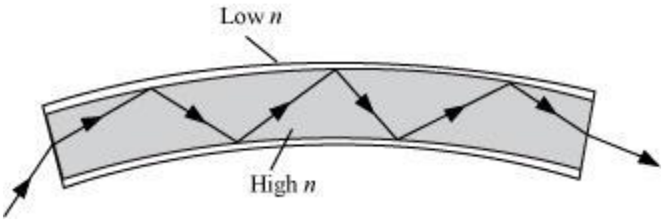
$= 3 \times 10^8 \times \frac{1}{2} \times \sqrt{2}$

$= \frac{3 \times 10^8}{\sqrt{2}}$

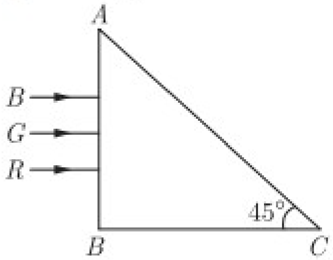
$= 2.13 \times 10^8$ m/s

2. Draw a schematic diagram of a single optical fibre structure. On what principle does such a device work? Explain the mechanism of propagation of light signal through an optical fibre.

Solution:

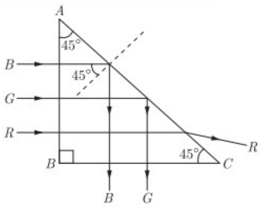


A single optical fibre works on the principle of total internal reflection.
An optical fibre consists of a core with higher refractive index and a cladding with a lower refractive index. When light enters the fibre at a suitable angle, it undergoes successive total internal reflections along the length of the fibre. This is how a light signal travels through the optical fibre.
3. Three light rays, red R, green G and blue B are incident on a right angled prism ABC at face AB. The refractive indices of the material of the prism for red, green and blue wavelengths are 1.39, 1.44 and 1.47, respectively. Out of the three, which colour of ray will emerge out of face AC ? Justify your answer. Trace the path of these

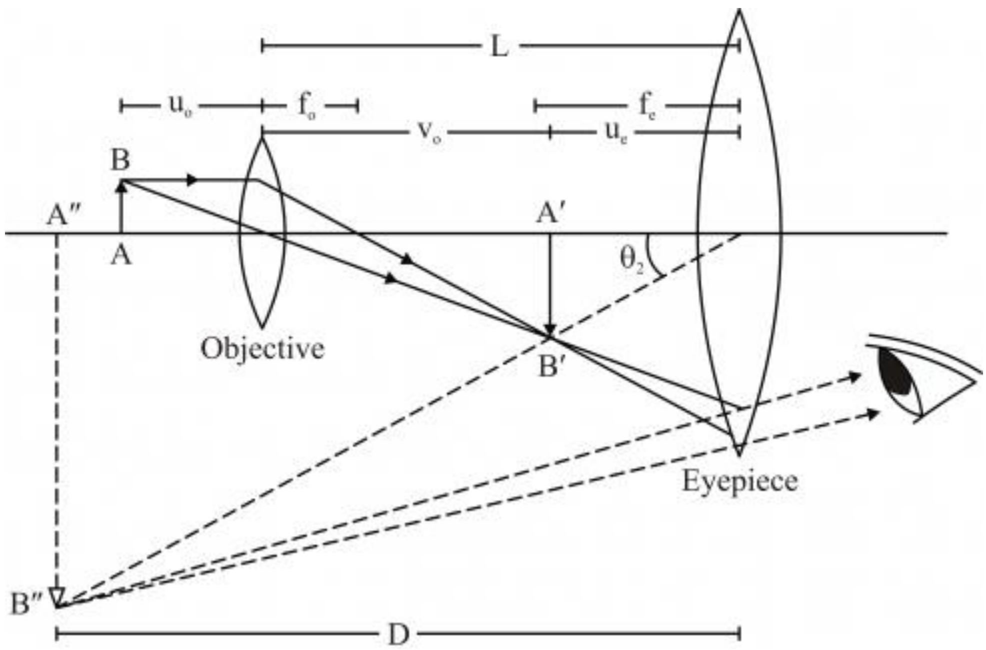


rays after passing through face AB.

Solution:
By geometry, angle of incidence i at face AC for all three rays is 45^0. Light suffers total internal reflection for which this angle of incidence is greater than critical angle.
$i > i_c$& $\sin i > \sin i_c$ or $\sin 45^0 > \sin i_c$ or $1/\sqrt{2} > 1/\mu$ or $\sqrt{2} < \mu$ or $\mu > \sqrt{2}$ or $\mu > 1.414$
Total internal reflection takes place on AC for rays with $\mu > 1.414$,
i.e. green and blue colours suffer total internal reflection whereas red undergoes refraction.



4. A compound microscope uses an objective lens of focal length 4 cm and eyepiece lens of focal length 10 cm. An object is placed at 6 cm from the objective lens. Calculate the magnifying power of the compound microscope. Also calculate the length of the microscope.



Solution:

First we shall find the image distance for the objective (v_o),

$$\frac{1}{f_o}=\frac{1}{v_o}-\frac{1}{u_o}; f_o=4cm, u_o=-6cm$$

$$\Rightarrow v_o=12cm$$

Magnification of the microscope is,

$$m=m_o m_e=\frac{v_o}{u_o}\left(1+\frac{D}{f_e}\right)=\left(\frac{12}{-6}\right)\left(1+\frac{25}{10}\right)$$

= − 7, negative sign indicates that the image is inverted.

The length of the microscope is v_o+ u, u=|u_e| is the object distance for the eyepiece. And u_e can be found using,

$$\frac{1}{f_o}=\frac{1}{D}-\frac{1}{u_e}$$; as D is the image distance for the eyepiece.

$$\Rightarrow \frac{1}{10}=\frac{1}{-25}-\frac{1}{u_e}\Rightarrow u_e=-7.14cm$$

Hence, u = |u_e| = 7.14 *cm.*

Length of the microscope v_o+ u= 19.14 *cm*

Length of the microscope is given as

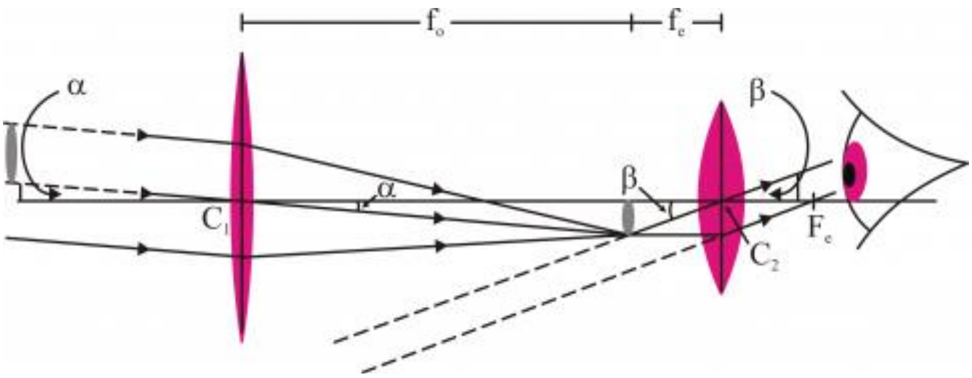
$$L=\frac{mf_o f_e}{D}=\frac{7\times 4\times 10}{25}=11.2 \text{ cm}$$

5. A giant refracting telescope at an observatory has an objective lens of focal length 15 m. If an eyepiece lens of focal length 1.0 cm is used, find the angular magnification of the telescope. If this telescope is used to view the moon, what is the diameter of the image of the moon formed by the objective lens? The diameter of the moon is 3.42×10^6 m and the radius of the lunar orbit is 3.8×10^8 m.

Solution:

$$\text{Angular magnification } =-\frac{f_o}{f_e}\left(1+\frac{f_e}{D}\right)=-\frac{1500}{1}\left(1+\frac{1}{25}\right)=-1560$$

Negative sign indicates that the image is inverted.



Diameter of the image of the moon formed by the objective lens = d (say)

$$\tan\alpha \approx \alpha = \frac{\text{diameter of the moon}}{\text{radius of the orbit}} = \frac{d}{f_o}$$

$$\text{or, } \frac{3.42\times10^{6}}{3.8\times10^{8}} = \frac{d}{15} \Rightarrow d = 0.135\,m$$

6. A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in (i) a medium of refractive index 1.6, (ii) a medium of refractive index 1.3.

(a) Will it behave as a converging or a diverging lens in the two cases?

(b) How will its focal length change in the two media?

-

Solution:

Given Refractive index of glass, ì$_a$ = 1.5

Refractive index of Ist medium, ì$_1$ = 1.6

Refractive index of IInd medium, ì$_2$ = 1.3

(a) For Ist medium

$$\mu_1 > \mu_a \Rightarrow \frac{\mu_a}{\mu_1} < 1$$

Hence, $f > 0$; concave lens or diverging lens

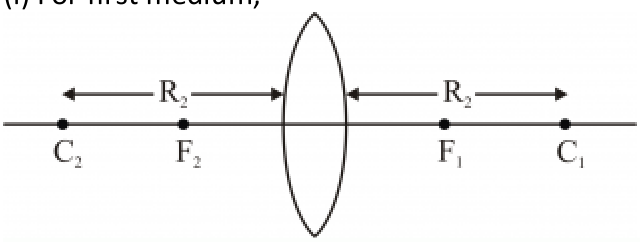
(ii) For IInd medium

$$\mu_2 > \mu_a \Rightarrow \frac{\mu_a}{\mu_2} > 1$$

Hence, $f < 0$; convex lens or converging lens

(b)

(i) For first medium,



$$\frac{1}{f_1} = \left(1-\frac{\mu_a}{\mu_1}\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \begin{matrix} R_1 > 0 \\ -R_2 > 0 \end{matrix}$$

$$= \left(1-\frac{1.5}{1.6}\right) \qquad (\text{Positive number})\text{ for convex lens}$$

$$= (1-0.9) \qquad (\text{Positive number})$$

$$= (0.1) \qquad (\text{Positive number})$$

Original focal length

$$\frac{1}{f} = (1-\mu_a)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = -0.5 \qquad \text{(Positive number)}$$

$$\Rightarrow \frac{f_1}{f} = -\frac{0.5}{0.1}$$

$$\Rightarrow f_1 = -5f$$

Hence, focal length will be 5 times the original focal length and its nature will become diverging.

(ii) For second medium

$$\frac{1}{f_2} = \left(1 - \frac{\mu_a}{\mu_2}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= \left(1 - \frac{1.5}{1.3}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= (1 - 1.15)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

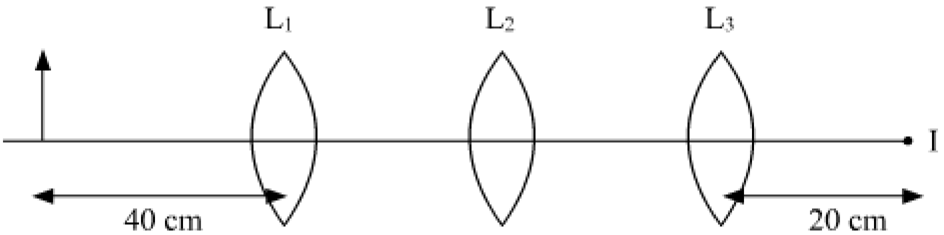
$$= 0.2\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{f_2}{f} = \frac{0.2}{0.1}$$

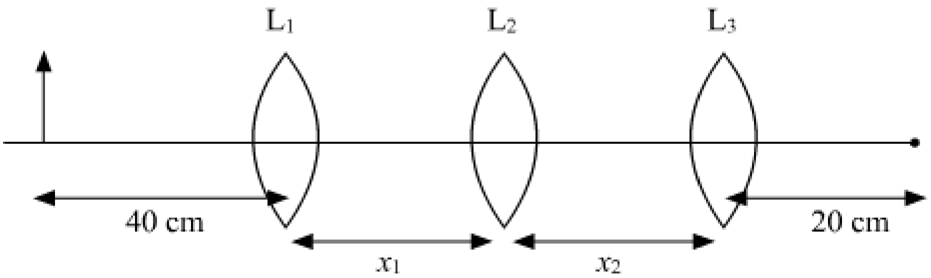
$$\Rightarrow f_2 = 2f$$

Hence, focal length will be twice the original focal length and its nature (Converging nature) will remain same.

7. You are given three lenses L_1, L_2 and L_3 each of focal length 20 cm. A object is kept at 40 cm in front of L_1, as shown. The final real image is formed at the focus 'I' of L_3. Find the separation between L_1, L_2 and L_3.



Solution:



Here $f_1 = f_2 = f_3 = 20$ cm

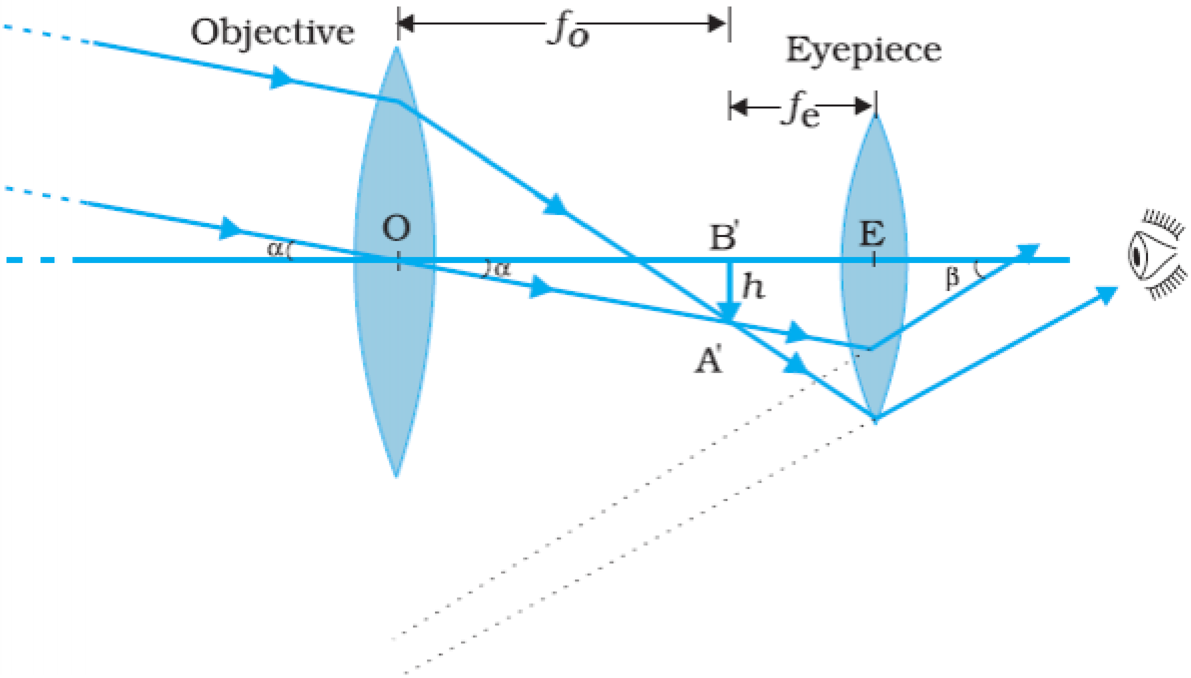
Now, $u_1 = -40$ cm

From lens makers formula

$$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$$
$$\frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1}$$
$$= \frac{1}{20} + \frac{1}{-40}$$
$$= \frac{2-1}{20} = \frac{1}{40}$$
$$v_1 = 40\,\text{cm}$$
Here, image by L_3 is formed at focus. So the object should lie at infinity for L_3. Hence, L_2 will produce image at infinity. So, we can conclude that object for L_2 should be at its focus.
But, we have seen above that image by L_1 is formed at 40 cm right of L_1 which is at 20 cm left of L_2(focus of L_2).
So X_1 = distance between L_1 and L_2 = (40 + 20) cm
= 60 cm
Again distance between L_2 and L_3 does not matter as the image by L_2 is formed at infinity so X_2can take any value.
8. Draw a labelled ray diagram of a refracting telescope. Define its magnifying power and write the expression for it.
Write two important limitations of a refracting telescope over a reflecting type telescope.

-
Solution:

Refracting telescope:

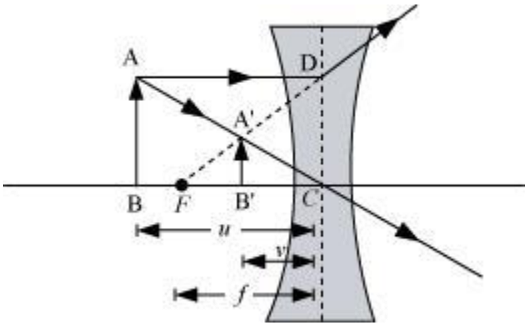


Magnifying Power: The magnifying power *m* is the ratio of the angle α subtended at the eye by the final image to the angle β which the object subtends at the lens or the eye.
$$m \approx \frac{\beta}{\alpha} \approx \frac{h}{f_e} \cdot \frac{f_o}{h} = \frac{f_o}{f_e}$$
Limitations of refracting telescope over reflecting type telescope:
(NOTE: Write any two)
(i) Refracting telescope suffers from chromatic aberration as it uses large sized lenses.
(ii) The image formed by refracting telescope is less bright than the image formed by the reflecting type telescope due to some loss of light by reflection at the lens and by absorption.

(iii) The resolving power of refracting telescope is less than the resolving power of reflecting type telescope as the mirror of reflecting type telescope has large diameter.
(iv) The requirements of big lenses tend to be very heavy and therefore difficult to make and support by their edges.
(v) It is also difficult and expensive to make such large sized lenses.

1. Derive the lens formula, $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ for a concave lens, using the necessary ray diagram.
Two lenses of powers 10 D and − 5 D are placed in contact.
(i) Calculate the power of the new lens.
(ii) Where should an object be held from the lens, so as to obtain a virtual image of magnification 2?
Solution:

Derivation of lens formula:



ABis an object held perpendicular to the principal axis of the lens. A virtual, erect, and smaller image $A'B'$ is formed due to refraction through concave lens as shown in figure.
As Δ*s* $A'B'C$ and ABC are similar,

$$\therefore \frac{A'B'}{AB}=\frac{CB'}{CB} \qquad (i)$$

Again as Δ*s* $A'B'F$ andCDF are similar,

$$\therefore \frac{A'B'}{CD}=\frac{B'F}{CF}$$

However, CD = AB

$$\therefore \frac{A'B'}{AB}=\frac{B'F}{CF} \qquad (ii)$$

From (i) and (ii),

$$\frac{CB'}{CB}=\frac{B'F}{CF} \qquad =\frac{CF - CB'}{CF} \qquad (iii)$$

Using new Cartesian sign conventions, let

$$CB=-u, CB'=-v$$
$$CF=-f$$
$$\frac{-v}{-u}=\frac{-f+v}{-f}$$
$$vf=uf=uv$$
$$uv=uf-vf$$

Dividing both sides by *uvf*, we obtain

$$\frac{uv}{uvf} = \frac{uf}{uvf} - \frac{vf}{uvf}$$

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

This is the required lens formula.

(i) Power of new lens, $P = P_1 + P_2$

$\therefore P = 10 - 5 = +5$ D

(ii) Here, u =?

$f = \frac{1}{P} = \frac{1}{5} m = \frac{100}{5}$ cm = 20 cm

$m = 2$ i.e., $\frac{-v}{-u} = 2$ or $v = 2u$

Using lens formula,

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

$$\frac{1}{20} = \frac{1}{2u} - \frac{1}{u}$$

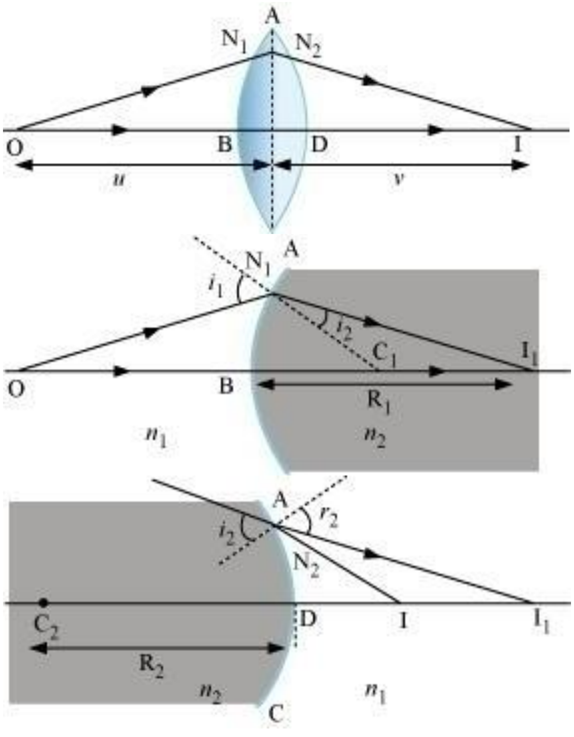
$$\frac{1}{20} = \frac{1-2}{2u} \Rightarrow \frac{1}{20} = -\frac{1}{2u} \therefore u = -110 \text{ cm}$$

∴ Object distance = 10 cm

2. Derive the relation between the focal length of a convex lens in terms of the radii of curvature of the two surfaces and refractive index of its material. Write the sign conventions and two assumptions used in the derivation of this relation.

A convex lens of focal length 40 cm and a concave lens of focal length 25 cm are kept in contact with each other. What is the value of power of this combination?

Solution:



The image I_1 of the object O behaves like a virtual object for the second surface.

For surface ABC,

$$\frac{n_1}{OB} + \frac{n_2}{BI} = \frac{n_2 - n_1}{BC_1} \quad ...(i)$$

For surface ADC,

$$-\frac{n_2}{DI_1} + \frac{n_2}{DI} = \frac{n_2 - n_1}{DC_2} \quad ...(ii)$$

For a thin lens, it is known that $BI_1 = DI_1$

Adding (i) and (ii),

$$\frac{n_1}{OB} + \frac{n_1}{DI} = (n_2 - n_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right)$$

Focus is the point where the image is formed when object is at infinity.

DI = f, when OB → ∞

$$\frac{n_1}{\infty} + \frac{n_1}{f} = (n_2 - n_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right)$$

$$\frac{n_1}{f} = (n_2 - n_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right)$$

Using sign convention,

$$BC_1 = +R_2$$

$$DC_2 = -R_2$$

We obtain:

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$n_{21} = \frac{n_2}{n_1}$$

n_{21} → Refractive index of medium 2 with respect to medium 1

The sign conventions used here are as follows:

(i) All distances are measured from the optical centre.

(ii) The distances measured in the same direction as incident light are taken as positive while the distances measured in a direction opposite to incident light are taken as negative.

The two assumptions used in this derivation are as follows:

(i) The lens is thin.

(ii) Aperture of the lens is small.

(iii) The rays are paraxial.

(Note: Any two of the above can be used to give the answer)

When two thin lenses are in contact then,

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

Where,

f is the focal length of both the lenses combined.

f_1 is the focal length of the convex lens.

f_2 is the focal length of the concave lens

Power (P) of the lens = $\frac{1}{f}$

It is given that

f_1 = −40 cm = −0.40 m (by sign convention)

f_2 = 25cm = 0.25 m

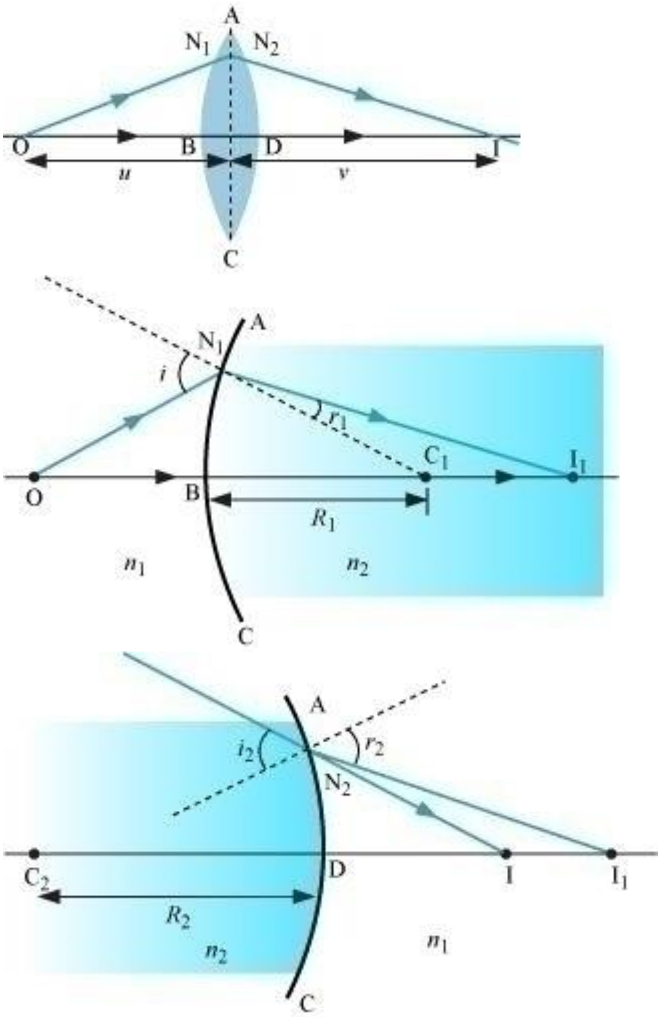
Therefore,

$$P = -\frac{100}{40} + \frac{100}{25}$$

P = 1.5 dioptre

3. Trace the rays of light showing the formation of an image due to a point object placed on the axis of a spherical surface separating the two media of refractive indices n_1 and n_2. Establish the relation between the distances of the object, the image and the radius of curvature from the central point of the spherical surface. Hence derive the expression of the lens maker's formula.

Solution:



In the given figure, image is I and object is denoted as O.

The centre of curvature is C.

The rays are incident from a medium of refractive index n_1 to another of refractive index n_2.

We consider NM to be perpendicular to the principal axis.

$$\tan \angle NOM = \frac{MN}{OM}$$

$$\tan \angle NCM = \frac{MN}{MC}$$

$$\tan \angle NIM = \frac{MN}{MI}$$

For ΔNOC, i is the exterior angle.

Therefore, $i = \angle NOM + \angle NCM$

$$i = \frac{MN}{OM} + \frac{MN}{MC}$$

Similarly,

$r = \angle NCM - \angle NIM$

i.e., $r = \frac{MN}{MC} - \frac{MN}{MI}$

According to Snell's law,

$n_1 \sin i = n_2 \sin r$

For small angles,

$n_i i = n_2 r$

Substituting *i* and *r*, we obtain

$$\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$$

Where, OM, MI, and MC are the distances

OM = $-u$

MC = $+R$

MI = v

Substituting these, we obtain

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R} \qquad ...(i)$$

Applying equation (i) to lens ABCD, we obtain for surface ABC,

$$\frac{n_1}{OB} + \frac{n_2}{BI_1} = \frac{n_2 - n_1}{BC_1} \qquad ...(ii)$$

For surface ADC, we obtain

$$\frac{-n_2}{DI_1} + \frac{n_1}{DI} = \frac{n_2 n_1}{DC_2} \qquad ...(iii)$$

For a thin lens,

$BI_1 = DI_1$

Adding (ii) and (iii), we obtain

$$\frac{n_1}{OB} + \frac{n_1}{DI} = (n_2 - n_1)\left[\frac{1}{BC_1} + \frac{1}{DC_2}\right]$$

Suppose object is at infinity and DI = f, then

$$\frac{n_1}{f} = (n_2 - n_1)\left[\frac{1}{BC_1} + \frac{1}{DC_2}\right]$$

Using sign convention,

$BC_1 = +R_2$

$DC_2 = -R_2$

We obtain:

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$n_{21} = \frac{n_2}{n_1}$$

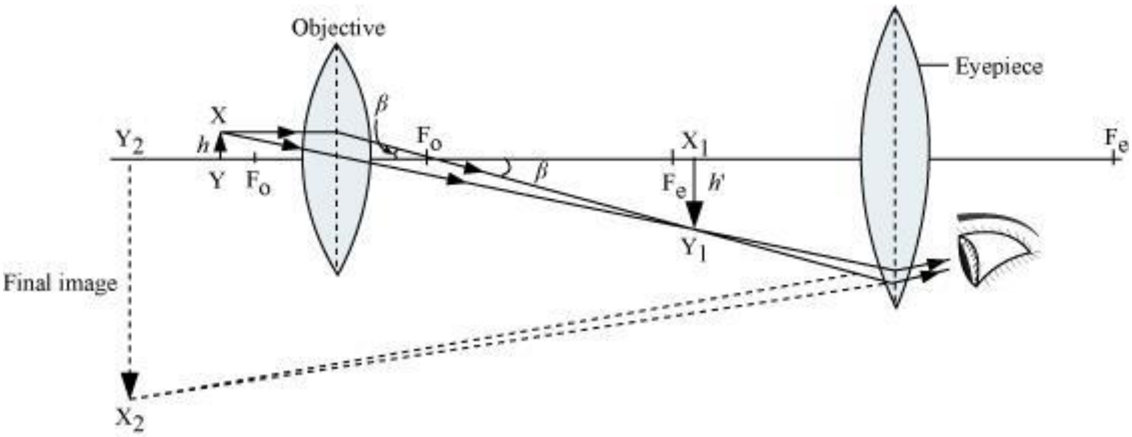
n_{21} → Refractive index of medium 2 with respect to medium 1

This is known as lens maker's formula.

4. Draw the labelled ray diagram for the formation of image by a compound microscope.

Derive the expression for the total magnification of a compound microscope. Explain why both the objective and the eyepiece of a compound microscope must have short focal lengths.

Solution:



$$\tan\beta = \frac{h}{f_0} \quad ...(i)$$

$$\tan\beta = \frac{h'}{L} \quad ...(ii)$$

$$\frac{h'}{h} = \frac{L}{f_0} \quad \left[\text{Using (i) and (ii)}\right]$$

$$m_0 = \frac{h'}{h} = \frac{L}{f_0} \quad \left[\text{Magnification due to objective}\right]$$

$$m_e = 1 + \frac{D}{f_e}$$

Net magnification (m) = $m_0 m_e$

$$\left| m = \left(\frac{L}{f_0}\right)\left(\frac{D}{f_e}\right) \right|$$

f_0 and f_e are in denominator.

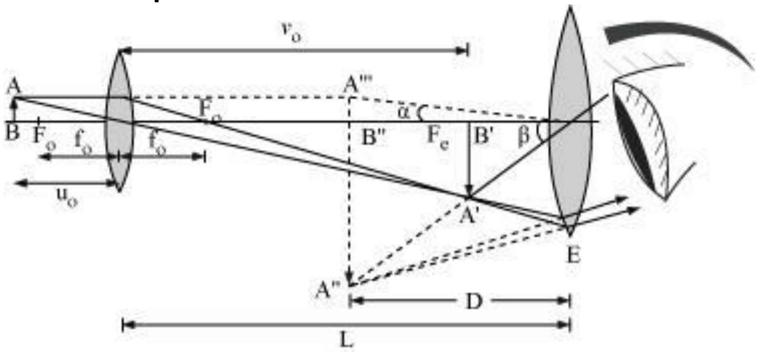
This formula contains f_o and f_e in denominator. Therefore, both the objective and the eyepiece of a compound microscope must have short focal lengths.

5. Draw a ray diagram to show the working of a compound microscope. Deduce an expression for the total magnification when the final image is formed at the near point.

In a compound microscope, an object is placed at a distance of 1.5 cm from the objective of focal length 1.25 cm. If the eye piece has a focal length of 5 cm and the final image is formed at the near point, estimate the magnifying power of the microscope.

Solution:

Ray diagram for a compound microscope



Total angular magnification, $m = \frac{\beta}{\alpha}$

β → Angle subtended by the image

α → Angle subtended by the object

Since α and β are small,

$$\tan\alpha \approx \alpha \text{ and } \tan\beta \approx \beta$$

$$m = \frac{\tan\beta}{\tan\alpha}$$

$$\tan\alpha = \frac{AB}{D}$$

And

$$\tan\beta = \frac{A''B''}{D}$$

$$m = \frac{\tan\beta}{\tan\alpha} = \frac{A''B''}{D} \times \frac{D}{AB} = \frac{A''B''}{AB}$$

On multiplying the numerator and the denominator with A′B′, we obtain

$$m = \frac{A''B'' \times A'B'}{A'B' \times AB}$$

Now, magnification produced by objective, $m_0 = \frac{A'B'}{AB}$

Magnification produced by eyepiece, $m_e = \frac{A''B''}{AB}$

Therefore,

Total magnification, (m) = $m_0\, m_e$

$$m_0 = \frac{v_0}{u_0} = \frac{\text{(Image distance for image produced by objective lens)}}{\text{(Object distance for the objective lens)}}$$

$$m_e = \left(1 + \frac{D}{f_e}\right)$$

f_e → Focal length of eyepiece

$$m = m_0 m_e$$

$$= \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$$

$v_0 \approx L$ (Separation between the lenses)

$$u_0 \approx -f_0$$

$$\therefore m = \frac{-L}{f_0}\left(1 + \frac{D}{f_e}\right)$$

$$u_0 = -1.5 \text{ cm}$$

$$f_0 = +1.5 \text{cm}$$

$$\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0}$$

$$\frac{1}{1.25} = \frac{1}{v_0} + \frac{1}{1.5}$$

$$\frac{1}{v_0} = \frac{1}{1.25} - \frac{1}{1.5}$$

$$= \frac{100}{125} - \frac{10}{15}$$

$$= \frac{1500 - 1250}{1875}$$

$$\frac{1}{v_0} = \frac{250}{1875}$$

$$v_0 = +7.5 \text{ cm}$$

$$f_e = +5 \text{ cm}$$

$$m = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$$

$$= \frac{7.5}{-1.5}\left(1 + \frac{25}{5}\right)$$

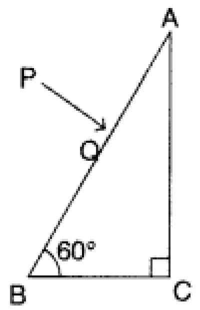
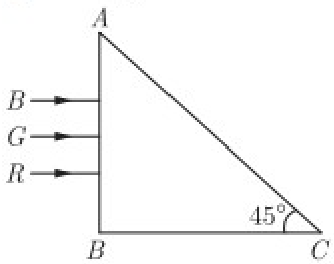
$$= -\frac{7.5}{1.5} \times 6$$

$$\boxed{m = -30}$$

Worksheet

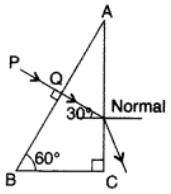
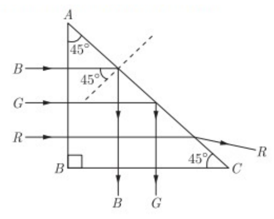
S.No.	Question	Marks
1	A glass lens of refractive index 1.5 is placed in a liquid. What must be the refractive index of the liquid in order to mark the lens disappear?	1
2	How does the power of a convex lens vary, if the incident red light is replaced by violet light?	1
3	State the conditions for the phenomenon of total internal reflection to occur	1
4	Calculate the speed of light in a medium whose critical angle is 30°.	1
5	A converging lens is kept coaxially in contact with a diverging lens, both the lenses being of equal focal lengths. What is the focal length of the combination?	1
6	When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a decrease in the energy carried by the light wave?	1
7	For the same value of angle of incidence, the angles of refraction in three media A, B and C are 15°, 25° and 35° respectively. In which medium would the velocity of light be minimum?	1
	For question numbers 8 and 9 two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below. **a) Both A and R are true and R is the correct explanation of A** **b) Both A and R are true but R is NOT the correct explanation of A** **c) A is true but R is false** **d) A is false and R is also false**	
8	Assertion: If objective and eye lenses of a microscope are interchanged then it can work as telescope. Reason: The objective of telescope has small focal length.	1
9	Assertion: Spherical aberration occur in lenses of larger aperture. Reason: The two rays, paraxial and marginal rays focus at different points.	1
10.	Optical fibre Optical fibre are long, thin strands of carefully drawn glass about the diameter of human hair. These strands are arranged in bundles called optical cables. We rely on them to transmit light signals over long distances. Light travels down fibre optic cables by bouncing off the walls of the cable repeatedly. Each light particle bounces down the pipe with internal reflection. The light beam travels down the core of the cable. The core is the middle of the cable and the glass structure. The cladding is another layer of glass wrapped around the core. Cladding is there to keep the light signals inside the core.	4

		
	(i). Optic fibers are used in a)Medical industry b) Communication c) lighting and decorations d) all of the above	
	(ii). The refractive index of diamond is 2.42. Then its critical angle is a) 24.4^0 b) 44.5^0 c) 42.4^0 d) 54.4^0	
	(iii). For total internal reflection in optical fibers a)Core has low refractiveindex than cladding b)Both core and cladding have same refractive index c)Core has high refractiveindex than cladding d)None of the above	
	(iv). A glass slab is immersed in water. Then the critical angle for total internal reflection of glass will be a)Increases b) Decreases c) Remains the same d) May be increase or decrease	
	(v). What is the principle of fibre optical communication? (a) reflection (b) total internal reflection (c) Interference (d) diffraction	
11	Give two reasons to explain why a reflecting telescope is preferred over a refracting telescope. **OR** State the advantages of reflecting telescope over refracting telescope.	2
12	The radii of curvature of the faces of a double convex lens are 10 cm and 15 cm. If focal length of the lens is 12 cm, find the refractive index of the material of the lens.	2
13	A ray PQ incident normally on the refracting face BA is refracted in the prism BAC made of material of refractive index 1.5. Complete the path of ray through the prism. From which face will the ray emerge out	2

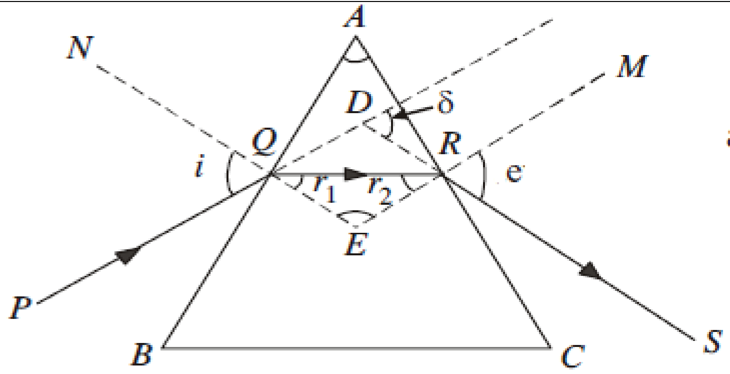
		
14	Three light rays, red R, green G and blue B are incident on a right-angled prism ABC at face AB. The refractive indices of the material of the prism for red, green and blue wavelengths are 1.39, 1.44 and 1.47, respectively. Out of the three, which colour of ray will emerge out of face AC? Justify your answer. Trace the path of these rays after passing through face AB. 	3
15	(i) Draw the ray diagram of an astronomical telescope when the final image is formed at infinity. Write the expression for the magnifying power of the telescope. (ii) An astronomical telescope has an objective lens of focal length 20m and eyepiece of focal length 1 cm. Find the length of the telescope tube in normal adjustment.	1 ½ + ½ ½ + ½
16.	(a) Deduce the expression, by drawing a suitable ray diagram, for the refractive index of a triangular glass prism in terms of the angle of minimum deviation (D) and the angle of prism (b) Draw a plot showing the variation of the angle of deviation with the angle of incidence.	2+1
17	Draw a ray diagram to show the working of a compound microscope. Deduce an expression for the total magnification when the final image is formed at the near point. In a compound microscope, an object is placed at a distance of 1.5 cm from the objective of focal length 1.25 cm. If the eye piece has a focal length of 5 cm and the final image is formed at the near point, estimate the magnifying power of the microscope.	1+2+2

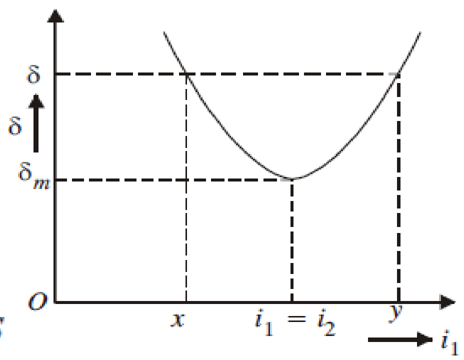
ANSWER

S.No.	Answers	Marks
1	1.5	1
2	Increases	1
3	i)Light should travel from an optically denser medium to an optically rarer medium. ii)The angle of incidence in the denser medium must be greater than the critical angle for the two media.	½ 1/2
4	1.5×10^{8}m/s	1
5	∞	1
6	Energy remains constant ($E=h\nu$)	1
7	A	1
8	Correct Answer: D Solution : We cannot interchange the objective and eye lens of a microscope to make a telescope. The reason is that the focal length of lenses in microscope are very small, of the order of mm or a few cm and the difference (fo & fe) is very small, while the telescope objective have a very large focal length as compared to eye lens of microscope.	1

<table>
<tr><td>9</td><td>Correct Answer: A
Solution: In wide beam of light, the light rays of light which travel close to the principal axis are called paraxial rays, while the rays which travel quite away from the principal axis is called marginal rays. In case of lens having large aperture, the behaviour of the paraxial and marginal rays are markedly different from each other. The two types of rays come to focus at different points on the principal axis of the lens, thus the spherical aberration occur. However, in case of a lens with small aperture, the two types of rays come to focus quite close to each other.</td><td>1</td></tr>
<tr><td>10</td><td>Ans.
(i) .(d) all of the above
(ii).(a) 24.4^0
(iii).(c) Core has high refractiveindex than cladding
(iv) .(a) Increases
(v). (b) total internal reflection</td><td>4</td></tr>
<tr><td>11</td><td>(i) No chromatic/spherical aberration as mirror is used as objective in reflecting telescope
(ii) Brighter image/ high resolving power as mirror of large aperture is used as objective in reflecting telescope</td><td>1+1</td></tr>
<tr><td>12</td><td>(formula+calculation +answer) 1.5</td><td>1/2+1+1/2</td></tr>
<tr><td>13</td><td>Explanation + diagram

</td><td>1+1</td></tr>
<tr><td>14</td><td>By geometry, angle of incidence i at face AC for all three rays is 45^0 . Light suffers total internal reflection for which this angle of incidence is greater than critical angle.
$i > i_c$& $\sin i > \sin i_c$ or $\sin 45^0 > \sin i_c$ or $1/\sqrt{2} > 1/\mu$ or $\sqrt{2} < \mu$ or $\mu > \sqrt{2}$ or $\mu > 1.414$
Total internal reflection takes place on AC for rays with $\mu > 1.414$,
i.e. green and blue colours suffer total internal reflection whereas red undergoes refraction.

</td><td>3</td></tr>
<tr><td>15</td><td>a) labeled ray diagram
Expression for magnifying power
b) Calculation of length of telescope tube
$L = f_o + f_e = 20.01$ m</td><td>1 ½
½
½ + ½</td></tr>
</table>

16 (1+2 = 3)





(*i*) Angle of deviation (δ): In triangle *QDR* , exterior angle is equal to sum of interior opposite angle.

$\delta = \angle DQR + \angle DRQ \quad \Rightarrow \delta = (i - r_1) + (e - r_2) \Rightarrow \delta = (i + e) - (r_1 + r_2)$-------(1)

This is the expression for the angle of deviation in a prism.

(*ii*) To prove that A = $r_1 + r_2$: In the triangle, $\angle A + \angle AQR + \angle ARQ = 180$.

$\angle A + (90 - r_1) + (90 - r_2) = 180$. Hence $\angle A = r_1 + r_2$ -------------(2) From equation (1) and (2)

$\delta = (i + e) - \angle A$ Or $\delta + \angle A = i + e$ -------------(3)

(*iii*) MINIMUM DEVIATION:- The deviation produced by a prism depends upon (I) the angle of incidence (II) the angle of prism and (III) therefractive index of the prism material w.r.t. the surrounding.It is found experimentally that as the angle of incidence changes,the angle of deviation also changes. If we plot a graph between anglesof incidence (*i*) and the corresponding angle of deviation (δ), we getthe curve shown in Fig.

(*a*) As the angle of incidence (*i*) increases, the angle of deviation first decreases, becomes minimum for a particular angle of incidence and then again increases.

(*b*) The angle of incidence for which the deviation produced by the prism is minimum is called *the angle of minimumdeviation* (δ_m). In the position of minimum deviation, a ray of light passes symmetrically through the prism *i.e.*

the refracted ray *QR* (Fig.2) is parallel to the base of the prism. In this position, $i = e$ and $r_1 = r_2 = r$ (let)

So from eq2 $\angle A = r + r$ Hence $r = \angle A/2$--------(4)

So from eq3 $\delta_m + \angle A = i + i$ Hence $i = (\delta_m + \angle A)/2$--------(5)

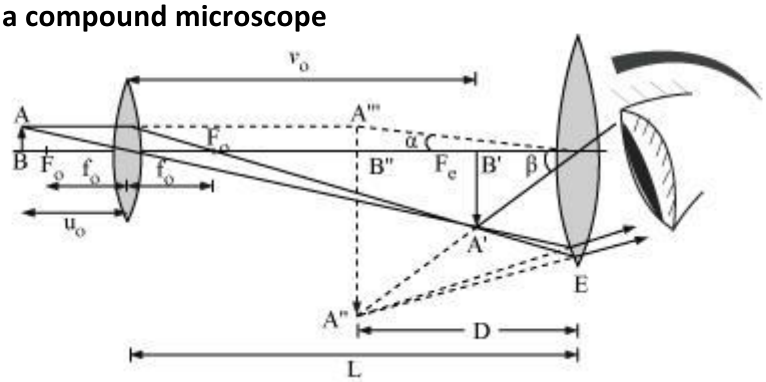
(*c*) Note that a prism can deviate incident ray through the same angle δ for two different angles of incidence *x* and *y* (Fig. 2). *However, for one and only one particular angle of incidence*, *theprism produces minimum deviation*.

(iv) REFRACTIVE INDEX OF PRISM MATERIAL from Snell's law $\mu = \frac{\sin i}{\sin r}$.

From equation 4 & 5. $\boxed{\mu = \frac{\sin(\delta m + \angle A)/2}{\sin \angle A/2}}$

17 (1+2+2 = 5)

Ray diagram for a compound microscope



Total angular magnification, $m = \frac{\beta}{\alpha}$

	β → Angle subtended by the image α → Angle subtended by the object Since α and β are small, $\tan\alpha \approx \alpha$ and $\tan\beta \approx \beta$ $m = \frac{\tan\beta}{\tan\alpha}$ $\tan\alpha = \frac{AB}{D}$ And $\tan\beta = \frac{A''B''}{D}$ $m = \frac{\tan\beta}{\tan\alpha} = \frac{A''B''}{D} \times \frac{D}{AB} = \frac{A''B''}{AB}$ On multiplying the numerator and the denominator with A'B', we obtain $m = \frac{A''B'' \times A'B'}{A'B' \times AB}$ Now, magnification produced by objective, $m_0 = \frac{A'B'}{AB}$ Magnification produced by eyepiece, $m_e = \frac{A''B''}{AB}$ Therefore, Total magnification, $(m) = m_0\, m_e$ $m_0 = \frac{v_0}{u_0} = \frac{\text{(Image distance for image produced by objective lens)}}{\text{(Object distance for the objective lens)}}$ $m_e = \left(1 + \frac{D}{f_e}\right)$ f_e → Focal length of eyepiece $m = m_0 m_e$ $= \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$ $v_0 \approx L$ (Separation between the lenses) $u_0 \approx -f_0$ $\therefore m = \frac{-L}{f_0}\left(1 + \frac{D}{f_e}\right)$	

	$u_0 = -1.5$ cm $f_0 = +1.5$ cm $\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0}$ $\frac{1}{1.25} = \frac{1}{v_0} + \frac{1}{1.5}$ $\frac{1}{v_0} = \frac{1}{1.25} - \frac{1}{1.5}$ $= \frac{100}{125} - \frac{10}{15}$ $= \frac{1500 - 1250}{1875}$ $\frac{1}{v_0} = \frac{250}{1875}$ $v_0 = +7.5$ cm $f_e = +5$ cm $m = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$ $= \frac{7.5}{-1.5}\left(1 + \frac{25}{5}\right)$ $= -\frac{7.5}{1.5} \times 6$ $\boxed{m = -30}$	

UNIT-6, CHAPTER 10, WAVE OPTICS

<u>LIGHT</u>: - It is a form of energy which on entering our eyes gives us the sensation of sight. Light is use to see the objects but the light is itself is invisible.

(A)-<u>Newton's Corpuscular Theory Of Light:-</u> first of all Newton studied about light and put Forward "NEWTONS CORPUS THEORY ".According to this theory light consist of tiny weightless particles called corpuscles which are shot out by luminous objects with speed of about 3000 km/sec.

By this theory Newton can able to explain reflection and refraction. In reflection the corpuscles bounce off from the surface while in reflection the corpuscles are attracted by the material of the medium and are allowed to penetrate through it.

<u>Drawbacks:</u> ***(1)*** the phenomenon like interference, diffraction, polarization etc. could not explained by corpuscular theory.***(2)*** Newton theoretically proved that the velocity of light in the medium 'v' is greater than the velocity of light in air vacuum 'c' i.e. $v > c$, which is not correct.

(B)-<u>Huygen's Wave Theory:-</u> Christian Huygen's gave a theory –According to this theory "light is a form of energy which propagate from source as a wave motion (i.e. disturbance in a medium) with speed $3\ 10^8$ m/sec in a hypothetical medium called ether.

This theory can explain reflection, refraction, diffractions, polarization interference etc. It also prove that $v < c$.

<u>Drawbacks</u>: ***(1)*** Either is not ever seen yet. ***(2)*** Photoelectric effect and Compton's effect cannot be explained by this theory.

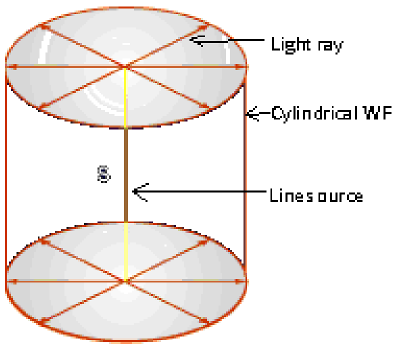
(C) <u>Maxwell's Electromagnetic Wave Theory</u>: -According to Maxwell- light propagate in the form of electromagnetic waves, consist of electric field and magnetic field mutually perpendicular to the direction of propagation of light. Electromagnetic waves are transverse wave with $c = 3\ 10^8$ m/sec in air. Thus difficult of either were removes. It is experimentally demonstrated by Hertz and gave support to the wave theory of light.

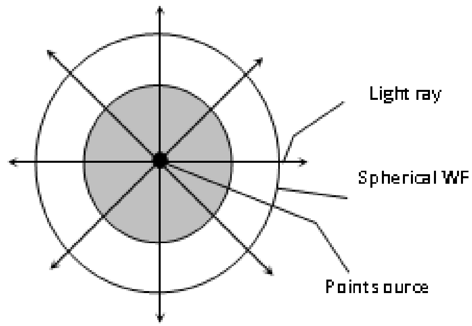
(D) <u>Quantum Theory</u> (E) <u>Dual Nature Of Light</u>

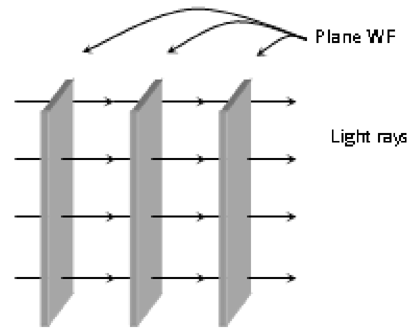
- ***<u>WAVE FRONT</u>: -*** The locus of all the particles of a medium, which are vibrating in the same phase, is defined as wave front. On the basis of the shape of the source wave front can be of three types: -

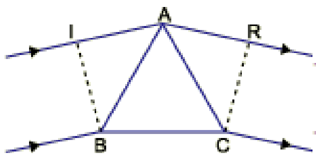
(A)Spherical Wave Front: - When the source of light is a point source, then the wave front is a sphere with center at the source i.e. A wave front is three dimensional space is called spherical wave front.

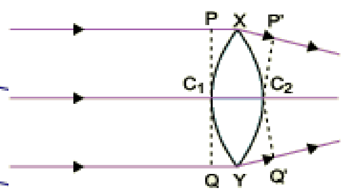
When the propagation of light is taken in two dimensions then wave front is called **circular wave front**.

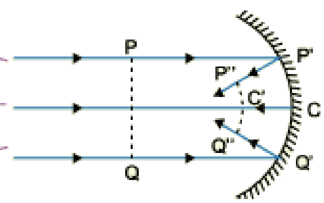


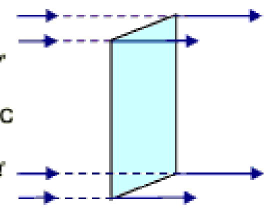












(B) **Cylindrical Wave Front: -** When the source of light is linear (i.e. slit), all the points' equidistance from the source lie on a cylinder, then wave front is called cylindrical.

(C)Plane Wave front: -When a source of light is at very distance, a small portion of the spherical or cylindrical wave front appears to be plane then it is called plane wave front.

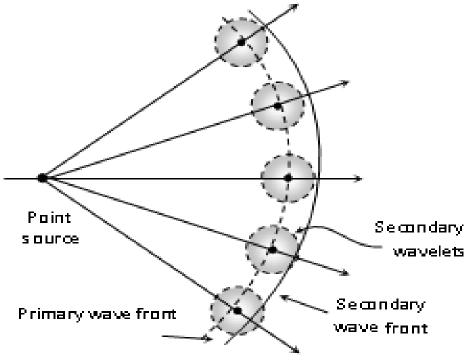
RAY: -A straight line normal (perpendicular) to the wave front is called ray.

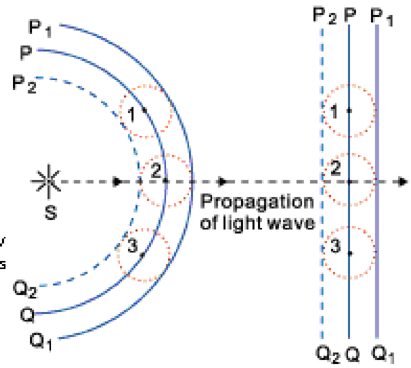
Huygen's Principle (Or Construction): -Huygens gave a hypothesis for geometrical construction of a wave front at any instant. This principle tells us how to predict a new wave front if position of an earlier wave front is known, and the way in which the wave front is propagated further in medium. It is based on following assumption.

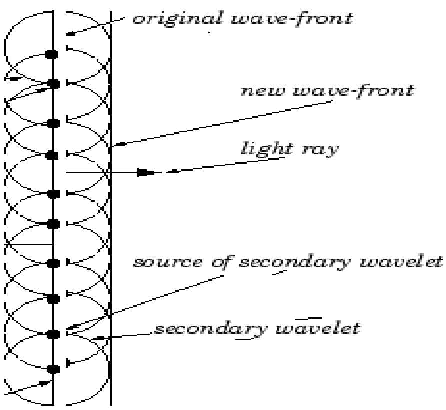
(1) Each point on a wave front acts as a new source of disturbance called secondary source. The disturbance from the points is called secondary wavelets, which travel in all direction with velocity of light in that medium.

(2) The new wave front at any later time is obtained by taking forward envelop of the secondary wavelets at that time

Illustration*:* Consider a primary wave front AB at any instant. Then according to Huygens principle each point on the wave front AB is center of a new disturbance called secondary wavelets. To find the position of secondary wave front after time 't' consider points 1,2,3,… on AB. Distance traveled by the light = c t. Take each point as a center draw spheres of radius (ct). These spheres represent secondary wavelets at time't'. If we draw a tangential surface A_1B_1 touching tangentially all the wavelets in forward direction then is called secondary wave front.







The surface A_2 B_2 touching tangentially all the secondary wavelets in backward flow direction called backward secondary wave front. Huygens assumed that Voigt and Kirchoff explained no backward wave front as such ex\is\t .The absence of balanced secondary wave front by mathematical treatment.

By superposition of wave the amplitude of the particles in a back wave front is zero and there is no backward flow of energy. The effective part of secondary wavelet is the portion, which lies on the forward secondary wave front.If radius of spherical wave front is large then it appears as a plane wave front as in Fig.-b.

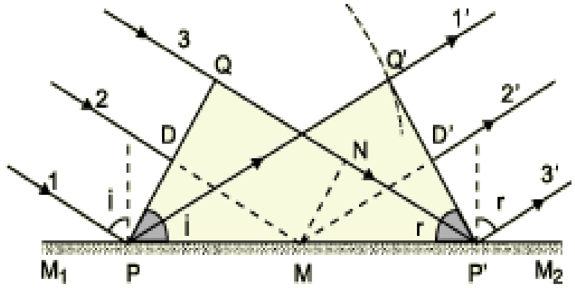
8.4 <u>Reflection Of Light By Wave Theory</u>: -Let M_1M_2 be a reflecting surface and PQ be a plane wavefront incident on it at $QPP^{/}$ (= *i angle of incident*). Let 1, 2 and 3 represent the corresponding incident rays perpendicular to wavefront PQ.

According to Huygens' principle, every point on wavefront PQ is a source of secondary wavelets. Let secondary wavelets originating from point Q strike the surface M_1M_2 at $P^{/}$ in t seconds. Therefore,

$QP^{/} = c \times t$ (1) c being the velocity of light.

Also, secondary wavelets from P will travel the same distance $c \times t$ in the same time. So with P as centre and (c × t) as radius, an arc Q' is drawn such that, $PQ^{/} = c \times t$ (2)

A tangent plane P'Q' is drawn touching the spherical arc tangentially at Q'. Thus P'Q' is the secondary wavefront after t seconds, moving in the direction of 1', 2' and 3', which are the corresponding reflected rays perpendicular to P'Q'.

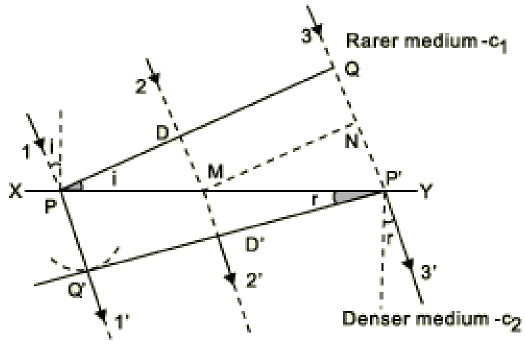


It can be proved that the secondary wavelets originating from point D on the incident wavefront PQ will reach D' in the same time as the secondary wavelets take to go from Q to P'.
$\angle Q'P'P$ = angle of reflection
Now, From $PP'Q$ and $PP'Q'$
(i) PP' is common, (ii) $QP' = PQ' = c \times t$ & (iii) $\angle Q = \angle Q' = 90°$
Hence, the two triangles are congruent. $\angle QPP' = \angle Q'P'P$
Since corresponding parts of congruent triangles are equal so we can write $\angle i = \angle r$ (3)
Equation (iii) represents, the first law of reflection.

Second law: **-** The incident wavefront PQ, the reflecting surface M_1M_2 and the reflected wavefront $P'Q'$ are perpendicular to the plane of the paper. In other words, the incident ray, the normal and the reflecting ray, all lie in the same plane, which is the statement of the second law of reflection.
Thus, the laws of reflection have been proved on the basis of the wave theory.

8.5 Refraction of Light By Wavefront Theory:-

Consider a denser medium (refractive index μ) be separated by a rarer medium by a plane XY.
Let c_1 & c_2 be the velocities of light in the rarer and the denser medium, respectively. Then $\mu = c_1 / c_2$ ………..(i)
Let PQ, a plane wave front be incident on the interface XY at $QPP' = i$.
Also 1, 2 & 3 are corresponding incident rays normal to wave front PQ.
From Huygens' principle, every point on the wavefront PQ acts as a source of secondary wavelets.
Let secondary wavelets from point Q strike interface XY at P' in t seconds. So, $QP' = c_1 t$ ……….(ii)
Secondary wavelets originating from P propagate in the denser medium with the velocity c_2 covering a distance $c_2 t$, in t seconds. Thus, with P as centre and $(c_2 t)$ as radius, an arc at Q' is drawn, so that $P'Q' = c_2 t$
A tangent plane touching the spherical arc tangentially at Q' is drawn from point P'. So $P'Q'$ represents the secondary wavefront after t seconds. This advances towards the corresponding refracted rays $1'$, $2'$ and $3'$, are the corresponding refracted rays, perpendicular to $P'Q'$.



It can be shown that the secondary wavelets originating from any point D on PQ, after refraction at P, must reach $D^/$ on $P^/Q^/$ in same time in which secondary wavelets from Q reach $P^/$.

$\angle QPP' = \angle i$ = angle of incidence & $\angle PP'Q' = \angle r$ = angle of refraction.

In $\Delta PP'Q$, $\sin i = \frac{QP'}{PP'} = \frac{c_1 \times t}{PP'}$ ...(iii) &

In $\Delta PP'Q'$, $\sin r = \frac{PQ'}{PP'} = \frac{c_2 \times t}{PP'}$ ...(iv)

Dividing equation (iii) by (iv)

$\frac{\sin i}{\sin r} = \frac{c_1}{c_2} = \mu$ or $\mu = \frac{\sin i}{\sin r}$ ...(v)

Equation (v) is the Snell's' law of refraction.

From the figure, it is evident that the incident ray, the normal and the refracted ray lie in the same plane. This proves the second law of refraction.

Thus, the laws of refraction have been proved on the basis of wave theory.

Refractive Index is defined as the ratio of the speed of light in a vacuum to the speed of light in the material.

The higher the refractive index of a material, the more slowly light travels through it. Glass, for example, has a refractive index of about 1.5, and water has a refractive index of about 1.3. This indicates that light travels more slowly through glass than it does through water.

Second law: -Incident ray, refracted rays and normal all lies in same plane.

8.6 <u>Interference Of Light</u>*: -* The phenomenon of non-uniform redistribution of energy in a medium & formation of bright & dark band due to superposition of two light waves from coherent sources is called interference of light. Interference is of two types –

a) ***Constructive Interference*: -** A point where two crests or two through of different waves falls on each other then amplitude or intensity of the resultant wave become maximum and the point appear bright. This is called constructive interference.

b) Destructive Interference*: -* A Point where the through of one wave falls on the crest of other then amplitude or intensity of resultant wave becomes minimum and the point appear dark. This called Destructive Interference.

Conditions For Interference*: -*

(1) The two sources should emit monochromatic wave of same wave length and frequency continuously.

(2) To obtain completely dark fringes amplitude of the waves should be same.

(3) The two sources must lie very close to each other.
(4) The waves emitted by the two sources should either be in same phase or should have a constant phase difference i.e. the sources must coherent source.

Coherent Source*: -* The source of light which emit continuous light wave of same wave length, same frequency same amplitude (nearly same) and in same phase or having constant phase difference are called coherent source.

Two independent sources of light cannot be coherent. So interference cannot obtain by two individual sources because: - (1) When an excited atom returns to ground state light is emitted. A smallest source contained billions of such atoms, which cannot emit light in the same phase. Then two independent source of light do not posses a constant phase difference. (2) Two independent sources cannot emit waves continuously: -

(a) Two coherent sources can be obtained form a single sources in this case phase difference will be constant.(b) In Fresnel's biprism two virtual images of sources acts as coherent sources. (c) In Lloyd's mirror a source and its image acts as coherent sources.

8.7 <u>Young's Double Slit Experiment(YDSE)</u>*: -* The phenomenon of interference of light was first observed by Thomas Young in 1802 by a simple experiment. This experiment led conclusion that light ha wave nature.

Young allowed sunlight to pass through a whole and then at some distance through two-pin hole $S_1$and S_2 which are
very close to each other. A screen placed in front of the sources then alternate bright and dark band (spots) was observed called interference band.

<u>Explanation</u>: -The source S emits monochromatic light, which send out spherical wave fronts. When disturbance reaches to $S_1$and S_2 secondary wavelets are emitted and they behaves as coherent source solid line semicircle represent crest, dotted line semicircle trough circle 'O' represent maxima (constructive interference) and '*' star represent minima (destructive interference). When crest or through of two waves falls on each other, according to principle of superposition the amplitude or intensity of the resultant wave becomes maximum and bright band is observed. When crest of one wave fall on trough of another, according to principle of superposition the amplitude or intensity of the resultant wave become minimum (zero) and dark band is observed.

8.8 <u>Interference Of Wave (Conditions for constructive and destructive interference)</u>*: -*Consider tow light wave of same amplitude 'a', same frequency and same velocity traveling with same velocity 'c' in same direction with phase difference .
The electric field vector of the waves can be represent as

y_1 = a sin t -- -- -- (1) & y_2 = a sin (t) -- -- -- -- (2)

According to principle of superposition of waves-"When two wave superimpose at a point then the resultant displacement (y) of the new wave is equal to vector sum of the displacements of the individual waves ".So magnitude of the electric field of the resultant wave at any instant

$y = y_1 + y_2$ from (1) and (2)

y = a sin t + a (sin t cos cos t sin)

y = a sin t (1 + cos) – a cos t sin

[sin (A B) = sinA cosB – cosA sinB]

y = [a (1 + cos)] sin wt [a sin] cos wt

Let a (1+ cos) = A cos -- -- -- (3) & a Sin = A Sin -- -- -- (4)

Then y = A cos sin t - A sin cos t

y = A [sin t cos cos t sin] Hence A = a sin (t _) -------- (5)

This eq. represents electric field vector of new at any instant, where A is amplitude of the wave.

Squaring and adding eq. (3) and (4) $a^2(1+ \cos\ )^2 + a^2 \sin^2\ = A^2 \cos^2\ + A^2 \sin^2$

$a^2[(1^2 + 2 \cos\ + \cos^2) + \sin^2\ ] = A^2 [\cos^2\ + \sin^2]$

$a^2[1 + 2 \cos\ +1] = A^2 [1]$ Hence $A^2 = 2 a^2[1 + \cos\ ]$ - - - (6)

Intensity of light I = k (amplitude)^2 where K is constant

$I = 2 k a^2 (1+ \cos\ )$ - -- -- - -- (7)

(1) **Resultant amplitude :** Resultant amplitude A $= \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos\varphi}$

(2) **Resultant intensity :** Resultant intensity $I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\phi$

<u>For constructive interference</u>: - The resultant intensity is maximum i.e.

$I = 2Ka^2 (1+ \cos\ )$ = maximum

It the possible only when cos = maximum i.e. cos = +1

It the possible only when phase difference = 0, 2, 4, 6 - - - 2n

OR path difference x = 0, , 2, 3, - - - n. Since path difference $x = \frac{\lambda}{2\pi} \times \phi$

For constructive interference the phase difference between the waves should be even integral multiple of

π or path difference between the waves should be equal to integral multiple of wavelength.

$I_{max} = 2 k a^2 (1+ 1)$ Hence $I_{max} = 4 k a^2$

$I = K \sqrt{a_1^2 + a_2^2 + 2\, a_1\, a_2 \cos\phi}$ So $I_{max} = K (a_1 + a_2)^2$

<u>For Destructive Interference</u>: - ***Interference*** fringes are dark so intensity

$I = 2 K a^2 (1+ \cos\ )$ = minimum

It is possible only when cos = minimum = - 1 So $I_{min} = 0$.

It is possible only when = =, 3, 5 - - - (2n – 1)

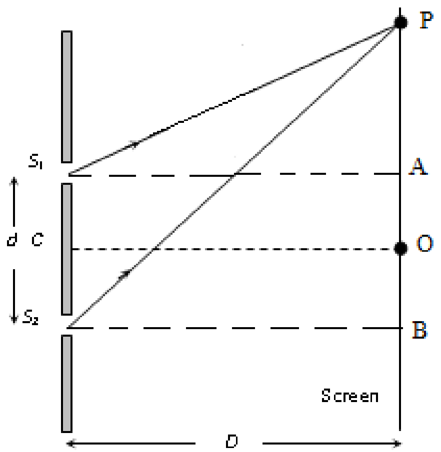
OR path difference x = /2, 3/2, 5/2, - - - (2n – 1)/2 Here n = 1, 2, 3, 4 - - -.

Hence interference will be destructive when the phase difference between the waves should be equal odd integral multiple of or path difference between them should be equal to odd integral multiple of half the wavelength.

$I_{min} = K (a_1 \ a_2)^2$

Constructive interference	Destructive interference
(i) When the waves meets a point with same phase, constructive interference is obtained at that point (*i.e.* maximum light)	(i) When the wave meets a point with opposite phase, destructive interference is obtained at that point (*i.e.* minimum light)
(ii) Phase difference between the waves at the point of observation $\phi = 0^o$ or $2n\pi$ $n = 0,1,2.....$	(ii) $\phi = 180^o$ or $(2n-1)\pi$; *n* = 1, 2, ... or $(2n+1)\pi$; $n = 0,1,2.....$
(iii) Path difference between the waves at the point of observation $\Delta = n\lambda$ (*i.e.* even multiple of /2).	(iii) $\Delta = (2n-1)\frac{\lambda}{2}$ (*i.e.* odd multiple of /2)
(iv) Resultant amplitude at the point of observation will be maximum. $A_{max} = a_1 + a_2$ If $a_1 = a_2 = a_0 \Rightarrow A_{max} = 2a_0$	(iv) Resultant amplitude at the point of observation will be minimum $A_{min} = a_1 - a_2$ If $a_1 = a_2 \Rightarrow A_{min} = 0$
(v) Resultant intensity at the point of observation will be maximum. $I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$, $I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$ If $I_1 = I_2 = I_0 \Rightarrow I_{max} = 2I_0$	(v) Resultant intensity at the point of observation will be minimum $I_{min} = I_1 + I_2 - 2\sqrt{I_1 I_2}$, $I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$ If $I_1 = I_2 = I_0 \Rightarrow I_{min} = 0$

8.9 Positions of bright and dark fringes & the fringe width (Theory Of Interference Of Light): - Diagram



Let $S_1$and S_2 are two coherent sources and 'd' is distance between them. D is distance between source and screen. Two waves starting from $S_1$and S_2 superimpose on each other, resulting in interference fringes. Let P is any point on screen at distance Y from O, then path difference between the waves reaching point P is $x = S_2P – S_1P$ - - - -(1)

In ΔPS_2B $S_2P^2 = S_2B^2 + PB^2$ $S_2P^2 = D^2 + (y + d/2)^2$ - - - - (2)

In ΔPS_2B $S_1P^2 = S_1A^2 + PA^2$ $S_1P^2 = D^2 + (y\ d/2)^2$ - - - - (2)

Subtracting eq3 from eq2 $S_2P^2\ \ S_1P^2 = [D^2 + (y^2 + d^2/4 + 2\ y\ d/2)] – [D^2 + (y^2 + d^2/4\ 2\ y\ d/2)]$

$(S_2P + S_1P)\ (S_2P\ \ S_1P) = D2 + y^2 + d^2/4 + 2\ y\ d/2\ \ D^2\ \ y2\ \ d^2/4 + 2\ y\ d/2$

(from eq1)

$(S_2P + S_1P)\ x = y\ d + yd$ But $S_2P\ \ \ S_1P\ \ \ D$

$(D + D)\ x = 2\ y\ d$ $2\ D\ x = 2\ y\ d$

Hence path difference $x = \frac{y\ d}{D}$ - - - - (4)

a. <u>For Bright Fringes (Maximum)</u>: - For constructive interference the path difference must be integral multiple of

wavelength i.e. Path difference $n\ \lambda = \frac{y\ d}{D}$

Distance of n^{th} bright band from central band $y_n = \frac{n \lambda D}{d}$ - - - - (5)

n = 0 then Y = 0 i.e. <u>central bright</u> fringe is obtained at central point 'O'. At this point there is no path difference between the waves.

n = 1, then, distance of first bright fringe from O is $y_1 = \frac{\lambda D}{d}$ In this case path difference is.

n = 2, then, distance of second bright fringe from O is $y_2 = \frac{2 \lambda D}{d}$ In this case path difference is 2.

b. <u>For Dark Fringes (Maximum)</u>: - For destructive interference the path difference must be odd number multiple of ½ wavelength i.e. Path difference $\frac{(2n+1)\lambda}{2} = \frac{y\,d}{D}$

Distance of n^{th} dark band from central band $y_n^{/} = \frac{(2n+1)\lambda D}{2d}$ - - - - (5)

n = 1, then, distance of first dark fringe from O is $y_1^{/} = \frac{\lambda D}{2d}$ In this case path difference is /2.

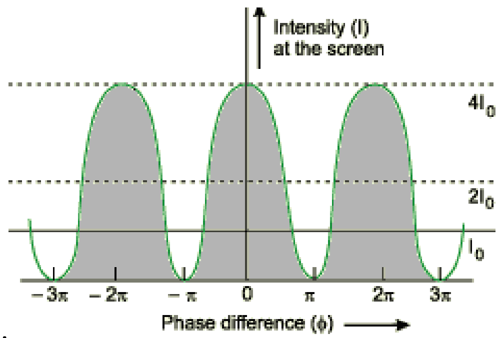
n = 2, then, distance of second dark fringe from O is $y_2^{/} = \frac{3\lambda D}{2d}$ In this case path difference is 3/2.

<u>Fringe Width</u>: -The separation between two consecutive bright or dark fringes is defined as fringe width.

For two consecutive bright fringes = $y_2 - y_1 = \frac{2\lambda D}{d} \quad \frac{\lambda D}{d}$ Hence $\beta = \frac{\lambda D}{d}$

For two consecutive dark fringes = $y_3^{/} - y_2^{/} = \frac{5\lambda D}{2d} \quad \frac{3\lambda D}{2d}$ Hence $\beta = \frac{\lambda D}{d}$

Conclusion: - **1)** fringe width of bright and dark band is same. **2)** Fringes are equally spaced and independent of order (n). **3)** For broad band, wave length of light must be large. **4)**. D For broad, band distance between source & screen must be large. **5)**. 1/d For broad band, distance between sources must be small.



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8.10<u>**Intensity Distribution**</u>: - If we plot a graph between intensity of the fringes I and the distance central fringe then the curve is called **energy distribution curve.**

If there is no interference then according to superposition principle average intensity $I_{av} = k A^2 + k A^2$ $I_{av} = 2 k A^2$ -- - - (1)

But in case of interference intensity, $I = 2 k A^2 (1 + \cos\ )$

For Bright Band: - $I = 2 K A^2 (1 + \cos\ ) =$ maximum

It is possible only when Cos = maximum = 1

It is possible only when = =, 3, 5 - - - 2n.

$I_{MAX} = 2 k A^2 (1 + 1)$ Hence $I_{max} = 4 k A^2$ - - - - (2)

For Dark Band: - $I = 2 K A^2 (1 + \text{Cos}\ ) =$ minimum

It is possible only when Cos = minimum = 1

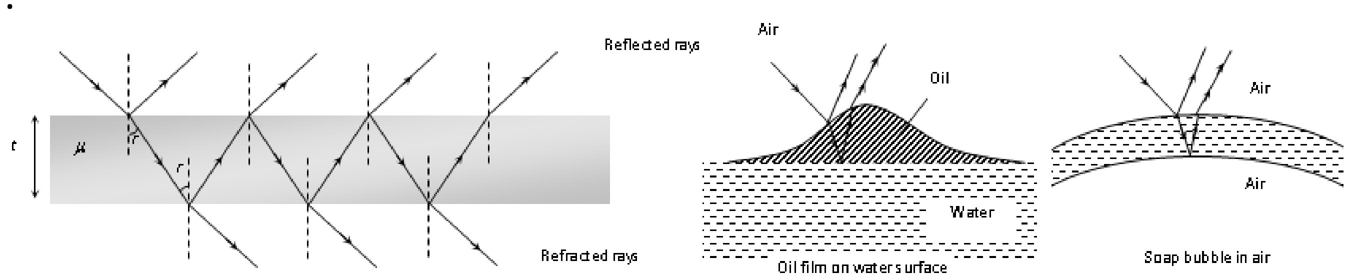
So $I_{min} = 0$ - - - (3)

It is possible only when = =, 3, 5 - - - (2n – 1).

$I_{av} = (I_{max} + I_{min})/2 = (4 k A^2 + 0)/2 = 2 k A^2$. This proves that there is only a redistribution of light intensity in the interference pattern. In other words, there is an energy transfer from regions of destructive interference to the regions of constructive interference. Since no energy is created or annihilated, the law of conservation of energy is followed.

Illustrations of Interference:-Interference effects are commonly observed in thin films when their thickness is comparable to

.



from the wavelength of incident light (If it is too thin as compared to wavelength of light it appears dark and if it is too thick, this will result in uniform illumination of film). Thin layer of oil on water surface and soap bubbles shows various colours in white light due to interference of waves reflected from the two surfaces of the film.

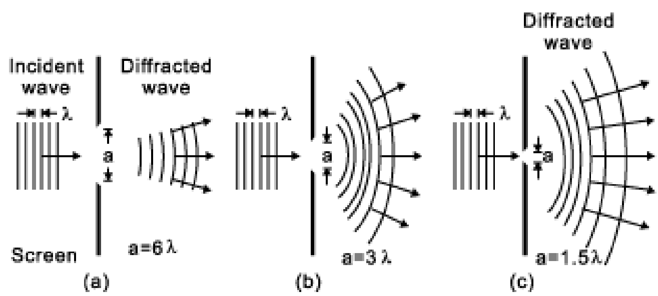
Thin films: In thin films interference takes place between the waves reflected from it's two surfaces & waves refracted through it.

The conditions for sustained interference are: (a) The two sources of light must be coherent. (b) The two coherent sources must lie very close to each other. (c) The two sources of light should be very narrow. (d)The amplitudes of the two waves originating from the two sources must be equal. (e) The two sources should be monochromatic.

Ratio of intensity of light at maximum and minimum $\frac{I_{max}}{I_{min}} = \frac{(a+b)^2}{(a-b)^2}$

<u>Diffraction</u>: The phenomenon of bending of light around an obstacle or round corner of aperture and spreading into the geometrical shadow is called **diffraction.**

A pattern of alternate bright and dark fringes (bonds) are obtained on the screen called **diffraction pattern.**



Central band is bright and other bright bands on either side with decreasing intensity.

Condition for diffraction: - Size of slit or obstacle must be nearly equal to wavelength of the wave (light)

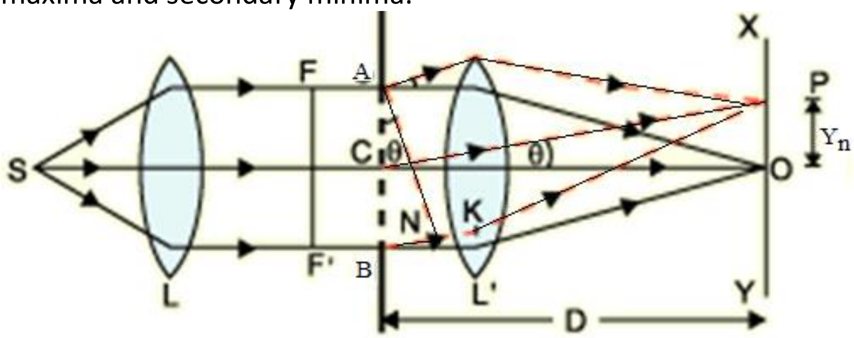
Example of diffraction: - Diffraction of sound is prominently observed because sound wave has large wavelength so it can diffract from buildings, walls stones etc. Similarly radio wave and microwave diffract due to their large wavelength so and are capable to receive signals of radio and TV etc. Hence diffraction of light can be observed only by allowing light to fall on extremely small tiny objects because wavelength = 3700 A to 7800 A

- If two razor blades are placed together to each other so that their sharp edges form a very narrow slit in between. Keeping this slit close and right in front of the eye, we look through the slit on bulb. A diffraction pattern with its bright and dark bands is seen by slight adjustment of the slit width.
- If we look at distant street lamp through a handkerchief we obtain a row of points of light arranged symmetrically around the bright central point. Light is diffracted through the various tiny spaces between the thread.

Fresnel diffraction	Fraunhofer diffraction
(i) If either source or screen or both are at finite distance from the diffracting device (obstacle or aperture), the diffraction is called Fresnel type.	(i) In this case both source and screen are effectively at infinite distance from the diffracting device.
(ii) Common examples : Diffraction at a	(ii) Common examples : Diffraction at

straight edge, narrow wire or small opaque disc etc.	single slit, double slit and diffraction grating.

<u>Diffraction at a single slit</u>:- Diffraction is explained by Fresnel in 1818 by Huygen's principle of the secondary wavelets in conjunction with the principle of inference. Source "S" of monochromatic light is placed at a distance equal to focal length of convex lens L" so that a parallel beam of light is obtained. The plane wave fronts are allowed to fall on a very narrow slit AB = d such that d   . Diffraction pattern are obtained on the screen by focusing with the help of lens L .The diffraction pattern on the screen consists of a central bright band with alternate dark and weak light (nearly dark) bands of decreasing intensity on both sides called secondary maxima and secondary minima.



Theory: - According to Huygens principle each point of the slit behaves as source of secondary wavelets. The slit is imagined to consist of strips of equal width parallel to the length of the slit. The total effect in particular direction is
found by adding the wavelets emitted in that particular direction by all the strips, using the superposition principle.

Formation of central maxima: - when light is incident on slit then according to Huygens Construction each point emits secondary wavelets in all directions in same phase. Therefore distance traveled by all wavelets to reach at a point O is same i.e. path difference between wavelets is zero. The secondary wave-lets reinforce each other and give rise to central maxima at O.

Formation of secondary minima: - Consider secondary wavelets are diffracted by an angle and reach at point P. The wavelets start from different part of the slit in same phase but they will not arrive at P in the same phase because they have to cover unequal distances in reaching P. Thus the intensity at point P will depend on the path difference BN.

In ANB sin $_n$ =BNd   For small angle sin $_n$ = $_n$

Hence angular separation of of nth band from central band $_n$ = x_nd —————— **(1)**

In ANB tan $_n$ =BNd   For small angle tan $_n$ = $_n$ $_n$ = y $_n$ D —————— (2)   Comparing eq

$y_n D = x_n d$ Hence distance of n^{th} band from central band $y_{n=} y_n = x_n Dd$

Formation of secondary minima: - (a) First secondary minima If path difference BN = then P will have minimum intensity and called first secondary maxima. In this case the whole wavefront (slit) can be considered to be divided into two equal strips AC and CB. If path difference between the wavelets emitted from A and B is then the path difference between the secondary wavelets from A and C or from C and B will be 2. Therefore path difference between the wavelets emitted by the two strips is 2 .i.e phase difference 2. Thus destructive interference takes place at point P because crest from one strip reaches at P with a trough from the other, and first minima is observed.

(b) Second secondary minima : If path difference BN = 2 then P will have minimum intensity . The path difference between the extreme wavelets from A & B is 2 so the slit may be divided into four equal strips AC_1, C_1C, CC_2 and C_2B . The wavelets from the correspond points in the two parts AC_1 & C_1C or CC_2 and C_2B etc. will have path difference /2 i.e. phase difference T_1 and cancel each other in effect due to destructive interference. So the point have minimum intensity called second secondary minima.

Similarly formation n^{th} secondary minima. can be dividing slit into 2n equal strips. From equation (1)

Angular separation of first secondary minima. $_1$= /d

Angular separation of second secondary minima. $_2$ = 2/d

For n^{th} secondary minima, the Angular separation $_n$ = n/d —————— (2)

n = 1,2,3------- x = , 2, 3 , 4--------

Formation of secondary maxima: First secondary maxima: If path difference BN = 3/2 then P will be bright . In this case the slit may be divided into three equal strips path difference between the secondary wavelets from corresponding points of strips AC_1 and C_1C_2 will be /2 They will give rise to destructive interference. However the secondary waves from the third part remain unused, since they are in same phase So they reinforce each other and produce First secondary maxima.

When a parallel beam of monochromatic light incident the grating diffraction pattern of alternate bright and dark fringes of varying intensities are obtain. With central maxima of max. intensity . If waves are diffracted by $_n$ then path difference x = d sin $_n$. For conservation interference x = n Where n = 1,2,3-----------.

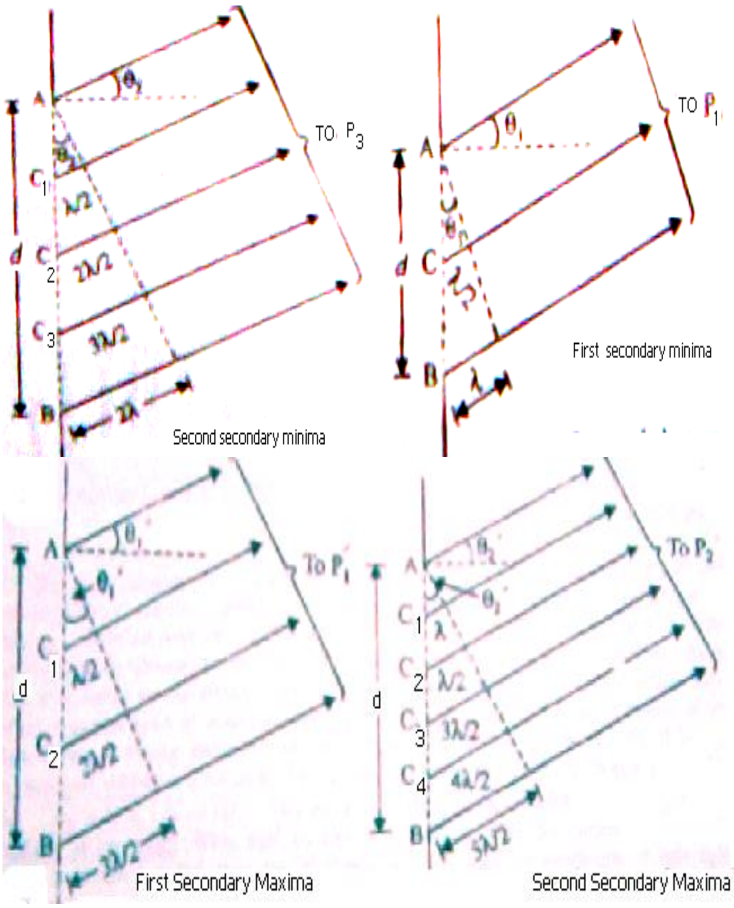
So n= d sin $_n$ **-------- (1)**

For I^{st} order maxima angle of diffraction $_1$, = d sin$_1$ $_1$= /d

For II^{nd} order maxima angle of diffraction $_1$, 2 = d sin$_2$ $_2$ = 2/d etc.

For n^{th} order maxima from equation (1) $_n$ = n/d

If we use white light then due to different value of for different colored light. The gravity will send different colours in different direction and we obtain a coloured diffraction pattern.



Second secondary maxima: If path difference BN = 5/2 then P will be bright . In this case the slit can be considered to be divided into five equal strips path difference between two consecutive strip so the first four strips cancel each other effect due to destructive interference. The wavelets from the fifth part remain unused, since they are in same phase So they reinforce each other and produce second secondary maxima.

To explain n^{th} maxima we can divide the slit into (2n + 1) equal parts (strips). From equation (1)

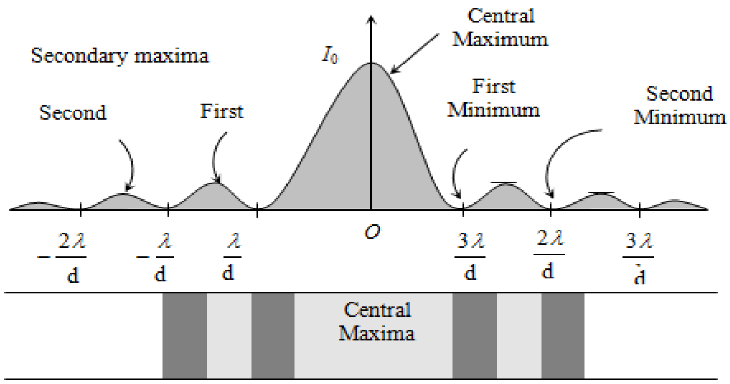
Angular separation of first secondary maxima. $^{/}{}_{1}$= 3/2d

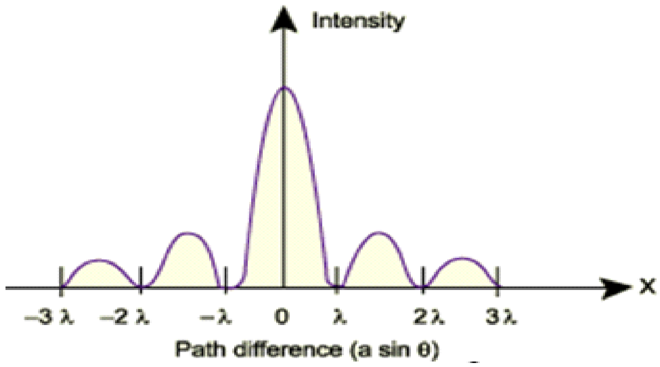
Angular separation of second secondary maxima. $^{/}{}_{2}$= 5/2d

For n^{th} secondary maxima. the Angular separation $^{/}{}_{n}$= (2n+1)/2d ————— (3)

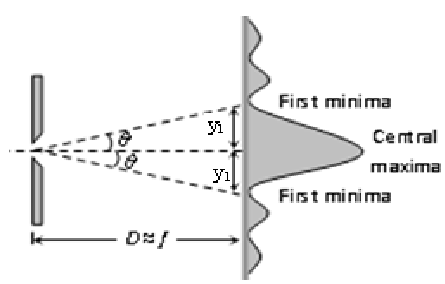
n = 1,2,3,------, *x = 3*/2, 5/2, 7/2 , --------

Intensity Distribution Curve: We plot a graph between intensity and angle . We find that the central maxima is the most intensive . The intensity falls to zero on either side of the central maxima.





Width of the central maxima:



Width of the secondary maxima $= y'_n - y'_{n-1} = \frac{n\lambda D}{d} - (n-1)\frac{\lambda D}{d}$ Hence $\beta = \frac{\lambda D}{d}$

Width of the central maxima $_0$= y_1 + y_1 Hence $\beta_0 = \frac{2\lambda D}{d}$

Where y_1 is distance of first minima . So Width of the central maxima is equal to the distance between the first secondary maxima of either side of hence central maxima is twice as wide as any other secondary maxima $_0$, $\beta_0 \alpha \frac{1}{d}$ So narrow slit is required. Also D.

Difference between interference and diffraction :

Interference	Diffraction
(1)Interference is result of interference of light coming from two different wave front originating from two different coherent source.	(1)Diffraction is result of the superposition of the secondary wavelets from different part of the same wavefront.
(2)In interference the fringe width is generally constant.	(2)In diffraction fringes are not of the same width.
(3) Point of minimum intensity are perfectly dark that is Intensity = 0.	(3)In diffraction the minima's are never perfectly dark.
(4) All the maxima have same intensity.	(4) The central maxima is most intense secondary maxima have varying intensity and rapidly fall is zero.

Q = Why the intensity of secondary maxima is less than that of central maxima ?

Ans. Intensity of central maxima is due to wavelets from all parts of the slit. While in first secondary maxima intensity is due to wavelets from one third part of the slit because the first two part cancel their effect . In second secondary maxima intensity is due to wavelets from one fifth part of the slit because the first four part cancel out their effect. Hence intensity of the secondary maxima for on decreasing .

Validity of ray optics : When light incident on big objects diffraction pattern are not observe so light travel in straight line. But when size of objects is nearly equal to wavelength of light deviate from rectilinear propagation.

So in ordinary circumstances light travel in straight line and ray optics is valid. but ray optics fail when size of object is equivalent to wavelength of light. Thus ray optics is limiting case of wave optics.

Proof: Distance from the slit at which the spreading of light due to diffraction become equal to the size of the slit is called Fresnel's distance 'Z_F'

At Fresnel's distance = d . So from $\beta = \frac{\lambda D}{d}$ $d = \frac{\lambda Z_F}{d} \Rightarrow$

$$Z_F = \frac{d^2}{\lambda}$$

If distance between slit and screen D is less than Fresnel's distance Z_F (D D_F) the diffraction effect will be absent . Hence ray optics may be regarded as limiting case of wave optics.

1Mark questions

- What type of wavefront will emerge from a (i) point source, and (ii) distance light source?
  Ans. (i) For point source, wavefront will be spherical.
  (ii) For a distant light source, the wavefronts will be plane wavefronts.
- Define a wavefront. How is it different from a ray?
  Ans. Wavefront: Continuous locus of all the particles of a medium vibrating in the same phase is called wavefront
  Difference from a ray:
  (i) A ray is always normal to the wavefront at each point.
  (ii) A ray gives the direction of propagation of light wave while the wavefront is the surface of constant phase.
- Why cannot two independent monochromatic sources produce sustained interference pattern?
  Ans. Two independent sources do not maintain constant phase difference, therefore the interference pattern will also
  change with time.
- In Young's double slit experiment, the two slits are illuminated by two different lamps having same wavelength
  of light. Explain with reason, whether interference pattern will be observed on the screen or not

Ans. Interference pattern will not be observed as two independent lamps are not coherent sources.

- Does the appearance of bright and dark fringes in the interference pattern violate, in any way, law of conservation of energy? Explain.

Ans. No , Appearance of the bright and dark fringes is simply due to a redistribution of energy.

- How would the diffraction pattern due to a single slit be affected when the monochromatic source of light is
  replaced by white light.

Ans. (i) The diffraction pattern is coloured. As βαλso red fringe is wider than violet fringe.

(ii) the central maxima is white/bright.
(iii) more dispersion is obtained for higher order spectra, it causes an overlapping of different colours.

- How does the angular separation between fringes in single slit diffraction experiment change when the distance
  of separation between the slit and screen is doubled?
  Ans. $\boldsymbol{\Theta_n = n\lambda/a}$, remains unchanged as it does not depend on D.
- How would the width of central maximum in diffraction pattern due to a single slit be affected, If the wavelength
  of the light used is increased?
  Ans. $\beta_0 = 2\lambda D/d$ ⇨ Width of central maximum will be increased.
- How would the width of central maximum in diffraction pattern due to a single slit be affected, when the width of

the slit is doubled?

Ans. $\beta_0 = 2\lambda D/d$ ⇨ Width of central maximum will be halved.

- Why do we not encounter diffraction effects of light in everyday observations?

  OR

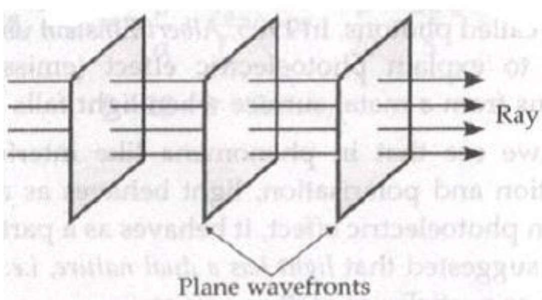
  Diffraction is common in sound but not common in light waves why?

  Ans. This is because objects around us are much bigger in size as compared to the wavelength of visible light($\approx 10^{-6}$m)
- In the Young's double slit experiment, how does the fringe width get affected if the entire experimental
  apparatus is immersed in water?

  Ans. fringe width will decrease**, Reason :** $\beta = \lambda D/d$ & $\beta_{water} = (D\lambda/\mu_{water})/d = \beta/\mu_{water}$
- In the Young's double slit experiment, how does the fringe width get affected if the entire experimental
  apparatus is immersed in water (refractive index 4/3)?

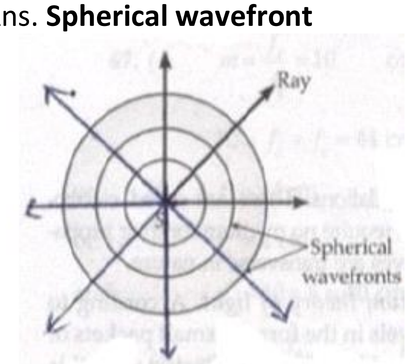
  Ans. $\beta_{water} = \beta/\mu_{water} = \beta/(4/3) = 3\beta/4$, so fringe width decreases to 3/4 times.
- Sketch the wavefront that will emerge from a distance source of light like a star.

  Ans. Plane wavefront



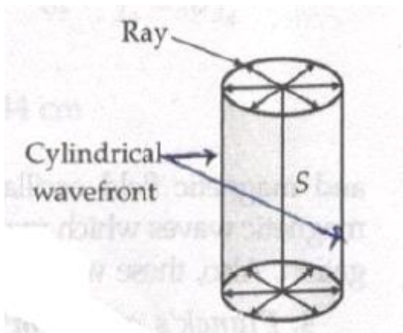
- Sketch the shape of wavefront emerging/diverging from a point source of light and also mark the rays.

  Ans. **Spherical wavefront**



- Sketch the wavefront that will emerge from a linear source of light like a slit.

  Ans. **Cylindrical Wavefront**



Assertion and Reasoning Based Questions

Instructions:
Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.
a) Both A and R are true and R is the correct explanation of A
b) Both A and R are true but R is NOT the correct explanation of A
c) A is true but R is false
d) A is false and R is also false

1) Assertion : When a light wave travels from a rarer to a denser medium, it loses speed. The reduction in speed imply a reduction in energy carried by the light wave.
Reason : The energy of a wave is proportional to velocity of wave.
Correct Answer: D
Solution : When a light wave travel from a rarer to a denser medium it loses speed, but energy carried by the wave does not depend on its speed. Instead, it depends on the amplitude of wave.

2) Assertion : No interference pattern is detected when two coherent sources are infinitely close to each other.
Reason : The fringe width is inversely proportional to the distance between the two slits.
Correct Answer: A
Solution : When d is negligibly small, fringe width β which is proportional to 1/d may become too large. Even a single fringe may occupy the whole screen. Hence the pattern cannot be detected.

3) Assertion : For best contrast between maxima and minima in the interference pattern of Young's double slit experiment, the intensity of light emerging out of the two slits should be equal.
Reason : The intensity of interference pattern is proportional to square of amplitude.
Correct Answer: B
Solution : When intensity of light emerging from two slits is equal, the intensity at minima, Imin = (√ Ia - √Ib)2=0, or absolute dark. It provides a better contrast.

4) Assertion: In Young's experiment, the fringe width for dark fringes is different from that for white fringes.
Reason : In Young's double slit experiment the fringes are performed with a source of white light, then only black and bright fringes are observed.
Correct Answer: D

Solution : In Young's experiments fringe width for dark and white fringes are same while in Young's double slit experiment when a white light as a source is used, the central fringe is white around which few coloured fringes are observed on either side.

5) Assertion : When a tiny circular obstacle is placed in the path of light from some distance, a bright spot is seen at the centre of shadow of the obstacle.

Reason : Destructive interference occurs at the centre of the shadow.

Correct Answer: C

Solution : As the waves diffracted from the edges of circular obstacle, placed in the path of light interfere constructively at the centre of the shadow resulting in the formation of a bright spot.

6) Assertion : Interference pattern is made by using blue light instead of red light, the fringes becomes narrower.

Reason : In Young?s double slit experiment, fringe width is given by relation $\beta = \lambda D/d$.

Correct Answer: A

Solution : $\beta = \lambda D/d$.

7) Assertion: Diffraction is common in sound but not common in light waves.

Reason : Wavelength of light is more than the wavelength of sound.

Answer (c)

Solution: If assertion is true but reason is false

8) Assertion : In Young's double slit experiment if wavelength of incident monochromatic light is just doubled, number of bright fringe on the screen will increase.

Reason : Maximum number of bright fringe on the screen is directly proportional to the wavelength of light used.

Answer: (d)

Solution: Wavelength is inversely proportional to the number of fringes, hence by doubling the wavelength the number of fringes decreases. Hence Assertion and reason are false.

9) Assertion : In interference and diffraction, light energy is redistributed.

Reason :There is no gain or loss of energy, which is consistent with the principle of conservation of energy.

Answer: (a)

Solution: In interference and diffraction, light energy is redistributed. If it reduces in one region, producing a dark fringe, it increases in another region, producing a bright fringe. There is no gain or loss of energy, which is consistent with the principle of conservation of energy.

10) Assertion : If complete YDSE (Young's Double Slit Experiment) is dipped in the liquid from the air, then fringe width decreases.

Reason : Wavelength of light decreases, when we move from air to liquid.

Answer: (a)

11) Assertion: No sustained interference pattern is obtained when two electric bulbs of the same power are taken.

Reason: Phase difference between waves coming out of electric bulbs is not constant.

Answer: (a)

12) Assertion: The maximum intensity in YDSE (Young's Double Slit Experiment) is four times the intensity due to each slit when they are identical.

Reason: The phase difference between the interfering waves is $2n\pi$ at the position of maxima where n = 0, 1, 2, ...

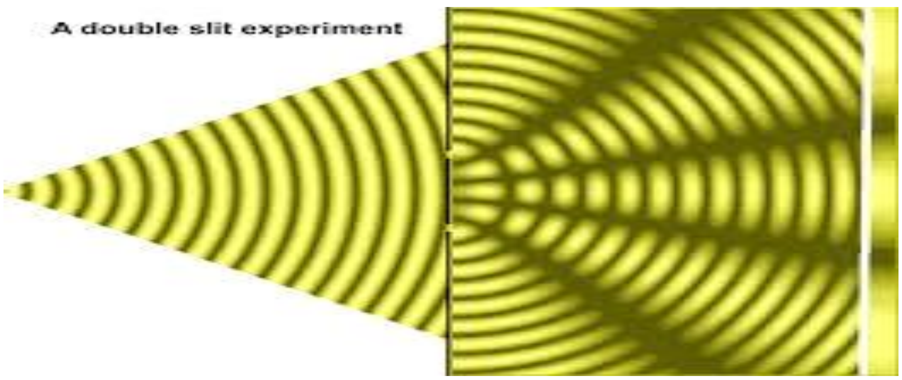
Answer: (a)

CASE STUDY BASED QUESTIONS

Following questions are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

- INTERFERENCE-

  When two or more waves interact and combine, they interfere with one another. But interference is not necessarily bad: waves may interfere constructively, resulting in a wave larger than the original waves. Or, they may interfere destructively, combining in such a way that they form a wave smaller than the original ones. Other examples of interference, both constructive and destructive, can be found wherever there are waves: in water, in sound, in light.



(i). Interference of light is evidence that:

a) the speed of light is very large

b) light is a transverse wave

c) light is electromagnetic in character

d) light is a wave phenomenon

(ii). In a Young's double-slit experiment the center of a bright fringe occurs wherever waves from the slits differ in the distance they travel by a multiple of:

a) a fourth of a wavelength

b) a half a wavelength

c) a wavelength

d) three-fourths of a wavelength

(iii). In a Young's double-slit experiment, the slit separation is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed to:

a. D/2

b. D/

c. D

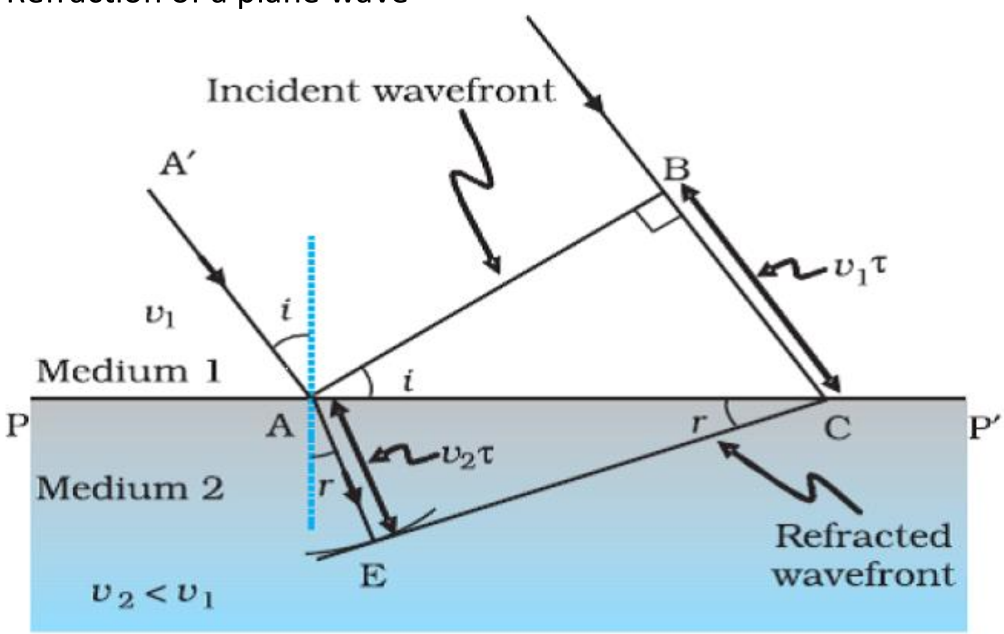
d. 2D

(iv).The shape of the fringes observed in interference is--
a) Straight
b) Circular
c) Hyperbolic
d) Elliptical

(v). The main principle used in Interference is -
a) Heisenberg's Uncertainty Principle
b) Superposition Principle
c) Quantum Mechanics
d) Fermi Principle

Ans. (i). (d) light is a wave phenomenon
(ii). (c) a wavelength
(iii). (d) 2D
(iv). (c) Hyperbolic
(v) (b) Superposition principle

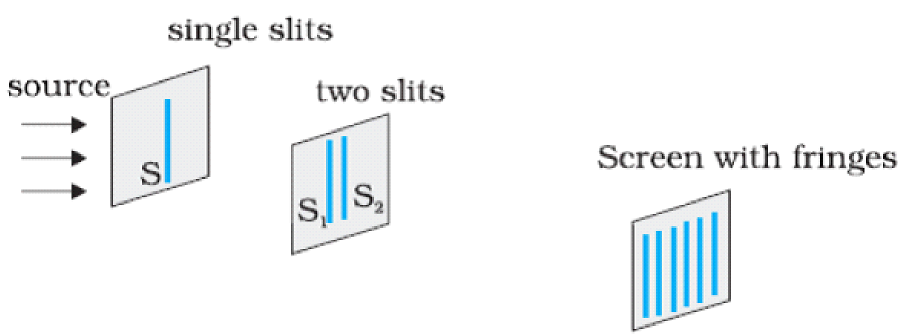
- Refraction of a plane wave

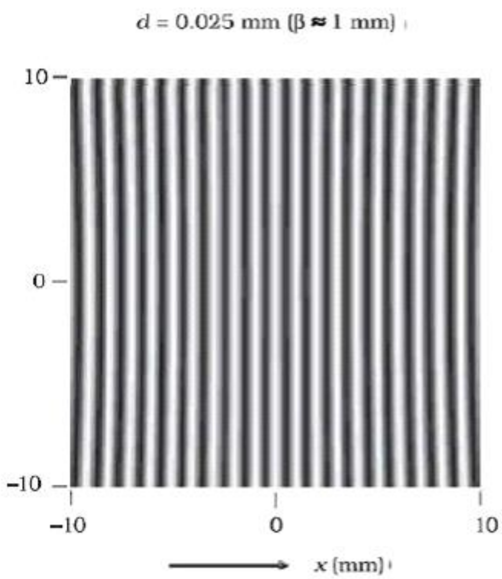


i) What is the angle made by the ray of light on the wavefront?
a) 90˚
b) 0˚
c) 45˚
d) None of the above
ii) Which parameter remains unchanged while a ray of light propagates from one medium to another?
a) velocity

b) Wave length
c) frequency
d) None of the above
iii) According to the above given fig., identify the correct expression for Snell's law.
a) $n_1 \sin i = n_2 \sin r$
b) $n_2 \sin i = n_1 \sin r$
c) $n_{21} = \sin r / \sin i$
d) None of the above
iv) When a ray of light travels from a denser to a rarer medium, it
a) it bends towards the normal
b) it travels in a straight line irrespective of angle of incidence.
c) it bends away from the normal
d) None of the above
Answers:
i) (a) 90˚
ii) (c) frequency
iii) (a) $n_1 \sin i = n_2 \sin r$
iv) (c) it bends away from the normal

- Interference (Young's Double slit experiment)

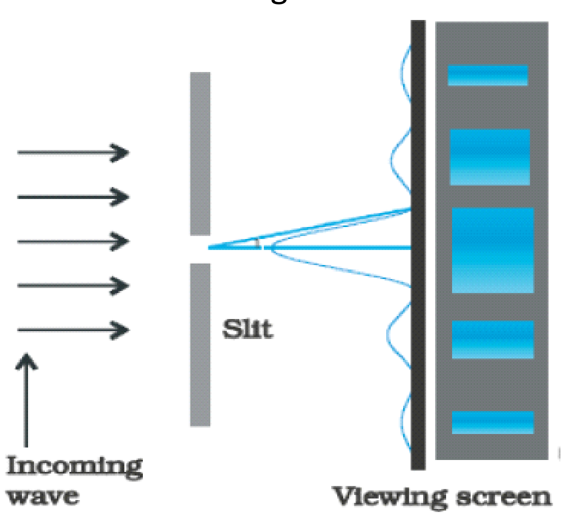




i) What is the path difference between the two light waves coming from coherent sources, which produces 3rd maxima.
a) λ

b) 2 λ
c) 3 λ
d 0
ii) What is the correct expression for fringe width(β).
a) λ d/D
(b) λ dD
(c) d/ λ D
(d) λ D/d
iii) what is the phase diff. between two interfering waves producing 1st dark fringe.
a) π
b) 2π
c) 3π
d) 4π
iv) The ratio of the widths of two slits in Young's double slit experiment is 4 : 1. Evaluate the ratio of intensities at maxima and minima in the interference pattern.
a) 1:1
b) 1:4
c) 3:1
d) 9:1
v) In a Young's double slit experiment, the separation between the slits is 0.1 mm, the wavelength of light used is 600 nm and the interference pattern is observed on a screen 1m away. Find the separation between bright fringes.
(a) 6.6 mm
(b) 6.0 mm
(c) 6 m
(d) 60cm
Answers:
(i) (c) 3 λ
(ii) (d) λ D/d
iii) (a) π
iv) (d) 9:1
v) (b) 6.0 mm

4. Diffraction at a single slit

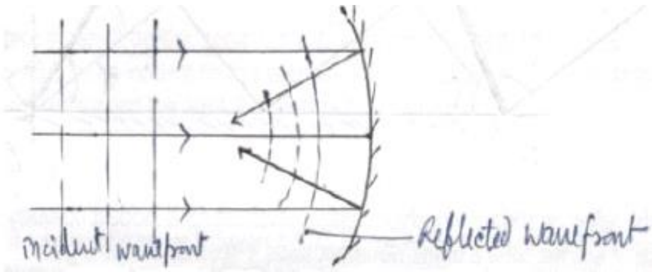


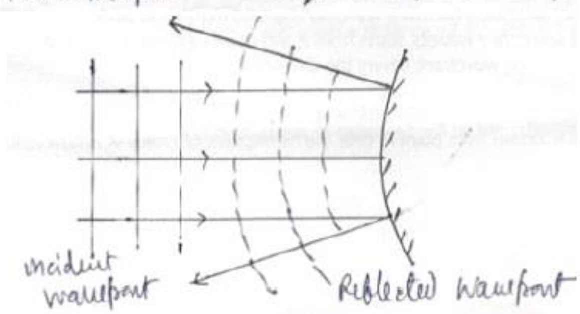
(i) In the phenomena of Diffraction of light when the violet light is used in the experiment is used instead of red light then,
(a) Fringe width increases
(b) No change in fridge width
(c) Fringe width decreases
(d) Colour pattern is formed
(ii) Diffraction aspect is easier to notice in case of the sound waves then in case of the light waves because sound waves
(a) Have longer wavelength
(b) Shorter wavelength
(c) Longitudinal wave
(d) Transverse waves
(iii) Diffraction effects show that light does not travel in straight lines. Under what condition the concepts of ray optics are valid. (D = distance of screen from the slit).
(a) $D < Z_f$
(b) $D = Z_f$
(c) $D > Z_f$
(d) $D << Z_f$
(iv) when 2^{nd} secondary maxima is obtained in case of single slit diffraction pattern, the angular position is given by
(a) λ
(b) $\lambda/2$
(c) $3 \lambda/2$
(d) $5 \lambda/2$
Answers:
(i) (c) Fringe width decreases
(ii) (a) Have longer wavelength
(iii) (d) $D << Z_f$
(iv) (d) $5 \lambda/2$

2Mark questions

- Sketch the reflected wavefront emerging from a (i) concave mirror (ii) convex mirror, if plane wavefront is incident
  normally on it.

Ans. **(i) reflected wavefront from a concave mirror** **(ii) reflected wavefront from a convex mirror**





- What is interference of light? Give one example of interference in daily life.

Ans. Interference of light : It the phenomenon of non-uniform distribution of resultant intensity when two light waves from two coherent sources superimpose on each other

Example in daily life : colours in bubbles of soap solution/ in thin oil films in white light.

- What are coherent sources of light? Why are coherent sources necessary to produce a sustained interference

pattern?

Ans. Coherent sources : Two sources producing light waves of same frequency and zero or constant initial phase difference are called coherent sources of light

Necessity : Coherent sources produce waves with constant phase difference, due to which positions of and minima does not change with time and a sustained interference pattern is obtained

- What is diffraction of light ? State the essential condition for diffraction of light.

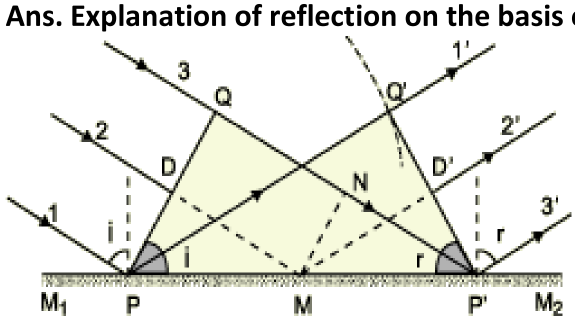
Ans. Diffraction : The phenomenon of bending of light round the corners of small obstacles or apertures is called diffraction of light.

Essential condition : Size of slit/ aperture must be of the order of wavelength of light

i,e, $a \approx \lambda$

- Using Huygen's construction draw a figure showing the propagation of a plane wavefront reflecting at a plane surface. Show that the angle of incidence is equal to the angle of reflection.

Ans. Explanation of reflection on the basis of Huygen's wave theory



QPP' (= *i angle of incident*).

$\angle Q'P'P$ = angle of reflection
In $PP'Q$ and $PP'Q'$
(i) PP' is common, (ii) $QP' = PQ' = c \times t$ & (iii) $\angle Q = \angle Q' = 90°$
Hence, the two triangles are congruent. $\angle QPP' = \angle Q'P'P$
Since corresponding parts of congruent triangles are equal so we can write $\angle i = \angle r$ (3)
Equation (3) represents, the first law of reflection.

- State two differences between interference and diffraction patterns.

Ans.

Interference	**Diffraction**
1. It is due to superposition of two waves from two coherent sources	1. It is due to superposition of secondary wavelets from different parts of the same wavefront
2. Width of fringes/ bands is equal	2. Width of fringes/bands is not equal
3. All maxima have same intensity	3. Maxima have different intensity and intensity decreases rapidly with the order of maxima

3Mark questions

- In a single slit diffraction experiment, when tiny circular obstacle is placed in path of light from a distance source, a bright spot is seen at the centre of the shadow of the obstacle. Explain why?
  State two points of difference between the interference patterns obtained in Young's double slit experiment and the diffraction pattern due to a single slit.

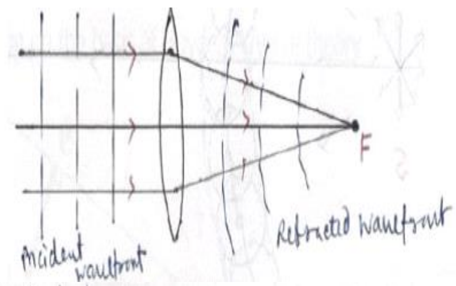
Ans.

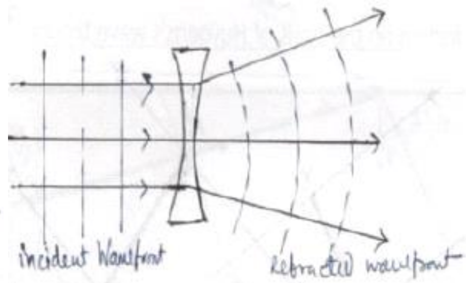
A bright spot is observed when a tiny circular object is placed in path of light from a distant source in a single slit diffraction experiment because light rays flare into the shadow region of the circular object as they pass the edge of the tiny circular object. The lights from all the edges of the tiny circular object are in phase with each other. Thus, they form a bright spot at the centre of the shadow of the the tiny circular object.
The two differences between the interference patterns obtained in Young's double slit experiment and the diffraction pattern due to a single slit are as follows:
(i) The fringes in the interference pattern obtained from diffraction are of varying width, while in case of interference, all are of the same width.

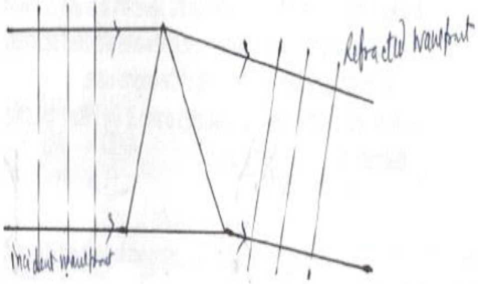
(ii) The bright fringes in the interference pattern obtained from diffraction have a central maximum followed by fringes of decreasing intensity, whereas in case of interference, all the bright fringes are of equal width.

- Sketch the refracted wavefront emerging from a (i) convex lens, (ii) concave lens and (iii) prism, if plane wavefront is incident normally on it.

Ans. **(i) refracted wavefront from a convex lens (ii) concave lens and (iii) refracted wavefront from a prism**

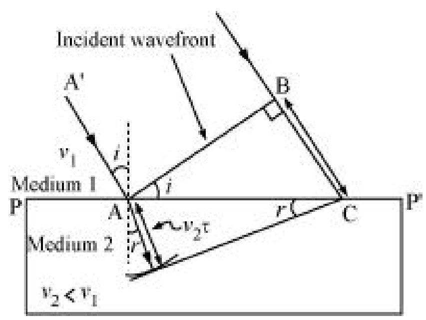






- Using Huygen's construction of a wavefront, explain the refraction of a plane wavefront at a plane surface and hence verify Snell's law.

Ans.



Wavefront AB strikes the surface PP' with an angle of incidence '*i*'.

Speed of light in medium 1 is v_1.

Speed of light in medium 2 is v_2.

Let '*τ*' be the time taken by the wavefront to travel the distance BC.

BC = $v_1\tau$

$$\sin i = \frac{BC}{AC} = \frac{v_1\tau}{AC} \qquad ...(i)$$

$$\sin r = \frac{AE}{AC} = \frac{v_2\tau}{AC} \qquad ...(ii)$$

Dividing (i) by (ii), we obtain

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} \quad ...(iii)$$

Refractive index(n_1) of medium 1 is $\frac{c}{v_1}$

$\Rightarrow v_1 = \frac{c}{n_1}$

Refractive index (n_2)of medium 2 is $\frac{c}{v_2}$

$\Rightarrow v_2 = \frac{c}{n_2}$

Putting these values in equation (iii),

$$\frac{\sin i}{\sin r} = \frac{\frac{c}{n_1}}{\frac{c}{n_2}} = \frac{n_2}{n_1}$$

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} \quad \text{(Snell's Law)}$$

- Why is no interference pattern is observed when two coherent sources are-
  (i) infinitely close to each other (ii) far apart from each other

Ans. β = $\lambda D/d$

(i) when sources are placed infinitely close to each other, $d \to 0 \Rightarrow \beta \to \infty$

Even a single fringe may occupy the entire screen. Hence no interference pattern will be observed

(ii) when the distance d becomes too large, fringe width becomes too small to be detected. Hence no interference pattern will be observed.

- A beam of light consisting of two wavelengths, 800nm and 600nm, is used to obtain the interference fringes in a Young's double slit experiment on a screen is placed 1.4m away. If two slits are separated by 0.28mm, Calculate the least distance from the central bright maximum where the bright fringes of the two wavelengths coincide.

Ans. Given, $\lambda 1$ = 800nm = $8X10^{-7}$m, $\lambda 2$ = 600nm = $6X10^{-7}$m, D = 1.4m,

d = 0.28mm = $0.28X10^{-3}$m, Least distance of coincide y =?

condition for coincide is $n\beta_1 = (n+1)\beta_2$

$\Rightarrow n\lambda_1 D/d = (n+1)\lambda_2 D/d$

$\Rightarrow n\lambda_1 = (n+1)\lambda_2$

$\Rightarrow nX8X10^{-7} = (n+1)X\ 6\ X10^{-7}$

$\Rightarrow 8n = 6n + 6$

$\Rightarrow 2n = 6$

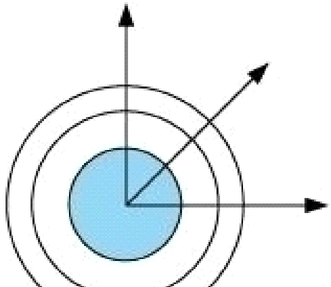
$\Rightarrow n = 3$

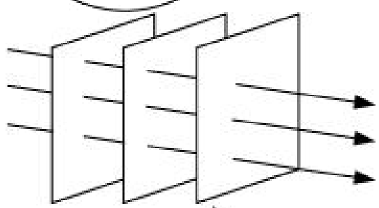
Required least distance

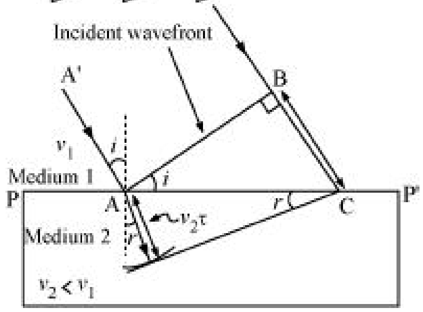
$Y = n\beta_1 = 3\ \lambda_1 D/d = (3X800X10^{-7}X1.4)/\ 0.28X10^{-3}m$
$= 1.2\ X\ 10^{-2}m$

5 Mark questions

1. Define the term 'wavefront'. Draw the wavefront and corresponding rays in the case of a (i) diverging spherical wave, (ii) plane wave.
Using Huygen's construction of a wavefront, explain the refraction of a plane wavefront at a plane surface and hence verify Snell's law.
The locus of all the particles of the medium, which at any instant are vibrating in the same phase, is called the wavefront.
Solution:







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Dividing (i) by (ii), we obtain

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$\Rightarrow v_1 = \frac{c}{n_1}$

Refractive index (n_2)of medium 2 is $\frac{c}{v_2}$

$\Rightarrow v_2 = \frac{c}{n_2}$

Putting these values in equation (iii),

$$\frac{\sin i}{\sin r} = \frac{\frac{c}{n_1}}{\frac{c}{n_2}} = \frac{n_2}{n_1}$$

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} \qquad \text{(Snell's Law)}$$

2. State Huygens's principle. Show, with the help of a suitable diagram, how this principle is used to obtain the diffraction pattern by a single slit.

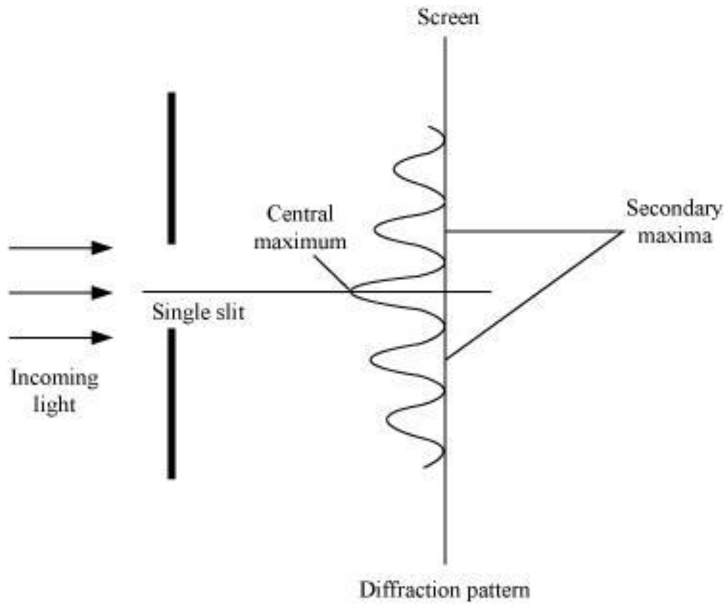
Draw a plot of intensity distribution and explain clearly why the secondary maxima becomes weaker with increasing order (n) of the secondary maxima.

Solution:

Huygen's principle states that

- Each point on a wave front behaves as a source of secondary wavelets
- The secondary wavelets travel with the speed of light in that medium
- The position of new wave front at a later time can be found out by drawing a common tangent to all these secondary wavelets

Intensity distribution of single slit distribution



For the first secondary maxima (n = 1), only one-third of the slit contributes to its intensity.
Secondly, for n = 2, only one-fifth of the slit contributes to the intensity.
Therefore, with increasing n, the intensity decreases.
3.(a) What are coherent sources of light? Two slits in Young's double slit experiment are illuminated by two different sodium lamps emitting light of the same wavelength. Why is no interference pattern observed?
(b) Obtain the condition for getting dark and bright fringes in Young's experiment. Hence write the expression for the fringe width.
(c) If S is the size of the source and its distance from the plane of the two slits, what should be the criterion for the interference fringes to be seen?
Solution:
(a) Coherent sources of light:
The sources of light, which emit continuous light waves of the same wavelength, same frequency, and in same phase, are called coherent sources of light.
If the two slits in Young's double slit experiment are illuminated by two different sodium lamps emitting light of the same wavelength, then no interference pattern will be observed because phase difference between the light waves emitted from two different sodium lamps will change continuously.
(b) For bright fringes (maxima), path difference,

$$\frac{xd}{D} = n\lambda$$

$$\therefore x = n\lambda\frac{D}{d},$$ where n = 0, 1, 2, 3, …

For dark fringes (minima),

Path difference, $\frac{xd}{D} = (2n-1)\frac{\lambda}{2}$

$\therefore x = (2n-1)\frac{\lambda}{2}\frac{D}{d}$, where n = 0, 1, 2, 3, …

The separation between the centres of two consecutive bright fringes is the width of a dark fringe.

∴Fringe width, $P = X_n - X_{n-1}$

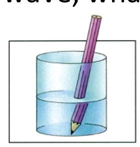
$$\beta = \frac{n\lambda D}{d} - (n-1)\frac{\lambda D}{d}$$

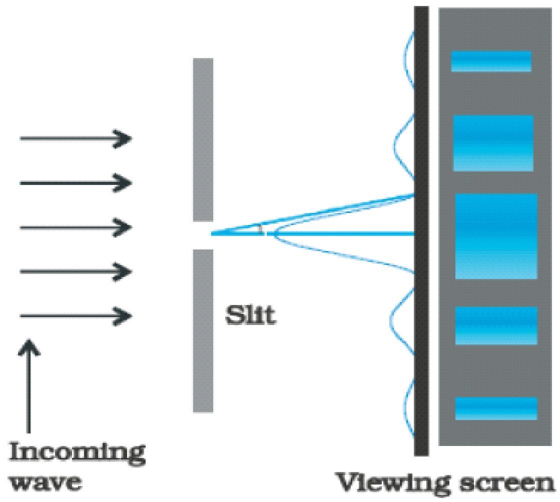
$$\therefore \beta = \frac{\lambda D}{d}$$

(c) Criterion is

$$\frac{S}{d} < \frac{\lambda}{a}$$

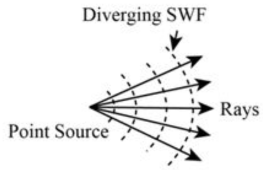
Worksheet

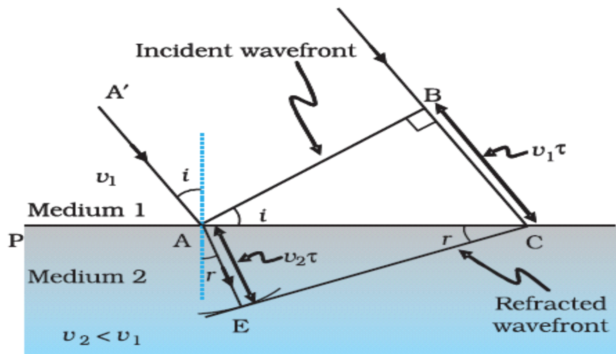
S.NO.	QUESTION	MARK
1	What is the phase difference between two pints in waterfront?	1
2	Sketch the shape of wave front in which the ray of light diverges.	1
3	What is the ratio of the fringe width of bright and dark fringe in young's double slit experiment?	1
4	Observe the image. If the light is considered as wave, what will be the phase change of the light ray inside the water. 	1
5	Can you get interference pattern by two coherent sources but kept very close (not infinitesimally) to each other and very narrow?	1
6	What is the resultant intensity at the region of bright fringe when, two identical coherent waves, each of intensity , are produces an interference pattern?	1
7	What happens to the light energy when light waves interfere destructively at a point?	1
8	**Instructions:** **Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.** **a) Both A and R are true and R is the correct explanation of A** **b) Both A and R are true but R is NOT the correct explanation of A** **c) A is true but R is false** **d) A is false and R is also false** Assertion : For best contrast between maxima and minima in the interference pattern of Young's double slit experiment, the intensity of	1

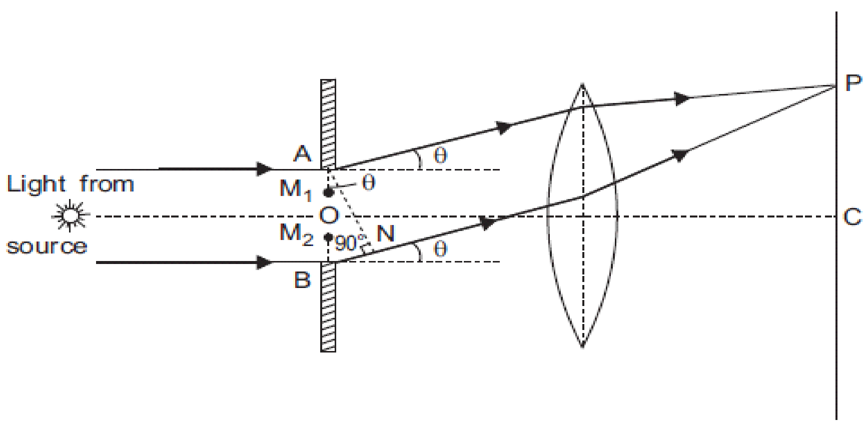
	light emerging out of the two slits should be equal. Reason : The intensity of interference pattern is proportional to square of amplitude.	
9	Assertion: Diffraction is common in sound but not common in light waves. Reason : Wavelength of light is more than the wavelength of sound.	1
10	Diffraction at a single slit  (i) In the phenomena of Diffraction of light when the violet light is used in the experiment is used instead of red light then, (a) Fringe width increases (b) No change in fridge width (c) Fringe width decreases (d) Colour pattern is formed (ii) Diffraction aspect is easier to notice in case of the sound waves then in case of the light waves because sound waves (a) Have longer wavelength (b) Shorter wavelength (c) Longitudinal wave (d) Transverse waves (iii) Diffraction effects show that light does not travel in straight lines. Under what condition the concepts of ray optics are valid. (D = distance of screen from the slit). (a) $D < Z_f$ (b) $D = Z_f$ (c) $D > Z_f$ (d) $D << Z_f$ (iv) when 2^{nd} secondary maxima is obtained in case of single slit diffraction pattern, the angular position is given by (a) λ (b) λ/2	4

	(c) 3 λ/2 (d) 5 λ/2	
	2- Marks	
1	Why are visible light, do not diffract around the buildings unlike Radio waves?	2
2	A light of wave length of 600 nm is incident on a single slit of width 0.6 mm at normal incident calculate the width of the two dark bands on either side of the central maximum if the pattern observed is on a screen kept at distance of 1m.	2
3	What is the wave length of the wave used when first diffraction minima due to a single slit of width 1.0 x 10^{-5}cm is at	2
4	How does the fridge width changes when in a Young's double slit experiment when the distance of separation between the slits and the screen is increased to	2
5	Diffraction of sound may be a regular phenomena in daily life but the same phenomena is not observable in the case of light, State the reason behind it.	
6	A beam of light consisting of two wavelengths, 600nm and 450nm, is used to obtain the interference fringes in a Young's double slit experiment on a screen is placed 1.4m away. If two slits are separated by 0.28mm, Calculate the least distance from the central bright maximum where the bright fringes of the two wavelengths coincide.	3
7		
8		
9	Define the term wave front. State Huygens principle. Using this principle draw a diagram to show the refraction of a plane wave and prove the Snell's law of refraction.	1+1+1+2=5
10	(a) Explain the phenomena of diffraction. (b)Explain the formation of central bright fringe and secondary minima's using single slit diffraction pattern. (c)What is the difference between single slit and double slit experiment.	1+3+1=5

SL.NO.	ANSWERS	MARK
1	zero	

2		
3	1	
4	No phase change	
5	Yes, (it is the necessary and sufficient condition)	
6	$I=I_0+I_0+2\sqrt{I_0I_0}\cos 0^0=4I_0$	
7	Energy is rearranged	
8	Correct Answer: B Solution : When intensity of light emerging from two slits is equal, the intensity at minima, $I_{min} = (\sqrt{Ia} - \sqrt{Ib})^2=0$, or absolute dark. It provides a better contrast.	
9	Answer (c) Solution: If assertion is true but reason is false	
10	**Answers:** **(i) (c)** Fringe width decreases **(ii) (a)** Have longer wavelength **(iii) (d)** $D << Z_f$ **(iv) (d)** $5\lambda/2$	
	ANSWERS TO 2- MARK QUESTIONS	
1	• For diffraction to take place, the wavelength should be of the order of the size of the obstacle • wavelength of the light waves is very small	
2	• 2 • 2mm	
3	• asin Ө= n • 500	
4	• B= • Fringe width also increases by	
5	• Diffraction of light I observed only when the slit width is of the order of wave length of the light • Sound wave is a mechanical wave has a large wave length as compared with the size pf the objects in daily life	
6	**Given, $\lambda 1$ = 600nm = $6X10^{-7}$m**, **$\lambda 2$ = 450nm = $4.5X10^{-7}$m**, D = 1.4m, d = 0.28mm = $0.28X10^{-3}$m, Least distance of coincide y =? condition for coincide is $n\beta_1 = (n+1)\beta_2$ ⇨$n\lambda_1D/d = (n+1)\lambda_2D/d$ ⇨$n\lambda_1 = (n+1)\lambda_2$ ⇨ $nX6X10^{-7} = (n+1)X\ 4.5\ X10^{-7}$ ⇨ 6n = 4.5n +4.5	 ½ ½

	⇨ $1.5n = 4.5$ ⇨ $n = 3$ Required least distance $Y = n\beta_1 = 3\lambda_1 D/d = (3X6X10^{-7}X1.4)/ 0.28X10^{-3}m$ $= (3X6X1.4X10^{-3})/2.8 = 9 X 10^{-3}m = 9mm$	 1 ½ ½
7		
8		
9	The locus of all the points which are vibrating in the same phase, is called wave front. Huygens's Principle: It states that each point of the wave front is the source of the secondary wavelets which spread out in all direction with the speed of wave. All the points on the wave front are going to become a secondary source. All the Tangent drawn to all the wavelets is the new position of the waveform  *A plane wave* AB is incident at an angle *i* on the surface PP′ separating medium 1 and medium 2. The plane wave undergoes refraction and CE represents the refracted wavefront. The figure corresponds to $v_2 < v_1$ so that the refracted waves bends towards the normal. If ' t ' represents the time taken by the wavefront from the point B to C then the distance, $BC = v_1 t$ Let CE represent a tangent plane drawn from the point C on to the sphere. Then, $AE = v_2t$ CE would represent the refracted wave front. If we now consider the triangles ABC and AEC, we readily obtain $\sin i = BC/ AC = v_1t/AC$ $\sin r = AE/AC = v_2t/AC$	1+1+1+2=5

	where' i ' and ' r ' are the angles of incidence and refraction, respectively. Substituting the values of v_1 and v_2 in terms of we get the Snell's Law, $$n_1 \sin i = n_2 \sin r$$	
10	(a) Diffraction of light is defined as the bending of light around corners of an obstacle or aperture such that it spreads out and illuminates areas where a shadow is expected.We can observe single slit diffraction when light passes through a single slit whose width (w) is on the order of the wavelength of the light. (b).All the secondary wavelets going straight across the slit are focussed at the central point O adding constructively to produce central bright fringe. **Condition for nth dark fringe** **$a\sin\Theta_n = n\lambda$ n= 1,2,3…..** **condition for nth secondary maximum** **$a\sin\Theta_n' = (2n+1)\lambda/2$ n= 1,2,3…..**  In single slit experiment we get interference pattern and in double slit experiment we get diffraction pattern.	1+3+1=5

UNIT 7, CHAPTER 11: DUAL NATURE OF MATTER & RADIATION

ELECTRON EMISSION

- There are three types of electron emission, namely, Thermionic Emission, Photoelectric Emission and Field Emission.
- The minimum energy required by an electron to escape from the metal surface is called work function.
- Work function is conveniently expressed in electron volts (eV).
- One electron volt is the energy gained or lost by an electron while passing through a potential difference of one volt.

PHOTOELECTRIC EFFECT

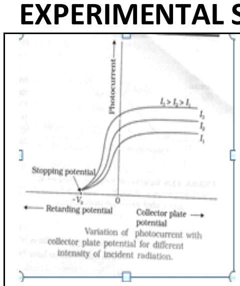
- The minimum energy required by an electron to come out from metal surface is called the work function of a metal.
- Photo electric effect is the phenomenon of electrons by metals when illuminated by light of suitable frequency.
- Photo electric current depends on

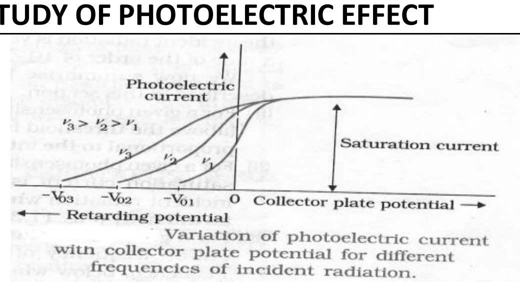
(a). The intensity of incident light

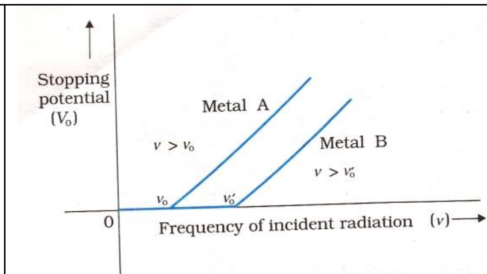
(b). The potential difference applied between two electrodes

(c). The nature of the emitter material

EXPERIMENTAL STUDY OF PHOTOELECTRIC EFFECT







- The minimum negative potential given to the anode plate for which the photo electric current becomes zero is called stopping potential.
- The stopping potential Vo depends on i) The frequency of incident light and ii) the nature of emitter material. For a given frequency of incident light, the stopping potential is independent of its intensity.

$$eV_0 = \frac{1}{2} m\, v_{max}^2 = K_{max}$$

- Below a certain frequency (threshold frequency) ν_0 , characteristics of the metal , no photo electric emission takes place, no matter how large the intensity may be.

EINSTEINS PHOTO ELECTRIC EQUATION: ENERGY QUANTUM OF RADIATION

- Light is composed of discrete packets of energy called quanta or photons.
- The energy carried by each photon is E = hν, where ν is the frequency and momentum p= h/λ. The energy of the photon depends on the frequency ν_o of the incident light and not on its intensity.
- Photo electric emission from the metal surface occurs due to absorption of a photon by an electron
- Einstein's photo electric equation: $K_{max} = h\nu - \phi_0$ or $eV0 = h\nu - \phi_0$.

PARTICLE NATURE OF LIGHT: THE PHOTON

- Radiation has dual nature: wave and particle. The wave nature is revealed in phenomenon like interference, diffraction and polarization. The particle nature is revealed by the phenomenon photo electric effect.
- By symmetry, matter also should have dual nature: wave and particle. The waves associated with the moving material particle are called matter waves or De Broglie waves.

- The De Broglie wave length (λ) associated with the moving particle is related to its moment p as: $\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE_k}}$

- An equation for the De Broglie wavelength of a accelerated charge particle through a potential V. Consider an electron with mass 'm' and charge 'e' accelerated from rest through a potential V.

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

For accelerated electron:

$$\lambda = \frac{12.27}{\sqrt{V}} \dot{A}$$

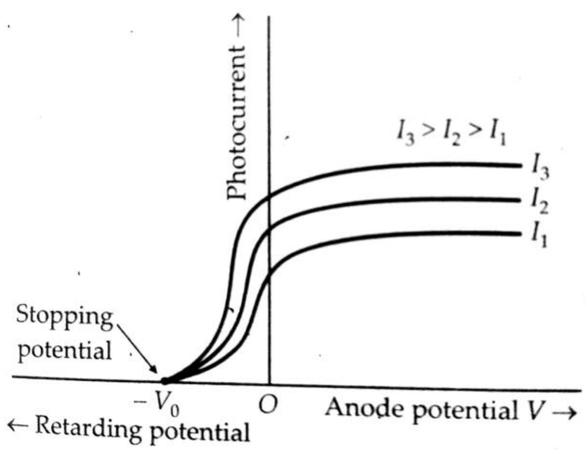
Very Short Answer Type Questions (1 Mark)

1. Name the phenomenon which shows the quantum nature of electromagnetic radiation.
2. Plot a graph showing the variation of photoelectric current as a function of anode potential for two light beams having the same frequency but different intensities I_1, I_2 and I_3($I_1 < I_2 < I_3$).
3. A photosensitive surface emits photoelectrons when red light falls on it. Will the surface emit photoelectrons when blue light is incident on it? Give reason.
4. If the intensity of the incident radiation in a photoelectric emission experiment is increased, how does the stopping potential vary?
5. Write Einstein's photoelectric equation.

6. Work function of Na is 2.3 eV.Does Na show photoelectric emission for light of wavelength 6800 A^{O} ?
7. The stopping potential in an experiment is 1.5 V. What is the maximum K.E. of photoelectrons emitted?
8. de-Broglie waves are also called matter waves. Why?
9. Write two characteristic features in photoelectric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation.
10. An electron is accelerated through a potential difference of 100 Volts. What is the de-Broglie wavelength associated with it? To which part of the electromagnetic spectrum does this value of wavelength corresponds?

Answers (Very Short Answer Type Questions,1 Mark)

1. Photoelectric effect or Compton effect
2.



3. Yes, since $\nu_{Blue} > \nu_{Red}$ therefore $(h\,\nu)_{Blue} > (h\,\nu)_{Red}$
4. Stopping potential remains unaffected by the increase in the intensity of incident radiation.
5. $h\vartheta = h\vartheta_0 + \frac{1}{2}mv^2$ ***OR*** $h\vartheta = W_0 + \frac{1}{2}mv^2$ **OR** $h\vartheta = W_0 + eV_o$
6. $E = \frac{hC}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{6800 \times 10^{-10}} = 2.92 \times 10^{-19}$ J = 1.825 eV
7. Since $K_{max} = eV_o$, therefore V_o = 1.5 eV
8. Because to be associated with a de-Broglie wave, a particle need not have a charge.
9. (i) Maximum Kinetic energy of emitted photoelectrons is independent of intensity of incident light

   (ii) Instantaneous emission of photoelectrons

   (iil) Existence of threshold frequency **(Any Two)**
10. $\lambda = \frac{12.27\dot{A}}{\sqrt{V}} = \frac{12.27\dot{A}}{\sqrt{100}}$ = 1.227 A^0 , Belongs to X-rays

Short Answer Type 1 Questions (2 Mark)

1. State the laws of photoelectric emission.
2. Why photoelectric effect cannot be explained on the basis of wave nature of light? Give any two reasons.
3. An alpha (α) particle and a proton are accelerated from rest through the same potential difference. Find the ratio of their de-Broglie wavelengths associated with them.
4. A proton and an α- particle have the same de-Broglie wavelength. Determine the ratio of (i) their accelerating potentials (ii) their speeds.
5. When an electron in hydrogen atom jumps from the third excited state to the ground state, how would the de-Broglie wavelength associated with the electron change? Justify your answer.

Answers (Short Answer Type 1 Questions, 2 Mark)

1. (i) For a given photosensitive surface, photoelectric current is directly proportional to the intensity of incident light.
   (ii) The maximum kinetic energy of photoelectrons does not depend on intensity but it depends on frequency of incident radiation and is directly proportional to it.
   (iii) For a given photosensitive surface, there exists a certain minimum frequency of incident radiation, called threshold frequency below which no photoelectric emission takes place, whatever may be the intensity of incident radiation.
   (iv)The photoelectric emission is an instantaneous process.
2. (i) According to wave theory, Kinetic energy of photoelectrons must increase as the intensity of light is increased. But, experimental observations show that, K.E. of photoelectrons does not depend on intensity of incident light.
   (ii)According to wave theory, if the intensity of incident radiation is sufficient photoelectron emission should take place, whatever may be the frequency. But, experimental observations shows that, if , no emission of photoelectrons takes place, whatever may be the intensity.
3. $\boldsymbol{\lambda} = \frac{h}{\sqrt{2mqV}}$ and V = Constant
   ⇨ $\frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{m_p}{m_\alpha}} \times \sqrt{\frac{q_p}{q_\alpha}} = \sqrt{\frac{m_p}{4m_p}} \times \sqrt{\frac{q_p}{2q_p}} = \frac{1}{2\sqrt{2}}$
4. (i) $\boldsymbol{\lambda} = \frac{h}{\sqrt{2mqV}}$ $\Rightarrow V = \frac{h^2}{2mq\lambda^2}$
   ⇨ $\frac{V_P}{V_\alpha} = \frac{m_\alpha q_\alpha}{m_P\, q_P} = \frac{4m_P q_P}{m_P\, q_P} = \frac{8}{1}$

(ii) $\lambda = \frac{h}{mv}$ => $v = \frac{h}{m\lambda}$

=> $\frac{v_P}{v_\alpha} = \frac{m_\alpha}{m_P} = \frac{4m_P}{m_P} = \frac{4}{1}$

5. For 3rd exited state n = 4,for ground state n = 1

   Now $= \frac{h}{mv}$ => $\propto \frac{1}{v}$ but $v \propto \frac{1}{n}$

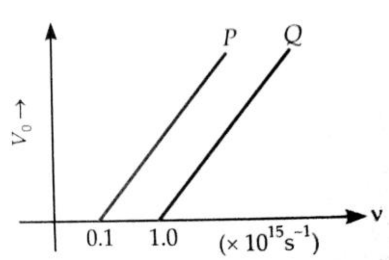
   Therefore $\boldsymbol{\lambda} \propto n$

   ⇨ $\frac{\lambda_2}{\lambda_1} = \frac{n_2}{n_1} = \frac{1}{4}$

   ⇨ $\boldsymbol{\lambda}_2 = \frac{\lambda_1}{4}$, Hence, de-Broglie wavelength will decrease to one fourth of its value in third excited state.

Short Answer Type 2 Questions (3 Mark)

1. The threshold frequency of a metal is f. When the light of frequency 2f is incident on the metal plate, the maximum velocity of photo-electrons is v_1. When the frequency of the incident radiation is increased to 5f, the maximum velocity of photo-electrons is v_2 . Find the ratio $v_1 : v_2$.
2. The work function for the following metals is given: Na = 2.75eV and Mo = 4.175eV
   (i) Which of these will not give photoelectron emission from a radiation of wavelength 3300 A^0 from a laser beam?
   (ii) What happens if the source of laser beam is brought closer?
3. X-rays of wavelength '$\boldsymbol{\lambda}$' fall on a photo sensitive surface, emitting electrons. Assuming that the work function of surface can be neglected, prove that the de-Broglie wavelength of electrons emitted will be $\sqrt{\frac{h\lambda}{2mc}}$.
4. The wavelength λ of a photon and the de-Broglie wavelength of an electron have the same value. Show that the energy of a photon is $\frac{2\lambda mc}{h}$ times the kinetic energy of electron. Where m, h and h have their usual meaning.
5. Figure shows the variations of stopping potential V_o with the frequency v of the incident radiations of the incident radiation for two photosensitive metals P and Q:
   (i) Explain which metal has smaller threshold wavelength.
   (ii) Explain, giving reason, which metals emits photo electrons having smaller kinetic energy, for the same wavelength of incident radiation.



Answers (Short Answer Type Questions, 2 Mark)

1. K_{max} = h ν – W and W = hf

   ⇨ $\frac{\frac{1}{2}mv_1^2}{\frac{1}{2}mv_2^2} = \frac{h\nu_1 - W}{h\nu_2 - W} = \frac{h(2f) - hf}{h(5f) - hf} = \frac{hf}{4hf} = \frac{1}{4}$

   ⇨ $\frac{v_1^2}{v_2^2} = \frac{1}{4}$

   ⇨ $\frac{v_1}{v_2} = \frac{1}{2}$

2. (i) For $\lambda = 3300 A^0$

   Energy of photon $\frac{hC}{\lambda} = \frac{6.62 \ x \ 10^{-34} \ x \ 3 \ x \ 10^{8}}{3300 \ x \ 10^{-10} x \ 1.6 \ x \ 10^{-19}}$ = 3.75 eV < 4.175 eV

   Hence Mo will not given photoelectric emission as $\frac{hC}{\lambda}$ < work function.

   (ii)In case of Na, photocurrent will increase but in case of Mo no effect.

3. As, work function W is negligible…

   E_k = h ν – W = h ν – 0 = h ν = $\frac{hC}{\lambda}$

   Now de-Broglie wavelength

   $\lambda_1 = \frac{h}{\sqrt{2mE_k}} = \frac{h}{\sqrt{2m\frac{hc}{\lambda}}} = \sqrt{\frac{h\lambda}{2mc}}$

4. Energy of photon E = $\frac{hc}{\lambda}$

   de-Broglie wavelength of electron $\lambda = \frac{h}{p}$

   Kinetic energy of electron $E_k = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$

   $\frac{E}{E_k} = \frac{\frac{hc}{\lambda}}{\frac{h^2}{2m\lambda^2}} = \frac{2\lambda mc}{h}$

   ⇨ $E = \frac{2\lambda mc}{h} E_k$

5. (i) Threshold wavelength $\lambda_o = \frac{c}{\nu_o}$

   As $\nu_o(Q) > \nu_o(P)$

   Therefore $\lambda_0(Q) < \lambda_0(P)$

   Thus the metal Q has smaller threshold wavelength.

   (ii) According to Einstein's photoelectric equation ,

   $\frac{hc}{\lambda} = \frac{hc}{\lambda_o} +$ K.E. of photoelectrons

   For the same λ of incident radiation, L.H.S. is constant. So metal Q with smaller value of λ_o will emit photoelectrons of smaller K.E.

Assertion & Reason type Question

Directions: In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it. Of the statements, mark the correct answer as:

(A)If both assertion and reason are true and reason is the correct explanation of assertion

(B)If both assertion and reason are true but reason is not the correct explanation of assertion

(C)If assertion is true and reason is false

(D)If both assertion and reason are false

1. Assertion: A photon has no rest mass , yet it carries definite momentum.
   Reason: Momentum of photon is due to its energy and hence its equivalent mass.
2. Assertion: Mass of moving photon varies inversely as the wavelength.
   Reason: Energy of the particle = mass x (speed of light)^2
3. Assertion: In photoelectron emission, the velocity of electron ejected from near the surface is larger than that coming from interior of metal.
   Reason. The velocity of ejected electron will be zero.
4. Assertion: A photocell is called an electric eye.
   Reason: When light is incident on some semiconductor, its electrical resistance is reduced.
5. Assertion: The de Broglie equation has significance for any microscopic or sub microscopic particle.
   Reason: The de Broglie wavelength is inversely proportional to the mass of the object if velocity is constant.
6. Assertion : A particle of mass M at rest decay into particles of masses m_1 and m_2,having non-zero velocities will have ratio of de-Broglie wavelengths unity.
   Reason. Here we cannot apply conservation of linear momentum.
7. Assertion: Photoelectric effect demonstrates the wave nature of light.
   Reason. The number of photoelectrons is proportional to the frequency of light.
8. Assertion: When ascertain wavelength of light falls on a metal surface it ejects electron.
   Reason. Light has wave nature.
9. Assertion: As work function of a material increases by some mechanism, it requires greater energy to excite the electrons from its surface.

Reason. A plot of stopping potential (V_o) versus frequency (v) for different materials,has greater slope for metals with greater work functions.

10. Assertion : Light of frequency 1.5 times the threshold frequency is incident on photo-sensitive material. If the frequency is halved and intensity is doubled the photo current remains unchanged.

Reason. The photo electric current varies directly with the intensity of light and frequency of light.

11. Assertion. The de-Broglie wavelength of a neutron when its kinetic energy is k is λ. Its wavelength is 2 λ when its kinetic energy is 4k.

Reason. The de - Broglie wavelength λ is proportional to square root of the kinetic energy.

12. Assertion. The de–Broglie wavelength of a molecule varies inversely as the square root of temperature.

Reason. The root mean square velocity of the molecule depends on the temperature.

Answers:

Q1. (a)	Q2. (a)	Q3. (c)	Q4. (c)	Q5. (a)
Q6. (a)	Q7. (d)	Q8. (b)	Q9. (c)	Q10. (d)
Q11. (d)	Q12. (a)			

CASE STUDY BASED QUESTION

1. The photoelectric emission is possible only if the incident light is in the form of packets of energy, each having a definite value, more than the work function of the metal. This show that light is not of wave nature but of particle nature. It is due to this reason that photoelectric emission was accounted by quantum theory of light.

1. Packet of energy are called….

(a)electron

(b) quantum

(c) frequency

(d) neutron

2. One quantum of radiation is called

(a)meter

(b) Meson

(c) Photon

(d) Quark

3. Energy associated with each photon

(a)hc

(b) mc

(c) hv

(d)hk

4. Which of the following waves can produce photo electric effect…

(a). UV radiation

(b). Infrared radiation

(c). Radio waves

(d). Microwaves

5. Work function of alkali metals is..

(a)less than zero

(b) just equal to other metals

(c) greater than other metals

(d) quite less than other metals

Answer:

1.(b) 2.(c) 3.(c) 4.(a) 5.(d)

PRACTICE QUESTIONS

Directions: In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it. Of the statements, mark the correct answer as:

(A) If both assertion and reason are true and reason is the correct explanation of assertion

(B) If both assertion and reason are true but reason is not the correct explanation of assertion

(C)If assertion is true and reason is false

(D)If both assertion and reason are false

1. Assertion : Light of frequency 1.5 times the threshold frequency is incident on photo-sensitive material. If the frequency is halved and intensity is doubled the photo current remains unchanged.

Reason. The photo electric current varies directly with the intensity of light and frequency of light.

2. Assertion. The de-Broglie wavelength of a neutron when its kinetic energy is k is λ. Its wavelength is 2 λ when its kinetic energy is 4k.

   Reason. The de - Broglie wavelength λ is proportional to square root of the kinetic energy.

3. Assertion. The de–Broglie wavelength of a molecule varies inversely as the square root of temperature.

   Reason. The root mean square velocity of the molecule depends on the temperature.

4. Assertion : A particle of mass M at rest decay into particles of masses m_1 and m_2,having non-zero velocities will have ratio of de-Broglie wavelengths unity.

   Reason. Here we cannot apply conservation of linear momentum.

5. Assertion: Photoelectric effect demonstrates the wave nature of light.

   Reason. The number of photoelectrons is proportional to the frequency of light.

6. According to de-Broglie a moving material particle sometimes acts as a wave and sometimes as a particle or a wave is associated with moving material particle which controls the particle in every respect. The wave associated with moving material particle is called matter wave or de-Broglie wave whose wavelength called de-Broglie wavelength, is given by λ = h/mv.

   1. The dual nature of light is exhibited by…

   (a) diffraction and photo electric effect

   (b) photoelectric effect

   (c) refraction and interference

   (d) diffraction and reflection.

   2. If the momentum of a particle is doubled , then its de-Broglie wavelength will…

   (a) remain unchanged (b)become four times

   (c) become two times (d) become half

   3. If an electron and proton are propagating in the form of waves having the same λ , it implies that they have the same

   (a) energy (b) momentum

   (c) velocity (d) angular momentum

   4. Velocity of a body of mass m, having de-Broglie wavelength λ , is given by relation

   (a) v = λ h/m (b) v = λm/h

   (c) v = λ/hm (d) v = h/ λm

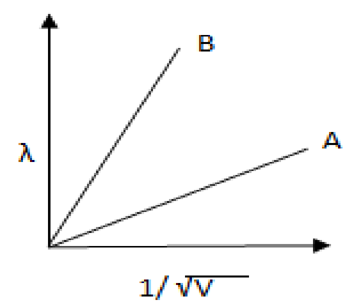
   5. Moving with the same velocity , which of the following has the longest de Broglie wavelength?

   (a)β -particle (b) α -particle

   (c) proton (d) neutron.

7. If the intensity of incident radiation in a photoelectric experiment is doubled what, happens to kinetic energy of emitted photo electrons?

8. Calculate the frequency associated with photon of energy 3.3 x 10-10 J ?
9. If the frequency of incident radiation in a photocell is increased, does it affect the stopping potential? If so how?
10. The threshold wave length for photoelectric emission from a given surface is 5200Ǻ. Will photoelectric emission takes place, if an ultra violet radiation of one watt power is incident on it?
11. A source of light is placed at a distance of 50cm from a photocell and the cut off potential is found to be V0. If the distance between the light source and the cell is made 20cm, what will be the new cut off potential?
12. An electron and an alpha particle have same kinetic energy. Which of these particles has the shortest de- Broglie wavelength? Explain.
13. Find the ratio of wavelength of a 10 keV photon to that of a 10 keV electron.
14. A proton and an alpha particle are accelerated through the same potential difference. Find the ratio of the wavelengths associated with the two.
15. Why macroscopic objects in our daily life do not show wave like properties?
16. The two lines A and B shown in the graph plot the de-Broglie wavelength λ as function of 1/ √V (V is the accelerating potential) for two particles having the same charge. Which of the two represents the particle of heavier mass?



UNIT 8,Chapter 12 – ATOMS

- Eletcron was discovered by J J Thomson.
- All atoms radiate different light spectra which show these atoms are different and may be the smallest particles.
- Different atomic models such as plum-pudding model, Rutherford's atomic model, Bohr's atomic model, Somerfield's atomic model etc.
- Geiger Marsden experimentally proved Rutherford's atomic model.
- Radioactive element $_{83}Bi^{214}$ was taken as α- particles generating source. Detector was made od Zns.
- Existance of nucleus ---- from Rutherford's experiment.
- How the electrons revolve around the nucleus given by Neils Bohr.
- The atom shows range of spectral lines. Hydrogen is the simplest atom and has the simplest spectrum.
- The spacing between lines within certain Sets of hydrogen spectrum decreases in a regular way. Each of these sets is called a spectral series.
- These series are Lyman, Balmer, Paschen, Bracket and Pfund series etc.
- Drawbacks of Rutherford's atomic model (i) it could not explain the stability of the atom and (ii) It could not explain nature of energy spectrum.
- Bohr's atomic model is for hydrogen like atoms.

SECTION A

Q1. Calculate radius of first orbit of singly ionized He atom, when radius of first orbit of hydrogen atom is $0.53A^0$.

Ans. Radius = $R_h/Z = 0.265A^0$

Q2. The energy of electron in first orbit of hydrogen atom is -13.6eV. What will be the energy of doubly ionised $_3Li^7$ atom in the first orbit?

Ans. Z =3 and n=1 then E = -13.6 eV x Z^2 / n^2

= -122.4eV

Q3. Find the ground state energy of an electron in case of ionised $_3Li^7$ atom.

Ans. Z =3 and n=1 then E = -13.6 eV x Z^2 / n^2

= -122.4eV

Q4. Name the series of Hydrogen spectrum which lies in visible region.

Ans. Balmer series

Q5. Find the ratio of radii of orbits corresponding to first and second excited state of Hydrogen atom.

Ans. $R1/R_2 = (2/3)^2 = 4/9$

Q6. Name the spectral series of Hydrogen atom lie in UV region.

Ans. Lyman series

Q7.Why did Thomson atom model fail?

Ans. This model could not explain Scattering of α- particle through large angles.

Q8. When is H_α line of Balmer series in the emission spectrum of Hydrogen atom obtained?

Ans. H_α line of Balmer series is obtained when an electron jumps to second orbit from third orbit of Hydrogen atom.

Q9. What is the energy possessed by an electron for n = infinity.

Ans. Zero

Q10. What is the ionisation potential of Hydrogen atom?

Ans. 13.6eV

SECTION B (2 Marks)

Q11. In a Geiger Marsden experiment, what is the distance of closest approach to the gold nucleus of a 7.7 MeV alpha particle before it comes to rest momentarily and reverses its direction?

Ans. $KE = 7.7 \times 1.6 \times 10^{13}$ J

$Z = 79$ for gold, $r_0 = ?$

Radius = k (Ze) x (2e) / KE

(Where $k = 9.0 \times 10^{9}\ N\ m^2/C^2$)

$= 29.5 \times 10^{-15}$m

Q 12. Energy of electron in first excited state of hydrogen atom is -3.4 eV. Find KE and PE of electron in ground state.

Ans. For first excited state n =2

Total energy of electron in ground state = -3.4 eV (2)2 = -13.6 eV

KE = 13.6 eV

PE = -2 x 13.6 eV = -27.2 eV

Q13. Define distance of closest approach and impact parameter.

Ans. Distance of closest approach is the distance between the centre of the nucleus and the point from which the alpha particle approaching directly to the nucleus returns.

Impact parameter is the perpendicular distance of the velocity vector of the alpha particle from the central line of the nucleus, when the particle is far away from the atom.

SECTION C (3 Marks)

Q14. Define distance of closest approach. A hydrogen atom initially in the ground state absorbs a photon which excites it to the n = 4 level. Find the frequency of the photon.

Ans . For ground state n1 = 1 and n2 = 4

As E = E2 – E1

Or $h\nu = -13.6/(4)^2 - (-13.6/1^2)$

Or $h\nu = -0.85 + 13.6 = 12.75$ eV

Or $h\nu = 12.75 \times 1.6 \times 10^{-19}$ J

Or $\nu = 12.75 \times 1.6 \times 10^{-19}$ J / 6.6×10^{-34}

Thus $\nu = 3.09 \times 10^{15}$ Hz

Q15. Define ionization potential. What is the shortest wavelength present in the Paschen series of spectral lines?

Ans. From Rydberg formula $h\nu = 13.6 \times 1.6 \times 10\text{-}19\ [1/n1^2 - 1/n2^2]$

For shortest wavelength n1 = 3 and n2 = Infinity

From Rydberg formula $hc/\lambda = 2.42 \times 10^{-19}$

Wavelength $\lambda = 818.18$ m

Q16. The total energy of electron in the first excited state of hydrogen atom is -3.4eV.

(a) What is kinetic energy of electron in this state?

(b) What is potential energy of electron in this state?

(c) Which of the answers above would change if the choice of zero of potential energy is changed?

Ans. KE = $k Z e^2/(2r)$

PE = $-k Z e^2/(r)$

PE = - 2 KE

And Total energy = PE + KE = -KE

(a) TE = -3.4 eV, KE = 3.4 eV

(b) PE = - 6.8 eV

(c) If zero of potential energy is changed, KE does not change , however PE and TE will change.

Q17. Explain how Rutherford's experiment on scattering of alpha particle led to the estimation of the size of the nucleus. What is its drawback?

Ans. As most of α – particle passed straight through gold foil and a very few scattered back. It indicates that central part of the atom is + ve and it should be very small part of the atom.

Drawbacks...

(a) It couldn't explain the stability of the atom.

(b) As an electron can move in all possible orbit and should emit continuous energy spectrum.

SECTION D

DIRECTIONS:- Read the following questions and choose any one of the following four responses.

A. If both Assertion and Reason are true and the reason is the correct explanation of the assertion.

B. If both Assertion and Reason are true but the reason is not the correct explanation of the assertion.

C. If Assertion is true but the Reason is false.

D. If both Assertion and Reason are false.

Q18. Assertion – Balmer series lies in visible reason of electromagnetic spectrum.

Reason – Balmer means visible, hence series lies in visible region.

Ans - C

Q19. Assertion – Rydberg's constant varies with mass number of the given element.

Reason – The reduced mass of the electron is dependent on the mass of the nucleus.

Ans - D

Q20. Assertion – Large angle of scattering of alpha particles led to the discovery of atomic nucleus.

Reason – Entire positive charge of atom is concentrated in the central core.

Ans - A

Q21. Assertion – Impact parameter for scattering of alpha particles by 180^0 or zero.

Reason – Zero impact parameter means alpha particle tends to hit to the centre of the nucleus.

Ans - A

Q22. Assertion – Distance of the closest approach of alpha particle to the nucleus is always greater than the size of the nucleus.

Reason – Strong nuclear repulsion does not allow alpha particle to reach the surface of the nucleus.

Ans - A

Q23. Assertion – Energy of an electron in an orbit is independent of n.

Reason – Momentum of an electron revolving in an orbit is directly proportional to n^2.

Ans - D

Q24. Assertion – Wave number is reciprocal of frequency.

Reason – Total energy of an electron revolving in an orbit is always positive.

Ans – D

SECTION E (4 Marks) [CASE STUDY BASED QUESTIONS]

BOHR'S ATOMIC MODEL

To study about atom, various scientists perform various experiments such as Thomson's plum pudding model and Rutherford's alpha particle scattering experiment ,Bohr's atomic model and Sommerfield's atomic model etc. According to Bohr's atomic Model, an atom consists of a small positively –charged nucleus and negatively charged electrons orbits around the nucleus. These orbital's can have different sizes, energies etc. energy is also emitted due to the transitions of electrons from one orbit to another orbit in the form of photons with different frequencies. Expression for wavelength of radiation is given by Rydberg. By this formula wavelengths of different lines like Lyman, Balmer, Paschen, Bracket and Pfund series etc can be calculated.

Q25. The formula which gives the wavelength of emitted photon was given by

(A)Paschen

(B) Rydberg

(C) Balmer

(D) Pfund

Q26. What is true about Bohr's atomic model

(A) This model was unique totally different from other.

(B)This model is modification of Rutherford's atomic model.

(C) This model is modification of Thomson's atomic model.

(D) None of the above.

Q27. Bohr's atomic model is applicable for

(A) All types of atom

(B) Only for hydrogen atom

(C) for hydrogen like atoms

(D) For Helium gas

Q28. The cause of rejection of Rutherford's atomic model was

(A) It was totally wrong.

(B) It could not justify its stability.

(C) R was unable to explain it.utherford

(D) None of the above.

Answers : Q25 --- B,   Q26 --- B,   Q27 … C,   Q28 .. D

PRACTICE TEST (MM –20)

CHAPTER COVERED ---- ATOMS

NOTE: - All questions are compulsory. Q1 to Q 5 is of 1 mark each. Q6 to Q8 is of 2 marks each. Q9 to Q11 is of 3 marks each.

Q1. What is the ionisation potential of Hydrogen atom?

Q2. Define excitation potential. Write its unit also.

Q3. Name the electromagnetic region where Lyman series lies.

Q4. Find the value of angular momentum of an electron revolving in first excited state in Hydrogen atom.

Q5. Write expression for the energy of an electron in Hydrogen atom in terms of n.

Q6. Write two drawbacks of Ruherford's atomic model.

OR

Find the shortest wavelength of Balmer series in Hydrogen atom.

Q7. Define distance of closest approach and impact parameter.

Q8. Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom.

Q9. The total energy of electron in the first excited state of hydrogen atom is -3.4eV.

(a) What is kinetic energy of electron in this state?

(b) What is potential energy of electron in this state?

(c) Which of the answers above would change if the choice of zero of potential energy is changed?

Q10. By using Rutherford's atomic model, derive expression for the Kinetic energy, potential energy and total energy of an electron revolving in hydrogen atom.

Q11. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. Upto which energy level the the hydrogen atom would be excited? Calculate the wavelength of the first member of Lyman and the first member of Balmer series.

UNIT 8,Chapter 13- NUCLEI

- Chadwick discovered Neutron a neutral particle.
- Composition of nucleus – neutron and proton called nucleons.
- Isotopes are the elements having same number of atomic number but different mass number.
- Isobars are the elements having same mass number but different atomic number.
- Isotones have same number of neutrons.
- Size of nucleus Radius $R= R_0 A^{1/3}$ where R_0 = 1.2fermi
- Mass energy relation $E = m \times c^2$ where c = speed of light = 3×10^8 m/c
- Mass defect is the difference in the mass of the nucleus and its constituent.
- In nuclear fission, a heavy nucleus is broken into two smaller nuclei with huge amount of energy.
- Nuclear reactor is based on controlled nuclear fission reaction.
- In nuclear fusion, two smaller nuclei get combine into a big nucleus with huge amount of energy.
- Thermal nuclear fusion reaction is carried out in the sun.

In nuclear reactor, Nuclear fuel -- It is a fissionable material to be used for the fission process to take place. Ex U-233, U-235

Moderator.. Its function to slow down the fast moving secondary neutrons produced during the fission. Heavy water, graphite.

Control rods.. Its ability to capture the slow neutrons. Ex Boron, cadmium rods.

Coolant.. It is a substance used to remove the heat produced and transfer it from the core of the nuclear reactor to the surroundings. Liquid sodium.

SECTION A (1 MARKS)

Q1. Name the absorbing material used to control the reaction rate in nuclear reactor.

Ans. Cadmium rod.

Q2. Name the phenomenon by which energy is produced in the stars.

Ans. Nuclear fusion reactions.

Q3. What is the ratio of nuclear densities of two nuclei having mass numbers in the ratio 1:4?

Ans. 1:1

Q4. Compare the radii of two nuclei with mass numbers 1 and 27 respectively.

Ans. Ratio r1/ r2 = $(A1 /A2)^{1/3}$ = 1/3

Q5. How is nuclear size related to its mass number?

Ans. Radius $r \alpha A^{1/3}$

Q6. Why are heavy nuclei usually unstable?

Ans. Due to large repulsive force between the large numbers of protons in the nucleus.

Q7. What holds nucleon together in a nucleus?

Ans. Nuclear forces amongst the nucleons in a nucleus.

Q8. Two nuclei have mass numbers in the ratio 2:5. What is the ratio of their nuclear densities?

Ans. 1:1

Q9. Nuclera forces are short range forces. Explain.

Ans. They operate upto distances of 10 fermi.

Q10. A fusion reaction is much more energetic than a fission reaction. Comment.

Ans. True. This is because energy released per unit mass of fuel is much higher in fusion than fission.

SECTION B (2 MARKS)

Q11. Write any two characteristics of nuclear force.

Ans . It is charge independent. It is non central force.

Q12. Express 1 Joule in eV. 1 amu = 931MeV

Ans. As 1 eV = 1.6×10^{-19} J

Mass of C-12 atom = 12 amu =12 x 931 MeV

$= 12 \times 931 \times 1.6 \times 10^{-13}$ J

M = 1.986×10^{-26} Kg

Q13. Name two radioactive elements which are not found in observable quantities. Why is it so?

Ans. Tritium and Plutonium are two radioactive elements. This is because their half live s is short.

Q14. Safety of nuclear reactors is an important issue. Guess some of the safety problems that a nuclear engineer must cope within reactor design.

Ans. One of the major safety problems in reactor is that the nuclear waste from the reactor contains some long lived radioactive isotopes. Further, accidents due to excessive heating and melting of the reactor core have to be prevented by designing appropriate cooling systems.

Q15. Why heavy stable nucleus must contain more neutrons than protons?

Ans. Coulomb forces between protons are repulsive and nuclear forces are are ordinarily attractive.. For nuclei is to be stable nuclear force must dominate the repulsive forces. Therefore the number of neutrons must be greater than the number of protons.

Q16. Calculate the energy equivalent of 1amu in MeV.

Ans. Energy $E = m c^2$

M = 1.67×10^{-27}kg

E = $1.67 \times 10^{-27} \times (3 \times 10^{8})2/1.6 \times 10^{-13}$

= 933.75 MeV

SECTION C (3 MARKS)

Q17. Define isotopes. A chain reaction dies out some times , why?

Ans. Isotope are the elements having same atomic number but different mass number.

A chain reaction may die out due to any of the following reasons:

1. size of fissionable material may be less than the critical size.

2. mass of the fissionable materialmay be less than the critical mass.

3. Neutron absorbing material might absorb neutrons at a faster rate than the rate at which they are being produced.

Q18. Define nuclear fusion. Nuclear fusion is not possible in laboratory. Explain.

Ans. In nuclear fusion reaction, two or more than two smaller nucei get combine together to more stable nucleus. Nuclear fusion is not possible in laboratory because it requires very high temperature such as 10^6 to 10^7K. Such high temperature are often generated in nuclear fission. That is why fission precedes fusion. These processes cannot be carried out in laboratory.

Q19. Write the name of reaction on which nuclear reactor is based. Also write the functions of nuclear fuel, moderator, controlling rod and coolant in it with example.nuclear chain reaction.

Ans. It is based upon controlled nuclear fission process.

SECTION D

DIRECTIONS:- Read the following questions and choose any one of the following four responses.

A. If both Assertion and Reason are true and the reason is the correct explanation of the assertion.

B. If both Assertion and Reason are true but the reason is not the correct explanation of the assertion.

C. If Assertion is true but the Reason is false.

D. If both Assertion and Reason are false.

Q20. Assertion – If a heavy nucleus is split into two medium sized parts, each of new nucleus will have more binding energy per nucleon than the original nucleus.

Reason – Joining two light nuclei together to give a single nucleus of medium size means more binding energy per nucleon in new nucleus.

Ans - B

Q21. Assertion – In the process of nuclear fission, the fragments emit two or three neutrons as soon as they are formed and subsequently emit particles.

Reason – As the fragments contain an excess of neutrons over protons, emission of neutrons and particles bring their neutron / proton ratio to stable values.

Ans – A

Q22. Assertion – fragments produced in the fission of U-235 are active.

Reason – the fragments have abnormally high proton to neutron ratio.

Ans - D

Q23. Assertion – Nuclei of different atoms have same size.

Reason – Volume of nucleus is proportional to $A^{1/3}$.

Ans - D

Q24. Assertion – Density of nuclear matter is same for all nuclei.

Reason – Density has nothing to do with mass and size of the nucleus.

Ans - B

Q25. Assertion – isotopes are the elements having same mass number.

Reason –Isobars are the elements having same atomic number.

Ans - D

Q26. Assertion – Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion.

Reason – For heavy nuclei, binding energy per nucleon increases with increasing atomic number while for light nuclei, it decreases with increasing Z.

Ans - A

SECTION E (4 Marks) [CASE STUDY BASED QUESTIONS**]**

NUCLEAR ENERGY

As per the population rise in our country, energy demand is also increasing especially the electrical energy. For fulfilment of such demand, one of the option is to utilize nuclear sources. Nuclear energy is obtained through the nuclear fission process, where a bi nucleus gets split into two or more than two smaller nuclei along with tremendous amount of energy. This energy can be used for either constructive purpose or destructive purpose for the humans. Nuclear reaction is of two types- nuclear fission and nuclear fusion. In nuclear reactor , controlled nuclear fission reaction is carried out.

Q27. The process taking out in the sun, due which we get light and heat energy

(A) Nuclear fission

(B) Nuclear fusion

(C) Thermal reactions

(D) Nuclear holocaust

Q28.The atomic energy programme in our country was launched under the leadership of

(A) C V Raman

(B) H J Bhabha

(C) A P J Abdul Kalam

(D) Amit Bhatnagar

Q29. The temperature of the core of the sun is about

(A) 10^3 to 10^4K

(B) 10^6 to 10^7K

(C) 10^9 to 10^{10}K

(D) None of the above

Q30. To slow down the fast moving neutrons in nuclear reactor by

(A) Control rods

(B) Moderator

(C) Coolant

(D) Plasamon

Ans:--- Q27 … B, Q28 .. B, Q29 .. B, Q30 .. B

PRACTICE TEST (MM –20)

CHAPTER COVERED --- NUCLEI

NOTE: - All questions are compulsory. Q1 to Q 5 is of 1 mark each. Q6 to Q8 is of 2 marks each. Q9 to Q11 is of 3 marks each.

Q1. Define isobar. Write its one example.

Q2. Define coolant.

Q3. Compare the radii of two nuclei with mass numbers 1 and 27 respectively.

Q4. Why are heavy nuclei usually unstable?

Q5. Name the absorbing material used to control the reaction rate in nuclear reactor.

Q6.Prove that nuclear density of nuclei remains almost same for all nuclei.

Q7. Why heavy stable nucleus must contain more neutrons than protons?

Q8. Define mass defect. Write its formula.

Q9. Write any three differences between nuclear fission and nuclear fusion.

Q10. Define isotopes. A chain reaction dies out some times , why? Give any three possibilities.

Q11. Write the functions of Moderator, Controlling rods, Coolant in Nuclear reactor. Also write two uses of nuclear reactor.

UNIT 9, CHAPTER 14: ELECTRONIC DEVICES

- In metals, the conduction band and valence band partly overlap each other and there is no forbidden energy gap.
- In insulators, the conduction band is empty and valence band is completely filled and forbidden gap is quite large = 6 eV. No electron from valence band can cross over to conduction band at room temperature, even if electric field is applied. Hence there is no conductivity of the insulators.
- In semiconductors, the conduction band is empty and valence band is totally filled. But the forbidden gap between conduction band and valence band is quite small, which is about 1 eV. No electron from valence band can cross over to conduction band. Therefore, the semiconductor behaves as insulator. At room temperature, some electrons in the valence band acquire thermal energy, greater than energy gap of 1 eV and jump over to the conduction band where they are free to move under the influence of even a small electric field. Due to which, the semiconductor acquires small conductivity at room temperature.

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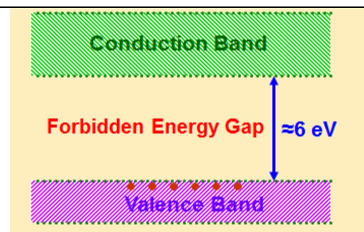
<td>
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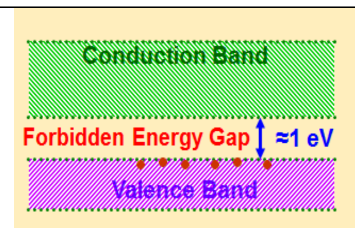
<td>
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Distinction between Intrinsic and Extrinsic Semiconductor:

Intrinsic		Extrinsic	
1	It is pure semiconducting material and no impurity atoms are added to it.	1	It is prepared by doping a small quantity of impurity atoms to the pure semiconducting material.
2	Examples are crystalline forms of pure silicon and germanium.	2	Examples are silicon and germanium crystals with impurity atoms of arsenic, antimony, phosphorous etc. or indium, boron, aluminum etc.
3	The number of free electron in conduction band and the number of holes in valence band is exactly equal and very small indeed.	3	The number of free electrons and holes is never equal. There is excess of electrons in n-type semiconductors and excess of holes in p-type semiconductors.
4	Its electrical conductivity is low	4	Its electrical conductivity is high.

5	Its electrical conductivity is a function of temperature alone.	5	Its electrical conductivity depends upon the temperature as well as on the quantity of impurity atoms doped in the structure.

Distinction between n-type and p-type semiconductors

n-type semiconductors		p-type semiconductors	
1	It is an extrinsic semiconductors which is obtained by doping the impurity atoms of 15^{th} group of periodic table to the pure germanium or silicon semiconductor.	1	It is an intrinsic semiconductors which is obtained by doping the impurity atoms of 13^{th} group of periodic table to the pure germanium or silicon semiconductor.
2	The impurity atoms added, provide extra electrons in the structure, and are called donor atoms.	2	The impurity atoms added, create vacancies of electrons (i.e. holes) in the structure and are called acceptor atoms.
3	The electrons are majority carriers and holes are minority carriers.	3	The holes are majority carriers and electrons are minority carriers.
4	The electron density (n_e) is much greater than the hole density (n_h)i.e. n_e>>(n_h)	4	The hole density (n_h) is much greater than the electron density (n_h)i.e. n_h>> n_e
5	The donor energy level is close to the conduction band and far away from valence band.	5	The acceptor energy level is close to valence band and is far away from the conduction band.
6	The Fermi energy level lies in between the donor energy level and conduction band.	6	The Fermi energy level lies in between the acceptor energy level and valence band.

- **p-n junction diode**

Two important processes occur during the formation of p-n junction diffusion and drift. The motion of majority charge carriers give rise to diffusion current.

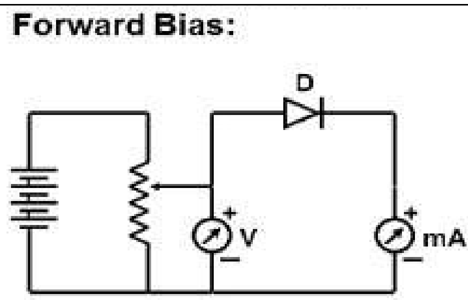
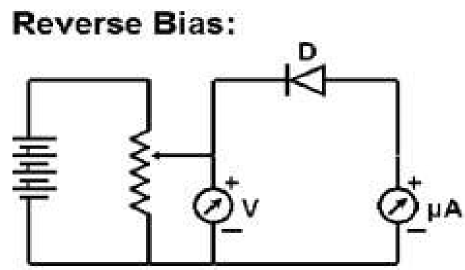
Due to the space charge on n-side junction and negative space charge region on p-side the electric field is set up and potential barrier develops at the junction Due to electric field e- on p-side moves to n and holes from n-side to p-side which is called drift current.

In equilibrium state, there is no current across p-n junction and potential barrier across p-n junction has maximum value .

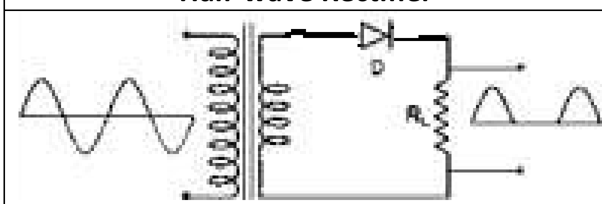
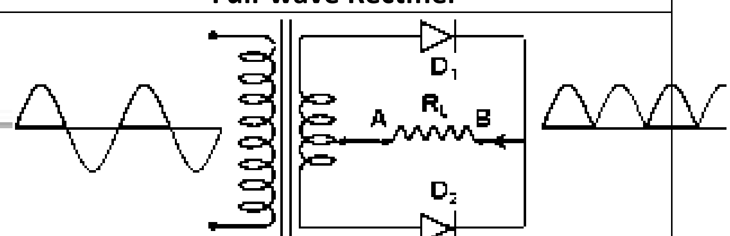
The width of the depletion region and magnitude of barrier potential depends on the nature of semiconductor and doping concentration on two sides of p-n junction.

Forward Bias:
p-n junction is forward bias when p-type connected to the +ve (high potential)of battery and n-type connected to –ve(low potential) battery Potential barrier height is reduced and width of depletion layer decreases.
Reverse Bias:
p-n junction is reverse bias bias when p-type connected to the -ve (low potential)of battery and n-type connected to +ve(high potential) battery Potential barrier height is increased and width of depletion layer increases.

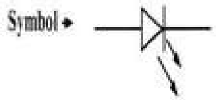
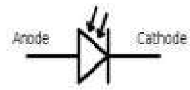
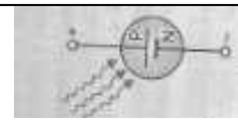
Circuit diagrams:

Forward Bias	Reverse Bias
	

Rectifier:
The Device is used to converting alternating current to direct current is called rectifier and the process of conversion of AC into DC is called rectification. The unidirectional property of a diode enables it to be used as a rectifier.
The p-n junction diode can be used as
(i) a half-wave rectifier
(ii) a full wave rectifier

Half-wave Rectifier	Full-wave Rectifier
	

Special purpose Diodes:

LED	PHOTODIODE	SOLARCELL
		
Forward biased	Reverse biased	No external baising,It generates emf when solar radiation falls on it.
Recombination of electrons and holes take place at the junction and emits electromagnetic radiations.	Energy is supplied by light to take an electron from valence band to conduction band.	Generation of emf by solar cells is due to three basic process generation of e-h pair, separation and collection.
It is used in Burglar alarm, remote Control	It is used in photo detectors in Communication.	It is used in satellites, space vehicles calculators.

Very Short Answer Type Questions (1 Mark)

1. At what temperature would an intrinsic semiconductor behave like a perfect insulator?

2. How does the energy band gap vary in a semiconductor when doped with penta-valent element?

3. How does the conductivity change with temperature in semiconductor?

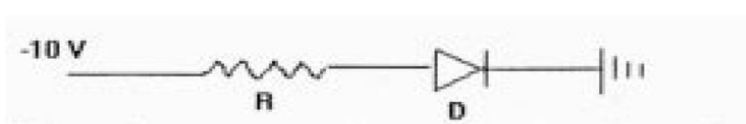
4. What type of semiconductor we get when: (i) Ge is doped with Indium? and (ii) Si is doped with As?

5. How does the width of depletion layer change, in reverse bias of a p-n junction diode?

6. In a semiconductor concentration of electron is $8 \times 10^{13} cm^{-3}$ and holes $5 \times 10^{12} cm^{-2}$: is it p or n- type semiconductor?

7. Energy gap of a conductor, semiconductor, insulator are E_1, E_2, E_3 respectively. Arrange them in increasing order.

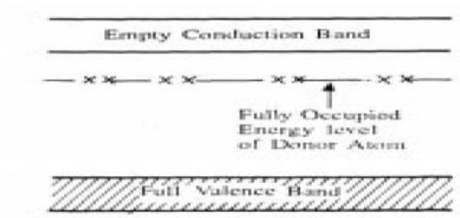
8. In a given diagram, is the diode reverse or forward biased?

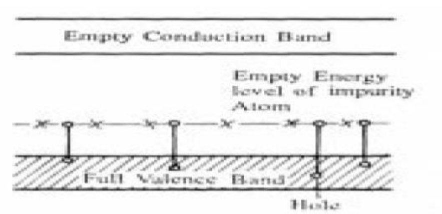


9. Why semiconductors are opaque to visible light but transparent to infrared radiations?

10. The ratio of number of free electrons to holes n_e/n_h for two different materials A and B are 1 and <1 respectively. Name the type of semiconductor to which A and B belongs.

11. Differentiate the electrical conductivity of both types of extrinsic semiconductors in terms of the energy band picture.





12. What is an ideal diode?

13. In a full wave rectification what is the output frequency of pulsating DC if input frequency is 60 Hz?

14. A junction diode has an avalanche breakdown. Is it heavily or lightly doped?

15. How much is the resistance of a p-n junction when it is reverse biased?

Answers (Very Short Answer Type Questions,1 Mark)

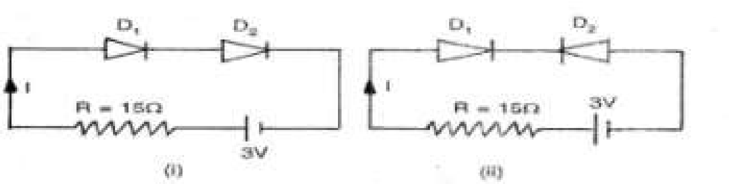
1. 0 K
2. Decreases
3. conductivity increases with increase temperature in semiconductor
4. (i) p-type (ii) n-type
5. Decreases
6. n- type semiconductor
7. $E_1 < E_2 < E_3$
8. Reverse biased
9. The photons of infrared radiation have smaller energies, so they fall to excite the electrons in the valence band. Hence infrared radiations pass through the semiconductors as such; i.e. a semiconductor is transparent to infrared radiation.

10. If $n_e/n_h=1$. Hence A is intrinsic semiconductor. If $n_e/n_h<1$, $n_e<n_h$ hence B is p-type.
11. (i) n-type (ii) p-type
12. Ideal diode is a diode which offers zero resistance in forward biasing and infinite resistance in reverse bias.
13. 120 Hz
14. Lightly doped
15. Very high of the order of few k Ω.

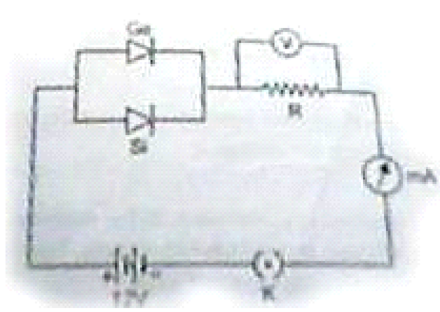
Short Answer Type 1 Questions (2 Mark)

1. State the factor which controls wave length and intensity of light emitted by LED.
2. With the help of a diagram show the biasing of light emitting diode. Give two advantages over conventional incandescent Lamp.
3. A semiconductor has equal electron and hole concentrations of $6x10^8m^{-3}$.On doping with a certain impurity, the electron concentration increases to $9x10^{12}m^{-3}$.

   Identify the new semiconductor obtained after doping.Calculate the new hole concentrations.
4. Determine the current through resistance "R" in each circuit. Diodes D_1 and D_2 are identical and ideal.



5. Germanium and silicon junction diodes are connected in parallel. A resistance R, a 12 V battery, a milli ammeter (mA) and Key (K) is closed, a current began to flow in the circuit. What will be the maximum reading of voltmeter connected across the resistance R?



6. A germanium diode is preferred to a silicon one for rectifying small voltages. Explain why?
7. A photodiode is fabricated from a semiconductor with a band gap of 2.8eV.Can it detect a wavelength of 600nm? Justify.

Answers (Short Answer Type 1 Questions, 2 Mark)

1. (i)Nature of semi-conductor (ii) Forward Current
2. Mono chromatic, Consume less power, Very less reaction time
3. (i) n-type semiconductor. (ii) $n_e n_h = n_i^2$

   ⇨ $n_h = \frac{6 \times 10^8 \times 6 \times 10^8}{9 \times 10^{12}} = 4 \times 10^4\ m^{-3}$
4. In circuit (i) Both D_1 and D_2 are forward biased hence both will conduct current and resistance of each diode is "0".Therefore I = 3/15 = 0.2 A
   Diode D_1 is forward bias and D_2 is reverse bias, therefore resistance of diode D1 is "0" and resistance of D_2 is infinite. Hence D_1 will conduct and D_2 do not conduct. No current flows in the circuit.
5. The potential barrier of germanium junction diode is 0.3v and silicon is 0.7V, both are forward biased. Therefore for conduction the minimum potential difference across junction diode is 0.3V.Max.reading of voltmeter connected across R=12-0.3=11.7V.
6. Because the energy gap for Ge (Eg = 0.7 ev) is smaller than the energy gap for Si (Eg = 1.1eV) or barrier potential for Ge<Si.
7. Energy corresponding to wavelength 600 nm is …
   $E=hc/\lambda = 6.6 \times 10^{-34} \times 3 \times 10^8 / 600 \times 10^{-9} \times 1.6 \times 10^{-19} = 0.2eV$
   It cannot detect because E<Eg

Short Answer Type 2 Questions (3 Mark)

1. Draw energy band diagrams of n-type and p-type semiconductors. Also write two differences between n-type and p-type semiconductors.

2. (a) Explain how a potential barrier is developed in a p-n junction diode.

(b) Draw the circuit arrangements for studying the V-I characteristics of a p-n junction diode in reverse bias. Plot the V-I characteristics in this case.

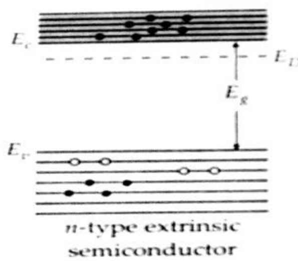
3. Draw a circuit diagram of full-wave rectifier. Write its working principle. Draw input and output waveform.

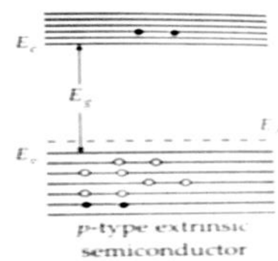
4. (a) Draw a diagram of an illuminated p-n junction solar cell.

(b) Explain briefly the three processes due to which generation of emf takes place in a solar cell.

Answers (Short Answer Type 2 Questions, 3 Mark)

1.

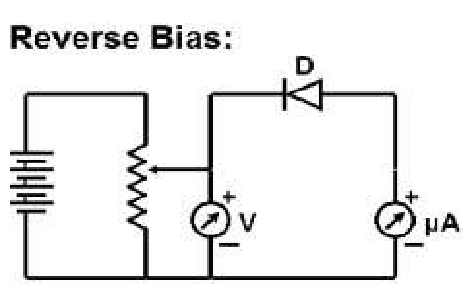


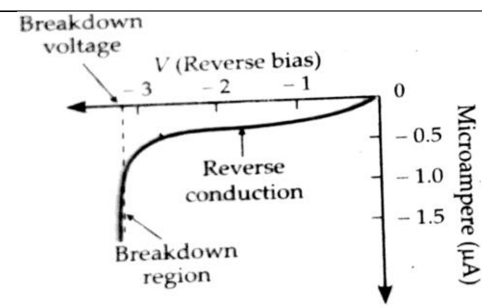


Two differences:

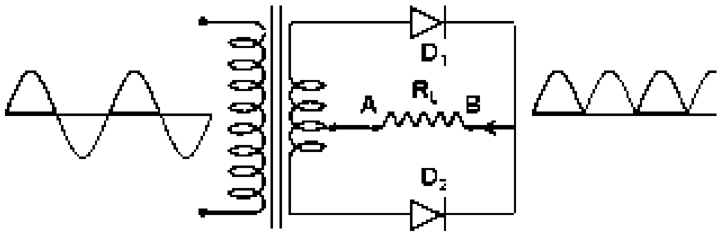
n-type semiconductors	p-type semiconductors
It is an extrinsic semiconductors which is obtained by doping the impurity atoms of 15th group of periodic table to the pure germanium or silicon semiconductor.	It is an intrinsic semiconductors which is obtained by doping the impurity atoms of 13th group of periodic table to the pure germanium or silicon semiconductor.
The impurity atoms added, provide extra electrons in the structure, and are called donor atoms.	The impurity atoms added, create vacancies of electrons (i.e. holes) in the structure and are called acceptor atoms.

2. (a). Two important processes occur during the formation of p-n junction diffusion and drift. The motion of majority charge carriers give rise to diffusion current.
Due to the space charge on n-side junction and negative space charge region on p-side the electric field is set up and potential barrier develops at the junction Due to electric field e- on p-side moves to n and holes from n-side to p-side which is called drift current.
In equilibrium state, there is no current across p-n junction and potential barrier across p-n juncion has maximum value .
The width of the depletion region and magnitude of barrier potential depends on the nature of semiconductor and doping concentration on two sides of p-n junction.
(b).



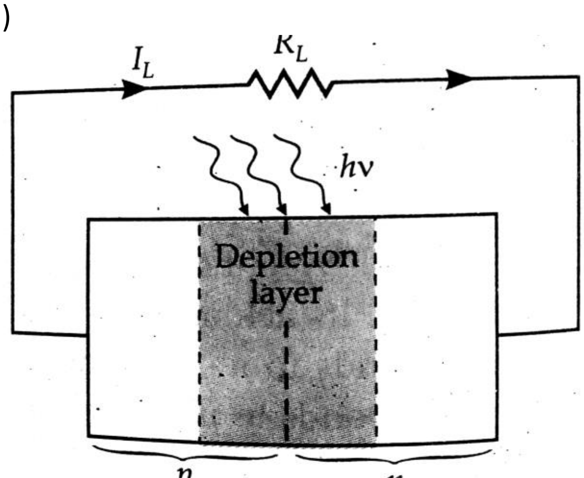


3.



Principle: When a p-n junction diode is forward biased, it offers less resistance and a current flows through it; but when it is reverse biased, it offers high resistance and almost no current flows through it. This unidirectional property of a diode enables it to be used as a rectifier.

4. (a)



(a)

(b) **Generation**:Incident light generates electron-hole pairs.
Separation:Electric field of the deletion layer separates the electrons and holes
Collections: Electrons reaching the n-sides are collected by the front contact and holes reaching the p-side are collected by the back contact.

Assertion & Reason type Question

Directions: In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it. Of the statements, mark the correct answer as:

(A)If both assertion and reason are true and reason is the correct explanation of assertion

(B)If both assertion and reason are true but reason is not the correct explanation of assertion

(C)If assertion is true and reason is false

(D)If both assertion and reason are false

1. Assertion (A): A Pure semiconductor has negative temperature coefficient of resistance.

Reason (R): On raising the temperature, more charge carriers are released, conductance increases and resistance decreases.

2. Assertion (A): At a fix temperature, silicon will have a minimum conductivity when it has a smaller accepter doping.

   Reason (R): The conductivity of and intrinsic semiconductor is slightly higher than of a lightly doped p-type.
3. Assertion (A): The electrons in the conduction band have higher energy than those in the valance band of a semi-conductor.

   Reason (R): The conduction band lies above the energy gap and valance band lies below the energy gap.
4. Assertion (A): The energy gap between the valance band and conduction band is greater in silicon than a germanium.

   Reason (R): Thermal energy produces fewer minority carriers in silicon than in germanium.
5. Assertion (A): p- n junction diode can be used even at ultra-high frequencies.

   Reason (R): Capacitative reactance p- n junction diode increases as frequency increases.
6. Assertion (A): The colour of light emitted by LED depends on its forward biasing.

   Reason (R): The reverse biasing of p-n junction will lower the width of depletion layer.
7. Assertion (A) : The number of electrons in a p- type silicon semi-conductor is less than the number of electrons in a pure silicon semiconductor at room temperature.
8. Reason (R): It is due to law of mass action.
9. Assertion (A): Electron has higher mobility than hole in a semiconductor. Reason (R): Mass of electron is less than the mass of hole.
10. Assertion (A): An n type semiconductor has a large number of electrons but still it is electrically neutral.

CASE STUDY BASED QUESTION

1. **SEMICONDUCTOR:**

   A pure semiconductor germanium or silicon, free of every impurity is called intrinsic semiconductor. At room temperature, a pure semiconductor has very small number of current carriers (electrons and holes),Hence its conductivity is low.

When the impurity atoms of valance five or three are doped in a pure semiconductor, we get respectively n- type or p- type extrinsic semiconductor. In case of doped semiconductor ne $n_h=n_i^2$. Where n_e and n_h are the number density of electron and hole charge carriers in a pure semiconductor. The conductivity of extrinsic semiconductor is much higher than that of intrinsic semiconductor.

Answer the following questions:

1. Which of the following statements is not true?

a. The resistance of intrinsic semiconductor decreases with increase of temperature.

b. Doping pures Si with trivalent impurities gives p- type semiconductors.

c. The majority charges in n- type semiconductors are holes.

d. A p-n junction can act as semiconductor diode.

2. The impurity atoms with which pure Si should be doped to make a p- type semiconductor is

a. Phosphorus
b. Boron
c. Arsenic
d. Antimony

3. Holes are majority charge carriers in

a. Intrinsic semiconductors.
b. Ionic Solids
c. p- type semiconductors
d. Metals

4. At absolute zero, Si acts as

a. Non- metal
b. Metal
c. Insulator
d. None of these

Answers

1. (c) The majority Charge carriers in n-type semiconductor as holes
2. (b) BORON
3. (c) p-type semiconductors
4. (c) Insulators

2. **Rectifiers :**

A semiconductor device is used as a rectifier that allows the voltage to flow in positive direction and very small value in the reverse direction. Now a days, there is a problem of supply of less voltage that damages the household appliances.

1. In the depletion region of a diode

3. There are no mobile charges
4. Equal number of holes and electrons exist, making the region neutral.
5. Recombination of holes and electrons has taken place.
6. Immobile charge ions exist.

2.When a p-n junction diode is reverse biased then

a. No Current flows

b. The depletion reason is increased

c. The depletion reason is reduced

d. Height of potential
barrier is reduced

3. Diode is used as

a. Oscillator

b. Amplifier

c. Rectifier

d. Modulator

4.Which one statement is incorrect?

a. Diode is used as rectifier

b. Diode is used as half wave rectifier

c. Diode is used as Amplifier

d. Diode is used as full wave rectifier

Answers:

1. (d)
2. (b)
3. (c)
4. (c)

PRACTICE QUESTIONS

1. What is the order of energy band gap in an intrinsic semiconductor?
2. Draw energy gap diagram of a p- type semiconductor?
3. Why Photo diode usually operated at reverse bias?
4. Name the factor that determines the element as a conductor or semiconductor?
5. Name the two important processes involved in the formation of a p-n junction diode.
6. Name the optoelectronic device used for detecting optical signals and mention the biasing in which it is operated.
7. On the basis of energy band diagrams, distinguish between metals, insulators and semiconductors.
8. Draw the V-I characteristics for (a) Photo diode (b) LED and (c) photo diodes.
9. With the help of a diagram, show the biasing of a light emitting diode and explain its action. Give its two advantages over conventional incandescent lamps.
10. What is half wave rectifier? Write its working principle. Draw its diagram and also draw its input and output waveform.

Directions: In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it. Of the statements, mark the correct answer as:

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14. Assertion (A): p- n junction diode can be used even at ultra-high frequencies.

Reason (R): Capacitative reactance p- n junction diode increases as frequency increases.

15. **p-n junction diode** :

p-n junction is a semiconductor diode. It is obtained by bringing p-type semiconductor in close contact with n- type semiconductor. A thin layer is developed at the p- n junction which is devoid of any charge carrier but has immobile ions. It is called depletion layer. At the junction a potential barrier appears, which does not allow the movement of majority charge carriers across the junction in the absence of any biasing of the junction. p-n junction offers low resistance when forward biased and high resistance when reverse biased.

1. In the middle of depletion layer of reverse biased p- n junction, the

a. Electric field is zero
b. Potential is zero
c. Potential is maximum
d. Electric field is maximum

2. The energy band gap is maximum in

a. Metals
b. Superconductors
c. Insulators
d. Semiconductors

3. The number of majority carriers crossing the junction of diode depends primarily on the

a. Concentration of doping impurities
b. Magnitude of potential barriers
c. Magnitude of the forward bias voltage
d. Rate of thermal generation of

electron –hole pairs Q 4. Hole is

a. Antiparticle of electron
b. A vacancy created when an electron leaves covalent bond
c. Absence of free electrons
d. An artificially created particle.