FREQUENTLY ASKED QUESTIONS

SUBJECT-PHYSICS

CLASS-XII

SUNEEL KUMAR VISHWAKARMA

PGT (PHYSICS)

K V NO.1 AFS CHAKERI KANPUR

Suneel19761976@gmail.com

Mobile No. 7523988747

"For fruitful discussion and feedback, Students may call between 6:00 PM to 7:00 PM"

CLASS XII (2019-20)

(THEORY)

Time: 3 hrs. Max Marks: 70

		No. of Periods	Marks
Unit–I	**Electrostatics**	22	16
	Chapter–1: Electric Charges and Fields		
	Chapter–2: Electrostatic Potential and Capacitance		
Unit-II	**Current Electricity**	20	
	Chapter–3: Current Electricity		
Unit-III	**Magnetic Effects of Current and Magnetism**	22	17
	Chapter–4: Moving Charges and Magnetism		
	Chapter–5: Magnetism and Matter		
Unit-IV	**Electromagnetic Induction and Alternating Currents**	20	
	Chapter–6: Electromagnetic Induction		
	Chapter–7: Alternating Current		
Unit–V	**Electromagnetic Waves**	04	18
	Chapter–8: Electromagnetic Waves		
Unit–VI	**Optics**	27	
	Chapter–9: Ray Optics and Optical Instruments		
	Chapter–10: Wave Optics		
Unit–VII	**Dual Nature of Radiation and Matter**	08	12
	Chapter–11: Dual Nature of Radiation and Matter		
Unit–VIII	**Atoms and Nuclei**	15	
	Chapter–12: Atoms		
	Chapter–13: Nuclei		
Unit–IX	**Electronic Devices**	12	7
	Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuits		
Total		**150**	**70**

Unit I: Electrostatics **22 Periods**

Chapter–1: Electric Charges and Fields

Electric Charges; Conservation of charge, Coulomb's law-force between two point charges, forces between multiple charges; superposition principle and continuous charge distribution.

Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric field.

Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).

Chapter–2: Electrostatic Potential and Capacitance

Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges; equipotential surfaces, electrical potential energy of a system of two point charges and of electric dipole in an electrostatic field.

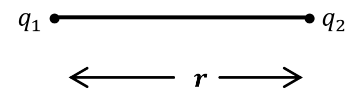
Conductors and insulators, free charges and bound charges inside a conductor. Dielectrics and electric polarisation, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of a parallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor.

101. State Coulomb's law in electrostatics. **CBSE(F)-2003,(AIC)-2001**

[Ans. Coulomb's law : The electrostatic force of attraction or repulsion between any two stationary point charges is directly proportional to the product of magnitude of charges and is inversely proportional to the square of the distance between them.

i,e, $F \propto \frac{q_1\, q_2}{r^2}$

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



102. Write Coulomb's law in vector form. What is the importance of expressing it in vector form ? **CBSE (AIC)-2011**

[Ans. Coulomb's law in vector form :

$$\vec{F} = \frac{1}{4\pi\, \varepsilon_0} \frac{q_1\, q_2}{r^2}\, \hat{\boldsymbol{r}} = \frac{1}{4\pi\, \varepsilon_0} \frac{q_1\, q_2}{r^2} \frac{\vec{r}}{|r|} = \frac{1}{4\pi\, \varepsilon_0} \frac{q_1\, q_2}{r^2} \frac{\vec{r}}{r^3}$$

Importance : (i) As $\hat{\boldsymbol{r}}_{21} = -\,\hat{\boldsymbol{r}}_{12}$ $\Rightarrow$ $\vec{F}_{21} = -\vec{F}_{12}$

Which shows that coulomb's force obey Newton's third law of motion

(ii) As the Coulomb's force acts along $\vec{F}_{21}$ or $-\vec{F}_{12,}$ i,e, along the line joining the centres of two charges, so they are central forces

103. Write any two limitations of Coulomb's law. **CBSE (AIC)-2001**

[Ans. (i) charges must be stationary point charges

(ii) distance between the point charges $r > 10^{-15}\, m$

104. (a) Name any two basic properties of electric charge.

(b) What does $q_1 + q_2 = 0$ signify in electrostatics ? **CBSE(F)-2003,(AIC)-2001**

[Ans. (a) (i) Quantization of charge (ii) Conservation of charge

(b) It signifies that charges are algebraically additive and here q_1 & q_2 are equal and opposite

105. Is the force acting between two point electric charges q_1 and q_2 kept at some distance apart in air, attractive or repulsive when (a) $q_1\, q_2 > 0$ (b) $q_1\, q_2 < 0$? **CBSE (F)-2007,2003**

[Ans. (a) when $q_1 q_2 > 0$, force is repulsive

(b) when $q_1 q_2 < 0$, force is attractive

106. Two insulated charged copper spheres A and B of identical size have charges q_A and $-3q_A$ respectively. When they are brought in contact with each other and then separated, what are the new charges on them ? **CBSE (F)-2011**

[Ans. Charge on each sphere $= \frac{q_1 + q_2}{2} = \frac{q_A\ -3q_A}{2} = -\, q_A$

107. Define dielectric constant of a medium in terms of force between electric charges. What is its S.I. unit ? **CBSE (AI)-2015**

[Ans. Dielectric constant : It is defined as the ratio of the force (F_{vacuum}) between any two point charges placed at certain distance apart in vacuum to the force (F_{medium}) between them when placed at equal distance in that medium

i,e, $K = \frac{F_{vacuum}}{F_{medium}}$ It has no unit

108. How does the Coulomb force between two point charges depend upon the dielectric constant of the intervening medium ?

[Ans. $F = \frac{1}{4\pi\, \varepsilon_0\, K} \frac{q_1\, q_2}{r^2}$ $\Rightarrow$ $F \propto \frac{1}{K}$ **CBSE (AI)-2005**

Coulomb's force varies inversely with the dielectric constant of medium

109. Two same balls having 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 ? **CBSE (AI)-2014**

[Ans. $F = \frac{1}{4\pi\, \varepsilon_0\, K} \frac{q_1\, q_2}{r^2}$ $\Rightarrow$ $F \propto \frac{1}{K}$ But for plastic $K > 1$ hence the force between the two balls will decrease

110. Force between two point electric charges kept at a distance d apart in air is F. If the charges are kept at the same distance in water, how does the force between them change ? **CBSE (AI)-2011**

[Ans. $F_{water} = \frac{F_{air}}{K} = \frac{F}{80}$

111. Two point charges having equal charges separated by $1m$ distance experience a force of $8N$. What will be the force experienced by them, if they are held in water, at the same distance ? $(Given : K_{water} = 80\,)$ **CBSE (AIC)-2011**

[Ans. $F_{water} = \frac{F_{air}}{K} = \frac{8}{80} = 0.1N$

112. Does the charge given to a metallic sphere depend on whether it is hollow or solid ? Give reason for your answer.
[Ans. No, Because the charge resides only at the surface of conductor **CBSE (D)-2017**

113. A comb run through one's dry hair attracts small bits of paper. Why ? What happens if the hair is wet or if it is a rainy day ? **NCERT-2017**
[Ans. When a comb is run through dry hair, it gets charged due to friction. Molecules in the paper gets polarized by the charged comb resulting in a net force of attraction. If the hair is wet or it is a rainy day, friction reduces, comb does not get charged and thus it will not attract small bits of paper

114.Define electric field intensity. Write its S.I. unit. Is it a scalar or vector quantity ? **CBSE (D)-2007**
[Ans. Electric field intensity : Electric field intensity at any point is defined as the electrostatic force acting on vanishingly small unit positive test charge placed at that point

i,e, $\vec{E} = \lim_{q_0 \to 0} \frac{\vec{F}}{q_0}$ Its. S.I. unit is N/C. It is a vector quantity.

115. The electric field intensity at any point is defined as $\lim_{q_0 \to 0} \frac{F}{q_0}$. What is the physical significance of the term $\lim_{q_0 \to 0}$ in this expression ? **CBSE (D)-2007**
[Ans. The term $\lim_{q_0 \to 0}$ indicates that the test charge q_0 is small enough so that its presence does not affect the distribution of source charge and hence does not change the value of electric field

116. (i) What is the physical significance of electric field ?
(ii) Write an expression for force acting on a test charge q_0 placed in a uniform electric field. **CBSE (D)-2007**
[Ans. (i) It gives the magnitude & direction of electric force $(\vec{F})$ experienced by any charge placed at any point.
(ii) $\vec{F} = q_0 \vec{E}$

117. A proton is placed in a uniform electric field directed along the positive x-axis. In which direction will it tend to move ?
[Ans. + x-axis, i,e, along the direction of electric field **CBSE (DC)-2011**

118. Why must electrostatic field at the surface of a charged conductor be normal to the surface at every point ? Give reason. **CBSE (AI)-2015,2002,(F)-2014,(AIC)-2002**
[Ans. $\vec{E}.\vec{dr} = dV$ but at the surface of a conductor $V =$ constant
⇨ $\vec{E}.\vec{dr} = 0$ ⇨ $E\,dr\,\cos\theta = 0$ ⇨ $\theta = 90^0$
Hence electric field at the surface of a charged conductor is always normal to the surface at every point

119. Define electric potential at a point. Write its S.I. unit. Is potential a scalar or vector ? **CBSE (AI)-2015**
[Ans. Electric Potential (V) : Electric potential at any point in an electric field may be defined as the work done by an external force in bringing a unit positive charge from infinity to that point

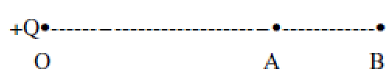
i,e, $V_A = \frac{W_{\infty A}}{q_0}$ It's S.I. unit is J/C or Volts (V) . It is a scalar quantity.

120.Name the physical quantity whose S.I. unit is JC^{-1}. Is it a scalar or vector quantity ? **CBSE (AI)-2010**
[Ans. Potential, it is a scalar quantity

121.Why is the potential inside a hollow spherical charged conductor constant and has the same value as on its surface ?
[Ans. $|E| = \frac{dV}{dr}$ ⇨ $dV = |E|\ dr$ **CBSE (F)-2012,(D)-2012**
As inside the hollow spherical conductor $E = 0$
⇨ $dV = 0$ ⇨ $V =$ constant

122.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 ? **CBSE (AI)-2011**
[Ans. $5\ V$, because potential of a metallic sphere remains unchanged inside the sphere

123. A point charge $+Q$ is placed at a point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero ? **[Ans.** Positive as $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$ ⇨ $V \propto \frac{1}{r}$] **CBSE (D)-2016**



124. Define electric line of force/electric field line. **CBSE (D)-2005,2003**
[Ans. An electric field line may be defined as the imaginary straight or curved path, along which a unit positive, isolated charge would tend to move if free to do so.

125. State any two properties of electric field lines. **CBSE (D)-2005**

[Ans. (i) Electric filed lines not form closed loops. They start from positive charge and end at negative charge
(ii) Tangent to any point on the electric field line gives the direction of electric field at that point
(iii) No two electric field lines can intersect each other
(iv) They are always normal to the surface of a conductor

126. What is the importance of electric field lines ? **CBSE (AIC)-2002**

[Ans. Importance : (i) Tangent to any point on the electric field line gives the direction of electric field at that point
(ii) Relative closeness of electric field lines indicates the strength of electric field

127. Why do the electrostatic filed lines not form closed loops ? **CBSE (AI)-2015,2014**

[Ans. Due to conservative nature of electric field/ These lines start from positive charges and terminates at the negative charges

128. Why do the electric field lines never cross each other ? **CBSE (AI)-2014,2005,(D)-2003**

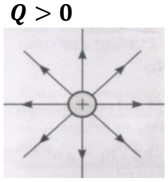
[Ans. Because if they do so, at the point of intersection two tangents can be drawn, which would represent two directions of electric field at that point, which is not possible

129. Why do the electrostatic filed lines are always normal to the surface of a conductor **CBSE (AI)-2009,(F)-2009**

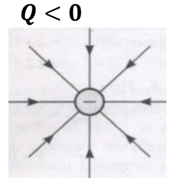
[Ans. If the field lines are not normal, then electric field $\vec{E}$ would have a tangential component which will make electrons move along the surface creating surface currents and the conductor will not be in equilibrium

130. Draw the electric field lines of an isolated point charge Q when (i) $Q > 0$ and (ii) $Q < 0$. **CBSE (D)-2007,2003**

[Ans. (i) $Q > 0$

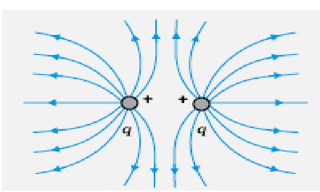


(ii) $Q < 0$

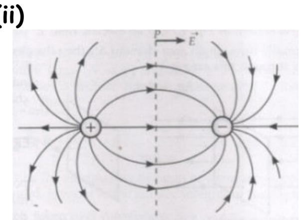


131. (i) Depict electric field lines due to two positive charges kept at a certain distance apart. **CBSE (AI)-2015,(D)-2003**
(ii) Depict electric field lines due to an electric dipole or due to two opposite charges kept at a certain distance apart.

[Ans. (i)

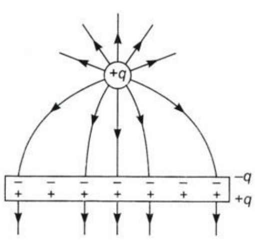


(ii)

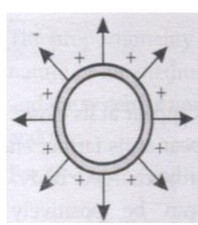


132. (i) A point charge $+Q$ is placed in the vicinity of a conducting surface. Trace the field lines between the charge and the conducting surface. **CBSE (AIC)-2017,(AI)-2015,2009**
(ii) Draw the electric field lines due to uniformly charged thin spherical shell when charge on the shell is (a) positive, (b) negative **CBSE (D)-2008**

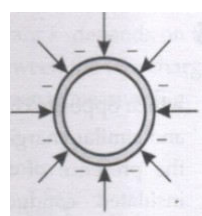
[Ans. (i)



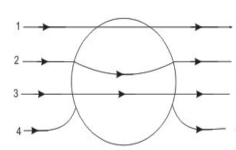
(ii) (a)



(ii) (b)



133. A metallic sphere is placed in a uniform electric field as shown in the figure. Which path is followed by the electric field lines and why ? **CBSE (AI)-2010**



[Ans. Path 4

Reason : Electric field lines are normal at each point of the surface and there are no electric field lines within the metallic sphere

134. Define dipole moment. Write its S.I. unit. Is it a scalar or vector quantity ? **CBSE (AI)-2013,2011, (D)-2012**

[Ans. Dipole moment : The product of magnitude of either charge of the electric dipole and the length of dipole is known as the dipole moment.

i,e, $|\vec{p}| = q \times |2\vec{a}|$

It's S.I. unit is Coulomb X metre ($C\ m$). It is a vector quantity

135. What is the charge of an electric dipole ? **CBSE (DC)-2010**

[Ans. Zero

136. An electric dipole is placed in a uniform electric field, what is the net force acting on it ? **CBSE (DC)-2001**

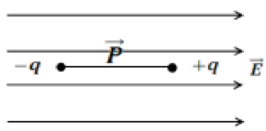
[Ans. Zero

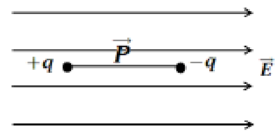
137. An electric dipole of dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$. Write the value of the angle between $\vec{p}$ and $\vec{E}$ for which the torque experienced by the dipole is minimum. **CBSE (DC)-2009**

[Ans. Zero because $\tau = pE\sin\theta = 0$

138. Depict the orientation of the dipole in (i) stable, (ii) unstable equilibrium in a uniform electric field. **CBSE (D)-2017,2010**

[Ans. (i) Stable equilibrium $\boldsymbol{\theta = 0}$ **(ii) Unstable equilibrium $\boldsymbol{\theta = 180}$**





139. Find the work done in rotating the dipole from stable to unstable equilibrium in a uniform electric field.

[Ans. For stable equilibrium, $\boldsymbol{\theta = 0}$ and for unstable equilibrium $\boldsymbol{\theta = 180}$ **CBSE (AI)-2016,2015,2012**

⇨ $W = pE\ (\cos\theta_1 - \cos\theta_2) = pE\ (\cos 0 - \cos 180) = pE\ [1-(-1)] = 2pE$

140. Find the work done in rotating the dipole from unstable to stable equilibrium in a uniform electric field.

[Ans. For unstable equilibrium $\boldsymbol{\theta = 180}$ and for stable equilibrium, $\boldsymbol{\theta = 0}$ **CBSE (AI)-2016**

⇨ $W = pE\ (\cos\theta_1 - \cos\theta_2) = pE\ (\cos 180 - \cos 0) = pE\ [-1-1] = -2pE$

141. Define electric flux. Write its S.I. unit. **CBSE (AIC)-2017,(AI)-2015,2012,2008,(F)-2006,(D)-2007,2006**

[**Ans. Electric flux :** It is defined as the total number of electric lines of force passing normally through a given surface

$$\phi_E = \oint \vec{E}.\vec{ds}$$

It's S.I. unit is Nm^2/C

142. State Gauss's law in electrostatics. **CBSE (AI)-2015,2012,2007,2004,(F)-2012,(D)-2008,2006,2004**

[**Ans. Gauss's Law :** " Electric flux passing through any closed surface is $\frac{1}{\epsilon_0}$ times the total charge enclosed by that surface".

i,e, $\phi_E = \oint \vec{E}.\vec{ds} = \frac{q}{\epsilon_0}$

143. A charge q is enclosed by a spherical surface R. If the radius is doubled/ reduced to half, how would the electric flux through the surface change ? **CBSE (AI)-2009, (AIC)-2008,(DC)-2007**

[**Ans.** No change as flux does not depend on radius/ shape /size of enclosing surface

144. A charge q is placed at the centre of a cube, what is the electric flux passing through one of its faces ?

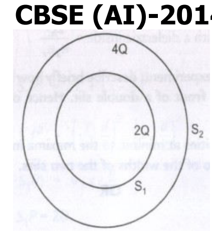
[**Ans.** $\phi = \frac{1}{6}\left(\frac{Q}{\epsilon_0}\right)$] **CBSE (AI)-2012, (F)-2010**

145. Consider two hollow concentric spheres, S_1 & S_2, enclosing charges 2Q & 4Q respectively as shown.

(i) Find out the ratio of the electric flux through them. **CBSE (AI)-2014,2002**

(ii) how will the electric flux through the sphere S_1 change, if a medium of dielectric constant ϵ_r is introduced in the space inside S_1 in place of air ?

Deduce the necessary expression.



[Ans. (i) $\phi_1 = \frac{2Q}{\varepsilon_0}$ & $\phi_2 = \frac{2Q+4Q}{\varepsilon_0} = \frac{6Q}{\varepsilon_0}$

⇨ $\frac{\phi_1}{\phi_2} = \frac{2Q}{\varepsilon_0} / \frac{6Q}{\varepsilon_0} = 1/3$

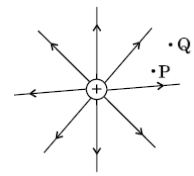
(ii) $\phi_1 = \frac{2\,Q}{\epsilon_0 K} = \frac{2\,Q}{\epsilon_0 \epsilon_r}$

146. (i) Define electric potential energy of a system of charges. **CBSE (AI)-2015**
(ii) Write an expression of electric potential energy of a system of two charges.

[Ans. (i) Electric potential energy of a system of charges : It is defined as the total amount of work done in placing the charges to their respective positions to constitute the system, by bringing them from infinity

(ii) $U = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$

147. The figure shows field lines of a positive point charge. What will be the sign of the potential energy deference of a small negative charge between the points Q and P. Justify your answer. **CBSE (AI)-2015, (F)-2014**

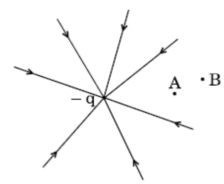


[Ans. Positive i,e, $(U)_Q - (U)_P > 0$

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

P.E. of a positive charge & a negative charge is negative hence P.E. of a negative charge is more negative at P, **i,e,** $(U)_Q > (U)_P$

148. Figure shows the field lines of a negative point charge. Give the sign of the potential energy deference of a small negative charge between the points A and B. **CBSE (F)-2014**

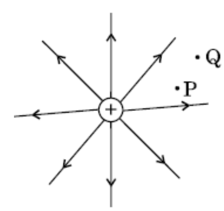


[Ans. Positive i,e, $(U)_A - (U)_B > 0$

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

P.E. of two negative charges is positive hence P.E. of a negative charge is more positive at A, **i,e,** $(U)_A > (U)_B$

140. The figure shows field lines of a positive point charge. Is the work done by the field in moving a small positive charge from Q to P is positive or negative ? Justify your answer. **CBSE (F)-2014**



[Ans. Negative,

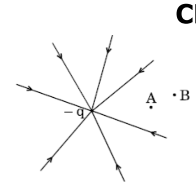
Reason : $V_P > V_Q$ ⇨ $V_P - V_Q > 0$

But $V_P - V_Q = \frac{W_{QP}}{q_0}$ ⇨ $W_{QP} > 0$

⇨ Work done by external agency is positive

⇨ Work done by electric field is negative

150. The field lines of a negative point charge are as shown in the figure. Does the kinetic energy of a small negative charge increase or decrease in going from B to A ? **CBSE (AI)-2015**



[Ans. K.E. decreases

Reason : As the negative charge moves from B to A, it experiences more repulsion, its velocity decreases and so, its K.E. decreases

151. (i) Define an equipotential surface ? **CBSE (AI)-2016,2015,2002,(D)-2003**
(ii) Write any two properties of an equipotential surface.

[Ans. (i) Equipotential surface : A surface drawn in an electric field at which every point has the same potential, is known as equipotential surface

(ii) Properties :

(a) No work is done in moving a test charge from one point to another over an equipotential surface

(b) Electric field is always normal to the equipotential surface at every point

(c) No two equipotential surfaces can intersect each other

(d) Equipotential surfaces are closer in regions of strong field and farther in regions of weak field

152. "For any charge configuration, equipotential surface through a point is normal to the electric field." Justify this statement. **CBSE (AI)-2016,(D)-2014**

[Ans. At an equipotential surface $V_1 = V_2$

Hence work done, $W = q_0(V_1 - V_2) = 0$

⇨ F S $\cos\theta = 0$, ⇨ $\cos\theta = 0$ ⇨ $\theta = 90^0$

153. No work done in moving a charge from one point to another on an equipotential surface. Why ? **CBSE (AIC)-2002**

[Ans. We know for any two points on an equipotential surface $V_1 = V_2$

Hence work done, $W = q_0 (V_1 - V_2) = 0$

154. Can electric field exist tangential to an equipotential surface ? Give reason. **CBSE (AI)-2016**

[Ans. No, It would mean some work will be done in moving charge from one point to another on equipotential surface which is not possible

155. Why do the equipotential surfaces due to uniform electric field not intersect each other ? **CBSE (F)-2013,(D)-2009**

[Ans. Because if they do so then at the point of intersection there will be two values of the electric potential, which is not Possible

156. Why the equipotential surfaces about a single charge are not equidistant ? **CBSE (AI)-2016,2015,(DC)-2011**

OR

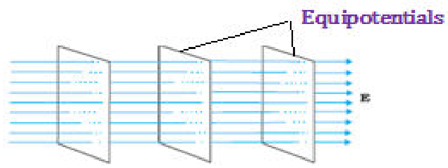
Why does the separation between successive equipotential surfaces get wider as the distance from the charges increases ?

[Ans. $|E| = \frac{dV}{dr}$ ⇨ $dr = \frac{dV}{|E|}$ -------------(1) **CBSE (AI)-2016**

As the distance increases, electric field $E\left(=\frac{1}{4\pi\,\varepsilon_0}\frac{q}{r^2}\right)$ decreases therefore from (1), dr will be large hence large hence equipotential surfaces get wider. That's why equipotential surfaces are not equidistant

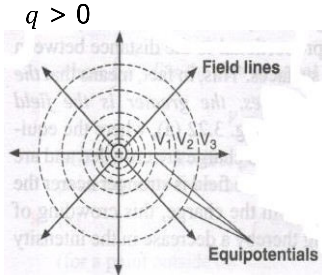
157. Draw an equipotential surface in a uniform electric field. **CBSE (F)-2008,2006,(D)-2001**

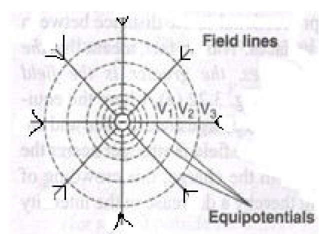
[Ans.



158. Draw an equipotential surface and corresponding electric field lines for a single point charge (i) $+q$ $(q > 0)$ (ii) $-q(q < 0)$.

[Ans. (i) $q > 0$ **(ii)** $q < 0$ **CBSE (AI)-2016,(F)-2006,(D)-2001**

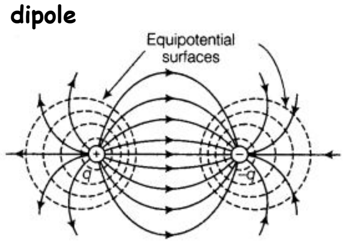


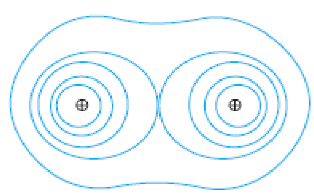


159. (i) Draw the equipotential surfaces for an electric dipole. **CBSE (AI)-2015**

(ii) Draw the equipotential surfaces due to two equal positive point charges placed at a certain distance.

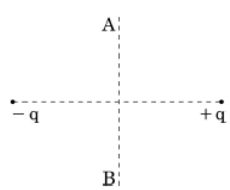
[Ans. (i) dipole **(ii) equal positive charges** **CBSE (AI)-2015,(D)-2010**





160. A charge $'q'$ is being moved from a point A above a dipole of dipole moment $'p'$ to a point B below the dipole in equatorial plane without acceleration. Find the work done in the process. **CBSE (AI)-2016**

[Ans. Zero, as AB is an equipotential surface]



161. What is the amount of work 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 ? **CBSE (AI)-2016**

[Ans. zero]

162. Define the capacitance of a conductor. Write its S .I. unit. **CBSE (AIC)-2003**

[Ans. It is defined as the charge required to raise the potential of conductor by unit amount.

i,e, $C = \frac{q}{V}$

Its S.I. unit is Farad (F)

163. Define the capacitance of a capacitor. On what factors does it depends ? **CBSE (F)-2017,(DC)-2001**

[Ans. **Capacitance :** Capacitance of a capacitor may be defined as the ratio of magnitude of charge on its either plate to the potential difference between them.

i,e, $C = \frac{q}{V}$

Factors : (i) geometrical configuration (shape, size, separation) of the system of two conductors and (ii) nature of the medium separating the two conductors

164. Define dielectric constant of a medium in terms of capacitance. **CBSE (D)-2006**

[Ans. The dielectric constant of a medium may be defined as the ratio of capacitance of capacitor completely filled with that dielectric medium to the capacitance of the same capacitor with vacuum between its plates.

i,e, $K = \frac{C}{C_0}$

165. A metal plate is introduced between the plates of a charged parallel plate capacitor. What is the effect on the capacitance of the capacitor ? **CBSE (F)-2009**

[Ans. Capacitance increase as the effective separation between the plates is decreased

166. (i) Define the term polarization of a dielectric. **CBSE (AI)-2016,2015,(D)-2015**

(ii) Write a relation for polarization $\vec{P}$ of a dielectric material in the presence of an external electric field $\vec{E}$.

[Ans. (i) Polarization of a dielectric : Induced dipole moment per unit volume, is called polarization P

(ii) Relation : $\vec{P} = \chi_e \vec{E}$

where χ_e is the electric susceptibility of the dielectric medium

167. How is the electric field due to a charged parallel plate capacitor affected when a dielectric slab is inserted between the plates fully occupying the intervening region ? **CBSE (F)-2010**

[Ans. Electric field decreases due to dielectric polarization and becomes

$E = E_0 - E_{in} = \frac{E_0}{K}$

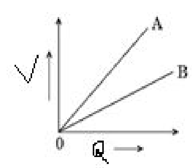
168. The graph shows the variation of voltage V across the plates of two capacitors A and B versus increase of charge Q stored on them. Which of the capacitors has higher capacitance ? Give reason for your answer. **CBSE (D)-2004**

[Ans. B has higher capacitance

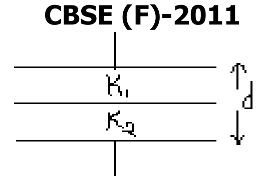
Reason : $C = \frac{q}{V}$

If $V =$ constant then $C \propto q$

As $q_B > q_A \Rightarrow C_B > C_A$



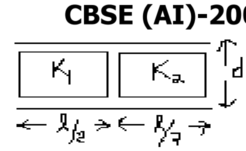
169. A parallel plate capacitor of plate area A and separation d is filled with dielectrics of dielectric constants K_1 and a K_2 shown in the figure. Find the net capacitance of the capacitor. **CBSE (F)-2011**



[Ans. $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{\frac{K_1 \varepsilon_0 A}{d/2}} + \frac{1}{\frac{K_2 \varepsilon_0 A}{d/2}} = \frac{d/2}{K_1 \varepsilon_0 A} + \frac{d/2}{K_2 \varepsilon_0 A}$

$\Rightarrow \frac{1}{C} = \frac{d}{2\varepsilon_0 A}\left(\frac{1}{K_1} + \frac{1}{K_2}\right) = \frac{d}{2\varepsilon_0 A}\left(\frac{K_1 + K_2}{K_1 K_2}\right) \Rightarrow C = \left(\frac{2K_1K_2}{K_1 + K_2}\right) C_0$

170. Two dielectric slabs of dielectric constants K_1 and K_2 are filled in between the two plates, each of area A, of the parallel plate capacitor as shown. Find net capacitance of the capacitor. **CBSE (AI)-2005,(F)-2011**



[Ans. $C = C_1 + C_2 = \frac{K_1 \varepsilon_0 A/2}{d} + \frac{K_2 \varepsilon_0 A/2}{d}$

$\Rightarrow C = \frac{\varepsilon_0 A}{2d}(K_1 + K_2) = \frac{\varepsilon_0 A}{d}\left(\frac{K_1 + K_2}{2}\right) = \left(\frac{K_1 + K_2}{2}\right) C_0$

171. How will the (i) energy stored and (ii) the electric field inside the air capacitor be affected when it is completely filled with a dielectric material of dielectric constant K ? **CBSE (AI)-2012**

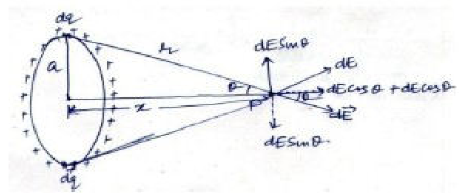
[Ans. (i) $U_0 = \frac{q^2}{2C_0}$ & $U = \frac{q^2}{2C} = \frac{q^2}{2KC_0}$ ⇨ $U = \frac{U_0}{K}$ **(ii)** $E_0 = \frac{\sigma}{\varepsilon_0}$ & $E = \frac{\sigma}{K\varepsilon_0}$ ⇨ $E = \frac{E_0}{K}$

172. A charge is distributed uniformly over a ring of radius $'a'$. Obtain an expression for the electric field intensity E at a point on the axis of the ring. Hence show that for points at large distances from the ring, it behaves like a point charge. **CBSE (D)-2016**

[Ans. linear charge density, $\lambda = \frac{q}{2\pi a}$

charge on the small element dl

$$dq = \lambda\, dl = \frac{q}{2\pi a}\, dl$$



Electric field intensity due to small element dl at P

$$dE = \frac{1}{4\pi\,\varepsilon_0}\frac{dq}{r^2} = \frac{1}{4\pi\,\varepsilon_0}\frac{\lambda\, dl}{r^2}$$

On resolving dE in to horizontal and vertical components the resultant electric field intensity at P is given by

$$E = \int dE\,\cos\theta = \int \frac{1}{4\pi\,\varepsilon_0}\frac{\lambda\, dl}{r^2} \times \frac{x}{r} \qquad [\because \cos\theta = \frac{x}{r}]$$

$$\Rightarrow E = \frac{\lambda\,x}{4\pi\,\varepsilon_0\, r^3}\int dl = \frac{x}{4\pi\,\varepsilon_0\, r^3}\left(\frac{q}{2\pi a}\right)(2\pi a) = \frac{1}{4\pi\,\varepsilon_0}\frac{qx}{r^3}$$

$$\Rightarrow \boldsymbol{E = \frac{1}{4\pi\,\varepsilon_0}\frac{qx}{(x^2+a^2)^{3/2}}}$$

At the centre of the ring x = 0 ⇨ $\boldsymbol{E = 0}$

for large distances $x \gg a$

$$\Rightarrow \boldsymbol{E = \frac{1}{4\pi\,\varepsilon_0}}\frac{q}{x^2}$$

This is the electric field intensity due a point charge at distance x

173. (i) An electric dipole is held in a uniform electric field. Using suitable diagram show that it does not undergo any translatory motion. Derive the expression for the torque acting on it.

(ii) What would happen if the field in non-uniform ?

(iii) What would happen if the external electric field E is increasing

(a) parallel to $\vec{p}$ and (b) anti-parallel to $\vec{p}$? **CBSE (AI)-2016,2014,2008,(F)-2016,(DC)-2015**

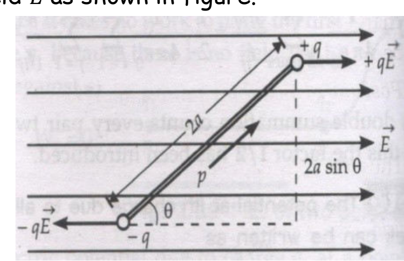
[Ans. (i) Let an electric dipole of dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$ as shown in figure.

Force : Force on $+q$, $F_1 = qE$

Force on $-q$, $F_2 = -qE$

Hence net force on the dipole

$F = qE - qE = 0$



x

Torque : Two equal and opposite forces $-qE$ and $+qE$ forms a couple which tries to rotate the dipole. Torque due to this couple

τ = either force X ⊥ distance $= qE$ x $2a\sin\theta$

$= qE$ x $2a\sin\theta$

⇨ τ = p$E\sin\theta = \vec{p} \times \vec{E}$

(ii) If the electric field is non-uniform, the net force on the dipole will not be zero hence there will be the translator motion of the dipole.

(iii) (a) Net force will be in the direction of increasing electric field.

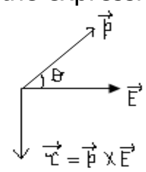
(b) Net force will be in the direction opposite to the increasing field

174. An electric dipole is held in a uniform electric field. Write the expression for the torque acting on it. Express it in vector form and specify its direction. Identify two pairs of perpendicular vectors in the expression.

[Ans. **Torque :** $\tau = pE\sin\theta$

Vector form : $\vec{\tau} = \vec{p} \times \vec{E}$

Direction of $\vec{\tau}$: Direction of torque is $\perp$ to the plane containing $\vec{p}$ and $\vec{E}$ given by right hand screw rule

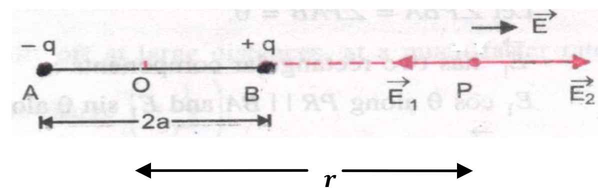


Two pairs of $\perp$ vectors : (i) $\vec{\tau}$ and $\vec{p}$ (ii) $\vec{\tau}$ and $\vec{E}$

175. (a) Derive an expression for the electric field E due to a dipole of length '2a' at a point distant r from the centre of the dipole on the axial line. **CBSE (AI)-2017,2013,(D)-2015**

(b) Draw a graph of E versus r for r >> a.

[Ans. Let $\vec{E_1}$ and $\vec{E_2}$ be the electric field at P due to $-q$ and $+q$ charges respectively then



$$\left|\vec{E_1}\right| = \frac{q}{4\pi\varepsilon_0 (r+a)^2} \quad \text{along PA}$$

& $$\left|\vec{E_2}\right| = \frac{q}{4\pi\varepsilon_0 (r-a)^2} \quad \text{along BP}$$

Obviously the resultant electric field intensity at P

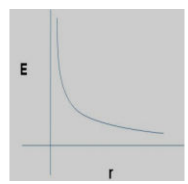
$$\left|\vec{E}\right| = \left|\vec{E_2}\right| - \left|\vec{E_1}\right| = \frac{q}{4\pi\varepsilon_0 (r-a)^2} - \frac{q}{4\pi\varepsilon_0 (r+a)^2} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right] = \frac{q}{4\pi\varepsilon_0}\left[\frac{(r+a)^2-(r-a)^2}{\left(r^2-a^2\right)^2}\right]$$

$$\Rightarrow \left|\vec{E}\right| = \frac{q}{4\pi\varepsilon_0}\frac{4ar}{\left(r^2-a^2\right)^2}$$

$$\Rightarrow \left|\vec{E}\right| = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{\left(r^2-a^2\right)^2} \qquad [\because p = 2qa\ ]$$

Obviously, if $r \gg a$, then

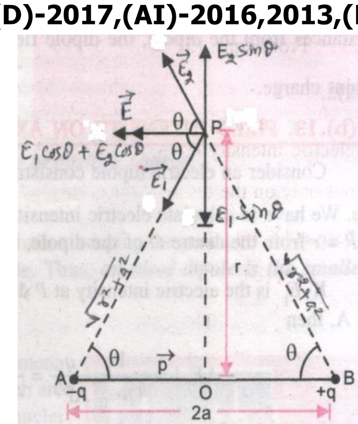
$$E = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{\left(r^2\right)^2} \Rightarrow \boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}}$$



direction of $\vec{E}$ is along the direction of dipole moment $\vec{p}$

176. Derive an expression for the electric field intensity at a point on the equatorial line of an electric dipole of dipole moment $\vec{p}$ and length $2a$. What is the direction of this field ? **CBSE (D)-2017,(AI)-2016,2013,(F)-2015,2009**

[Ans. Let, $\vec{E_1}$ and $\vec{E_2}$ be the electric field intensity at at P due to $-q$ & $+q$ charges respectively, then



$$\left|\vec{E_1}\right| = \left|\vec{E_2}\right| = \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(\sqrt{r^2+a^2}\right)^2}$$

$$\Rightarrow \left|\vec{E_1}\right| = \left|\vec{E_2}\right| = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)} \quad \text{---------(1)}$$

On resolving $\vec{E_1}$ and $\vec{E_2}$ in horizontal and vertical components, resultant electric field intensity

$$\left|\vec{E}\right| = E_1\cos\theta + E_2\cos\theta = 2\,E_1\cos\theta$$

$$\Rightarrow \left|\vec{E}\right| = 2\,\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}\frac{a}{\sqrt{r^2+a^2}} \qquad [\because \cos\theta = \frac{a}{\sqrt{r^2+a^2}}$$

$$\Rightarrow \left|\vec{E}\right| = \frac{1}{4\pi\varepsilon_0}\frac{2qa}{\left(r^2+a^2\right)^{3/2}}$$

$$\Rightarrow \left|\vec{E}\right| = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2+a^2)^{3/2}} \qquad [\because p = 2qa\ ]$$

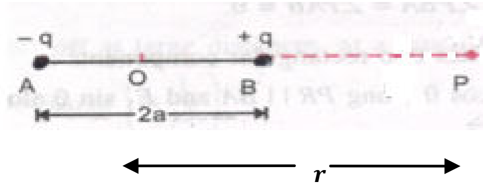
Obviously, if $r \gg a$, then

$$\boxed{\left|\vec{E}\right| = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}}$$

direction of $\vec{E}$ is opposite to that of dipole moment $\vec{p}$

177. Derive an expression for the potential at a point along the axial line of a short dipole. For this dipole draw a plot showing the variation of potential V versus r, where r $(r \gg 2a)$, is the distance from the point charge $-q$ along the line joining the two charges. **CBSE (AI)-2015, (D)-2008,2007**

[Ans. Let V_1 and V_2 be the electric potential at P due to $-q$ and $+q$ charges respectively then



$$V_1 = \frac{-q}{4\pi\,\varepsilon_0(r+a)}$$

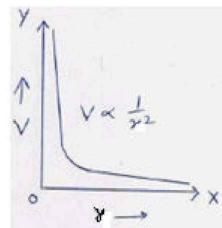
& $$V_2 = \frac{q}{4\pi\,\varepsilon_0(r-a)}$$

Resultant electric potential at P

$$V = V_1 + V_2 = \frac{-q}{4\pi\,\varepsilon_0(r+a)} + \frac{q}{4\pi\,\varepsilon_0(r-a)} = \frac{q}{4\pi\,\varepsilon_0}\left[\frac{1}{(r-a)} - \frac{1}{(r+a)}\right] = \frac{q}{4\pi\,\varepsilon_0}\left[\frac{r+a-(r-a)}{(r^2-a^2)}\right]$$

⇨ $$V = \frac{1}{4\pi\,\varepsilon_0}\frac{2qa}{(r^2-a^2)}$$

⇨ $$V = \frac{1}{4\pi\,\varepsilon_0}\frac{p}{(r^2-a^2)} \qquad [\because p = 2qa\,]$$



Obviously, if $r \gg a$, then

$$\boxed{V = \frac{1}{4\pi\,\varepsilon_0}\frac{p}{r^2}}$$

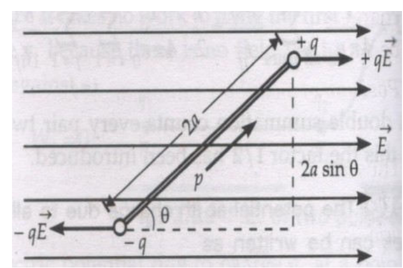
==

178 (i) Derive the expression for the potential energy of an electric dipole of dipole moment $\vec{p}$ placed in a uniform electric field $\vec{E}$.
(ii) Find out the orientation of the dipole when it is in (a) stable equilibrium (b) unstable equilibrium.
CBSE (AI)-2016,2015,2012

[Ans. (i) Two equal and opposite forces $-qE$ and $+qE$ forms a couple which tries to rotate the dipole. Torque due to this couple

τ = either force X ⊥ distance = qE X $2a\sin\theta$

$\tau = pE\,\sin\theta$



Work done in rotating the dipole through an angle $d\theta$

$dW = \tau\, d\theta = pE\,\sin\theta\; d\theta$

⇨ $W = \int_{\theta_1}^{\theta_2} pE\,\sin\theta\;d\theta = pE\int_{\theta_1}^{\theta_2}\sin\theta\;d\theta = pE\,[-\cos\theta]_{\theta_1}^{\theta_2}$

⇨ $W = pE\,(\cos\theta_1 - \cos\theta_2)$ -------(1)

When θ_1= 90^0 and θ_2= θ, then $W = U$

⇨ $U = pE\,(\cos 90^0 - \cos\theta) = pE\,(0-\cos\theta) = \mathbf{-\,pE\cos\theta}$

⇨ $\boldsymbol{u(\theta) = -\vec{p}.\vec{E}}$

(ii) (a) When $\theta = 0^0$, $U = -\,pE\,\cos 0 = -\,pE$

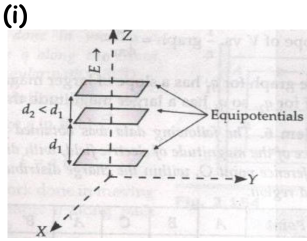
In this case P.E. is minimum hence it is the orientation of stable equilibrium.

(b)When $\theta = 180^0$, $U = -\,pE\,\cos 180 = +\,pE$

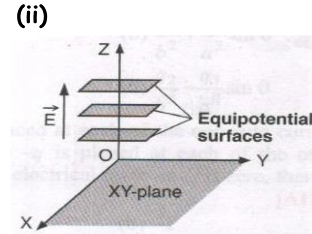
In this case P.E. is maximum hence it is the orientation of unstable equilibrium.

179 (i) Draw 3 equipotential surfaces corresponding to a field that uniformly increases in magnitude but remains constant along z-direction. **CBSE (AI)-2016,2009,(F)-2008**
(ii) How are these surfaces different from that of a constant electric field along z- direction ?

[Ans. (i)



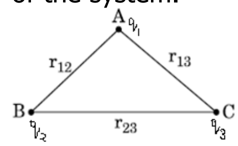
(ii)



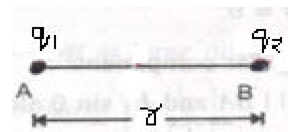
Difference : In the first case, as the magnitude of field increases, equipotential surfaces get closer
In the second case, equipotential surfaces are equidistant planes parallel to XY planes

180. (i) Derive an expression for electric potential energy of a system of two point charges.

(ii) Three point charges q_1, q_2 and q_3 are kept respectively at points A, B and C as shown in the figure. Derive the expression for the electric potential energy of the system. **CBSE (AI)-2015**



[Ans. Electric potential energy of a system of two point charges :

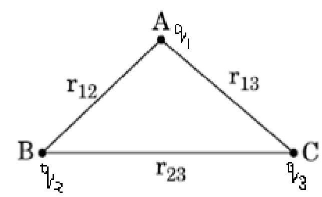


$$W_1 = 0$$

$$W_2 = V_1 \, X \, q_2 = \left(\frac{1}{4\pi\varepsilon_0}\frac{q_1}{r}\right) X \, q_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$

⇨ $$U = W_1 + W_2 = 0 + \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$

(ii) Electric potential energy of a system of three point charges :



$$W_1 = 0$$

$$W_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$$

$$W_3 = \frac{1}{4\pi\varepsilon_0}\frac{q_2 q_3}{r_{23}} + \frac{1}{4\pi\varepsilon_0}\frac{q_3 q_1}{r_{31}}$$

⇨ $$U = W_1 + W_2 + W_3 = 0 + \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}} + \frac{1}{4\pi\varepsilon_0}\frac{q_2 q_3}{r_{23}} + \frac{1}{4\pi\varepsilon_0}\frac{q_3 q_1}{r_{31}}$$

⇨ $$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1 q_2}{r_{12}} + \frac{q_2 q_3}{r_{23}} + \frac{q_3 q_1}{r_{31}}\right]$$

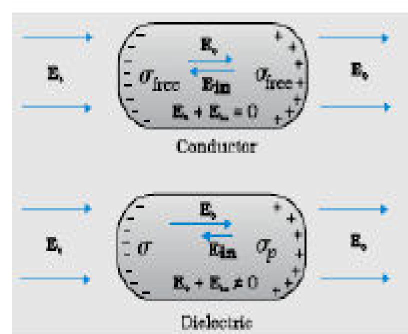
==

181. (i) What is a dielectric ? Give one example. **CBSE (AI)-2016,(D)-2015,(F)-2006**

(ii) Distinguish with the help of a suitable diagram, the difference in the behaviour of a conductor and a dielectric placed in an external electric field. How does polarized dielectric modify the original external filed ?

[Ans. (i) Dielectric : Dielectrics are non-conducting substances which allows electric induction to take place through them but do not allow the flow of charge through them.

for example : Air, glass, mica



(ii) In a conductor, in the presence of external electric field the free charge carriers move and charge distribution in the conductor adjusts itself in such a way that the net electric field within the conductor becomes zero. i,e, $E = \mathbf{0}$

In a dielectric, external electric field induces net dipole moment by stretching or re-orienting molecules. The electric field due to this induced dipole moment opposes the external field but does not exactly cancel it. As a result net electric field is reduced.

$$E = \boldsymbol{E_0} - \boldsymbol{E_{in}} = \frac{E_0}{K}$$

==

182. Define the term 'dielectric strength'. What does this term signify ? What is its value for (a) air (b) vacuum ? **CBSE (AIC)-2015**

[Ans. (i) Dielectric strength : The maximum electric field that a dielectric medium can withstand without break-down (of its insulating property) is called its dielectric strength.

Significance : This signifies the maximum value of electric field, up to which the dielectric can safely play its role

(ii) (a) for air it is about $3 \, X \, 10^6 \, Vm^{-1}$ (b) for vacuum it is infinity

==

183. What is electrostatic shielding ? How is this property used in actual practice ? Is the potential in the cavity of a charged conductor zero ? **CBSE (AI)-2016**

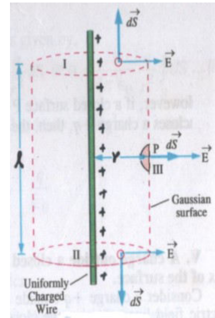
[Ans. Electrostatic shielding : Whatever be the charge and field configuration outside, any cavity in a conductor remains shielded from outside electric influence : the field inside the cavity is always zero. This is known as electrostatic shielding.

Use : The effect can be made use of in protecting sensitive instruments from outside electrical influence by enclosing them in a hollow conductor. ⇨ Potential inside the cavity is not zero. It is constant

184. Using Gauss's law, derive an expression for the electric field intensity due to an infinitely long, straight wire of linear charge density λ C/m. **CBSE (AIC)-2017,(AI)-2007,2006,2005,(D)-2009,04**

[**Ans**. Charge enclosed by Gaussian surface, $q = \lambda l$

At the part I and II of Gaussian surface $\vec{E}$ and $\hat{n}$ are $\perp$, so flux through surfaces I and II is zero.



By Gauss's law, $\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$

$\Rightarrow \oint E ds \cos 0 = \frac{q}{\varepsilon_0}$

$\Rightarrow E \oint ds = \frac{q}{\varepsilon_0}$

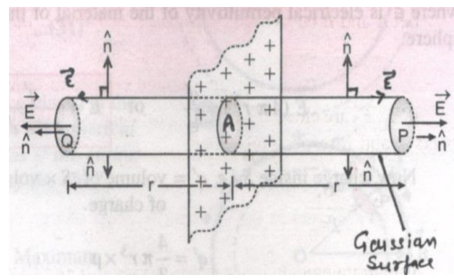
$\Rightarrow E(2\pi r l) = \frac{\lambda l}{\epsilon_0}$

$\Rightarrow \boldsymbol{E = \frac{\lambda}{2\pi\varepsilon_0 r}}$

185. Using Gauss's law, obtain the expression for electric field intensity at a point due to an infinitely large, plane sheet of charge of charge density σ C/m^2. How is the field directed if the sheet is (i) positively charged (ii) negatively charged? **CBSE (AI)-2015,2010,2005,2004,(D)-2012,2009,06,(DC)-2002,01,(F)-2003**

[**Ans**. Let us consider a Gaussian surface as shown.

At the curved part of Gaussian surface $\vec{E}$ and $\hat{n}$ are $\perp$, so flux through curved surface is zero.



By Gauss's law, $\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$

$\Rightarrow \oint E ds \cos 0 = \frac{q}{\varepsilon_0}$

$\Rightarrow E \oint ds = \frac{q}{\varepsilon_0}$

$\Rightarrow E(2A) = \frac{q}{\varepsilon_0}$

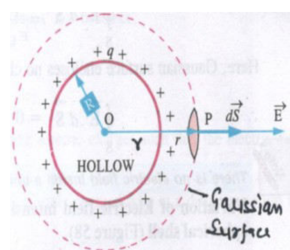
$\Rightarrow \boldsymbol{E = \frac{q}{2\varepsilon_0 A} = \frac{\sigma}{2\varepsilon_0}}$

Direction of field : (i) If the sheet is positively charged the field is directed away from it
(ii) If sheet is negatively charged the field is direct towards it

186. Using Gauss's law, deduce the expression for the electric field due to uniformly charged spherical conducting shell of radius R at a point (i) outside and (ii) inside the shell.
Plot a graph showing variation of electric field as a function of r > R and r< R.
CBSE (AI)-2015,2013,2007,2004,(D)-2011,2009,2008,2006,2004

[**Ans**. **(i) Outside the shell** $(r > R)$

Let us consider the Gaussian surface as shown



by Gauss's law, $\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$

$\Rightarrow \oint E ds \cos 0 = \frac{q}{\varepsilon_0}$

$\Rightarrow E \oint ds = \frac{q}{\varepsilon_0}$

$\Rightarrow E\,(4\pi r^2) = \frac{q}{\epsilon_0}$

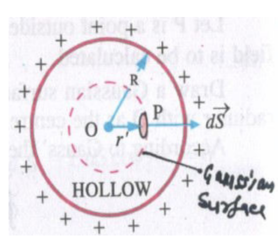
$\Rightarrow \boldsymbol{E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}}$

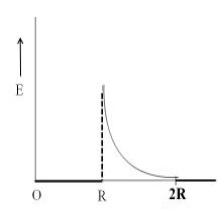
(ii) Inside the shell $(r < R)$

Let us consider the Gaussian surface as shown

By Gauss's law

$\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$





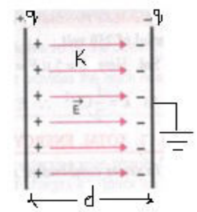
But, charge inside the spherical shell, i,e, q = 0

$\Rightarrow \oint E\, ds \cos 0 = 0 \quad \Rightarrow \boldsymbol{E = 0}$

187. What is a capacitor? Deduce an expression for the capacitance of a parallel plate capacitor with air as the medium between the plates. **CBSE (F)-2017,2006,(AI)-2003,2001,(DC)-2005,2004**

[**Ans**. **Capacitor** :It is an arrangement required to increase the capacity of a conductor so that a large amount of charge can be stored in it without changing its dimensions

Capacitance of ‖ plate capacitor : let us consider a parallel plate capacitor filled with a medium of dielectric constant K as shown



Electric field between the plates

$$E = \frac{\sigma}{\varepsilon_0 K} = \frac{q}{\varepsilon_0 KA}$$

⇨ potential difference between the plates

$$V = E\,d = \frac{q\,d}{\varepsilon_0 KA}$$

⇨ $$C = \frac{q}{V} = \frac{q}{\frac{q\,d}{\varepsilon_0 KA}} = \boldsymbol{K}\frac{\boldsymbol{\varepsilon_0 A}}{\boldsymbol{d}}$$

If air is as the medium between the plates then, $K = 1$

⇨ $$\boldsymbol{C_0} = \frac{\boldsymbol{\varepsilon_0 A}}{\boldsymbol{d}}$$

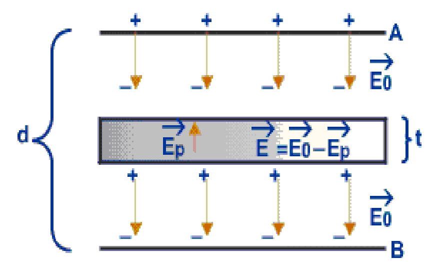
===

188. A dielectric slab of thickness 't' is introduced without touching between the plates of a parallel plate capacitor separated by a distance 'd' (t < d). Derive an expression for the capacitance of the capacitor.

[**Ans**. Electric field between the plates in air **CBSE (AIC)-2005,2001**

$$E_0 = \frac{q}{\varepsilon_0 A}$$

Electric field in dielectric slab



$$E = \boldsymbol{E_0} - \boldsymbol{E_p} = E_0 - \frac{\boldsymbol{\sigma_p}}{\boldsymbol{\varepsilon_0}} = \frac{E_0}{K} = \frac{q}{\varepsilon_0 KA}$$

⇨ potential difference between the plates

$$V = E_0\,(d-t) + \frac{E_0}{K}\,t = E_0\left[(d-t) + \frac{t}{K}\right] = \frac{q}{\varepsilon_0 A}\left[(d-t) + \frac{t}{K}\right]$$

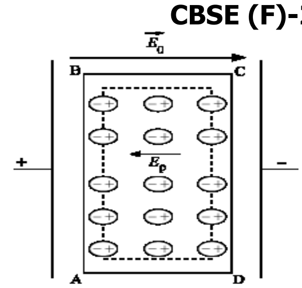
⇨ $$C = \frac{q}{V} = \frac{q}{\frac{q}{\varepsilon_0 A}\left[(d-t)+\frac{t}{K}\right]}$$

⇨ $$\boldsymbol{C} = \frac{\boldsymbol{\varepsilon_0 A}}{(\boldsymbol{d}-\boldsymbol{t})+\frac{\boldsymbol{t}}{\boldsymbol{K}}}$$

===

189. Why does the capacitance of a parallel plate capacitor increase on introduction of a dielectric in between its plates ?

[**Ans**. Due to dielectric polarization, an electric field is induced in the dielectric opposite to external electric field. Hence net electric field decreases to **CBSE (F)-2006**



$$E = \boldsymbol{E_0} - \boldsymbol{E_{in}} = E_0 - \frac{\boldsymbol{\sigma_p}}{\boldsymbol{\varepsilon_0}} = \frac{E_0}{K}$$

It reduces potential difference to $V = \boldsymbol{Ed} = \frac{E_0}{K}d = \frac{V_0}{K}$

⇨ $$C = \frac{q_0}{V} = \frac{q_0}{V_0/K} = K\left(\frac{q_0}{V_0}\right) = KC_0$$

Hence capacitance increases K times

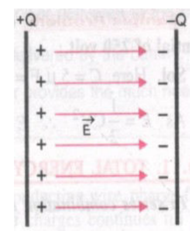
190. A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness 3d/4, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor. **CBSE (F)-2017,2010,(AI)-2013,NCERT-2017**

[Ans. $V = E_0\,(d-t) + \frac{E_0}{K}\,t = E_0\left[(d-3d/4) + \frac{3d/4}{K}\right] = \frac{E_0\,d}{4}\left(1+\frac{3}{K}\right) = \frac{V_0}{4}\left(\frac{K+3}{K}\right)$

$$C = \frac{q_0}{V} = \frac{q_0}{\frac{V_0}{4}\left(\frac{K+3}{K}\right)} = \frac{4K}{(K+3)}\frac{q_0}{V_0} = \frac{4K}{(K+3)}C_0$$

191. Prove that the total electrostatic energy stored in a parallel plate capacitor is $\frac{1}{2}\,C\,V^2$. Hence derive an expression for energy density of the capacitor. How does the stored energy change if air is replaced by medium of dielectric constant 'K' ? **CBSE (AI)-2015,2012,2008,2002,(F)-2013,2006,(D)-2006,2002**

[Ans. Energy stored in a capacitor : When a capacitor is charged by a battery, work is done by the battery at the expense of its chemical energy. This work done is stored between the plates as electrostatic potential energy



Small work done in giving a charge dq

dW = V X $dq = \frac{q}{C}\,dq$

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

$$W = \frac{1}{C}\int_0^Q q\,dq = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q = \frac{Q^2}{2C}$$

⇨ $\boldsymbol{U} = \frac{Q^2}{2C} = \frac{(CV)^2}{2C} = \frac{1}{2}\,\mathbf{C}\,V^2$

Energy density: $u = \frac{U}{Volume} = \frac{\frac{1}{2}C\,V^2}{A\,d} = \frac{\frac{1}{2}\left(\frac{\varepsilon_0\,A}{d}\right)(Ed)^2}{A\,d} = \frac{1}{2}\,\varepsilon_0\,E^2$

⇨ $u = \frac{1}{2}\,\varepsilon_0\,E^2$

If air is replaced by a medium of dielectric constant K then

$$U' = \frac{1}{2}\,C'\,(V')^2 = \frac{1}{2}\,KC\left(\frac{V}{K}\right)^2 = \frac{1}{2}\,\frac{CV^2}{K} = \frac{U}{K}$$

==

192. Three capacitors of capacitances C_1, C_2 & C_3 are connected (a) in series (b) in parallel. Show that the energy stored in the series combination is the same as that in the parallel combination. **CBSE (AI)-2003**

[Ans. (i) In series, $U_s = \frac{Q^2}{2C_s} = \frac{1}{2}Q^2\left(\frac{1}{C_s}\right) = \frac{1}{2}Q^2\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right) = \frac{1}{2}\frac{Q^2}{C_1} + \frac{1}{2}\frac{Q^2}{C_2} + \frac{1}{2}\frac{Q^2}{C_3}$

⇨ $U_s = U_1 + U_2 + U_3$

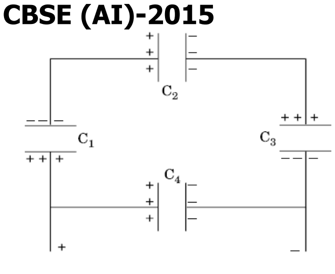
(ii) In parallel, $U_P = \frac{1}{2}\,C_P\,V^2 = \frac{1}{2}\,(C_1 + C_2 + C_3)V^2 = \frac{1}{2}C_1V^2 + \frac{1}{2}C_1V^2 + \frac{1}{2}C_1V^2$

⇨ $U_P = U_1 + U_2 + U_3$

==

193. A network of four capacitors each of $10\,\mu F$ capacitance is connected to a $500\,V$ supply as shown in the figure. Determine the - **CBSE (AI)-2015**

(i) equivalent capacitance of the network and (ii) charge on each capacitor



[Ans. (i) $\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{10} + \frac{1}{10} + \frac{1}{10} = \frac{3}{10}$ ⇨ $C' = \frac{10}{3}\,\mu F$

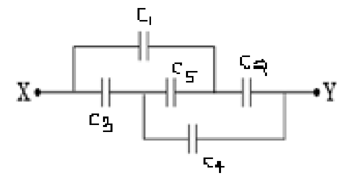
⇨ equivalent capacitance, $C = C' + C_4 = \frac{10}{3} + 10 = \frac{40}{3}\,\mu F$

(ii) charge on C_4, $q_4 = C_4 \text{ X } V = 10 \text{ X } 10^{-6} \text{ X } 500 = 5 \text{ X } 10^{-3} C$

$q_1 = q_2 = q_3 = C' \text{ X } V = \frac{10}{3} \text{ X } 10^{-6} \text{ X } 500 = \frac{5}{3} \text{ X } 10^{-3} C$

194. Find the equivalent capacitance of the network shown in the figure, when each capacitor is of $1\ \mu F$. When the ends X and Y are connected to a $6\ V$ battery, find out (i) the charge and (ii) energy stored in the network.

CBSE (AI)-2015,(AIC)-2003,(D)-2001



[**Ans.** $\frac{C_1}{C_2} = \frac{C_3}{C_4}$ ⇨ $\frac{1}{1} = \frac{1}{1}$

this is the condition of balance so there will be no current in C_5

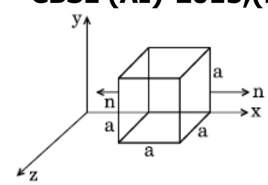
Now C_1 & C_2 are in series ⇨ $C_{12} = \frac{C_1\ C_2}{C_1 + C_2} = \frac{1 \text{ X } 1}{1+1} = 1/2\ \mu F$

C_3 & C_4 are in series, ⇨ $C_{34} = \frac{C_3\ C_4}{C_3 + C_4} = \frac{1 \text{ X } 1}{1+1} = 1/2\ \mu F$

⇨ $C = C_{12} + C_{34} = \frac{1}{2} + \frac{1}{2} = 1\ \mu F$

⇨ **(i)** $q = CV = 1 \text{ X } 6 = 6\ \mu C$ (ii) $U = \frac{1}{2} qV = \frac{1}{2} \text{ X } 1 \text{ X } 10^{-6} \text{ X } 6 = 31 \text{ X } 10^{-6}\ J$

195. Given the components of an electric field as $E_x = \alpha x$, $E_y = 0$ and $E_z = 0$, where α is dimensional constant. Calculate the flux through the cube of side 'a' as shown in the figure and the effective charge inside the cube. **CBSE (AI)-2015,(F)-2012**



[**Ans. (i)** $\phi = \phi_L + \phi_R = E_x\ ds\ \cos 180 + E_x\ ds\ \cos 0$

⇨ $\phi = (\alpha a)a^2(-1) + [\alpha\ (a + a)]a^2(1) = -\alpha a^3 + 2\alpha a^3$

⇨ $\phi = \alpha a^3$

(ii) $\phi = \frac{q}{\varepsilon_0}$ ⇨ $q = \varepsilon_0\ \phi = \varepsilon_0\ \alpha a^3$

==

196. Given a uniform electric field $\mathbf{E} = 6 \text{ X } 10^3\ \hat{\imath}$ N/C, Find the flux of this field through a square of 10 Cm on a side whose plane is parallel to Y-Z plane. What would be the flux through the same square if the plane makes a 30^0 angle with the x- axis ? **CBSE (D)-2014**

[**Ans. Given** : $\mathbf{E} = 6 \text{ X } 10^3\ \hat{\imath}$ N/C, $a = 10\ cm = 10X10^{-2}m$, $\phi = ?$

In first case, $\phi = E\ ds\ \cos 0 = 6 \text{ X } 10^3 \text{ X } (10\ X\ 10^{-2})^2 = 60$ N m$^2/C$

In second case, $\phi = E\ ds\ \cos(90 - 30) = E\ ds\ \cos 60 = 6 \text{ X } 10^3 \text{ X } (10 \text{ X } 10^{-2})^2 \text{ X } \frac{1}{2} = 30$ N m$^2/C$

197. Two point charges 4 μC and +1 μC are separated by a distance of 2 m in air. Find the point on the line-joining charges at which the net electric field of the system is zero. **CBSE (AIC)-2017**

[**Ans.** $\frac{1}{4\pi\epsilon_0}\frac{q_1}{r_1^2} = \frac{1}{4\pi\epsilon_0}\frac{q_2}{r_2^2}$ ⇨ $\frac{4}{x^2} = \frac{1}{(2-x)^2}$ ⇨ $2(2-x) = x$ ⇨ $x = \frac{4}{3}m$

==

198. Two point charges $20\ X\ 10^{-6}C$ and $-4\ X\ 10^{-6}C$ are separated by a distance of $50\ cm$ in air. Find-

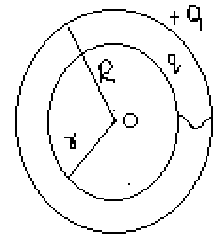
(i) the point on the line joining the charges, where the electrostatic potential is zero.

(ii) calculate the electrostatic potential energy of the system. **CBSE (AI)-2008**

[**Ans. (i)** $\frac{1}{4\pi\epsilon_0}\frac{q_1}{r_1} + \frac{1}{4\pi\epsilon_0}\frac{q_2}{r_2} = 0$ ⇨ $\frac{20\ X\ 10^{-6}}{x} + \frac{-4\ X\ 10^{-6}}{(50-x)} = 0$ ⇨ $\frac{20}{x} = \frac{4}{(50-x)}$ ⇨ $x = \frac{250}{6} = 41\ cm$

(ii) $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} = -9X10^9 \text{ X } \frac{20 \text{ X } 10^{-6} \text{ X } 4 \text{ X } 10^{-6}}{50X\ 10^{-2}} = -\ 1.44$ J

199. Show that if we connect the smaller and the outer sphere by a wire, the charge q on the former will always flow to the latter, independent of how large Q is. **CBSE (F)-2015,(AI)-2009**



[**Ans**. Potential at a point on the inner sphere

$$V_1 = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} + \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

Potential at a point on the spherical shell

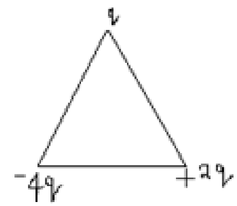
$$V_2 = \frac{1}{4\pi\varepsilon_0}\frac{q}{R} + \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

⇨ $V_1 - V_2 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{r} - \frac{Q}{R}\right] = \frac{q}{4\pi\varepsilon_0}\left[\frac{R-r}{rR}\right]$

⇨ $V_1 - V_2 > 0$ ⇨ $V_1 > V_2$, hence the charge will flow from inner sphere to outer shell]

===

199*. Calculate the work done to dissociate the system of three charges placed on the vertices of an equilateral triangle of ide 10 cm as shown in figure. Here $q = 1.6\ X\ 10^{-10}C$. **CBSE (AI)-2016,2013, (D)-2008**



[**Ans**. Required work done = − potential energy of the system

$$W = -\frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{r_{12}} + \frac{q_2q_3}{r_{23}} + \frac{q_3q_1}{r_{31}}\right] = -\frac{1}{4\pi\epsilon_0}\left[\frac{q(-4q)}{a} + \frac{(-4q)(2q)}{a} + \frac{q\,(2q)}{a}\right]$$

⇨ $W = -\frac{1}{4\pi\epsilon_0}\left[-\frac{4q^2}{a} - \frac{8q^2}{a} + \frac{2q^2}{a}\right] = +\frac{1}{4\pi\epsilon_0}\frac{10q^2}{a}$

⇨ $W = 9X10^9\ \frac{10\ X\ (1.6\ X\ 10^{-10})^2}{10X\ 10^{-2}} = \ 2.304X10^{-8}$ J

Unit II: Current Electricity **20 Periods**

Chapter–3: Current Electricity

Electric current, flow of electric charges in a metallic conductor, drift velocity, mobility and their relation with electric current; Ohm's law, electrical resistance, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity, Carbon resistors, colour code for carbon resistors; series and parallel combinations of resistors; temperature dependence of resistance.

1

Internal resistance of a cell, potential difference and emf of a cell, combination of cells in series and in parallel, Kirchhoff's laws and simple applications, Wheatstone bridge, metre bridge.

Potentiometer - principle and its applications to measure potential difference and for comparing EMF of two cells; measurement of internal resistance of a cell.

201. Define current density. Write its S.I. unit. Is it a scalar or vector quantity ? **CBSE(AIC)-2010**

[Ans. Current density : Electric current flowing normally per unit area of cross section is called current density

$\vec{J} = \frac{\vec{I}}{A}$,Its S.I. unit is A/m^2. It is a vector quantity

202. (a) Define resistance of a conductor. Write its S.I. unit.
(b) What are the factors on which the resistance of a conductor depends ? **CBSE(AIC)-2015,2001**

[Ans. (a) Resistance : It is the ratio of potential difference applied across the ends of a conductor to the current flowing through it

i,e, $R = \frac{V}{I}$, Its S.I. unit is Ohm (Ω)

(b) Factors : (i) Length of the conductor $R \propto L$
(ii) Area of cross section of the conductor $R \propto 1/A$
(iii) nature of material & temperature

203. (a) Define resistivity of a conductor. Write its S.I. unit.
(b) On what factors does the resistivity of a conductor depend ? **CBSE (D)-2016,(AI)-2015,2012,2011**

[Ans. (a) Resistivity : Resistivity of the material of a conductor is defined as the resistance of conductor of that material of unit length and unit area of cross section

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

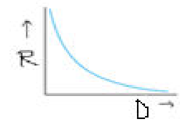
Its S.I. unit is Ohm metre ($\Omega\, m$)

(b) Factors : (i) relaxation time (i,e, temperature) and
(ii) number density of electrons

204.Draw a graph showing the variation of resistance of a metal wire as a function of its diameter keeping its length and material constant. **(Sample Paper)-2017**

[Ans. $R = \rho\frac{L}{\pi r^2} = \rho\frac{4l}{\pi D^2}$

⇨ $R \propto \frac{1}{D^2}$



205. Two wires, one of copper and the other of manganin, have same resistance and equal thickness. Which wire is longer? Justify your answer. **CBSE(AI)-2015**

[Ans. Copper wire will be longer

Reason : $\rho = \frac{R\,A}{L}$ but R and A are same ⇨ $\rho \propto 1/L$

Since $\rho_C < \rho_m$ ⇨ $L_c > L_m$

206. Two wires of equal length, one of copper and the other of manganin have the same resistance. Which wire is thicker ?

[Ans. Manganin wire is thicker **CBSE(AI)-2016,2012**

Reason : $\rho = \frac{R\,A}{L}$ but R and l are same ⇨ $\rho \propto A$

Since $\rho_m > \rho_C$ ⇨ $A_m > A_C$

207. Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Which wire gets heated up more ? Justify your answer. **CBSE(AI)-2017**

[Ans. Nichrome

Reason : $H = I^2Rt$ & $R_{Ni} > R_{Cu}$ (or Resistivity $_{Ni}$ > Resistivity $_{Cu}$)

208. Define the term conductivity of a conductor. Write its S.I. unit. On what factors does it depend ?
CBSE (AIC)-2017,(AI)-2016,(D)-2014,2008

[Ans. Conductivity : It is defined as the current flowing per unit area per unit electric field

i,e, $\sigma = \frac{J}{E}$

It is also defined as the reciprocal of resistivity i,e, $\sigma = 1/\rho$

Its S.I. unit is $\Omega^{-1}m^{-1}$

Factors : (i) nature of material and (ii) temperature (relaxation time)

209. Resistance of a conductor increases with the rise in temperature. Why ? **CBSE(DC)-2001**

[Ans. Due to increase in frequency of collision of electrons with ions/atoms in the conductor.

210 . If a wire is stretched to double its original length without loss of mass, what will be its new-
(a) resistivity (b) resistance ? **CBSE(AIC)-2001**

[Ans. (a) Resistivity will remain same

(b) Resistance will be 4 times the original resistance

$R' = (2)^2 R = 4R$

211. Two materials, Si and Cu, are cooled from 300K to 60K. What will be the effect on their resistivity ? **CBSE (F)-2013**

[Ans. For Si, resistivity will increase.

Reason : Semiconductors have negative temperature coefficient of resistivity.

For Cu, resistivity will decrease.

Reason : conductors have positive temperature coefficient of resistivity

212. Explain, why allows like constantan and manganin are used for making standard resistors ?

[Ans. Because they have **CBSE (D)-2016,(F)-2011,2004**

1. High resistivity 2. Very small temperature coefficient of resistivity

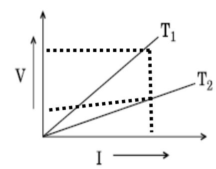
213. The I-V graph for a metallic wire at two different temperatures T_1 and T_2 is as shown in the figure. Which of the two temperatures is higher and why ? **CBSE(AI)-2015**

[Ans. T_1 is higher

Reason : for the same I, $V_1 > V_2$

⇨ $R_1 > R_2$ $[\because R = \frac{V}{I}]$

⇨ $T_1 > T_2$ as $R = R_0(1 + \alpha\, t)$



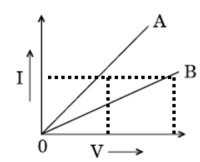
214. The I-V graph for two identical conductors of different materials A and B is shown in figure. Which one of the two has higher resistivity and why ? **CBSE(AI)-2015**

[Ans. B has higher Resistivity

Reason : As for the same I, $V_B > V_A$

⇨ $R_B > R_A$ $[\because R = \frac{V}{I}]$

⇨ $\rho_B > \rho_A$ $[\because \rho = \frac{R\,A}{L}]$

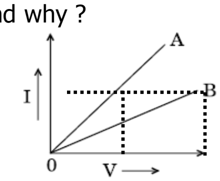


215. Two metallic resistors are connected first in series and then in parallel across a d.c. supply. Plot of I-V graph is shown for the two cases. Which one represents a parallel combination of the resistors and why ? **CBSE(AI)-2015,2004**

[Ans. A represents parallel combination

Reason : for the same I, $V_A < V_B$

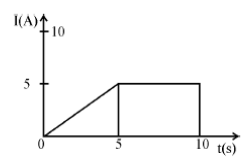
⇨ $R_A < R_B$ $[\because R = \frac{V}{I}]$



216. Figure shows a plot of current $'I'$ flowing through the cross section of a wire versus the time $'t'$. Use the plot to find the charge flowing in $10\ s$ through the wire. **CBSE(AIC)-2015**

[Ans. $q = I\,dt =$ area under I-t curve

$= \frac{1}{2}(5\ X\ 5) + (10 - 5)\ X\ 5 = 37.5\ C$



217. Show that the current density $\vec{j}$ is related to the applied electric field $\vec{E}$ by the relation **CBSE(AI)-2015, (F)-2014**

$$\vec{j} = \sigma\,\vec{E}$$

Where σ defines the conductivity of the material.

[Ans. $j = nev_d = ne\left(\frac{eE}{m}\tau\right) = \left(\frac{ne^2\tau}{m}\right)E$ $[\because \boldsymbol{v_d} = \frac{eE}{m}\tau]$

But, $\rho = \frac{m}{ne^2\tau}$

⇨ $\boldsymbol{j} = \frac{\boldsymbol{1}}{\boldsymbol{\rho}}\boldsymbol{E} = \boldsymbol{\sigma}\,\boldsymbol{E}$ ⇨ $\vec{j} = \sigma\,\vec{E}$

218. Define the term (a) Emf of a cell (b) Terminal voltage of a cell. **CBSE (DC)-2010**

[Ans. (a) Emf : Emf of a cell may be defined as the energy supplied by the cell in moving unit charge through the complete circuit (including the cell)

i,e, $E = W/q$

(b) Terminal voltage: It is the potential difference between the electrodes of a cell, when the cell is in closed circuit

$V = E - Ir$

219. Define internal resistance of a cell. Write any two factors on which it depends. **CBSE (AI)-2010**

[Ans. Internal resistance (r): It is the resistance offered by the electrolyte of a cell to the flow of current between its electrodes

Factors :(i) nature of electrolyte

(ii) concentration of electrolyte

(iii) nature of electrodes & distance between them

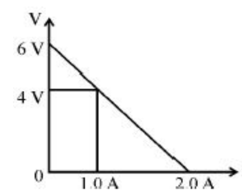
220. The emf of a cell is always greater than its terminal voltage. Give reason **CBSE (D)-2013**

[Ans. Because there is a potential drop across the internal resistance of the cell, when cell is in a closed circuit

221. Can the value of terminal potential difference be greater than the emf of a cell ? **CBSE (AI)-2013**

[Ans. yes. During the charging of the cell

222. The figure shows a plot of terminal voltage 'V' versus the current 'i' of a given cell. Calculate from the graph (a) emf of the cell and (b) internal resistance of the cell. **CBSE (AIC)-2017**



[Ans. (a) $V = E - Ir$

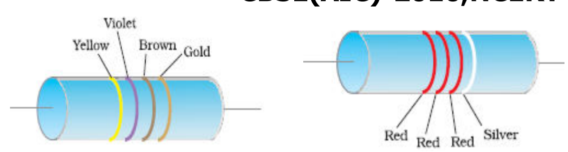
When $I = 0,\ V = E$

⇨ $E = 6\,V$

(b) $E = V + Ir$ ⇨ $6 = 4 + 1 \times r$

⇨ $r = 2\ \Omega$

223. Find the resistance of the following carbon resistors. **CBSE(AIC)-2010,NCERT-2017**



[Ans. (i) $R = 47 \times 10^1 \pm 5\,\%\ \Omega$

(ii) $R = 22 \times 10^2 \pm 10\,\%\ \Omega$

224. State Ohm's law. **CBSE(AI)-2013**

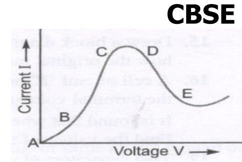
[Ans. Ohm's law : If the physical conditions of a conductor remains unchanged then the current flowing through it is directly proportional to the potential difference applied

i,e, $V \propto I$ ⇨ $V = IR$

225. Graph showing the variation of current versus voltage for a material GaAs as shown in figure. Identify the region of

(i) negative resistance **CBSE (D)-2015**

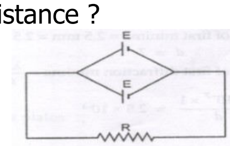
(ii) where Ohm's law is obeyed.



[Ans. (i) Region DE because current decreases on increasing voltage.

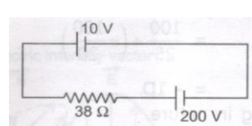
(ii) Region AB because current increases linearly on increasing voltage

226. Two identical cells each of emf E,having negligible internal resistance, are connected in parallel with each other across an external resistance R. What is the current through the resistance ? **CBSE (D)-2013**



[Ans. $I = \frac{E}{R}$

227. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω as shown. Find the value of the current in the circuit. **CBSE (D)-2013**



[Ans. $I = \frac{V}{R} = \frac{200-10}{38} = 5\ A$

228. Define the term drift velocity of charge carriers in a conductor and write its relation with the current flowing through it.

[Ans. Drift velocity (v_d) **:** **CBSE (AI)-2016,2014,(F)-2011**

The average velocity acquired by free electrons of a conductor in a direction opposite to the applied electric field is called drift velocity $(\boldsymbol{v_d \approx 10^{-4}\ m/s})$ **Relation :** $I = neAv_d$

229. How does the random motion of free electrons in a conductor gets affected when a potential difference is applied across its ends. **CBSE (AIC)-2014**

[Ans. Random motion is partially directed towards positive end of conductor

230. When electrons drift in a metal from lower to higher potential, does it mean that all the 'free' electrons of the metal are moving in the same direction? **CBSE (AI)-2012, NCERT-2017**

[Ans. By no means. The drift velocity is superposed over the large random velocities of electrons.

231. The electron drift speed is estimated to be only a few $mm\ s^{-1}$ for currents in the range of a few amperes ? How then is current established almost the instant a circuit is closed ? **NCERT-2017**

[Ans. When the circuit is closed, electric field is setup in the entire circuit instantly with the speed of em waves which causes electron drift at every portion of the circuit. A current starts flowing in the circuit almost instantly

232. If the electron drift speed is so small, and the electron's charge is small, how can we still obtain large amounts of current in a conductor ? **CBSE (AI)-2015,NCERT-2017**

[Ans. because the electron number density is very large $(\approx 10^{29}\ m^{-3})$

233. The electron drift arises due to the force experienced by electrons in the electric field inside the conductor. But force should cause acceleration. Why then do the electrons acquire a steady average drift speed ? **NCERT-2017**

[Ans. Each 'free' electron does accelerate, but due to frequent collisions with ions they acquire only an average speed known as drift speed

234. How does the drift velocity of electrons in a metallic conductor vary with increase in temperature ?

[Ans. Drift velocity will decrease on increasing the temperature **CBSE (AI)-2016,(F)-2011,(D)-2002**

Reason : $v_d = \frac{eE}{m}\tau$, when temperature is increased, relaxation time decreases or frequency of collision increases

235. If a potential difference V applied across a conductor is increased to $2V$, how will the drift velocity of electrons change ?

[Ans. drift velocity will be doubled as $v_d = \frac{e\ V}{m\ L}\tau \Rightarrow v_d \propto V$ **CBSE (AIC)-2001**

236. Define the term 'relaxation time' in a conductor. **CBSE(AI)-2016,2012,(F)-2014**

[Ans. Relaxation time : It is the average time between two successive collisions of electron with ions in a conductor

237. If the temperature of a good conductor increases, how does the relaxation time of electrons in the conductor change ?

[Ans. Relaxation time decreases **CBSE (AI)-2002**

Reason : with the increase in temperature, free electron collides more frequently with the ions/atoms of the conductor, resulting decrease in relaxation time

238. (i) How is the relaxation time related to the drift velocity of free electrons ?
(ii) Obtain an expression for the current density in terms of relaxation time. **CBSE(AI)-2016,2012,(F)-2014**

[Ans. $v_d = \frac{eE}{m}\tau$

Expression : $j = nev_d = ne\left(\frac{\boldsymbol{eE}}{\boldsymbol{m}}\boldsymbol{\tau}\right) = \frac{ne^2\tau}{m}E$

239. (i) Define mobility of a charge carrier. Write its S.I. unit.
(ii) What is its relation with relaxation time ? **CBSE(AI)-2016,2015,(D)-2014**
(iii) How does the electron mobility change if
(a) temperature is increased , (b) potential difference in doubled ?

[Ans. (i) Mobility: It is defined as the drift velocity per unit electric field

i,e, $\boldsymbol{\mu_m} = \boldsymbol{v_d}/\boldsymbol{E}$ Its S.I. unit is $ms^{-1}N^{-1}C$

(ii) Relation : $\boldsymbol{\mu_m} = \boldsymbol{v_d}/\boldsymbol{E} = \frac{1}{E}\left(\frac{eE}{m}\tau\right) = \frac{e}{m}\tau$

(iii) (a) μ_m decreases because if temperature is increased, relaxation time τ decreases
(b) No effect because μ_m does not depend on potential difference

240. What happens if the galvanometer and cell are interchanged at the balanced point of the Wheatstone bridge? Would the galvanometer show any current ?

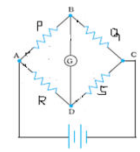
[**Ans.** balanced condition still remains satisfied hence galvanometer does not show any current

241. What is a meter bridge ? Write the principle of working meter bridge. **CBSE (AI)-2017,2016,(AIC)-2015**

[**Ans. Meter bridge :** It is the simplest practical application of Wheatstone bridge and is used to determine the unknown resistance

principle : It is based on the principle of Wheatstone bridge , i,e, in balanced condition of the bridge

$$\frac{P}{Q} = \frac{R}{S}$$



242. Why are the connections between the resistors in a meter bridge made of thick metal (copper) strips ? **CBSE(AI)-2016,2014**

[**Ans.** Thick copper strips have negligible resistance due to low resistivity & large area of cross section. It helps to maintain continuity without adding resistance to the circuit and accurate balance point is obtained

243. Why is it generally preferred to obtain the balance point in the middle of the meter bridge wire? **CBSE (D)-2014**

[**Ans.** sensitivity of meter bridge is higher when balance point lies in the middle of the wire

244. State the principle of potentiometer. **CBSE (F)-2017,2009,(D)-2016,(DC)-2014,(AI)-2014,2006**

[**Ans.** When a constant current flows through a conductor of uniform area of cross section, the potential difference across any length of the conductor is directly proportional to that length

i,e, $V \propto l$

245. Of which material a metre bridge/potentiometer wire normally made and why ?**CBSE (AI) -2016,2014,(F)-2013**

[**Ans.** Nichrome or manganin

Reason : Such an alloy has high resistivity and very small temperature coefficient of resistance, hence its resistance does not change with rise in temperature due to flow of current

246. Why should the potentiometer wire be of uniform cross section and composition ? **CBSE (AIC)-2014**

[**Ans.** A wire of uniform cross section and composition has the uniform resistance per unit length and only then potential difference per unit length will be directly proportional to the length, as required by the principle of potentiometer

247. Why do we prefer a potentiometer with a longer wire ? **CBSE (AIC)-2014**

[**Ans.** Sensitivity $\propto \frac{1}{Potential\ gradient\ K}$ & $K = \frac{V}{L}$

A longer bridge wire will have small potential gradient and hence it will be more sensitive, so it is preferred

248.. What is meant by sensitivity of a potentiometer ? **CBSE (AIC)-2014,(DC)-2011,(D)-2003**

[**Ans.** A potentiometer is said to be sensitive if

(i) It can measure very small potential differences, and

(ii) it shows a large change in balancing length ,for a small change in potential difference being measured,

249. How can a given potentiometer be made more sensitive ? **CBSE (F)-2017, (AIC)-2014,(DC)-2011,(D)-2003**

[**Ans.** It can be made more sensitive by

(i) decreasing current in the main circuit

(ii) decreasing potential gradient or increasing the length of potentiometer wire

(iii) increasing resistance put in series with the potentiometer wire

250. The emf of the driving cell used in the main circuit of the potentiometer should be more than the potential Difference to be measured. Why ? **CBSE (AIC)-2014, (DC)-2011, (D)-2003**

[**Ans.** If it is not so the balance point will not be obtained on the potentiometer wire

251. The variation of potential difference V with length l in case of two potentiometer wires P and Q is as shown.

(a) Which potentiometer is more sensitive ? **CBSE (F)-2017,(AI)-2016,2006**

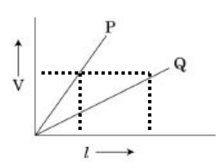
(b) Which of these will you prefer for comparing emfs of two primary cells and why ?

[**Ans. (a)** Potentiometer Q is more sensitive

Reason : Sensitivity $\propto \frac{1}{Potential\ gradient\ K}$

& Q has less potential gradient ($K = \frac{V}{L}$)

(b) Potentiometer Q as it is more sensitive

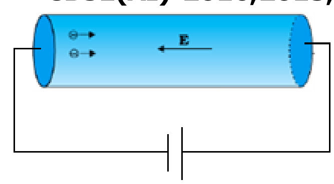


252. When a metallic conductor is subjected to a certain potential V across its ends, discuss briefly how the phenomenon of drift occurs. **CBSE (AI)-2015,(F)-2014**

[Ans. Drift : When a potential difference is applied to the ends of a conductor, electrons get accelerated due to electric field. After being accelerated for relaxation time (τ), each electron undergoes collisions with ions and their velocity again becomes random. The electrons move with an average velocity which is independent of time, although they are accelerated. This phenomenon is called drift and average velocity is called drift velocity.

253. Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time of electrons.

[Ans. Expression for drift velocity : **CBSE(AI)-2016,2015,2009**



Let a potential difference V is applied across the ends of a conductor, then each free electron will experience a force

$$\vec{F} = -e\vec{E} \quad \Rightarrow \quad \vec{a} = -\frac{e\vec{E}}{m}$$

Average of all random velocities under this acceleration is the drift velocity

$$\Rightarrow \quad \vec{v_d} = \frac{\vec{v_1}+\vec{v_2}+----------+\vec{v_N}}{N} = \frac{(\vec{u_1}+\vec{a}\,\tau_1)+(\vec{u_2}+\vec{a}\,\tau_2)+----------+(\vec{u_N}+\vec{a}\,\tau_N)}{N}$$

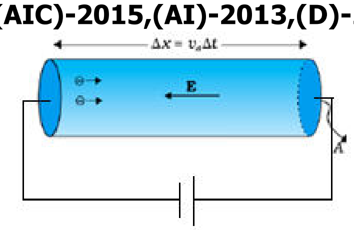
$$\Rightarrow \quad \vec{v_d} = \frac{\vec{u_1}+\vec{u_2}+----------+\vec{u_N}}{N} + \vec{a}\left(\frac{\tau_1+\tau_2+--------+\tau_N}{N}\right)$$

$$\Rightarrow \quad \vec{v_d} = 0 + \vec{a}\,\tau = \vec{a}\,\tau$$

$$\Rightarrow \quad \vec{v_d} = -\frac{e\vec{E}}{m}\tau$$

254. Deduce the relation between current I flowing through a conductor and drift velocity $\vec{v_d}$ of free electrons.

[Ans. Relation between current and drift velocity : **CBSE(AIC)-2015,(AI)-2013,(D)-2008**



Let a potential difference V is applied across the ends of a conductor as shown. If n be the number of free electrons per unit volume then charge crossing area A in time Δt

$$\Delta Q = \text{Ne} = (n\,A v_d\,\Delta t)\,e$$

$$\Rightarrow \quad \text{I} = \frac{\Delta Q}{\Delta t} = \frac{n\,e\,A\,v_d\,\Delta t}{\Delta t}$$

$$\Rightarrow \quad \text{I} = neAv_d$$

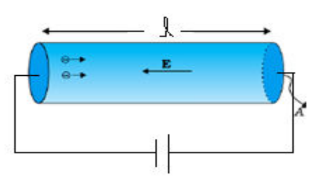
$$\& \quad \text{j} = \frac{\text{I}}{\text{A}} = \frac{n\,e\,A\,v_d}{A} \quad \Rightarrow \quad \text{j} = nev_d$$

255. Deduce Ohm's law using the concept of drift velocity. **CBSE(AI)-2013**

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. **CBSE (D)-2016,(AI)-2012**

[Ans. Let a potential difference V is applied across the ends of a conductor as shown.



Electric field produced, $E = \frac{V}{l}$

$$\Rightarrow \quad v_d = \frac{eE}{ml}\tau = \frac{eV}{ml}\tau$$

$$\Rightarrow \quad \text{I} = neAv_d = neA\left(\frac{eV}{ml}\tau\right) = \frac{ne^2\tau}{m}\left(\frac{A}{l}\right)\text{V}$$

$$\Rightarrow \quad \frac{V}{I} = \frac{m}{ne^2\tau}\left(\frac{l}{A}\right) \qquad ---------(1)$$

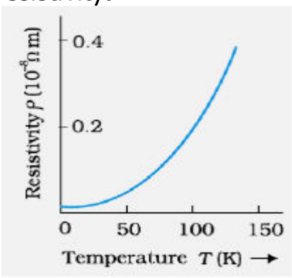
If the physical conditions of conductor such as temperature etc. remains constant then

$$\frac{m}{ne^2\tau}\left(\frac{l}{A}\right) = constant = R \qquad --------(2)$$

$\Rightarrow$ from (1) $\frac{V}{I} = \boldsymbol{R}$ $\Rightarrow$ $V = IR$, Now, $R = \frac{\rho l}{A}$ $\Rightarrow$ from (2) $\boldsymbol{\rho} = \frac{\boldsymbol{m}}{\boldsymbol{ne^2\tau}}$

256. (i) Plot a graph showing the variation of resistivity with temperature in the case of a conductor.
(ii) How does one explain such behaviour, using the mathematical expression of the resistivity.

[Ans. (i) Graph :



Conductor

(ii) explanation : $\boldsymbol{\rho = \frac{m}{ne^2\tau}}$

In conductors, with increase in temperature, number density (n) does not change but the average speed of electrons and hence frequency of collision increases due to which relaxation time (τ) decreases. Hence resistivity ρ increases.

Over limited range of temperature

$$\rho_T = \rho_0 \left(1 + \alpha \left(T - T_0\right)\right)$$

Where α is called temperature coefficient of resistivity.

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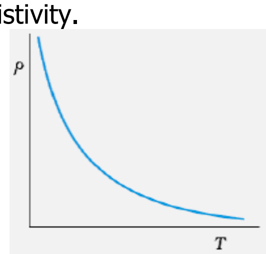
257. (i) Plot a graph showing the variation of resistivity with temperature in the case of a semiconductor.
(ii) How does one explain such behaviour, using the mathematical expression of the resistivity.

[Ans. (i) Graph :



Semiconductor

(ii) explanation : $\rho = \frac{m}{ne^2\tau}$ ⇨ $\rho \propto \frac{1}{n}$

& for semiconductors $n(T) = n_0\, e^{-E_g/K_BT}$ ⇨ $\rho(T) = \rho_0\, e^{E_g/K_BT}$

In semiconductors, with increase in temperature, number density (n) increases exponentially and dominates the decrease in relaxation time (τ)
Hence resistivity ρ decreases exponentially

==

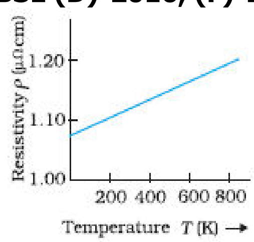
258. Explain by plotting a graph, variation of resistivity with temperature for an allow such as Nichrome (Constantan or manganin).

CBSE (D)-2016, (F)-2011,2004

[Ans. Graph & explanation :

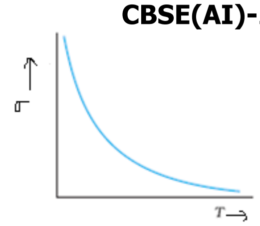
We have $\rho_T = \rho_0 \left(1 + \alpha \left(T - T_0\right)\right)$

For the allows such as Nichrome or constantan or manganin, coefficient of resistivity is negligible or very small hence these allows exhibit very weak dependence of resistivity with temperature as shown



259. Plot a graph showing the variation of conductivity with temperature for a metallic conductor. How does one explain such behaviour, using the mathematical expression of the conductivity of a material. **CBSE(AI)-2004**

[Ans. (i) Graph :



(ii) explanation : $\boldsymbol{\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m}}$

In conductors, with increase in temperature, number density (n) does not change but the average speed of electrons and hence frequency of collision increases due to which relaxation time (τ) decreases. Hence conductivity σ decreases

260. A wire whose cross sectional area is increasing linearly from it one end to another, is connected across a battery Of V volts. Which of following quantities remain constant in the wire ? **CBSE (D)-2017,(AIC)-2015**

(a) drift speed (b) current density (c) electric current (d) electric field. Justify your answer.

[Ans. Current Justification : all other quantities depends on area of cross section

261. 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 velocities of electrons in the two wires.

CBSE (AI)-2010

[Ans. $I = neAv_d$ & $\boldsymbol{I_X = I_Y}$

⇨ $(2n)\, eAv_X = n\, eAv_Y$ ⇨ $2v_X = v_Y$ ⇨ $v_X/v_Y = 1/2$

262. Explain giving reasons, how the internal resistance of a cell changes in the following cases : **CBSE(F)-2008**
(i) When concentration of the electrolyte is increased
(ii) When area of the anode is decreased
(iii) When temperature of the electrolyte is increased

[Ans. (i) Internal resistance increases
Reason : inter ionic attractions increase and the movement of the ions become difficult
(ii) Internal resistance increases
Reason : lesser area of the anode decreases its tendency to attract its oppositely charged ions
(iii) Internal resistance decreases
Reason : Both inter ionic attractions and viscous forces decrease at higher temperature

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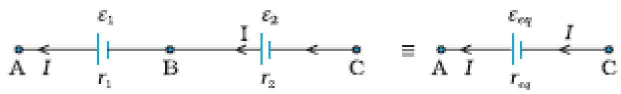
263. Derive an expression for the equivalent resistance of combination of cells in series. **NCERT-2017**



[Ans. $V_{AC} = V_A - V_C = (V_A - V_B) + (V_B - V_C)$

⇨ $V_{AC} = (E_1 - Ir_1) + (E_2 - Ir_2)$

⇨ $V_{AC} = (E_1 + E_2) - I(r_1 + r_2)$ ----------(1)

Let E_{eq} be the equivalent emf and r_{eq} be the equivalent internal resistance of this series combination then we have

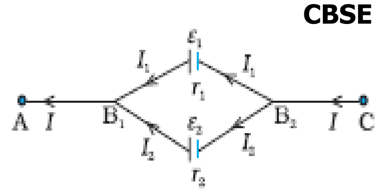
$V_{AC} = \mathrm{E_{eq}} - \mathrm{Ir_{eq}}$ ----------(2)

On comparing (1) & (2) we get

$E_{eq} = E_1 + E_2$ & $r_{eq} = r_1 + r_2$

==

264. Two cells of emfs E_1 and E_2 and internal resistances r_1 and r_2 are connected in parallel as shown in the figure. Deduce an expression for the **CBSE (AI)-2015, (F)-2012**
(i) equivalent emf of the combination
(ii) equivalent internal resistance of the combination
(iii) potential difference between the points A and C



[Ans. We have

$V = V_{B_1} - V_{B_2} = E_1 - I_1 r_1$ ⇨ $I_1 = \frac{E_1 - V}{r_1}$

& $V = V_{B_1} - V_{B_2} = E_2 - I_2 r_2$ ⇨ $I_2 = \frac{E_2 - V}{r_2}$

⇨ $\mathrm{I} = \mathrm{I_1} + \mathrm{I_2} = \left(\frac{E_1 - V}{r_1}\right) + \left(\frac{E_2 - V}{r_2}\right) = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right) = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}\right) - V\left(\frac{r_1 + r_2}{r_1 r_2}\right)$

⇨ $V\left(\frac{r_1 + r_2}{r_1 r_2}\right) = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}\right) - \mathrm{I}$

⇨ $V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}\right)\left(\frac{r_1 r_2}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$

⇨ $V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$ --------(1)

On comparing with, $\mathrm{V} = \mathrm{E_{eq}} - \mathrm{Ir_{eq}}$

(i) $E_{eq} = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right)$

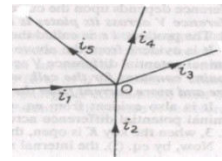
(ii) $r_{eq} = \left(\frac{r_1 r_2}{r_1 + r_2}\right)$ (iii) $V_{AC} = V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - \mathrm{I}\left(\frac{r_1 r_2}{r_1 + r_2}\right)$

265. State Kirchhoff's rules in electrostatics and explain on what basis they are justified ? **CBSE(AI)-2017,2015**

[Ans. Kirchhoff's Rules :

(i) Junction rule :The algebraic sum of all the currents meeting at any junction in an electric circuit is zero.

i,e, $\sum i = 0$

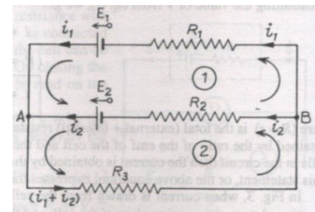


⇨ $i_1 + i_2 = i_3 + i_4 + i_5$

This rule is based on the conservation of charge.

(ii) Loop rule : In any closed mesh of an electric circuit, the algebraic sum of the products of the currents and the resistance in each part of the mesh is equal to the algebraic sum of emf's in that mesh.

i,e, $\sum iR = \sum E$



In mesh (1),

$$i_1 R_1 - i_2 R_2 = E_1 - E_2$$

Similarly, in mesh (2)

$$i_2 R_2 + (i_1 + i_2) R_3 = E_2$$

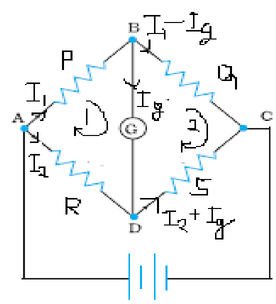
This rule is based on the conservation of energy

266. What is Wheatstone bridge ? When is the bridge said to be balanced ? Use Kirchhoff's rules to obtain conditions for the balanced condition in a Wheatstone bridge. **CBSE(D)-2015**

[Ans. Wheatstone bridge : It is an arrangement of four resistances which is used to determine one of these resistance in terms of the remaining three resistances

Balanced condition : If the resistances in the Wheatstone bridge are so arranged that current in the galvanometer (I_g) is zero then the bridge is said to be balanced and in this balanced condition

$$\frac{P}{Q} = \frac{R}{S}$$



Proof : In the balanced condition, $I_g = 0$

Applying Kirchhoff's loop rule to ABDA

$I_1 P + 0 - I_2 R = 0$

⇨ $I_1 P = I_2 R$ -------(1)

Again applying Kirchhoff's loop rule to BCDB

$I_1 Q - I_2 S - 0 = 0$

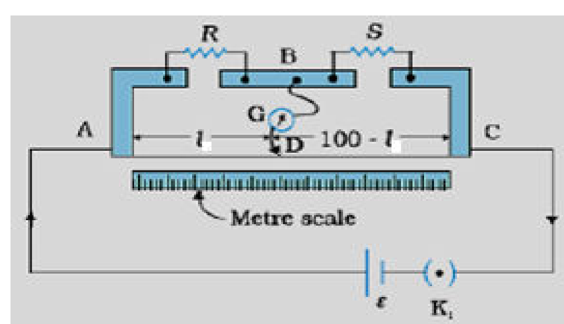
⇨ $I_1 Q = I_2 S$ -------(2)

⇨ from (1) & (2), $\frac{I_1 P}{I_1 Q} = \frac{I_2 R}{I_2 S}$ ⇨ $\frac{P}{Q} = \frac{R}{S}$

267. How a metre bridge is used to determine the unknown resistance of a given wire ? Write the necessary precautions to minimize the error in the result. **CBSE (AI)-2016, (AIC)-2015**

[Ans. <u>Determination of unknown resistance</u> (S)

Let l be the balancing length for unknown resistance S as shown then



$$\frac{P}{Q} = \frac{\rho l/A}{\rho(100-l)/A} = \frac{l}{(100-l)}$$

⇨ $\frac{R}{S} = \frac{l}{(100-l)}$

⇨ $S = R\left(\frac{100-l}{l}\right) = R\left(\frac{100}{l} - 1\right)$

By choosing three different values of R, we calculate S each time. Average of these values of S gives the value of unknown resistance

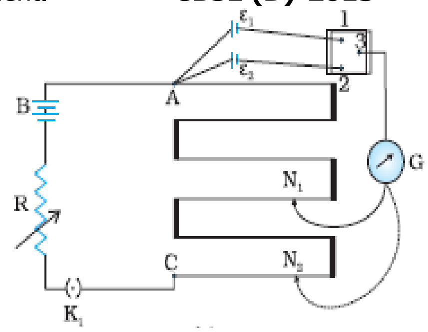
Precautions : (i) Make all the connections neat, clean and in tight manner

(ii) select those values of R for which the balancing length l is closed to the middle point of the wire

268. (i) With the help of a circuit diagram, explain how a potentiometer is used to compare the emf's of two primary cells. obtain the required expression used for comparing the emfs. **CBSE (D)-2013, (AIC)-2008**

(ii) Write two possible causes for one sided deflection in a potentiometer experiment. **CBSE (D)-2013**

[Ans. (i) Comparison of emf's of two primary cells :



If l is the balancing length the by the principle of potentiometer

$\varepsilon = K\,l$ -----------(1)

Where K is the potential gradient.

Let l_1 be the balancing length for cell of emf ε_1 then as per (1)

$\varepsilon_1 = K\,l_1$

Similarly, if l_2 be the balancing length for cell of emf ε_2 then

$\varepsilon_2 = K\,l_2$

⇨ from (1) & (2)

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{K\,l_1}{K\,l_2} = \frac{l_1}{l_2}$$

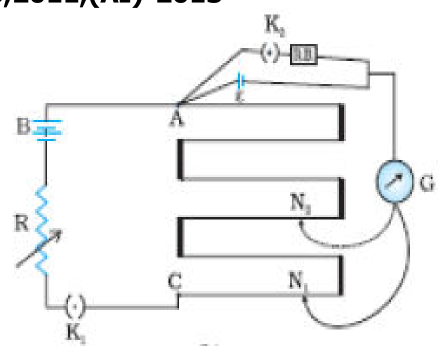
(ii) Possible causes :

(a) The emf ε_1 or ε_2 is more than the emf of driver cell

(b) Positive terminals of driver cell and the cell whose emf is to be measured may not be connected to the zero end of the potentiometer

269. With the help of a circuit diagram, explain how a potentiometer is used to determine the internal resistance of a cell. tain the required expression used. **CBSE (F)-2016,2011,(AI)-2013**

[Ans. Determination of internal resistance of a cell :



Let l_1 is the balancing length when key K_2 is open then by the principle of potentiometer

$\varepsilon = K\,l_1$ -----------(1)

Where K is the potential gradient.

Similarly, if l_2 be the balancing length when key K_2 is closed then

$V = K\,l_2$ ---------(2)

⇨ from (1) & (2)

$$\frac{\varepsilon}{V} = \frac{K\,l_1}{K\,l_2} = \frac{l_1}{l_2}$$

⇨ $\frac{I(R+r)}{IR} = \frac{l_1}{l_2}$ ⇨ $\left(1+\frac{r}{R}\right) = \frac{l_1}{l_2}$

⇨ $r = R\left(\frac{l_1}{l_2} - 1\right)$

270. Why is potentiometer preferred over a voltmeter for comparison of emf. of cells ? **CBSE(D)-2016,(AI)-2014**

[Ans. because a potentiometer does not draw current for any measurement unlike a voltmeter

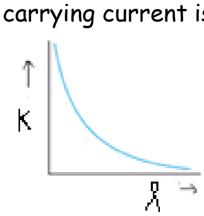
271. (i) Define potential gradient. Write its S.I. unit. Obtain an expression for potential gradient in terms of the resistivity of the potentiometer wire. **CBSE (D)-2016,(AI)-2014,2006,(F)-2009**

(ii) In a potentiometer experiment, if the area of cross section of the wire increases uniformly from one end to another, draw a graph showing how potential gradient would vary as the length of the wire increases from one end ? **CBSE (AIC)-2014**

[Ans. Potential gradient :

Potential drop per unit length of the wire carrying current is called potential gradient

i,e, $K = \frac{V}{L} = \frac{IR}{L} = \frac{I\rho L/A}{L} = \frac{I\rho}{A}$



⇨ $K \propto 1/A$

S.I. unit of potential gradient is V/m

272. A conductor of length $'l'$ is connected to a d.c. source of potential $'V'$. If the length of the conductor is tripled by gradually stretching it, keeping $'V'$ constant, how will (i) drift speed of electrons and (ii) resistance of the conductor be affected ? Justify your answer. **CBSE (F)-2012**

[Ans. (i) $v_d = \frac{eV}{ml}\tau$ ⇨ $v_d \propto 1/l$ drift velocity will become one third when length of the conductor is tripled

(ii) Now when the wire is stretched $A\,X\,l = constant$

As $R = \rho\frac{l}{A}$ ⇨ $R_2 = \rho\frac{l_2}{A_2} = \rho\frac{3l_1}{A_1/3} = 9\,\rho\frac{l_1}{A_1} = 9R_1$ Hence resistance will become 9 times

273. Two wires X and Y have the same resistivity but their cross sectional areas are in the ratio 2:3 and lengths in the ratio 1:2. They are first connected in series and then in parallel to a d.c. source. Find out the ratio of the drift speeds of the electrons in the two wires for the two cases. **CBSE (AI)-2008**

[Ans. Given : $A_X : A_Y = 2{:}3$ & $l_X : l_Y = 1{:}2$

(i) in series, $I_X = I_Y$ ⇨ $neA_X(v_d)_X = neA_Y(v_d)_Y$

⇨ $\frac{(v_d)_X}{(v_d)_Y} = \frac{A_Y}{A_X} = 3/2$

(ii) in parallel, $V_X = V_Y$ ⇨ $I_XR_X = I_YR_Y$

⇨ $neA_X(v_d)_X\,(\rho\,\frac{l_X}{A_X}) = neA_Y(v_d)_Y\,(\rho\,\frac{l_Y}{A_Y})$

⇨ $\frac{(v_d)_X}{(v_d)_Y} = \frac{l_Y}{l_X} = 2/1$

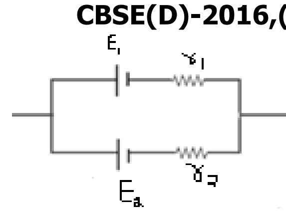
274. A potential difference V is applied across a conductor of length L and diameter D. How is the drift velocity v_d, of charge carriers in the conductor is affected when (i) V is halved (ii) L is doubled and (iii) D is halved ? Justify your answer in each case. **CBSE(AI)-2015**

[Ans. $v_d = \frac{eV}{ml}\tau$ **(i)** v_d will become half as $v_d \propto V$ **(ii)** v_d will become half as $v_d \propto 1/L$

(iii) v_d will remain same as it does not depend on diameter

275. Two cells of emf $1.5\,V$ and $2.0\,V$ having internal resistances 0.2Ω and 0.3Ω respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell. **CBSE(D)-2016,(AI)-2013**

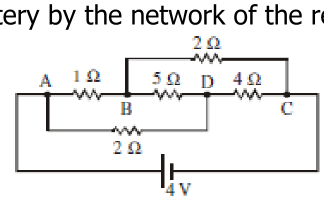
[Ans. Given : $E_1 = 1.5\,V, E_2 = 2.0\,V, r_1 = 0.2\Omega, r_2 = 0.3\Omega, E_{eq} = ?$ & $r_{eq} = ?$



$$E_{eq} = \frac{E_1r_2 + E_2r_1}{r_1 + r_2} = \frac{1.5\,X\,0.3 + 2.0\,X\,0.2}{0.2+0.3} = \frac{0.85}{0.5} = 1.7\,V$$

$$r_{eq} = \frac{r_1\,r_2}{r_1 + r_2} = \frac{0.2\,X\,0.3}{0.2+0.3} = \frac{0.06}{0.5} = 0.12\,\Omega\ ]$$

276. Calculate the current drawn from the battery by the network of the resistors shown in figure. **CBSE(AIC)-2015**



[Ans. given network is a balanced Wheatstone bridge, $\frac{1}{R} = \frac{1}{1+2} + \frac{1}{2+4} = \frac{1}{2}$ ⇨ $R = 2\,\Omega$ ⇨ $I = \frac{V}{R} = \frac{4}{2} = 2\,A$

277. In a meter bridge with R and S in the gaps, the null point is found at 40 cm from A. If the resistance of 30 Ω is connected in parallel with S, the null point occurs at 50 cm from A. Determine the value of R and S. **CBSE(AI)-2016, (D)-2010**

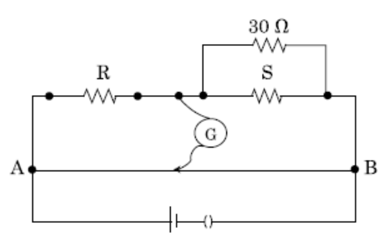
[Ans. $S = R\left(\frac{100-l}{l}\right)$

In I^{st} case, $S = R\left(\frac{100-40}{40}\right) = \frac{3}{2}R$ ⇨ $R = \frac{2}{3}S$

In II^{nd} case, $\frac{30\,S}{30+S} = R\left(\frac{100-50}{50}\right) = R$

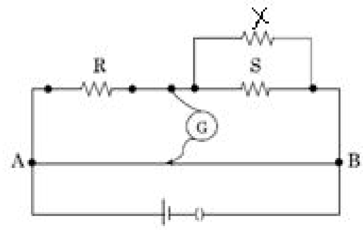
⇨ $\frac{30\,S}{30+S} = R = \frac{2}{3}S$ ⇨ 60 + 2S = 90 ⇨ S = 15 Ω

⇨ $R = \frac{2}{3}S = \frac{2}{3}$ X 15 = 10 Ω



278. In a meter bridge, the null point is found at a distance of l_1 cm from A. If now a resistance of X is connected in parallel with S, the null point occurs at l_2 cm from A. Obtain a formula for X in terms of l_1, l_2 and S.

[Ans. $S = R\left(\frac{100-l}{l}\right)$ **CBSE (AI)-2017,2009,(D)-2010**



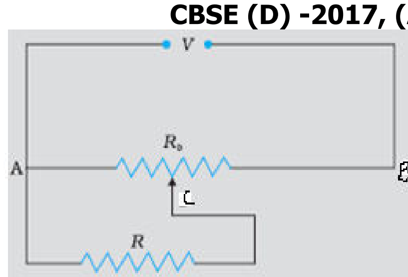
In I^{st} case, $S = R\left(\frac{100-l_1}{l_1}\right)$ -------(1)

In II^{nd} case, $\frac{X\,S}{X+S} = R\left(\frac{100-l_2}{l_2}\right)$ -------(2)

Dividing (1) by (2), $\frac{S}{\frac{X\,S}{X+S}} = \frac{R\left(\frac{100-l_1}{l_1}\right)}{R\left(\frac{100-l_2}{l_2}\right)}$ ⇨ $\frac{X+S}{X} = \frac{l_2}{l_1}\left[\frac{100-l_1}{100-l_2}\right]$

⇨ $1+\frac{S}{X} = \frac{l_2}{l_1}\left[\frac{100-l_1}{100-l_2}\right]$ ⇨ $\frac{S}{X} = \frac{l_2}{l_1}\left[\frac{100-l_1}{100-l_2}\right] - 1$ ⇨ $X = \frac{S}{\frac{l_2}{l_1}\left[\frac{100-l_1}{100-l_2}\right]-1}$

279. A resistance of $R\ \Omega$ draws current from a potentiometer. The potentiometer wire AB, has a total resistance of $R_0\ \Omega$. A voltage V is supplied to the potentiometer. Derive an expression for the voltage across R when the sliding contact is in the middle of the potentiometer wire. **CBSE (D) -2017, (AI)-2014**



[Ans. Resistance between A and C

$$R_1 = \frac{R\left(\frac{R_0}{2}\right)}{R+\frac{R_0}{2}} = \frac{R_0 R}{R_0 + 2R}$$

⇨ Effective resistance of the circuit

$$R_2 = R_1 + \frac{R_0}{2}$$

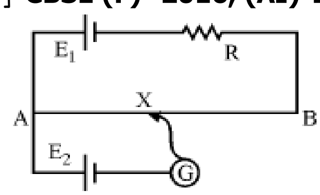
current through potentiometer wire

$$\mathrm{I} = \frac{V}{R_2} = \frac{V}{R_1+\frac{R_0}{2}} = \frac{2V}{2R_1 + R_0}$$

Required voltage,

$$\mathrm{V}_1 = \mathrm{I}\ R_1 = \left(\frac{2V}{2R_1 + R_0}\right)R_1 = \frac{2V}{2\left(\frac{R_0 R}{R_0+2R}\right)+R_0} \text{ X } \left(\frac{R_0 R}{R_0 + 2R}\right) = \frac{2V}{\frac{R_0\,[2R+R_0+2R]}{(R_0+2R)}} \text{ X } \left(\frac{R_0 R}{R_0 + 2R}\right) = \frac{2VR}{R_0 + 4R}$$

280. In the circuit diagram given below, AB is a uniform wire of resistance 15 Ω and length 1 m. It is connected to a cell E_1 of emf 2V and negligible internal resistance and a resistance R. The balance point with another cell E_2 of emf 75 mV is found at 30 cm from end A. Calculate the value of R. **[Ans** 105 Ω] **CBSE (F) -2016, (AI)-2015**



[Ans. $\varepsilon = K\,l$

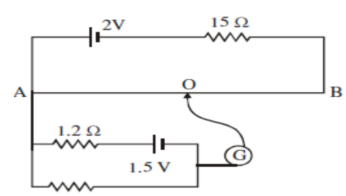
⇨ $E_2 = (IR')\,l = \left(\frac{E_1}{R+R_{AB}}\right)R'\,l$

$75\ X\ 10^{-3} = \left(\frac{2}{R+15}\right)15\ X\ 30X\ 10^{-2}$

⇨ $\boldsymbol{R+15} = \frac{2\ X\ 15\ X\ 30\ X\ 10^{-2}}{75\ X\ 10^{-3}} = 120$

⇨ $\boldsymbol{R} = 120 - 15 = 105\ \Omega$

281. In the following potentiometer circuit AB is a uniform wire of length 1 m and resistance 10 Ω. Calculate the
(i) potential gradient along the wire, and **[Ans** 0.8 V/m, 37.5 cm] **CBSE (D) -2016**
(ii) balance length AO (= l).



[Ans. **(i)** $K = \frac{V_{AB}}{l_{AB}} = \frac{\mathrm{I}\,R_{AB}}{l_{AB}} = \left(\frac{\boldsymbol{E}}{\boldsymbol{R_{total}}}\right)\left(\frac{R_{AB}}{l_{AB}}\right) = \left(\frac{2}{\boldsymbol{15+10}}\right)\left(\frac{10}{1}\right)$

⇨ $K = \left(\frac{20}{25}\right) = 0.8\ V/m$

(ii) Current flowing in the circuit containing cell

$\mathrm{I} = \frac{1.5}{1.2+0.3} = 1\ A$ ⇨ $\boldsymbol{V_{AO}} = 0.3 \text{ X } 1 = 0.3\ V$

Now, $K = \frac{V_{AO}}{l_{AO}}$ ⇨ $l_{AO} = \frac{V_{AO}}{K} = \frac{0.3}{0.8} = 0.375 \text{ m} = 37.5\ cm$

Unit III: Magnetic Effects of Current and Magnetism 22 Periods

Chapter–4: Moving Charges and Magnetism

Concept of magnetic field, Oersted's experiment.

Biot - Savart law and its application to current carrying circular loop.

Ampere's law and its applications to infinitely long straight wire. Straight and toroidal solenoids (only qualitative treatment), force on a moving charge in uniform magnetic and electric fields, Cyclotron.

Force on a current-carrying conductor in a uniform magnetic field, force between two parallel current-carrying conductors-definition of ampere, torque experienced by a current loop in uniform magnetic field; moving coil galvanometer-its current sensitivity and conversion to ammeter and voltmeter.

301. State the Lorenz's magnetic force and express it in vector form. Which pair of vectors are always perpendicular to each other ? **CBSE (DC)-2017**

[**Ans**. **Lorentz's magnetic force** : It is the force experienced by a charged particle of charge 'q' moving in magnetic field $\vec{B}$ with velocity $\vec{v}$

$\vec{F_m} = q(\vec{v} \times \vec{B})$ **Perpendicular pairs : (i)** $\vec{F_m} \perp \vec{v}$ **(ii)** $\vec{F_m} \perp \vec{B}$

302. Write the expression, in vector form, for the Lorentz magnetic force $\vec{F}$ due to a charge moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. What is the direction of the magnetic force ? **CBSE (D)-2016,2014,2008**

[**Ans**. $\vec{F} = q(\vec{v} \times \vec{B})$

The direction of magnetic force is perpendicular to the plane containing velocity and magnetic field vectors

303. Under what condition is the force acting on a charge(or an electron) moving through a uniform magnetic field maximum ?

[**Ans**. When it moves perpendicular to the direction of magnetic field **CBSE (D)-2007**

Reason : $F = B\,q\,v\,sin\theta$ ⇨ when $\theta = 90^0$, $F = F_{max}$

304. Under what condition is the force acting on a charge moving through a uniform magnetic field minimum ?

[**Ans**. When it moves parallel or antiparallel to the direction of magnetic field **CBSE (D)-2007,(AI)-2005**

Reason : $F = B\,q\,v\,sin\theta$ ⇨ when $\theta = 0^0$ or $\theta = 180^0$, $F = 0 = F_{min}$

305. State the condition under which a charged particle moving with velocity v goes undeflected in a magnetic field B.

[**Ans**. $\vec{F_m} = q(\vec{v} \times \vec{B})$ **CBSE (F)-2017**

The charge will go undeflected when $F_m = 0$ i,e, If $\vec{v}$ is parallel or antiparallel to $\vec{B}$, i,e, either $\theta = 0^0$ or $\theta = 180^0$

306. An electron does not suffer any deflection while passing through a region of uniform magnetic field. What is the direction of the magnetic field ? **CBSE (AI)-2009**

[**Ans**. The magnetic field $\vec{B}$ is parallel or antiparallel to velocity of electron $\vec{v}$, i,e, either $\theta = 0^0$ or $\theta = 180^0$

Then $\vec{F_m} = q(\vec{v} \times \vec{B}) = 0$

307. Define one Tesla using the expression for the magnetic force acting on a particle of charge 'q' moving with velocity $\vec{v}$ in a uniform magnetic field $\vec{B}$. **CBSE (F)-2014**

[**Ans**. $F = B\,q\,v\,sin\theta$ ⇨ $B = \frac{F}{q\,v\,sin\theta}$

If F = 1N, q= 1C and $\theta = 90^0$ then, B = 1T

Hence one Tesla is the magnetic field in which a charge of 1Coulomb moving with velocity 1m/s, normally to the magnetic field, experiences a force of 1N

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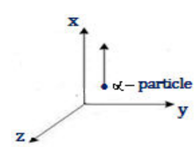
308. A beam of $\alpha - particles$ projected along $+\,x$ axis, experiences a force due to magnetic field along the $+\,y$ axis. What is the direction of magnetic field ? **CBSE (AI)-2010**

[**Ans**. $\vec{F} = q(\vec{v} \times \vec{B}) = q(v\hat{\imath} \times B\,\hat{\jmath}) = qvB\hat{k}$

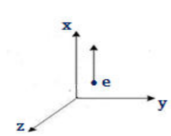
towards $+z$ axis



309. A beam of electrons projected along $+\,x$ axis, experiences a force due to magnetic field along the $+\,y$ axis. What is the direction of magnetic field ? **CBSE (AI)-2010**

[**Ans**. $\vec{F} = q(\vec{v} \times \vec{B}) = -q(v\hat{\imath} \times B\,\hat{\jmath}) = -qvB\hat{k}$

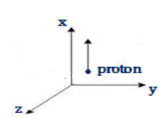
towards $-z$ axis



310. A beam of protons projected along $+\,x$ axis, experiences a force due to magnetic field along the – y axis. What is the direction of magnetic field ? **CBSE (AI)-2010**

[**Ans**. $\vec{F} = q(\vec{v} \times \vec{B}) = q(v\hat{\imath} \times -B\,\hat{\jmath}) = -qvB\hat{k}$

towards $-z$ axis



311. Two particles A and B of masses m and $2m$ have charges q and $2q$ respectively. Both these particles moving with velocities v_1 and v_2 respectively in the same direction enter the same magnetic field B acting normally to the direction of their motion. If the two forces F_A and F_B acting on them are in the ratio of 1:2, find the ratio of their velocities. **CBSE (D)-2011**

[Ans. $F = Bqv\sin 90 = Bqv$

⇨ $\frac{F_1}{F_2} = \frac{Bqv_1}{B(2q)v_2} = \frac{v_1}{2v_2}$ ⇨ $\frac{1}{2} = \frac{v_1}{2v_2}$ ⇨ $v_1 : v_2$ = 1:1

311a. When a charged particle moving with velocity $\vec{v}$ is subjected to a magnetic field $\vec{B}$, the force acting on it is non zero. Would the particle gain any energy ? **CBSE (F)-2013**

[Ans. As $\vec{F}$ is $\perp$ to $\vec{v}$, work done = 0

Hence the particle does not gain any energy

311b. In a certain region of space, electric field $\vec{E}$ and magnetic field $\vec{B}$ are perpendicular to each other. An electron enters in the region perpendicular to the direction of both $\vec{E}$ and $\vec{B}$ and moves undeflected. Find the velocity of electron. **CBSE (F)-2013**

[Ans. As electron moves undeflected ⇨ $F_e = F_m$ ⇨ $eE = Bev$ ⇨ $v = \frac{E}{B}$

311c. A long straight wire carries a steady current I along the positive y-axis in a coordinate system. A particle of charge $+Q$ is moving with a velocity $\vec{v}$ along the x-axis. In which direction will the particle experience a force ?

[Ans. towards y-axis **CBSE (F)-2013**

311d. What will be the path of a charged particle moving perpendicular to a uniform magnetic field ? **BSE (D)-2001**

[Ans. Circular path

311e. What will be the path of a charged particle moving in a uniform magnetic field at any arbitrary angle ?

[Ans. Helical path or helix **CBSE (F)-2001**

311b. What can be the cause of helical motion of a charged particle ? **CBSE (AI)-2016**

[Ans. Charged particle enters magnetic field at any arbitrary angle other than $\pi/2$ or 0 /

Component of $\vec{v}$, parallel to $\vec{B}$, is not zero

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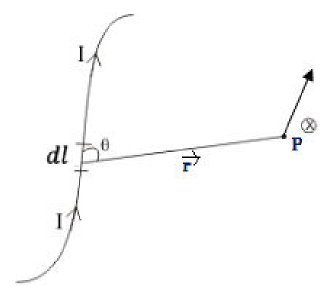
312. State Biot – Savart law and express this law in the vector form. **CBSE (AI)-2017,2016**

[Ans. Biot-Savart's law : It states that magnetic field $\vec{dB}$, due to a current element, I$\vec{dl}$, at a point, having a position vector $\vec{r}$ relative to the current element, is found to depend

(i) directly on the current element, $\left(B \propto |\mathrm{I}\,\vec{dl}|\right)$

(ii) inversely on the square of the distance, $\left(B \propto \frac{1}{|\vec{r}|^2}\right)$

(iii) directly on the sine of angle between the current element and the position vector $\vec{r}$, $(B \propto \sin\theta)$



i,e, $dB \propto \frac{Idl\,\sin\theta}{r^2}$

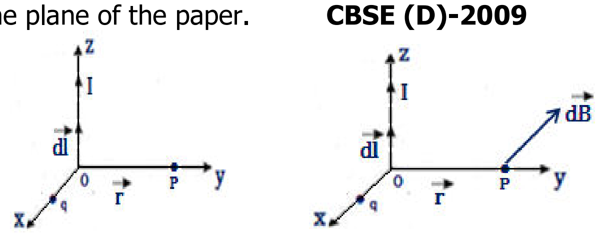
⇨ $dB = \frac{\mu_0}{4\pi}\frac{Idl\,\sin\theta}{r^2}$

In vector form, $\vec{dB} = \frac{\mu_0}{4\pi}\frac{(\mathrm{I}\,\vec{dl}\ \mathrm{X}\ \vec{r})}{r^3}$

==

313. A current I flows in a conductor placed perpendicular to the plane of the paper. **CBSE (D)-2009**

Indicate the direction of the magnetic field due to a small element $\vec{dl}$ at point P situated at a distance $\vec{r}$ from the element as shown in figure.



[Ans. $\vec{dB} = \frac{\mu_0}{4\pi}\frac{(\mathrm{I}\,\vec{dl}\ \mathrm{X}\ \vec{r})}{r^3} = \frac{\mu_0}{4\pi}\frac{(\mathrm{I\,dl}\,\hat{k}\ \mathrm{X}\ r\hat{j})}{r^3}$

$\vec{dB} = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}(-\hat{\imath})$

⇨ magnetic field will be in the negative x-direction

314. Write, using Biot – Savart's law, the expression for the magnetic field $\vec{B}$ due to an element $\mathrm{I}\,\vec{dl}$ carrying current I at a distance $\vec{r}$ from it in a vector form. **CBSE (AI)-2015**

[Ans. Biot-Savart's law in vector form

$$\overrightarrow{dB} = \frac{\mu_0}{4\pi}\frac{(\mathrm{I}\,\vec{dl}\ \mathrm{X}\ \vec{r})}{r^3}$$

315. State Ampere's circuital law. **CBSE (AI)-2016**

[Ans. Ampere's circuital law : " The line integral of the magnetic field, around a closed loop, equals μ_0 times the total current passing through the surface enclosed by that loop."

i,e, $\oint \vec{B}.\vec{dl} = \mu_0\,\mathrm{I}$

315a. What is the source of magnetic field (or magnetism) ? **CBSE (AIC)-2001**

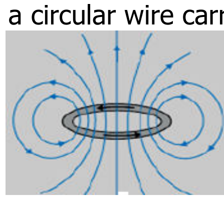
[Ans. The electrons revolving in atoms behave as current loops. These current loops give rise to magnetism

316. Does a magnetic monopole exists ? Justify your answer. **CBSE (AIC)-2002**

[Ans. No, a magnetic monopole does not exist. The reason is that magnetic field is produced by a current loop and not by monopole of a magnet

317. Draw the magnetic field lines due to a circular wire carrying current **I.** **CBSE (AIC)-2017,(AI)-2016**

[Ans.



318. How are the magnetic field lines different from the electrostatic field lines ? **CBSE (AI)-2016**

[Ans. The magnetic field lines form closed loops while the electrostatic field lines originate from positive charges and end at negative charges

319. Why do magnetic field lines for continuous closed loops ? **CBSE (F)-2011**

[Ans. Because a magnet is always a dipole and as a result, net magnetic flux is always zero

320. Can two magnetic lines of force intersect each other. Justify your answer. **CBSE (AIC)-2003**

[Ans. No, because if they do so then at the point of intersection two tangents can be drawn which would represent two directions of magnetic field. Which is not possible

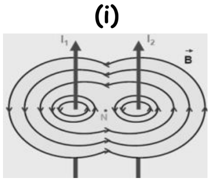
321. Magnetic field lines can be entirely confined within the core of a toroid, but not within a straight solenoid. Why ? **NCERT-2017, CBSE (AI)-2009**

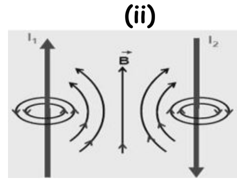
[Ans. Magnetic field lines can be entirely confined within the core of a toroid because toroid has no ends. But a straight solenoid has two ends. If the entire magnetic flux were confined between these ends, the magnetic field lines will no longer be continuous.

==

322. Depict magnetic field lines due to two straight, long, parallel conductors carrying steady currents I_1 and I_1 in the (i) same direction, (ii) opposite direction. **CBSE (AI)-2016**

[Ans. **(i)** **(ii)**





323. Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current.

[Ans. Definition of 1 Ampere : **CBSE (AI)-2014**

One Ampere is the current which when flowing through each of the two infinite long straight parallel conductors placed one meter apart from each other in free space will exert a force of $2\ \mathrm{X}\ 10^{-7}N$ per meter of their length

324. How is the magnetic field inside a given solenoid made strong ? **CBSE (AI)-2011**

[Ans. (i) by increasing number of turns in the solenoid

(ii) by increasing current flowing through the solenoid

(iii) by inserting soft iron core inside the solenoid

325. Write the expression for Lorentz's magnetic force on a particle of charge $'q'$ moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. Show that no work is done by this force on the charged particle. **CBSE (AI)-2011**

[Ans. Lorentz's magnetic force : $\vec{F_m} = q(\vec{v} \times \vec{B})$

Work done : $W = \int \vec{F_m}.\vec{dr} = \int q(\vec{v} \times \vec{B}).\vec{v}\,dt = \int q(\vec{v} \times \vec{v}).\vec{B}\,dt = 0$

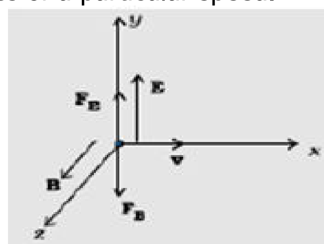
326. Which one of the following will experience maximum force, when projected with the same velocity v perpendicular to the Magnetic field : (i) $\alpha - particle$, and (ii) $\beta - particle$? **CBSE (AIC)-2002**

[Ans. $F_m = Bqv \sin 90^0 = Bqv$

⇨ $\frac{F_\alpha}{F_\beta} = \frac{B(2q)v}{Bqv} = 2$ ⇨ $F_\alpha = 2F_\beta$ Hence $\alpha - particle$ will experience maximum force

327. Find the condition under which the charged particles moving with different speeds in the presence of electric and magnetic field vectors can be used to select charged particles of a particular speed. **CBSE (AI)-2017,2016**

[Ans. (i) the velocity $\vec{v}$, of the charged particles, and the $\vec{E}$ & $\vec{B}$ should be mutually perpendicular



(ii) $F_e = F_m$

⇨ $qE = Bqv$

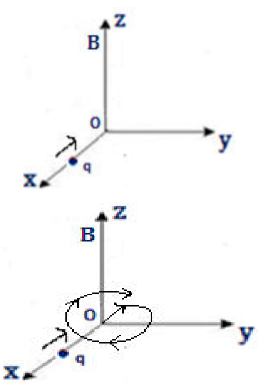
⇨ $v = \frac{E}{v}$

==

328. A charge $'q'$ moving along the x axis with velocity $\vec{v}$ is subjected to a uniform magnetic field B acting along the z axis as it crosses the origin O. **CBSE (D)-2009**

(i) Trace its trajectory.

(ii) Does the charge gain kinetic energy as it enters the magnetic field ? Justify your answer.



[Ans. (i) $\vec{F} = q(\vec{v} \times \vec{B}) = q(v\hat{i} \times B\,\hat{k}) = -qvB\hat{j}$

At the origin charge will move towards $-y$ axis.

Hence charge will trace circular path in XY plane as shown

(ii) Gain in kinetic energy = Work done

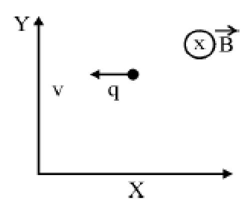
⇨ $W = \int \vec{F_m}.\vec{dr} = \int q(\vec{v} \times \vec{B}).\vec{v}\,dt = \int q(\vec{v} \times \vec{v}).\vec{B}\,dt = 0$

Hence the charge does not gain kinetic energy

329. (a) A point charge q moving with speed v enters a uniform magnetic field B that is acting into the plane of the paper as shown. What is the path followed by the charge q and in which plane does it move ? **CBSE (F)-2016**

(b) How does the path followed by the charge get affected if its velocity has a component parallel to $\vec{B}$?

(c) If an electric field $\vec{E}$ is also applied such that the particle continues moving along the original straight line path, what should be the magnitude and direction of the electric field $\vec{E}$?



[Ans. (a) The charge q describes a circular path ; anticlockwise in XY plane.

(b) The path will become helical.

(c) Direction of Lorentz magnetic force is -Y. Applied electric field should be in +Y direction

$F_e = F_m$ ⇨ $qE = Bqv$ ⇨ $E = Bv$

330. Uniform electric and magnetic fields are produced pointing in the same direction. An electron is projected in the Direction of the fields. What will be the effect on the kinetic energy of electron due to two fields? **CBSE (DC)-2001**

[Ans. As $\theta = 0^0$ ⇨ $F_m = Bqv \sin 0^0 = 0$ hence, there will not be any change in K.E. due to magnetic field

Electric field will exert a retarding force $F_e = -eE$, hence it will reduce K.E. of electron

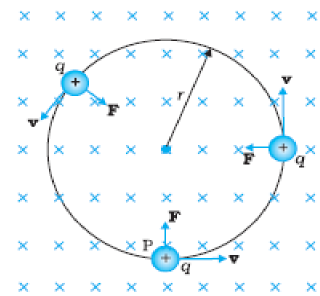
331. A particle of charge $'q'$ and mass $'m'$ is moving with velocity $\vec{v}$. It is subjected to a uniform magnetic field $\vec{B}$ directed perpendicular to its velocity. Show that it describes a circular path. Obtain the expression for its radius and show that frequency of revolution is independent of velocity. **CBSE (AI)-2014,(F)-2012**

[Ans. Motion of a charged particle in a uniform magnetic field :

Charged particle will experience a force,

$F_m = B\,q\,v\,\sin 90^0$

As this force acts perpendicular to both $\vec{v}$ & $\vec{B}$, particle will be deflected sideways continuously without changing its speed and hence it will move along a circular path. Thus F_m provides centripetal force



i,e, $B\,q\,v = \frac{mv^2}{r}$

⇨ $r = \frac{mv}{qB}$

Now the time period,

$T = \frac{2\pi r}{v} = \frac{2\pi}{v} \text{ X } \frac{mv}{qB} = \frac{2\pi m}{qB}$

& $f = \frac{1}{T} = \frac{qB}{2\pi m}$ Which is independent of velocity

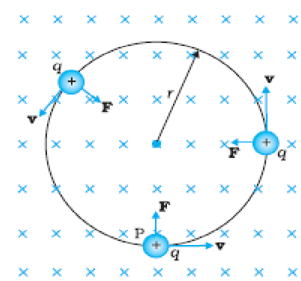
==

332. A charged particle q moving in a straight line is accelerated by a potential difference V. It enters a uniform magnetic field B perpendicular to its path. Deduce in terms of V an expression for the radius of the circular path in which it travels.

[Ans. Charged particle will experience a force, **CBSE (AI)-2001**

$F_m = B\,q\,v\,\sin 90^0$

As this force acts perpendicular to both $\vec{v}$ & $\vec{B}$, particle will move along a circular path. Thus F_m provides centripetal force



i,e, $B\,q\,v = \frac{mv^2}{r}$

⇨ $r = \frac{mv}{qB}$ --------(1)

Now, $E_k = \frac{1}{2}mv^2 = qV$

⇨ $v = \sqrt{\frac{2\,qV}{m}}$

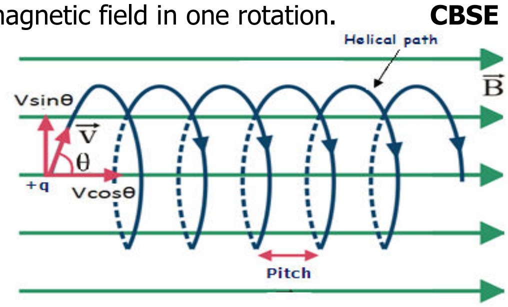
Hence from (1), $r = \frac{m}{qB}\sqrt{\frac{2\,qV}{m}} = \frac{1}{B}\sqrt{\frac{2\,mV}{q}} = \sqrt{\frac{2\,mV}{qB^2}}$

333. A uniform magnetic field is set up along the positive x-axis. A particle of charge 'q' and mass 'm' moving with a velocity $\vec{v}$ enters the field at the origin in X-Y plane such that it has velocity components both along and perpendicular to the magnetic field $\vec{B}$. Trace, giving reason, the trajectory followed by the particle. Find out the expression for the distance moved by the particle along the magnetic field in one rotation. **CBSE (AI)-2015**

[Ans. Trajectory will be a helix

Explanation/Reason :

The particle will move along a circular path due to v_y in y-z plane and along the magnetic field (along x-axis) due to v_x. Hence its trajectory would be helical.



Distance moved in one rotation (pitch)

$x = v_x \text{ X } T = \frac{2\pi m\, v_y}{qB}$

334. A charged particle enters a region of uniform magnetic field with its initial velocity directed (i) parallel to the field, and (ii) perpendicular to the field. Show that there is no change in kinetic energy of the particle in both cases. **CBSE (AIC)-2007**

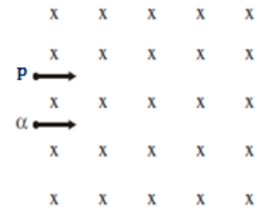
[Ans. (i) As $\theta = 0^0$ ⇨ $F_m = Bqv\,\sin 0^0 = 0$, hence ,there will not be any change in velocity or K. E.

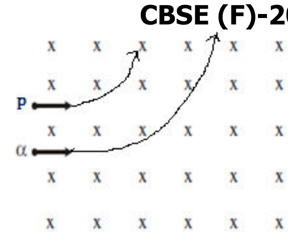
(ii) Change in kinetic energy = Work done = $\int \vec{F_m}.\,\vec{dr} = \int q(\vec{v} \text{ X } \vec{B}).\vec{v}\,dt = \int q(\vec{v} \text{ X } \vec{v}).\vec{B}\,dt = 0$

335. An $\alpha -$ particle and a proton moving with the same speed, enter the same magnetic field region at right angles to the direction of the field. **CBSE (F)-2010**

(i) Show the trajectories followed by the two particles in the region of the magnetic field.

(ii) Find the ratio of the radii of the circular paths which the two particles may describe.





[Ans. (i) trajectories

(ii) $r = \frac{mv}{qB}$

⇨ $\frac{r_\alpha}{r_p} = \frac{m_\alpha}{q_\alpha} X \frac{q_p}{m_p} = \frac{4m_p}{2q_p} X \frac{q_p}{m_p} = 2$

==

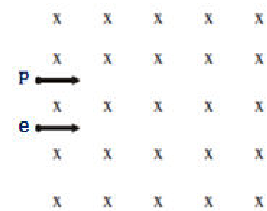
336. An electron and a proton moving parallel to each other in the same direction with equal momenta, enter in to a uniform magnetic field which is at right angles to their velocities. Trace their trajectories in the magnetic field.

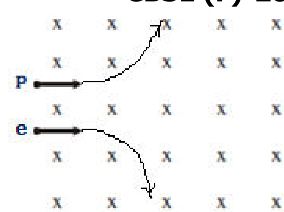
OR **CBSE (F)-2005**

An electron and a proton moving with the same speed, enter the same magnetic field region at right angles to the direction of the field. **CBSE (F)-2010**

(i) Show the trajectories followed by the two particles in the region of the magnetic field.

(ii) Find the ratio of the radii of the circular paths which the two particles may describe.





[Ans. (i) trajectories

(ii) $r = \frac{mv}{qB}$

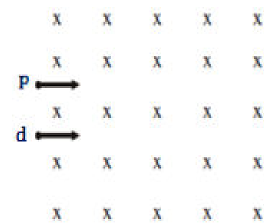
⇨ $\frac{r_p}{r_e} = \frac{m_p}{q_p} X \frac{q_e}{m_e} = \frac{m_p}{m_e}$ As $m_p \gg m_e$ ⇨ $r_p \gg r_e$

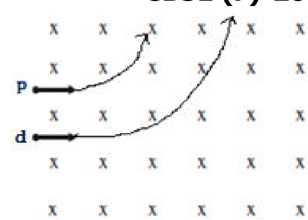
==

337. A deuteron and a proton moving with the same speed, enter the same magnetic field region at right angles to the direction of the field. **CBSE (F)-2010**

(i) Show the trajectories followed by the two particles in the region of the magnetic field.

(ii) Find the ratio of the radii of the circular paths which the two particles may describe.





[Ans. (i) trajectories

(ii) $r = \frac{mv}{qB}$

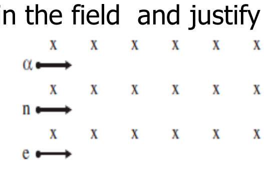
⇨ $\frac{r_d}{r_p} = \frac{m_d}{q_d} X \frac{q_p}{m_p} = \frac{m_d}{m_p}$ As $m_d \approx 2m_p$ ⇨ $r_d \approx 2r_p$

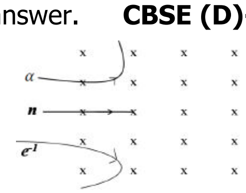
==

338. A neutron, an electron and an alpha particle moving with equal velocities, enter a uniform magnetic field going Into the plane of the paper as shown. Trace their paths in the field and justify your answer. **CBSE (D)-2016**

[Ans. Justification :

Direction of force experienced by the particle will be according to the Fleming's left hand rule





339. A proton and deuteron having equal momenta, enters a region of uniform magnetic field at right angles to the direction of field. Find the ratio of the radii of curvature of the paths of the particles. **CBSE (D)-2013**

OR

A narrow beam of protons and deuterons, each having the same momentum, enters a region of uniform magnetic field directed perpendicular to their direction of momentum. What would be the ratio of the circular paths described by them ? **CBSE (F)-2011**

[Ans. $r = \frac{mv}{qB} = \frac{p}{qB}$ ⇨ $r \propto \frac{1}{q}$ ⇨ $\frac{r_p}{r_d} = \frac{q_d}{q_p} = \frac{q_p}{q_p} = 1$

340. Draw a neat labelled diagram of a cyclotron. State the underlying principle of a cyclotron. Show that time period of ions in cyclotron is independent of both the speed of ion and radius of circular path. Also obtain an expression for maximum kinetic energy gained by the particle.

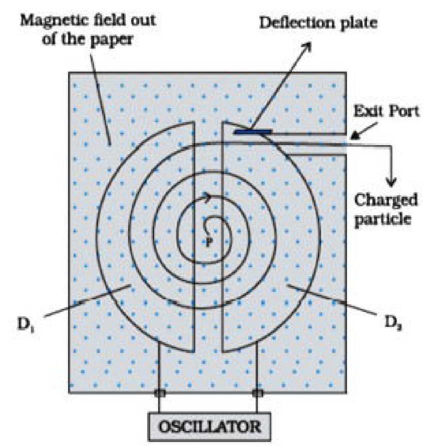
CBSE (AI)-2016,2015,2014,2013,2009,2007,(D)-2011,2009,2008,2004,2001,(F)-2006,2003

[**Ans. Cyclotron** : It is a device used to accelerate charged particles or ions to very high energies.

Principle : A charged particle can be accelerated to very high energy, by making it to pass through a small region of oscillating electric field again and again with the help of a strong perpendicular magnetic field.

Working :

Due to electric field particle enters in a Dee where it moves along a circular path due to normal magnetic field. At the moment particle comes out of a Dee, polarities of the Dees get reversed and particle is further accelerated to enter in another Dee and follows a circular path of larger radius with higher speed. This process goes on continuously, till the particle acquires sufficient speed and is taken out with the help of a deflection plate



$$B\,q\,v = \frac{m\,v^2}{r}$$

⇨ $$r = \frac{m\,v}{q\,B}$$

⇨ $$T = \frac{2\pi\,r}{v} = \frac{2\pi\,m}{qB}$$ ⇨ $$f_c = \frac{1}{T} = \frac{qB}{2\pi m}$$

Hence, time period or cyclotron frequency is independent of both the speed of ion and radius of circular path

Maximum K.E. : for maximum velocity we have,

$$B\,q\,v_0 = \frac{m\,v_0^2}{r_0} \quad ⇨ \quad v_0 = B\,q\,r_0/\mathrm{m} \quad ⇨ \quad E_{K_{max}} = \frac{1}{2}mv_0^2 = \frac{1}{2}m(B\,q\,r_0/\mathrm{m})^2 = \frac{q^2B^2r_0^2}{2m}$$

341. Explain clearly the role of crossed electric and magnetic field in accelerating charge in a cyclotron **CBSE (AI)-2013**

[**Ans. Electric field** : It is used to accelerate the charged particle

Magnetic field : It is used to restrict the particle to move in circular path

342. Where do the electric and magnetic fields exist in a Cyclotron. Write about their nature. **CBSE (AI)-2016**

[**Ans. Electric field** : It exists between the Dees an d it is alternating /oscillating in nature

Magnetic field : It exists both inside and outside the Dees and it is constant/uniform in nature

343. What is resonance condition in a cyclotron ? How is it used to accelerate charged particles ? **SE (AI)-2009**

[**Ans. Resonance condition** : "The frequency of oscillating electric field must be equal to the frequency of revolution of charged particle"

Due to it, charged particles remain in phase with frequency of the applied voltage and accelerated to high speeds

344. What is the requirement of the frequency of the applied voltage so as to ensure that the ions get accelerated across the gap of the Dees in a cyclotron ? **CBSE (F)-2008**

[**Ans.** "The frequency of oscillating electric field must be equal to the frequency of revolution of charged particle"

345. In a cyclotron, the time period of ions is independent of both the speed of ion and radius of circular path. What is the ignificance of this property ? **CBSE (AIE)-2016**

[**Ans.** It helps in achieving resonance condition/Due to it, particle remains in phase with frequency of the applied voltage

346. Is there an upper limit on the energy acquired by the particle ? Give reason. **CBSE (D)-2011**

[**Ans.** When the charged particle moves in a path of radius equal to that of Dees, it gains maximum speed and hence maximum energy which cannot be further increased . Hence, there is an upper limit on the energy acquired by the charged particle in a cyclotron

347. Can we accelerate neutrons by a Cyclotron ? Give reason to your answer. **CBSE (AIC)-2010**

[**Ans. No,** neutrons cannot be accelerated by using Cyclotron

Reason : Being neutral, neutrons will not experience electric or magnetic force

348. Why is a Cyclotron not suitable for accelerating electrons ? Give reason. **CBSE (AIC)-2010**

[Ans. Electrons cannot be accelerated by using Cyclotron. The device which can accelerate electrons is called Betatron

Reason : They are very light particles and acquire very high speed quickly. As a result their mass ($m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$) and consequently time spend in a Dee ($t = \frac{\pi m}{q\,B}$) increases and they get out of resonance very quickly.

349. Explain briefly, at very high speeds charged particle in a cyclotron can be thrown out of resonance. How this drawback can be overcome ? **CBSE (DC)-2010**

[Ans. At very high speeds mass of the charged particle ($m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$) increases due to which frequency of revolution ($f = \frac{qB}{2\pi m}$) decreases. It will throw the particle out of resonance with the electric field and it cannot be accelerated further. This drawback can be overcome in two ways-

(i) either by increasing magnetic field accordingly as is done in a 'Synchrotron', or

(ii) by decreasing the frequency of alternating electric field as is done in a device 'Synchro-cyclotron.'

350. State any two limitations and two uses of a cyclotron. **CBSE (AIC)-2011**

[Ans. limitations : (i) neutrons cannot be accelerated being neutral

(ii) electrons cannot be accelerated being light particle

Uses : (i) to accelerate charged particles, which are used to bombard nuclei

(ii) to implant ions in to solids and modify their properties or even synthesize new materials

351. An $\alpha - particle/deutron$ and a proton are released from the centre of the cyclotron and made to accelerate.

(i) Can both be accelerated at the same cyclotron frequency ? Give reason to justify your answer.

(ii) When they are accelerated in turn, which of the will have higher velocity at the exit slit of the dees ?

[Ans. (i) No, **CBSE (D)-2017,(AI)-2013**

Reason : $f_c = \frac{qB}{2\pi m}$

⇨ $f_c \propto \frac{q}{m}$ & charge/mass of both the particles is different

(ii) Proton will have higher velocity at the exit of Dees

Reason : $r_0 = \frac{m\,v_0}{q\,B}$ ⇨ $v_0 = \frac{qB\,r_0}{m}$ ⇨ $v_0 \propto \frac{q}{m}$ for the same B & r_0

⇨ $\frac{v_{0proton}}{v_{0\alpha-particle}} = \frac{q_p}{q_\alpha} \text{ X } \frac{m_\alpha}{m_p} = \frac{q_p}{2q_p} \text{ X } \frac{4m_p}{m_p} = 2$

⇨ $v_0(proton) = 2 \text{ X } v_0(\alpha - particle\ )$

==

352. A proton and an $\alpha - particle$ move perpendicular to a magnetic field. Find the ratio of radii of the circular paths described by them when both (i) have equal momenta, and (ii) were accelerated through the same potential difference. **CBSE (F)-2017**

[Ans. (i) $r = \frac{mv}{qB} = \frac{p}{qB}$ ⇨ $r \propto \frac{1}{q}$ ⇨ $\frac{r_p}{r_\alpha} = \frac{q_\alpha}{q_p} = \frac{2\,q_p}{q_p} = 2$

(ii) $r = \frac{mv}{qB} = \frac{1}{B}\sqrt{\frac{2mV}{q}}$

⇨ $\frac{r_p}{r_\alpha} = \sqrt{\frac{m_p}{q_p} \text{ X } \frac{q_\alpha}{m_\alpha}} = \sqrt{\frac{m_p}{q_p} \text{ X } \frac{2q_p}{4m_p}} = \frac{1}{\sqrt{2}}$

353. A proton and an $\alpha - particle$ move perpendicular to a magnetic field. Find the ratio of radii of the circular paths described by them when both (i) have equal velocities, and (ii) equal kinetic energies. **CBSE (F)-2017**

[Ans. (i) $r = \frac{mv}{qB}$ ⇨ $r \propto \frac{m}{q}$ ⇨ $\frac{r_p}{r_\alpha} = \frac{m_p}{q_p} \text{X} \frac{q_\alpha}{m_\alpha} == \frac{m_p}{q_p} \text{ X } \frac{2q_p}{4m_p} = \frac{1}{2}$

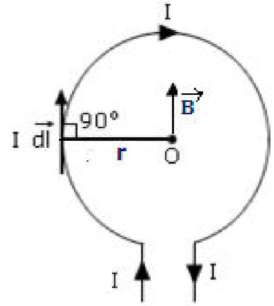
(ii) $r = \frac{mv}{qB} = \frac{1}{qB}\sqrt{2mE_k}$

⇨ $\frac{r_p}{r_\alpha} = \frac{q_\alpha}{q_p}\sqrt{\frac{m_p}{m_\alpha}} = \frac{2q_p}{q_p}\sqrt{\frac{m_p}{4m_p}} = 1$

354. Use Biot-Savart's law to find expression for the magnetic field due to a circular loop of radius 'r' carrying current 'I' at its centre. **CBSE (AI)-2015**

[**Ans.** **<u>Magnetic field due to a circular loop of radius 'r' carrying current 'I' at its centre</u>**

According to Biot-Savart's law, magnetic field due to current element $I\,\vec{dl}$ as shown



$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin 90}{r^2} = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}$$

⇨ Magnetic field at O due to whole loop

$$B = \int \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2} = \frac{\mu_0}{4\pi}\frac{I}{r^2}\int dl$$

⇨ $$B = \frac{\mu_0}{4\pi}\frac{I}{r^2}(2\pi r)$$

⇨ $$\boldsymbol{B = \frac{\mu_0 I}{2r}}$$

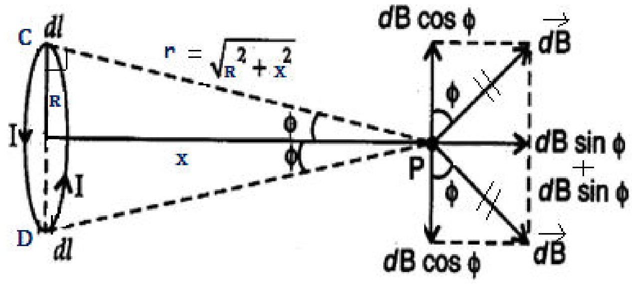
For a coil having N turns

$$\boldsymbol{B = \frac{\mu_0 N I}{2r}}$$

355. Using Biot-Savart law, deduce the expression for the magnetic field at a point (x) on the axis of a circular current carrying loop of radius R. How is the direction of the magnetic field determined at this point ?

[**Ans. Magnetic field due to a current carrying loop at a point on its axis :** **CBSE (F)-2017,(AI)-2016**

According to Biot-Savart's law the magnetic field at P due to current element $I\,\vec{dl}$ at C



$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\sin 90^0}{r^2}$$

⇨ $$dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}$$

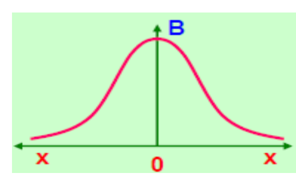
Resolving $\vec{dB}$ in to horizontal and vertical Components, resultant magnetic field at P

$$B = \int dB\,\sin\phi = \int \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}\sin\phi = \frac{\mu_0}{4\pi}\frac{I}{r^2}\sin\phi \int dl$$

⇨ $$B = \frac{\mu_0}{4\pi}\frac{I}{r^2}\left(\frac{R}{r}\right)(2\pi R)$$

⇨ $$B = \frac{\mu_0}{4\pi}\frac{I\,R}{r^3}(2\pi R)$$

$$B = \frac{\mu_0 I R^2}{2\,(R^2 + x^2)^{3/2}}$$



For a coil of N turns

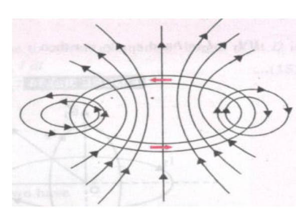
$$\boldsymbol{B = \frac{\mu_0 N I R^2}{2\,(R^2 + x^2)^{3/2}}}$$

Direction of this magnetic field can be determined by the right hand thumb rule

356. Draw the magnetic field lines due to a circular loop of area $\vec{A}$ carrying current I. Show that it acts as a bar magnet of magnetic moment $\vec{M} = I\,\vec{A}$ **CBSE (AI)-2015**

[**Ans.** Magnetic field due to a circular loop at a far off point on its axis

$$B = \frac{\mu_0}{4\pi}\frac{2\,IA}{x^3} \qquad \text{----------(1)}$$



& magnetic field due to a bar magnet at an axial point

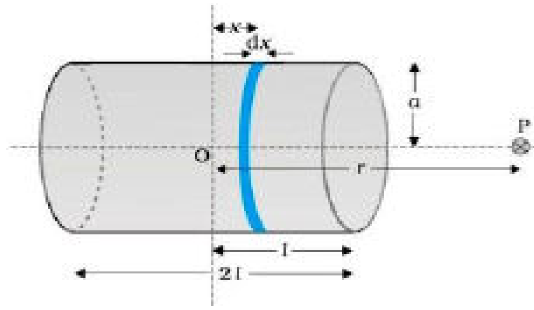
$$B = \frac{\mu_0}{4\pi}\frac{2\,M}{x^3} \qquad \text{---------(2)}$$

From (1) & (2), $\vec{M} = I\,\vec{A}$

⇨ loop will behave like a bar magnet of magnetic moment $\vec{M} = I\,\vec{A}$

357. Drive the expression for the magnetic field due to solenoid of length $'2l'$, radius $'a'$ having $'n'$number of turns per unit length and carrying a steady current $'I'$ at a point on axial line, distant $'r'$ from the centre of the solenoid.
(i) How does this expression compare with the axial magnetic field due to a bar magnet of magnetic moment $'M'$.
(ii) under what condition does the field become equivalent to that produced by a bar magnet ?

[**Ans**. Magnetic field due to element dx at P **CBSE (AI)-2016,2015**



$$dB = \frac{\mu_0 n\, dx\, Ia^2}{2[(r-x)^2 + a^2]^{3/2}}$$

If point P lies very large distance from O,
i,e, $r \gg a$ and $r \gg x$, then
$[(r-x)^2 + a^2]^{3/2} = r^3$

⇨ $$dB = \frac{\mu_0 n\, dx\, Ia^2}{2r^3}$$

⇨ $$B = \int_{-l}^{+l} \frac{\mu_0 n\, dx\, Ia^2}{2r^3} = \frac{\mu_0 n\, Ia^2}{2r^3}\int_{-l}^{+l} dx$$

⇨ $$B = \frac{\mu_0 n\, Ia^2}{2r^3}[x]_{-l}^{+l} = \frac{\mu_0 n\, Ia^2}{2r^3}[l-(-l)] = \frac{\mu_0 n\, Ia^2}{2r^3}(2l)$$

⇨ $$B = \frac{\mu_0 2n(2l)I\pi a^2}{4\pi r^3} \quad \text{--------------------(1)}$$

If M is the magnetic moment of the solenoid then,

$M = NIA = n(2l)I(\pi a^2)$ ⇨ from (1), $\boldsymbol{B = \frac{\mu_0}{4\pi}\frac{2M}{r^3}}$

Which is exactly equal to the far axial magnetic field due to a bar magnet of magnetic moment 'M'.

(ii) Condition : When $r \gg a$ and $r \gg x$

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358. A wire of length L is bent round in the form of a coil having N turns of same radius. If a steady current I flows through it in a clockwise direction, find the magnitude and direction of the magnetic field produced at its centre

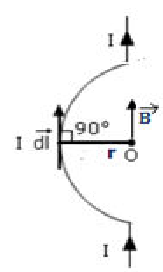
[**Ans**. $N \text{ X } (2\pi r) = L$ ⇨ $r = \frac{L}{2\pi N}$ **CBSE (F)-2009**

⇨ $$B = \frac{\mu_0 NI}{2r} = \frac{\mu_0 NI}{2(L/2\pi N)} = \frac{\mu_0 \pi N^2 I}{L}$$

==

359. A straight wire of length L is bent into a semicircular loop. Use Biot-Savart's law to deduce an expression for the magnetic field at its centre due to current **I** passing through it. **CBSE (D)-2011**

[**Ans**. According to Biot-Savart's law, magnetic field due to current element $I\vec{dl}$ as shown



$$dB = \frac{\mu_0}{4\pi}\frac{I\, dl \sin 90}{r^2} = \frac{\mu_0}{4\pi}\frac{I\, dl}{r^2}$$

⇨ Magnetic field at O due to given loop

$$B = \int \frac{\mu_0}{4\pi}\frac{I\, dl}{r^2} = \frac{\mu_0}{4\pi}\frac{I}{r^2}\int dl$$

⇨ $$B = \frac{\mu_0}{4\pi}\frac{I}{r^2}(\pi r)$$

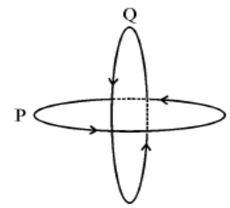
⇨ $$B = \frac{\mu_0 I}{4r}$$

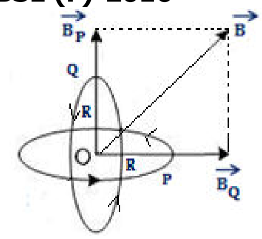
But, $\pi r = L$

⇨ $$r = \frac{L}{\pi}$$

⇨ $$B = \frac{\mu_0 \pi I}{4L}$$

360. 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 of the two coils, if they carry currents equal to I and $\sqrt{3}$ I respectively. **CBSE (F)-2016**





[Ans. $B_P = \frac{\mu_0 \text{I}}{2R}$ & $B_Q = \frac{\mu_0 \sqrt{3}\,\text{I}}{2R} = B_P\sqrt{3}$

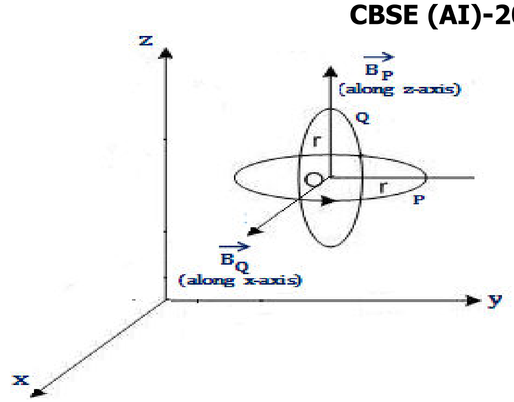
⇨ $B = \sqrt{{B_P}^2 + {B_Q}^2} = \sqrt{{B_P}^2 + (B_P\sqrt{3})^2}$

⇨ $B = B_P\sqrt{1+3} = 2 \text{ X } \frac{\mu_0 \text{I}}{2R} = \frac{\mu_0 \text{I}}{R}$

$\tan\theta = \frac{B_P}{B_Q} = \frac{B_P}{B_P\sqrt{3}} = \frac{1}{\sqrt{3}}$

⇨ $\theta = 30^0$ with B_Q

361. Two identical circular coils, P and Q each of radius R, carrying currents $1\ A$ and $\sqrt{3}\ A$ respectively, are placed concentrically and perpendicular to each other lying in the XY and YZ planes. Find the magnitude and direction of the net magnetic field at the centre of the coils. **CBSE (AI)-2017**



[Ans. $B_P = \frac{\mu_0 \text{ X } 1}{2R} = \frac{\mu_0}{2R}$ (along z- direction)

$B_Q = \frac{\mu_0 \text{ X } \sqrt{3}}{2R} = B_P\sqrt{3}$ (along x - direction)

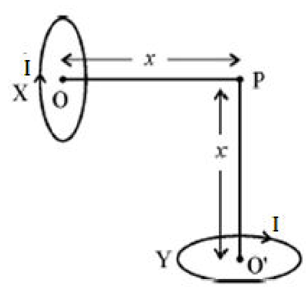
⇨ $B = \sqrt{{B_P}^2 + {B_Q}^2} = \sqrt{{B_P}^2 + (B_P\sqrt{3})^2} = 2 \text{ X } \frac{\mu_0}{2R} = \frac{\mu_0}{R}$

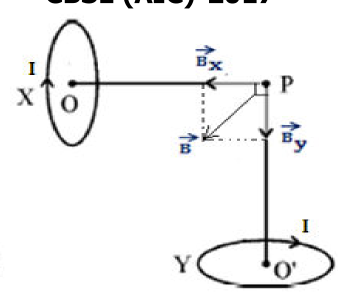
$\tan\theta = \frac{B_Q}{B_P} = \frac{B_P\sqrt{3}}{B_P} = \sqrt{3}$

⇨ $\theta = 60^0$ with B_P in XZ plane

==

362. Two identical circular loops X and Y of radius R and carrying the same current are kept in perpendicular planes such that they have a common centre at P as shown in the figure. Find the magnitude and direction of the net magnetic field at the point P due to the loops. **CBSE (AIC)-2017**





[Ans. $B_X = B_Y = \frac{\mu_0\ \text{I}\,\text{R}^2}{2\,(R^2 + x^2)^{3/2}}$

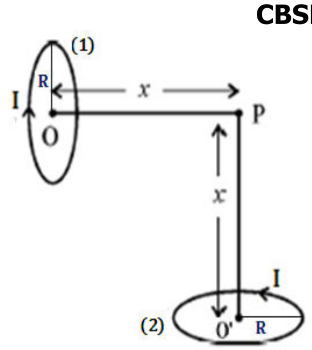
⇨ $B = \sqrt{{B_X}^2 + {B_Y}^2} = B_X\sqrt{2} = \frac{\mu_0\ \text{I}\,\text{R}^2\sqrt{2}}{2\,(R^2 + x^2)^{3/2}}$

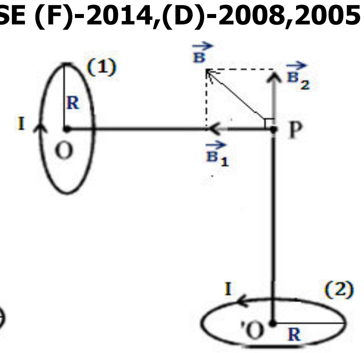
$\tan\theta = \frac{B_X}{B_Y} = 1$

⇨ $\theta = 45^0$ with either B_X or B_Y

==

363. Two identical circular loops (1) and (2)of radius R and carrying the same current are kept in perpendicular planes such that they have a common centre at P as shown in the figure. Find the magnitude and direction of the net magnetic field at the point P due to the loops. **CBSE (F)-2014,(D)-2008,2005**





[Ans. $B_1 = B_2 = \frac{\mu_0\ \text{I}\,\text{R}^2}{2\,(R^2 + x^2)^{3/2}}$

⇨ $B = \sqrt{{B_1}^2 + {B_2}^2} = B_1\sqrt{2} = \frac{\mu_0\ \text{I}\,\text{R}^2\sqrt{2}}{2\,(R^2 + x^2)^{3/2}}$

$\tan\theta = \frac{B_X}{B_Y} = 1$

⇨ $\theta = 45^0$ with either B_1 or B_2

364. Write any two important points of similarities and differences each between Coulomb's law for the electrostatic field and Biot-Savart's law for the magnetic field. **CBSE (AI)-2015**

[Ans. According to Coulomb's law, electric field due to a point charge dq

$$dE = \frac{1}{4\pi\,\varepsilon_0}\,\frac{dq}{r^2}$$

According to Biot-Savart's law, magnetic field due to a current element $I\,\vec{dl}$

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

Similarities	Differences
1. Both electric field and magnetic field obey inverse square law	1. Electric field is produced by a scalar source (charge q) while magnetic field is produced by a vector source ($I\,\vec{dl}$)
2. Both electric field and magnetic field obey principle of superposition	2. Electric field is produced along $\vec{r}$ while magnetic field is , produced along the direction of ($I\,\vec{dl}$ X $\vec{r}$)
2. Both electric field and magnetic field are long range fields	3. Electric field does not depend on angle θ between q and $\vec{r}$ while magnetic field depends on angle θ between $I\,\vec{dl}$ & $\vec{r}$

365. Derive the expression for the force acting on a current carrying conductor of length L in a uniform magnetic field 'B'.

[Ans. Force on each free electron in the conductor **CBSE (DC)-2017**

$F' = Be\,v_d\,\sin\theta$

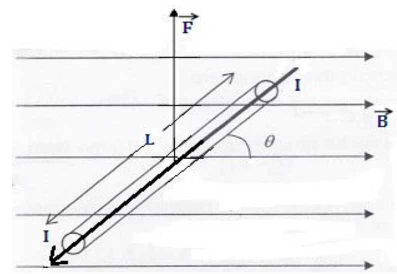
Let n be the number density of electrons then force experienced by the conductor

F = Force on each electron X total number of electrons

$F = Be\,v_d\,\sin\theta$ X nAL

$F = B(neA\,v_d)\,L\sin\theta$

⇨ $\boldsymbol{F = BIL\sin\theta} = \boldsymbol{I(\vec{L}\,\mathrm{X}\,\vec{B})}$



366. Derive an expression for the force per unit length between the two infinitely long straight parallel current carrying conductors. Hence define S.I. unit of current. **CBSE (D)-2016,(AI)-2016,2015,2012,2010,2009**

[Ans. Magnetic field due to conductor '1' at any point on conductor '2'

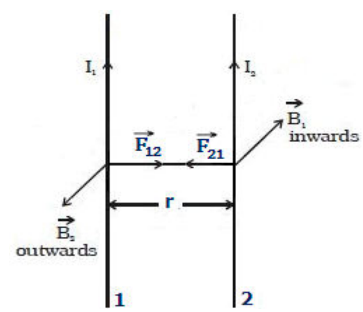
$$B_1 = \frac{\mu_0\,I_1}{2\pi r}$$

By right hand rule $\vec{B_1}$ will act perpendicular to conductor '2' and into the plane of the paper

Due to this magnetic field force on length l of wire '2'

$$F_{21} = B_1\,I_2\,l\,\sin 90 = \left(\frac{\mu_0\,I_1}{2\pi r}\right)I_2\,l$$

⇨ $$F_{21} = \frac{\mu_0\,I_1 I_2\,l}{2\pi r}$$



Similarly, force on length l of wire '1

$$F_{12} = B_2\,I_1\,l\,\sin 90 = \left(\frac{\mu_0\,I_2}{2\pi r}\right)I_1\,l = \frac{\mu_0\,I_1 I_2\,l}{2\pi r}$$

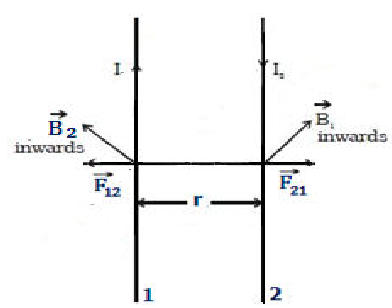
⇨ $$F_{21} = F_{12} = \frac{\mu_0\,I_1 I_2\,l}{2\pi r} = F$$

Hence force per unit length

$$f = \frac{F}{l} = \frac{\mu_0\,I_1 I_2}{2\pi r} \qquad \text{-----------(1)}$$

By Fleming's left hand rule $\vec{F_{21}}$ will act towards conductor '1' and $\vec{F_{12}}$ will act towards conductor '2'. Obviously the two conductors will attract each other

If the currents are in opposite directions, then there will be repulsion between the two conductors



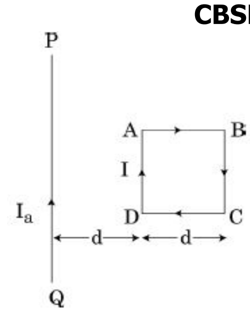
367. In the figure given below, wire PQ is fixed while the square loop $ABCD$ is free to move under the influence of currents flowing in them. State with reason, in which direction does the loop begin to move or rotate ? **CBSE (AI)-2016**

[Ans. Loop ABCD will move towards wire PQ

Wires PQ and AD will attract each other as currents are in same direction, while wires PQ and BC will repel each other as the currents are in opposite direction

Contribution due to currents in AB and CD nullify each other

Since from wire PQ, AD is nearer than BC so net force on the loop is attractive. Therefore, the loop will move towards the wire PQ



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368. Use Ampere's circuital law to find magnetic field due to straight infinite current carrying wire. **CBSE (AI)-2015**

[Ans. Magnetic Field due to straight infinite current carrying wire using Ampere's circuital law :

Let an infinite straight wire carry a current I. By right hand rule, the magnetic field is tangential at every point of the Amperian loop

By the Ampere's circuital law

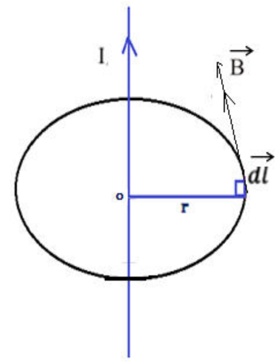
$$\oint \vec{B}.\vec{dl} = \mu_0 \mathrm{I}$$

$$\oint B\, dl \cos 0 = \mu_0 \mathrm{I}$$

$$B \oint dl = \mu_0 \mathrm{I}$$

$$B\ (2\pi r) = \mu_0 \mathrm{I}$$

⇨ $$\boldsymbol{B = \frac{\mu_0 \mathrm{I}}{2\pi r}}$$



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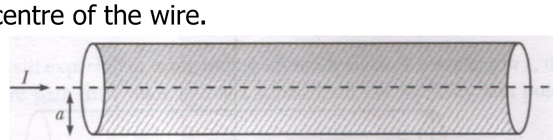
369. Consider a long straight cylindrical wire of circular cross section of radius 'a' as shown in the figure. The current I is uniformly distributed across this cross section. Calculate the magnetic field B in the region r<a and r >a. Plot a graph of B versus r from the centre of the wire. **CBSE (AI)-2015**



[Ans.(i) For $r < a$

Current flowing through the loop 1

$$\mathrm{I}' = \frac{\mathrm{I}}{\pi a^2} \times \pi r_1^2 = \frac{\mathrm{I}\, r_1^2}{a^2}$$

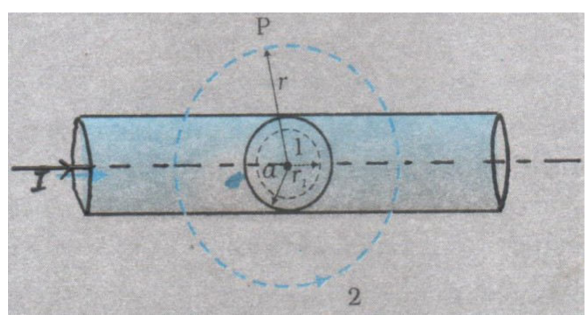
By the Ampere's circuital law

$$\oint \vec{B}.\vec{dl} = \mu_0 \mu_r \mathrm{I}'$$

$$\oint B\, dl \cos 0 = \mu_0 \mu_r \frac{\mathrm{I}\, r_1^2}{a^2}$$

$$B\ (2\pi r_1) = \mu_0 \mu_r \frac{\mathrm{I}\, r_1^2}{a^2}$$

⇨ $$\boldsymbol{B = \frac{\mu_0 \mu_r I r_1}{2\pi a^2}}$$



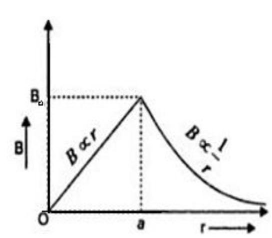
(ii) For $r >$ a, applying Ampere's circuital law for loop 2

$$\oint \vec{B}.\vec{dl} = \mu_0 \mathrm{I}$$

$$\oint B\, dl \cos 0 = \mu_0 \mathrm{I}$$

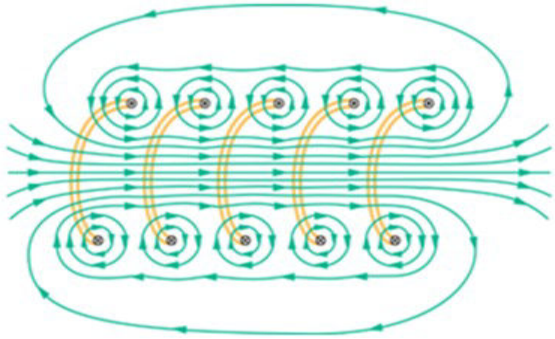
$$B\ (2\pi r) = \mu_0 \mathrm{I}$$

⇨ $$\boldsymbol{B = \frac{\mu_0 \mathrm{I}}{2\pi r}}$$



370. Using Ampere's circuital law, obtain an expression for the magnetic field due to a long solenoid at a point inside The Solenoid on its axis. **CBSE (AI)-2013,2011,(F)-2013,2010**

[Ans. Magnetic field due to a long current carrying solenoid :



Let n be the number of turns per unit length of solenoid and I be the current flowing through solenoid.
Let us consider the Amperian loop $abcd$ as shown. By the Ampere's circuital law

$\oint \vec{B}.\vec{dl} = \mu_0$ X total current through loop $abcd$

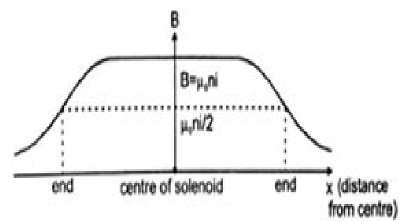
⇨ $\int_a^b \vec{B}.\vec{dl} + \int_b^c \vec{B}.\vec{dl} + \int_c^d \vec{B}.\vec{dl} + \int_d^a \vec{B}.\vec{dl} = \mu_0 (nLI)$

⇨ $\int_a^b Bdl\cos 0 + \int_b^c Bdl\cos 90 + 0 + \int_d^a Bdl\cos 90 = \mu_0\, nL\, I$

⇨ $B\int_a^b dl = \mu_0\, nL\, I$

⇨ $BL = \mu_0\, nL\, I$

⇨ $\boldsymbol{B = \mu_0\, n\, I} = \frac{\mu_0 N I}{L}$



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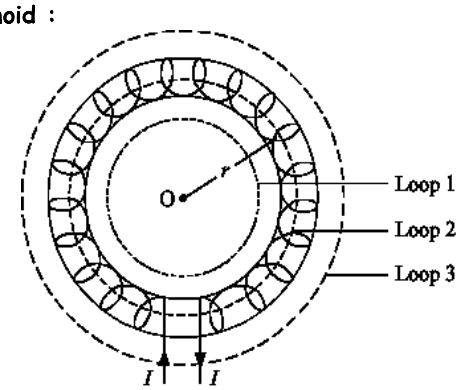
371. Using Ampere's circuital law, obtain an expression for the magnetic field inside a current carrying toroid. Show that the magnetic field in the open space inside and exterior to the toroid is zero. **(AI)-2013,(D)-2010**

[Ans. Magnetic field due to a current carrying toroid/toroidal solenoid :

Let n be the number of turns per unit length of toroid & I be the current flowing through toroid
Let us consider the Amperian loop 2 as shown.



By Ampere's circuital law

$\oint \vec{B}.\vec{dl} = \mu_0$ X total current through loop

$\oint B\, dl\, cos\, 0 = \mu_0 (n\, 2\pi r I)$

$B \oint dl = \mu_0\, n\, I\, (2\pi r)$

$B\ (2\pi r) = \mu_0\, n\, I\, (2\pi r)$

⇨ $\boldsymbol{B = \mu_0\, n\, I}$

(i) in the open space inside toroid

As Amperian loop 1 inside the toroid encloses no current
i,e, $I = 0$
By Ampere's circuital law

$\oint \vec{B}.\vec{dl} = \mu_0 I = 0$ ⇨ $\boldsymbol{B = 0}$

(ii) in the open space outside toroid

For the Amperian loop 3, for each turn, current coming out of the plane of the paper just cancels the current going into plane of paper

i,e, net current, $I = 0$ By Ampere's circuital law

$\oint \vec{B}.\vec{dl} = \mu_0 I = 0$ ⇨ $\boldsymbol{B = 0}$

372. Explain how Biot-Savart's law enables one to express the Ampere's circuital law in the integral form, i,e,

$$\oint \vec{B}.\,\vec{dl} = \mu_0 \mathbf{I}$$

Where I is the total current passing through the surface. **CBSE (AI)-2015**

[**Ans**. Biot-Savart's law can be expressed as Ampere's circuital law by considering the surface to be made up a large number of loops. The sum of the tangential components of the magnetic field multiplied by the length of all such elements, gives the result $\oint \vec{B}.\,\vec{dl} = \mu_0 \mathbf{I}$

Moreover, both the laws relate the magnetic field and the current, and both express the same physical consequences of a steady current

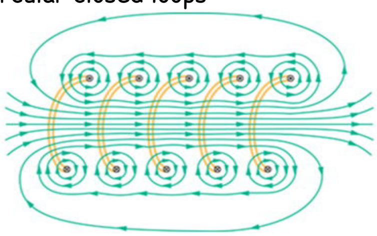
373. What does a toroid consists of ? **CBSE (AI)-2013**

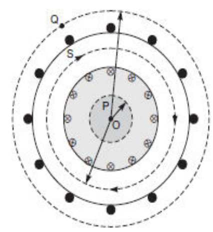
[**Ans**. **Toroid** : It is a hollow circular ring on which a large number of metallic wires are closely wound. In fact toroid is a solenoid bent into the form of a close ring

374. In what respect does a toroid different from a solenoid ? Draw and compare the pattern of magnetic field lines in the two cases. **CBSE (AI)-2011**

[**Ans**. A solenoid bent into the form of a close ring is called a toroid

In solenoid, the pattern of magnetic field lines is similar to a bar magnet, while in a toroid the magnetic field lines are circular closed loops

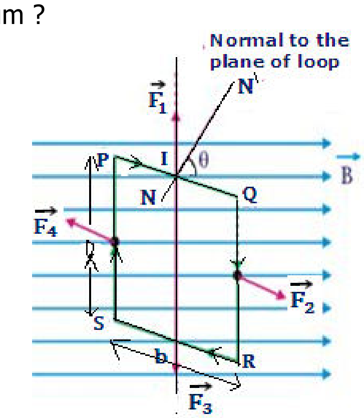




375. Derive an expression for the torque acting on a rectangular current carrying loop kept in a uniform magnetic field B. (i) Indicate the direction of torque acting on the loop. **CBSE (AI)-2015,(D)-2013,(F)-2009**

(ii) If the loop is free to rotate, what would be its orientation in stable equilibrium ?

[**Ans**. Let a loop $PQRS$ is suspended in a uniform magnetic field as shown



$$\left|\vec{F_1}\right| = \left|\vec{F_3}\right| = BIl\sin(90-\theta) = BIl\cos\theta$$

By Fleming's left hand rule, $\vec{F_1}$ & $\vec{F_3}$ are equal & opposite and acts along the same line of action. Hence their resultant become s zero

$$\left|\vec{F_2}\right| = \left|\vec{F_4}\right| = BIl\sin 90 = BIl$$

By Fleming's left hand rule, $\vec{F_2}$ & $\vec{F_3}$ are equal & opposite but acts along the different line of action. Hence they form a couple known as deflecting couple.

Torque of the couple

$\tau =$ magnitude of either force X perpendicular distance

$$\tau = BIl \,\mathrm{X}\, \mathrm{b}\sin\theta \;= BI(l\,\mathrm{X}\,\mathrm{b})\sin\theta$$

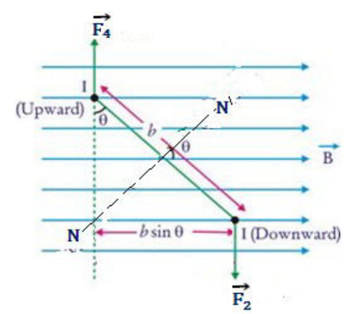
⇨ $\tau = BIA\sin\theta$

For a coil having N turns

$$\tau = BINA\sin\theta$$

⇨ $\tau = (N\,IA)B\sin\theta$

⇨ $\boldsymbol{\tau = MB\sin\theta = \vec{M}\,\mathrm{X}\,\vec{B}}$



Where $M = NIA$ is the magnetic dipole moment

(i) Direction of τ : Torque is perpendicular to the direction of area of loop as well as direction of magnetic field i,e, along $N\,I(\vec{A}\,\mathrm{X}\,\vec{B})$

(ii) The current loop will be in equilibrium when $\tau = 0$, i,e, when $\theta = 0$, i,e, when dipole moment ($\vec{M}$) is in the direction of magnetic field $(\vec{B})$

376. With the help of a neat and labelled diagram, explain the principle and working of a moving coil galvanometer.
(i) What is the function of uniform radial field and how is it produced ?
(ii) Why is it necessary to introduce a cylindrical soft iron core inside the coil of a galvanometer ?

CBSE (D)-2017,2015,(F)-2016,2012,(AI)-2014,2010

[**Ans**. **Moving coil galvanometer** : It is a device used to detect small currents in an electric circuit.

Principle : When a current carrying coil is placed in a uniform magnetic field, it experiences a torque (τ = BINA $\sin\theta$) which tends to rotate the coil and produces an angular deflection

Working : When current I is passed in the coil, it experiences a torque, known as deflecting torque

τ = BINA $\sin 90^0$ [$\because$ for radial field, $\theta = 90^0$]

⇨ τ = BINA

This magnetic torque tends to rotate the coil. Spring S_p provides the counter torque known as restoring torque which balances this magnetic torque and is given by

$\tau' = K\phi$

Where K is the restoring torque per unit twist or torsional Constant of the spring

i,e, In equilibrium, $\tau = \tau'$

⇨ BINA $= K\phi$

⇨ $I = \frac{K}{BNA}\phi$

⇨ $I \propto \phi$

Hence, deflection of coil is directly proportional to the current flowing in the coil which can be measured by the linear scale.

(i) Function of radial magnetic field : It makes the scale of galvanometer linear or $I \propto \phi$

Production of radial magnetic field : It can be produced by making the pole pieces of the magnet cylindrical in shape

(ii) Necessity of soft iron core : (i) to increases the strength of the magnetic field hence increases the sensitivity of the galvanometer, and
(ii) to make the field more radial

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377.-Define the terms (i) current sensitivity and (ii) Voltage sensitivity of a galvanometer. How is current sensitivity increased ?

CBSE (F)-2016,(AI)-2015

[Ans. (i) **Current Sensitivity** : It is defined as the deflection produced in the galvanometer, when unit current flowing in it

i,e, $I_s = \frac{\phi}{I}$

(ii) **Voltage Sensitivity** : It is defined as the deflection produced in the galvanometer, when unit potential difference is applied across its ends

i,e, $V_s = \frac{\phi}{V}$

Current sensitivity can be increased by increasing the number of turns

378.-"Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity." Justify this statement.

CBSE (AI)-2015,2014,2001,(D)-2009

[Ans. Current sensitivity $I_s = \frac{\phi}{I} = \frac{NBA}{K}$ & Voltage sensitivity $V_s = \frac{\phi}{V} = \frac{NBA}{KR}$

current sensitivity can be increased by increasing N,B,A and by decreasing K

let N is doubled, then the length of wire is also doubled. But, $R \propto l$ ⇨ R will also be doubled.

⇨ $V_s' = \frac{(2N)BA}{K(2R)} = V_s$

Which shows that the Voltage sensitivity remains unchanged

379. Explain why the galvanometer as such cannot be used as an ammeter ? **CBSE (D)-2017, NCERT-2017**

[Ans. because-(i) Galvanometer is a very sensitive device, it gives a full scale deflection for a current of the order of μA
(ii) it has large resistance, when connected in series it will change the value of current in the circuit

380. What is the function of soft iron core, in a moving coil galvanometer ? **CBSE (AI)-2015**

[Ans. It increases the sensitivity of the galvanometer and make the magnetic field to be more radial

381. What is the importance of radial magnetic field in a moving coil galvanometer ? **CBSE (AI)-2010**

[Ans. It always keeps the plane of the coil parallel to the magnetic field in every orientation

382. What is meant by figure of merit of a galvanometer ? **CBSE (DC)-2002**

[Ans. **<u>Figure of merit</u>** : It is defined as the amount of current which produces one scale deflection in the galvanometer

==

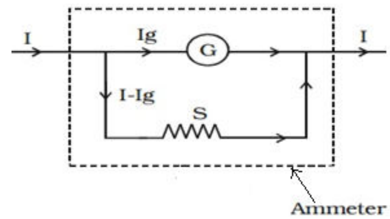
383. How is a galvanometer converted into a voltmeter and an ammeter ? Draw the relevant diagrams and find the resistance of the arrangement in each case. Take resistance of galvanometer as G. **CBSE (AI)-2016**

[Ans. **(i) Conversion of galvanometer in to Ammeter :**

A galvanometer is converted in to an ammeter by connecting a very small resistance (called shunt) in parallel with it.

$(I - I_g) \times S = I_g \times G$

⇨ $S = \dfrac{I_g \times G}{(I - I_g)}$



Effective resistance of ammeter

$\frac{1}{R_A} = \frac{1}{S} + \frac{1}{G}$ ⇨ $R_A = \frac{S\,G}{S + G}$

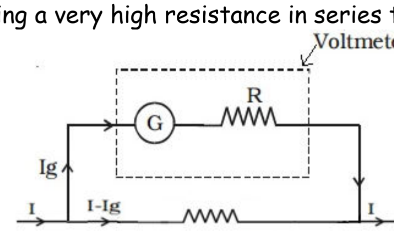
$R_A < G$ always

(ii) Conversion of galvanometer in to Voltmeter :

A galvanometer can be converted in to a voltmeter by connecting a very high resistance in series to it.

$V = I_g\,(R + G)$

⇨ $R = \frac{V}{I_g} - G$



Effective resistance of voltmeter

$R_V = R + G$

$R_V > G$ always

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384. Explain giving reasons, the basic difference/ underlying principle used, in converting a galvanometer into- (i) an ammeter, and (ii) a Voltmeter. **CBSE (AI)-2015,2012**

OR

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 ? **CBSE (DC)-2013,(AI)-2012,2010**

[Ans. (i) A galvanometer is converted into an ammeter by connecting a shunt in parallel with it, so that when ammeter is connected in series, it does not reduce the current in the circuit

(ii) A galvanometer is converted into voltmeter by connecting high resistance in series with it, so that when voltmeter is connected in parallel a negligible current flows through it and the p.d. across the given component is not affected

385. What is shunt ? Write its S.I. unit. Why is it used in a galvanometer ? **CBSE (AI)-2010**

[Ans. **<u>Shunt</u>** : Shunt is a very small resistance used in parallel with a galvanometer. S.I. unit of shunt is Ohm(Ω)

Use : It is used to protect galvanometer from high currents/ to convert galvanometer into ammeter/ to increase range of ammeter

386. The current sensitivity of a moving coil galvanometer increases by 20 % when its resistance is increased by a Factor of 2. Calculate by what factor the voltage sensitivity changes ? **CBSE (DC)-2001**

[Ans. Given $I_S' = I_S + 20\,\%$ of $I_S = \frac{120}{100} I_S$ & $R' = 2R$

Now, $V_S = \frac{I_S}{R}$ ⇨ $V_S' = \frac{I_S'}{R'} = \left(\frac{120}{100} I_S\right) \times \frac{1}{2R} = \frac{3}{5} V_S$

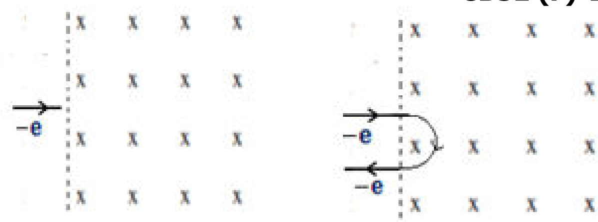
⇨ % decrease in voltage sensitivity = $\frac{V_S - V_S'}{V_S} \times 100 = \frac{V_S - \frac{3}{5} V_S}{V_S} \times 100 = 40\%$

387. An electron, after being accelerated through a potential difference of $100\ V$, enters a uniform magnetic field of $0.004\ T$, perpendicular to its direction of motion. Calculate the radius of the path described by the electron.

[Ans. $r = \frac{mv}{qB} = \frac{1}{B}\sqrt{\frac{2mV}{q}}$ **CBSE (F)-2017,(AI)-2016**

⇨ $r = \frac{1}{0.004}\ X \sqrt{\frac{2\ X\ 9.1\ X\ 10^{-31}\ X\ 100}{1.6\ X 10^{-19}}} = 8.4\ X\ 10^{-3} m$

388. An electron moving horizontally with a velocity of $4\ X\ 10^4\ m/s$ enters a region of uniform magnetic field of 10^{-5}T acting vertically downward as shown. Draw its trajectory and find the time it takes to come out of the region of magnetic field. **CBSE (F)-2015**



[Ans. $r = \frac{mv}{qB} = \frac{9.1\ X\ 10^{-31}\ X\ 4\ X\ 10^4}{1.6\ X\ 10^{-19}\ X\ 10^{-5}}$

⇨ $r = 2.23\ X\ 10^{-2} m$

$t = \frac{\pi r}{v} = \frac{3.14\ X\ 2.23\ X\ 10^{-2}}{4\ X\ 10^4}$

⇨ $t = 1.8\ X\ 10^{-7} s$

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389. A beam of proton passes undeflected with a horizontal velocity v, through a region of electric and magnetic fields, mutually perpendicular to each other and normal to the direction of beam. If the magnitudes of electric and magnetic fields are $100\ \mathrm{KV/m}$ and $50\ m\ T$, respectively. Calculate : **CBSE (AI)-2008**
(i) velocity v of the beam,
(ii) force with which it strikes a target on the screen, if the proton beam current is equal to $0.80\ mA$.

[Ans. (i) $qE = B\ qv$ ⇨ $v = \frac{E}{B} = \frac{100\ X\ 10^3}{50\ X\ 10^{-3}} = 2\ X\ 10^6\ m/s$

(ii) number of protons striking per second

$n = \frac{I}{e}$

⇨ $F = \frac{dp}{dt} = mnv = m(\frac{I}{e})v = 1.675\ X\ 10^{-27}\ X \left(\frac{0.80\ X\ 10^{-3}}{1.6\ X\ 10^{-19}}\right) X\ 2\ X\ 10^6 = 1.675\ X\ 10^{-5}\ N$

390. A uniform magnetic field of $6.5\ X\ 10^{-4}\ T$ is maintained in a chamber. An electron enters into the field with a speed of $4.8\ X\ 10^6\ m/s$ normal to the field. Explain why the path of the electron is a circle. Determine its frequency of revolution in the circular orbit. Does the frequency depend on the speed of the electron ? Explain. **CBSE (AI)-2015**

[Ans. The force, on the electron, due to the magnetic field, at any instant is perpendicular to its instantaneous velocity.

Frequency does not depends on speed of electron

$f = \frac{qB}{2\pi m} = \frac{1.6\ X\ 10^{-19} X\ 6.5\ X\ 10^{-4}}{2\ X\ 3.14\ X\ 9.1\ X\ 10^{-31}} = 1.8\ X\ 10^7\ \mathrm{Hz}$

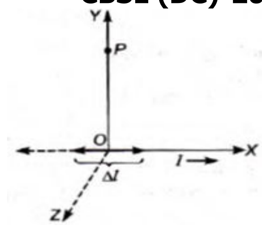
391. A cyclotron's oscillator frequency is 10 MHz. What should be the operating magnetic field for accelerating protons? If the radius of its 'dees' is 60 cm, what is the kinetic energy (in MeV) of the proton beam produced by the accelerator. (e =1.60 X 10^{-19} C, m_p = 1.67 X 10^{-27} kg, 1 MeV = 1.6 X 10^{-13}J **NCERT-2017, CBSE (AI)-2015, 2005**

[Ans. $f = \frac{qB}{2\pi m}$

⇨ $B = \frac{2\pi f m}{q} = \frac{2X\ 3.14X\ 10\ X\ 10^6 X 1.67\ X\ 10^{-27}}{1.60\ X\ 10^{-19}}$ = 0.66 T

$E_{K_{max}} = \frac{q^2 B^2 r_0^2}{2m} = \frac{(1.60\ X\ 10^{-19})^2\ (0.66)^2 (60X10^{-2})^2}{2\ X\ 1.67\ X\ 10^{-27}} = 1.2\ X\ 10^{-12}\mathrm{J} = \frac{1.2\ X\ 10^{-12}}{1.6\ X\ 10^{-13}} = 7.4$ MeV

392. An element $\overrightarrow{\Delta l} = \Delta x\,\hat{\imath}$ is placed at the origin and carries a current $\mathrm{I} = 2A$. Find out the magnetic field at a point P on the $y - axis$ at a distance of $1.0\ m$ due to the element $\Delta x = 1\ \ cm$. Also give the direction of magnetic field produced. **CBSE (DC)-2009**



[Ans. $\Delta B = \frac{\mu_0}{4\pi}\frac{I\,\Delta l\,\sin\theta}{r^2}$

⇨ $\Delta B = 10^{-7}\ \mathrm{X}\ \frac{2\ \mathrm{X}\ 1\ \mathrm{X}\ 10^{-2}\ \mathrm{X}\ \sin 90^0}{(1)^2} = 2\ \mathrm{X}\ 10^{-9}\,T$

Now, $\overrightarrow{\Delta l}\ \mathrm{X}\ \vec{r} = \Delta x\,\hat{\imath}\ \mathrm{X}\ y\,\hat{\jmath} = \Delta x\,y\,(\hat{\imath}\ \mathrm{X}\ \hat{\jmath}) = \Delta x\,y\,\hat{k}$

Hence ΔB will be along $+z$ direction

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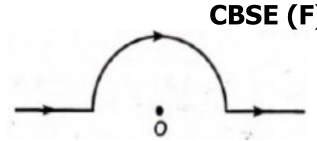
393. A straight wire carrying a current of $12\ A$ is bent in to a semi-circular arc of radius $2.0\ cm$ as shown. What is the magnetic field B at O due to (i) straight segments (ii) semicircular arc ? **CBSE (F)-2010**



[Ans. (i) $B = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin\theta}{r^2} = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin 0^0}{r^2} = 0$

(ii) $B = \frac{1}{2}\left(\frac{\mu_0\,\mathrm{I}}{2r}\right) = \frac{4\pi\ \mathrm{X}\ 10^{-7}\ \mathrm{X}\ 12}{4\ X\ 2\ \mathrm{X}\ 10^{-2}} = 3.14\ \mathrm{X}\ 6\ \mathrm{X}10^{-5} = 1.88\ \mathrm{X}\ 10^{-4}\ T$

394. Find the ratio of the magnitudes of the magnetic field of a current carrying coil at the centre and at an axial point for which $x = R\sqrt{3}$. **CBSE (AI)-2016**

[Ans. $B_1 = \frac{\mu_0\,\mathrm{I}}{2R}$ & $B_2 = \frac{\mu_0\,\mathrm{I}\,R^2}{2\,(R^2 + x^2)^{3/2}} = \frac{\mu_0\,\mathrm{I}\,R^2}{2\,(R^2 + 3R^2)^{3/2}} = \frac{\mu_0\,\mathrm{I}\,R^2}{2\,(4R^2)^{3/2}} = \frac{\mu_0\,\mathrm{I}}{16\,R}$

⇨ $\frac{B_1}{B_2} = \frac{\mu_0\,\mathrm{I}}{2R}\ \mathrm{X}\ \frac{16\,R}{\mu_0\,\mathrm{I}} = 8$

395. A square shaped plane coil of area $100\ cm^2$ of 200 turns carries a steady current of 5A. It is placed in a uniform magnetic field of 0.2 T acting perpendicular to the plane of the coil. Calculate the torque on the coil when its plane makes an angle of 60° with the direction of the field. In which orientation will the coil be in stable equilibrium ?

[Ans. $\theta = 90^0 - 60^0 = \mathbf{30^0}$

$\boldsymbol{\tau} = BINA\ \sin\theta\ = 0.2\ \mathrm{X}\ 5\ \mathrm{X}\ 200\ \mathrm{X}100\ \mathrm{X}\ 10^{-4}\ \mathrm{X}\sin 30^0$

⇨ $\boldsymbol{\tau} = 2\ \mathrm{X}\frac{1}{2} = 1\ \ N - m$

396. A closely wound solenoid of 2000 turns and cross sectional area $1.6\ X\ 10^{-4}\ m^{\,2}$ carrying a current of 4.0 A is suspended through its centre allowing it to turn in a horizontal plane. Find – **CBSE (AIC)-2015**

(i) the magnetic moment associated with the solenoid,

(ii) magnitude and direction of the torque on the solenoid if a horizontal magnetic field of $7.5\ \mathrm{X}\ 10^{-2}\ T$ is set up at an angle of 30° with the axis of the solenoid.

[Ans. (i) $M = NIA = 2000\ \mathrm{X}\ 4\ \mathrm{X}\ 1.6\ \mathrm{X}\ 10^{-4} = 1.28\ Am^2$

(ii) $\boldsymbol{\tau} = MB\ \sin\theta\ = 1.28\ \mathrm{X}\ 7.5\ \ \mathrm{X}\ 10^{-2}\ \mathrm{X}\sin 30^0$

⇨ $\boldsymbol{\tau} = 0.096\ \mathrm{X}\frac{1}{2} = 0.048\ \ N - m$

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397. A straight wire of mass $200\ \mathrm{g}$ and length $1.5\ m$ carries a current of $2A$. It is suspended in mid air by a uniform magnetic field B. What is the magnitude of the magnetic field ? **CBSE (F)-2015**

[Ans. $\mathrm{BIL} = mg$ ⇨ $B = \frac{\mathrm{mg}}{\mathrm{IL}} = \frac{200\ \mathrm{X}\ 10^{-2}\ \mathrm{X}\ 9.8}{2\ \mathrm{X}\ 1.5} = 0.653\ T$

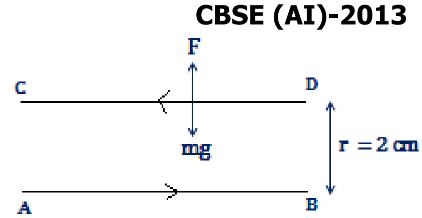
398. A wire AB carrying a steady current of $10A$ and is lying on the table. Another wire CD carrying $6A$ is held directly above AB at a height of $2\ mm$. Find the mass per unit length of the wire CD so that it remains suspended at its position when left free. Give the direction of current flowing in CD with respect to that in AB. $(\,\mathrm{g} = 10\ m/s^2)$

[Ans. $\mathrm{F} = mg$ **CBSE (AI)-2013**

⇨ $\frac{\mu_0\,\mathrm{I_1 I_2}}{2\pi r}L = mg$

⇨ $\frac{\mathrm{m}}{\mathrm{L}} = \frac{\mu_0\,\mathrm{I_1 I_2}}{2\pi r g} = 2\ \mathrm{X}10^{-7}\mathrm{X}\frac{10\ \mathrm{X}\ 6}{2\ \mathrm{X}\ 10^{-2}\mathrm{X}\ 10}$

⇨ $\frac{\mathrm{m}}{\mathrm{L}} = 1.2\ \mathrm{X}\ 10^{-3}\ \ \mathrm{Kg/m}$



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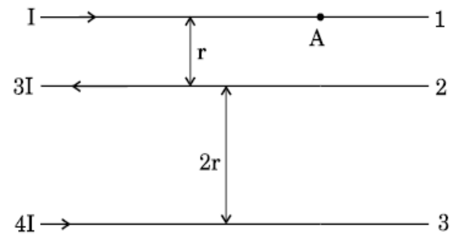
399. The figure shows three infinitely long straight parallel current carrying conductors. Find the- **CBSE (F)-2017**
(i) magnitude and direction of the net magnetic field at point A lying on conductor 1,
(ii) magnetic force on conductor 2



[Ans. (i) $B_A = B_2 - B_3 = \frac{\mu_0 \text{ X } 3I}{2\pi r} - \frac{\mu_0 \text{ X } 4I}{2\pi(3r)}$

⇨ $B_A = \frac{\mu_0 \text{ I}}{2\pi r}(3 - 4/3) = \frac{\mu_0 \text{ 5I}}{6\pi r}$ (⊗)

(ii) $F_{net} = F_{23} - F_{21} = \frac{\mu_0 \text{ 3I X 4I}}{2\pi(2r)} - \frac{\mu_0 \text{ I X 3I}}{2\pi r}$

⇨ $F_{net} = \frac{\mu_0 \text{ I}^2}{2\pi r}(6-3) = \frac{\mu_0 \text{ 3I}^2}{2\pi r}$ towards wire 1

==

399a. An ammeter of resistance $0.8\ \Omega$ can measure current up to $1.0\ A$. **CBSE (D)-2013**
(i) What must be the value of shunt resistance to enable the ammeter to measure current up to $5.0\ A$?
(ii) What is the combined resistance of the ammeter and the shunt ?

[Ans. (i) $S = \frac{\text{I}_\text{g} \text{ X G}}{(\text{I}-\text{I}_\text{g})} = \frac{1 \text{ X } 0.8}{(5-1)} = 0.2\ \Omega$

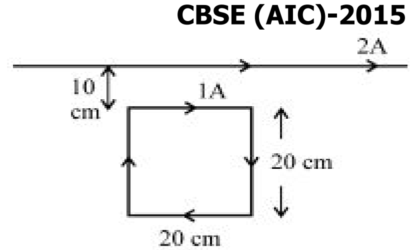
(ii) $R_A = \frac{S\ G}{S + G} = \frac{0.2 \text{ X } 0.8}{0.2 + 0.8} = 0.16\ \Omega$

399b. A galvanometer with a coil of resistance $12\ \Omega$ shows full scale deflection for a current $2.5\ mA$. How will you convert the meter in to : **NCERT-2017, CBSE (D)-2005**
(i) an ammeter of range 0 to $7.5\ A$
(ii) a voltmeter of range 0 to $10.0\ V$

(i) $S = \frac{\text{I}_\text{g} \text{ X G}}{(\text{I}-\text{I}_\text{g})} = \frac{2.5 \text{ X } 10^{-3}\ X12}{(7.5 - 2.5 \text{ X } 10^{-3})}$ =

(ii) $S = \frac{V}{Ig} - G = \frac{10}{(2.5 \text{ X } 10^{-3})}$ **-12**=

399c. A square loop of side 20 cm carrying current of 1A is kept near an infinite long straight wire carrying a current of 2A in
the same plane as shown in the figure. Calculate the magnitude and direction of the net force exerted on the loop due to the current carrying conductor. **CBSE (AIC)-2015**



[Ans. $F = \frac{\mu_0 \text{ I}_1\text{I}_2 \text{X L}}{2\pi r} \text{X} \left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

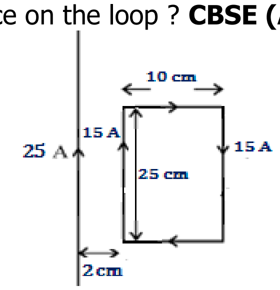
⇨ $F = 2 \text{ X } 10^{-7} \text{X } 2 \text{ X } 1 \text{ X } 20 \text{ X } 10^{-2} \text{ X} \left[\frac{1}{10 \text{ X } 10^{-2}} - \frac{1}{30 \text{ X } 10^{-2}}\right]$

⇨ $F = 4 \text{ X } 10^{-7} \text{ X } 20 \text{ X} \left[\frac{1}{10} - \frac{1}{30}\right] = 4 \text{ X } 10^{-7} \text{ X } 20 \text{ X} \left[\frac{30-10}{10 \text{ X } 30}\right]$

⇨ $F = \frac{16}{3} \text{ X } 10^{-7}\ N = 5.33 \text{ X } 10^{-7}\ N$

This force is directed towards infinite long wire

399d. A rectangular loop of sides $25\ cm$ and $10\ cm$ carrying a current of $15\ A$ is placed with its longer side parallel to a long straight conductor $2\ cm$ apart carrying a current of $25\ A$. What is the net force on the loop ? **CBSE (AI)-2005**



[Ans. $F = \frac{\mu_0 \text{ I}_1\text{I}_2 \text{X L}}{2\pi r} \text{X} \left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

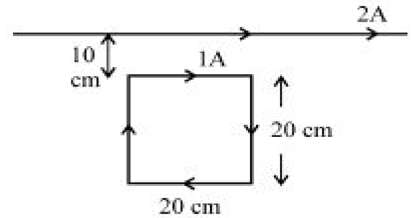
⇨ $F = 2 \text{ X } 10^{-7} \text{X } 25 \text{ X } 15 \text{ X } 25 \text{ X } 10^{-2} \text{ X} \left[\frac{1}{2 \text{ X } 10^{-2}} - \frac{1}{12 \text{ X } 10^{-2}}\right]$

⇨ $F = 1.8750 \text{ X } 10^{-3} \text{ X } \left[\frac{1}{2} - \frac{1}{12}\right] = 1.8750 \text{ X } 10^{-3} \text{ X } \left[\frac{5}{12}\right]$

⇨ $F = 7.8 \text{ X } 10^{-4}\ N$

==

399e. A square loop of side 20 cm carrying current of 1A is kept near an infinite long straight wire carrying a current of 2A in the same plane as shown in the figure. Calculate the magnitude and direction of the net force exerted on the loop due to the current carrying conductor. **CBSE (AIC)-2015**



[**Ans**. $F = \frac{\mu_0 I_1 I_2 X L}{2\pi r} X \left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

⇨ $F = 2 X 10^{-7} X 2 X 1 X 20 \ X 10^{-2} X \left[\frac{1}{10 X 10^{-2}} - \frac{1}{30 X 10^{-2}}\right]$

⇨ $F = 4 X 10^{-7} X 20 X \left[\frac{1}{10} - \frac{1}{30}\right] = 4 X 10^{-7} X 20 X \left[\frac{30-10}{10 \ X 30}\right]$

⇨ $F = \frac{16}{3} X 10^{-7} \ N = 5.33 X 10^{-7} N$

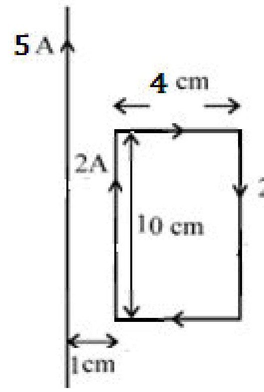
This force is directed towards infinite long wire

==

399f. A rectangular loop of wire of size $4\ cm\ X\ 10\ cm$ carries a steady current of $2A$. A straight long wire carrying $5\ A$ current is kept near the loop as shown. If the loop and wire are coplanar, find - **CBSE (D)-2012**

(i) the torque acting on the loop and

(ii) the magnitude and direction of the net force on the loop due to the current carrying wire.



[**Ans**. **(i)** As the wire and loop are coplanar

$\boldsymbol{\tau} = MB \sin\theta \ = MB \sin 0^0 = 0$

(ii) $F = \frac{\mu_0 I_1 I_2 X L}{2\pi r} X \left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

⇨ $F = 2 X 10^{-7} X 5 X 2 X 10 \ X 10^{-2} X \left[\frac{1}{1 X 10^{-2}} - \frac{1}{5 X 10^{-2}}\right]$

⇨ $F = 2 X 10^{-5} X \left[\frac{1}{1} - \frac{1}{5}\right] = 2 X 10^{-5} X \left[\frac{4}{5}\right]$

⇨ $F = \frac{8}{5} X 10^{-5} \ N = 1.6 X 10^{-5} N$

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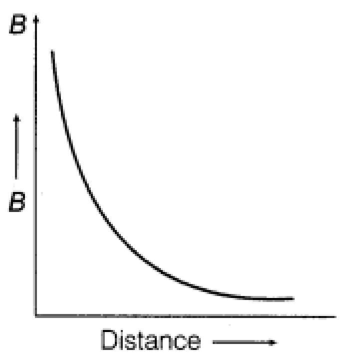


Chapter–5: Magnetism and Matter

Current loop as a magnetic dipole and its magnetic dipole moment, magnetic dipole moment of a revolving electron, magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis, torque on a magnetic dipole (bar magnet) in a uniform magnetic field; bar magnet as an equivalent solenoid, magnetic field lines; earth's magnetic field and magnetic elements.

Para-, dia- and ferro - magnetic substances, with examples. Electromagnets and factors affecting their strengths, permanent magnets.

301*. Define the term magnetic dipole moment of a current loop. **CBSE (AI)-2008**

[Ans. Magnetic moment of a current loop is defined as the product of current (I) and the area (A) enclosed by the current loop i,e, $M = \mathrm{I}A$

302*. Write the expression for the magnetic moment of a circular coil of area A, carrying current I, in a vector form.

[Ans. $\vec{M} = NI\,\vec{A}$ **CBSE (F)-2014,(AI)-2002**

303*. An electron in an atom revolves around the nucleus in an orbit of radius r with frequency ν. Write the expression for the magnetic moment of the electron. **CBSE (F)-2014**

[Ans. $M = \mathrm{I}A = \frac{e}{T}\,\mathrm{X}\,\pi\, r^2 = e\nu\pi\, r^2$

304*. What are S.I. units of pole strength and magnetic moment ? **CBSE (AI)-2003**

[Ans. S.I. unit of pole strength : Ampere-metre

S.I. unit of magnetic moment: Ampere-$metre^2$

305*. What is the direction of magnetic moment ? **CBSE (AIC)-2003**

[Ans. from south to north pole

306*. How does the (i) pole strength and (ii) magnetic moment of each part of a bar magnet is change, if it is cut into two equal pieces transverse to its length ? **CBSE (AI)-2003**

[Ans. (i) pole strength (m) will remain same

(ii) magnetic moment(M) will be halved as $M' = m\ \mathrm{X}\ \frac{2l}{2} = M/2$

307*. How does the (i) pole strength and (ii) magnetic moment of each part of a bar magnet is change, if it is cut into two equal pieces along its length ? **CBSE (AI)-2003**

[Ans. (i) pole strength (m) will be halved

(ii) magnetic moment(M) will be halved as $M' = \frac{m}{2}\ \mathrm{X}\ 2l = M/2$

308*. Why is current loop considered as a magnetic dipole ? **CBSE (AIC)-2001**

[Ans. Like a bar magnet, a current loop possesses magnetic moment (M =NIA) and experiences a torque in magnetic field

==

309*. Write two properties of a material suitable for making (a) a permanent magnet, and (b) an electromagnet.

[Ans. (a) For making permanent magnet : **CBSE (AI)-2017,2016,(D)-2010,(F)-2009**

(i) High retentivity (ii) High coercivity (iii) High permeability

(b) For making electromagnet :

(i) High permeability (ii) Low retentivity (iii) Low coercivity

310*. Mention the two characteristic properties of a material suitable for making core of a transformer.**CBSE (AI)-2012**

[Ans. (i) Low coercivity/ Low retentivity (ii) High permeability

311*. What are permanent magnets ? Give one example. **CBSE (D)-2013**

[Ans. Permanent magnets are the materials, which retain their magnetic properties at room temperature for a long time

For example : Magnets used in speakers made by steel

312*. Which material is used in making permanent magnets and why ? **CBSE (AI)-2010**

[Ans. Steel/alnico, because it has high coercivity and high retentivity

313*. Why do we prefer to use the alloy alnico for making permanent magnets ? **CBSE (AI)-2004**

[Ans. because alnico has high coercivity and high retentivity

314*. Which material is used to make electromagnet and why ? **CBSE (AI)-2010**

[Ans. Soft iron, because it has low hysteresis loss/low coercivity and high permeability

315*. Why is soft iron preferred for making the core of a transformer ? **CBSE (AIC)-2010**

OR

Why is the core of an electromagnet made of ferromagnetic materials ? **CBSE (D)-2010**

[Ans. Because soft iron (ferromagnetic materials) has low hysteresis loss/low retentivity and high permeability

316*. Which material is used for making the core of a moving coil galvanometer and why ? **CBSE (DC)-2006**

[Ans. Soft iron, because it has low hysteresis loss/low retentivity and high permeability

==

317*. Name the three elements of Earth's magnetic field. **CBSE (F)-2011**

[**Ans. Elements of Earth's magnetic field :**

(i) Magnetic declination (θ)

(ii) Angle of dip or magnetic inclination (δ)

(iii) Horizontal component of earth's magnetic field (B_H)

318* What is the angle of dip at equator ? **CBSE (AIC)-2010**

[**Ans.** zero (0^0)

319*. What is the angle of dip at magnetic poles ? **CBSE (AIC)-2001**

[**Ans.** 90^0

320*. How does angle of dip varies from equator to poles ? **CBSE (F)-2009,2003**

[**Ans.** angle of dip increases from zero to 90^0 on moving from equator to poles

321*. Where on the surface of Earth is the angle of dip zero ? **CBSE (AI)-2011**

[**Ans.** At equator

322*. Where on the surface of Earth is the angle of dip 90^0 ? **CBSE (AI)-2011**

[**Ans.** At poles

323*. Where on the Earth's surface is the value of angle of dip (i) minim um (ii) maximum ? **CBSE (D)-2003**

[**Ans.** (i) at equator $(\delta = 0^0)$ (ii) At poles $(\delta = 90^0)$

324*. Where on the surface of Earth is the vertical component of Earth' s magnetic field zero ?**CBSE (AI)-2011,2003,(F)-2010**

[**Ans.** At equator

Reason : At equator, $\delta = 0^0$ ⇨ $B_V = B_e \sin\delta = B_e \sin 0 = 0$

325*. What will be the value of the horizontal component of the Earth's magnetic field at the Earth's geometric pole ?

[**Ans. Zero**

Reason : At poles $\delta = 90^0$, ⇨ $B_H = B_e \cos\delta = B_e \cos 90^0 = 0$

326*. A small magnet is pivoted to move freely in the magnetic meridian. At what place on the surface of the earth will the magnet be vertical ? **CBSE (F)-2012**

[**Ans.** At poles

327*. A magnetic needle, free to rotate in a vertical plane, orients itself vertically at a certain place on the earth. What are the values of (i) angle of dip at this place, and (ii) horizontal component of earth's magnetic field **CBSE (F)-2012**

[**Ans.** (i) 90^0 (ii) $B_H = B_e \cos\delta = B_e \cos 90^0 = 0$

328* The horizontal component of earth's magnetic field at a place is B_H and the angle of dip is 60^0. What is the value of vertical component of earth's magnetic field at equator ? **CBSE (D)-2012**

[**Ans. Zero, Reason :** at equator, $\delta = 0$, so $B_V = B_H \tan\theta = B_H \tan 0 = 0$

329*. What is the angle of dip at a place where the horizontal and vertical components of the earth's magnetic field are equal ?

[**Ans.** As $B_V = B_H$ ⇨ $\tan\delta = \frac{B_V}{B_H} = \mathbf{1}$ ⇨ $\boldsymbol{\delta} = 45^0$ **CBSE (F)-2012,(AI)-2011**

330*. Horizontal component of earth's magnetic field at a place is $\sqrt{3}$ times the vertical component. What is the value of angle of dip at this place ? **CBSE (DC)-2007**

[**Ans.** As $B_H = \sqrt{3}\, B_V$ ⇨ $\tan\delta = \frac{B_V}{B_H} = \mathbf{1}/\sqrt{\mathbf{3}}$ ⇨ $\boldsymbol{\delta} = 30^0$

331*. The vertical component of earth's magnetic field at a place is $\sqrt{3}$ times the horizontal component. What is the value of angle of dip at this place ? **CBSE (D)-2006**

[**Ans.** As $B_V = \sqrt{3}\, B_H$ ⇨ $\tan\delta = \frac{B_V}{B_H} = \sqrt{\mathbf{3}}$ ⇨ $\boldsymbol{\delta} = 60^0$

332*. At a place the horizontal component of magnetic field is B and angle of dip is 60^0. What is the value of horizontal component of the Earth's magnetic field at equator ? **CBSE (D)-2017**

[**Ans. Given : In first case,** $B_H = B$, $\delta = 60^0$,

$$B_H = B_e \cos\delta \quad ⇨ \quad B_e = \frac{B_H}{\cos\delta} = \frac{B}{\cos 60^0} = \frac{B}{1/2} = 2\,B$$

In second case, at equator, $\delta = 0^0$ ⇨ $B_H = B_e \cos\delta = 2\,B \cos 0^0 = 2\,B$

333*. Which of the following substances are diamagnetic ? **CBSE (D)-2013,(AIC)-2009**

Bi, Al, Na, Cu, Ca and Ni

[Ans. Bi and Cu both are diamagnetic substances

334*. Which of the following substances are paramagnetic ? **CBSE (D)-2013**

Bi, Al, Cu, Ca Pb and Ni

[Ans. Al is a paramagnetic substance

335*. Define the term intensity of magnetization. **CBSE (AIC)-2006**

[Ans. Intensity of magnetization : It is defined as the magnetic moment per unit volume of the material when placed in a magnetizing field

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

336*. Define the term magnetic susceptibility. **CBSE (AIC)-2006**

[Ans. Magnetic susceptibility(χ_m): It is defined as the ratio of intensity of magnetization (I) to the magnetizing field intensity (H)

$$\chi_m = \frac{I}{H}$$

337*. What do you mean by the statement that "Susceptibility of Iron is more than that of copper" ? **CBSE (AIC)-2003**

[Ans. It means that iron can be magnetized more easily than copper

338*. Why do magnetic lines of force prefer to pass through ferromagnetic materials (e.g., Iron) than through air ?

[Ans. It is because magnetic permeability & susceptibility of ferromagnetic materials is very high than that of air

339*. What happens when a diamagnetic substance is placed in a varying magnetic field ? **CBSE (F)-2009**

[Ans. Diamagnetic substance tends to move from stronger to the weaker parts of the varying magnetic field

340*. What is the characteristic property of a diamagnetic material ? **CBSE (F)-2010**

[Ans. When a diamagnetic material is placed in an extern al magnetic field, it acquires a slight magnetism in a direction opposite to that of the magnetic field

341*. What is Curie point ? **CBSE (AIC)-2001**

[Ans. Curie Point : It is the temperature above which a ferromagnetic substance becomes paramagnetic

342*. State Curie law. **CBSE (AIC)-2001**

[Ans. Curie Law : The susceptibility of a paramagnetic material is inversely proportional to the absolute temperature

i,e, $\chi_m = \frac{C}{T}$

343*. The permeability of a magnetic material is 0.9983. Name the type of magnetic material it represents.

[Ans. As $\mu < 1$, so the given material is diamagnetic **CBSE (D)-2011**

344*. The susceptibility of a magnetic material is $-4.2 \text{ X } 10^{-6}$. Name the type of magnetic material it represents.

[Ans. As susceptibility is negative, so the given material is diamagnetic **CBSE (D)-2011**

345*. The susceptibility of a magnetic material is 1.9 X 10^{-5}. Name the type of magnetic material it represents.

[Ans. As susceptibility is positive, so the given material is Paramagnetic **CBSE (D)-2011**

346*. How does the intensity of magnetization of a paramagnetic material vary with increasing applied magnetic field ?

[Ans. for small magnetic field, intensity of magnetization increases with magnetic field ($I \propto B$) **CBSE (AIC)-2006** but at strong magnetic field, intensity of magnetization gets saturated and becomes independent of B

347*. How does the intensity of magnetization of a paramagnetic sample vary with temperature ? **BSE (AI)-2001**

[Ans. Intensity of magnetization decreases with increase in temperature $I \propto \frac{1}{T}$

Reason : on increasing the temperature, tendency to disrupt the alignment of atomic dipoles increases

348*. Why does the magnetization of a paramagnetic sample increase on cooling ? **CBSE (AIC)-2006**

[Ans. Intensity of magnetization increases with decrease in temperature $I \propto \frac{1}{T}$

Reason : on decreasing the temperature, tendency to disrupt the alignment of atomic dipoles decreases

349*. How does the magnetization of a diamagnetic material change on cooling ? **CBSE (AIC)-2006**

[Ans. No effect, because magnetism of a diamagnetic material does not depend on temperature

350*. Why is diamagnetism independent of temperature ? **CBSE (AIC)-2001**

[Ans. The induced dipole moment in a diamagnetic material is always opposite to the magnetizing field. It does not depend on the internal motion of atoms

351*. State Gauss's law in magnetism. How is it different from Gauss's law in electrostatics and why ? **CBSE (AI)-2016**

[Ans. Gauss's law in magnetism : The net magnetic flux through a closed surface is zero

i,e, $\phi_B = \oint \vec{B}.\vec{ds} = 0$

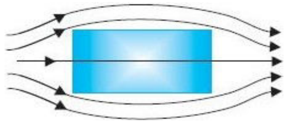
Gauss's law in electrostatics : The net electric flux through any closed surface is $\frac{1}{\varepsilon_0}$ times the net charge enclosed

i,e, $\phi_E = \oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$

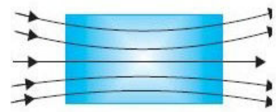
It indicates that mono pole does not exists/ magnetic poles always exists as unlike pairs of equal strengths

352*. Draw the magnetic field lines distinguishing between diamagnetic and paramagnetic materials. Give a simple explanation to account for the difference in the magnetic behaviour of these materials.

[Ans. **CBSE (DC)-2017,(F)-2016,(AI)-2015,2014**



(i) Diamagnetic



(ii) Paramagnetic

Explanation : When a diamagnetic material is placed in an external magnetic field, atoms acquire net magnetic moment opposite to field, and material acquires a slight magnetism in the opposite direction of field. Hence, magnetic field lines are repelled or expelled.

When a paramagnetic material is placed in an external magnetic field, atomic magnets align themselves along the field direction and material acquires a slight magnetism in the direction of field. Hence, magnetic field lines are attracted

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353*. In what way is the behaviour of a diamagnetic material different from that of a paramagnetic, when kept in an external magnetic field. **CBSE (AI)-2016**

[Ans. Behaviour of a diamagnetic and paramagnetic material in an external magnetic field

Diamagnetic	Paramagnetic
1. A diamagnetic specimen is repelled by a magnet	1. A paramagnetic specimen is attracted by a magnet
2. A diamagnetic specimen would move towards the weaker region of the magnetic field	2. A paramagnetic specimen would move towards the stronger region of the magnetic field
3. A diagrammatic rod aligned perpendicular to the magnetic field	3. A paramagnetic rod aligned along the magnetic field

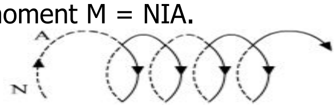
==

354*. The Earth's magnetic field at the Equator is approximately 0.4 G. Estimate the Earth's magnetic dipole moment. (Given : Radius of the Earth = 6400 km) **CBSE (AI)-2015**

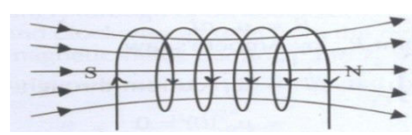
[Ans. $B = \frac{\mu_0}{4\pi}\frac{M}{R^3} = 10^{-7}\,X\,\frac{M}{R^3}$

⇨ $M = \frac{0.4\,X\,10^{-4}\,X\,(6400\,X\,10^3)^3}{10^{-7}} = 1.1\,X\,10^{23}\,Am^2$

355* An observer to the left of a solenoid of N turns each of cross section area A observes that a steady current I in it flows in the clockwise direction. Depict the magnetic field lines due to the solenoid specifying its polarity and show that it acts as a bar magnet of magnetic moment M = NIA. **CBSE (D)-2015**



[Ans. The solenoid contains N loops, each carrying a current I. Therefore, each loop acts as a magnetic dipole having dipole moment **m** = I**A**. The magnetic moments of all loops are aligned along the same direction. Hence, net magnetic moment equals M= N1**A**



Unit IV: Electromagnetic Induction and Alternating Currents — 20 Periods

Chapter–6: Electromagnetic Induction

Electromagnetic induction; Faraday's laws, induced EMF and current; Lenz's Law, Eddy currents. Self and mutual induction.

Chapter–7: Alternating Current

Alternating currents, peak and RMS value of alternating current/voltage; reactance and impedance; LC oscillations (qualitative treatment only), LCR series circuit, resonance; power in AC circuits, power factor, wattless current.

AC generator and transformer.

401. Define magnetic flux. Write its S.I. unit. Is it a scalar or vector quantity?

[**Ans. Magnetic flux** (ϕ) : It is defined as the total number of magnetic lines of force passing normally through a given surface

$$\phi = \vec{B}.\vec{A} = BA\ \cos\theta$$

It's S.I. is Weber (Wb). It is a scalar quantity

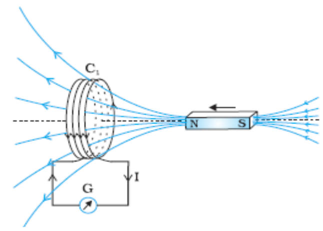
402. (i) What is electromagnetic induction ? **CBSE (AI)-2015**

(ii) Describe, with the help of a suitable diagram, how one can demonstrate that emf can be induced in a coil due to the change of magnetic flux.

[**Ans. (i) Electromagnetic Induction :** Whenever magnetic flux linked with a closed circuit is changed, an emf and hence a current is induced in the circuit. This phenomenon is known as electromagnetic induction.

(ii) Demonstration :

When a bar magnet is either pushed towards or pulled away from coil as shown, magnetic flux linked with the coil changes and galvanometer shows deflection. This shows that emf is induced



403. State Faraday's laws of electromagnetic induction. **CBSE (F)-2017,2009,(AI)-2016,2015**

[**Ans. Faraday's laws of electromagnetic Induction :**

(i) Whenever there is change in magnetic flux linked with a circuit, an emf is induced in the circuit. The induced emf lasts so long as the change in magnetic flux continues.

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

i,e, $e = -N\frac{d\phi}{dt} = -N\ \frac{\phi_2 - \phi_1}{t}$

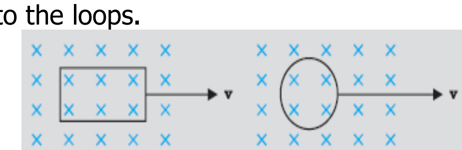
404. When a bar magnet is pushed towards or away from the coil connected to a galvanometer, pointer in galvanometer deflects. Identify the phenomenon causing this deflection and write the factors on which the amount and direction of the deflection depends. **CBSE (AI)-2016**

[**Ans. Phenomenon** : Electromagnetic induction

Factors : **(i)** Amount of deflection depends on the speed of movement of the magnet

(ii) Direction of deflection depends on the sense (towards or away) of the movement of the magnet

405. A rectangular loop and a circular loop are moving out of a uniform magnetic field region 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. **NCERT-2017**



[**Ans.** In rectangular loop

Reason : 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.

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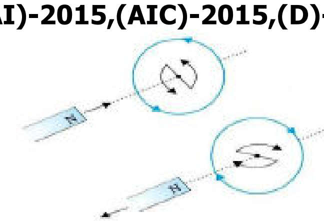
406. State Lenz's law. **CBSE (AI)-2015,(AIC)-2015,(D)-2014,2009**

[**Ans. Lenz's law** : The direction of induced current is such that it opposes the change in magnetic flux responsible for its production

407. Illustrate by giving an example, how Lenz's law helps in predicting the direction of the current in a loop in the presence of a changing magnetic flux ? **CBSE (AI)-2015,(AIC)-2015,(D)-2009**

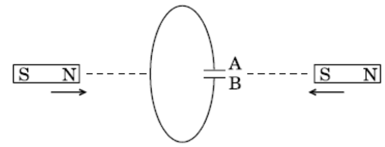
[**Ans. Illustration :**

When north pole is moved towards loop, due to Lenz's Law loop will repel it by inducing current in anticlockwise direction. Similarly, when north pole is taken away current will be induced in clockwise direction.

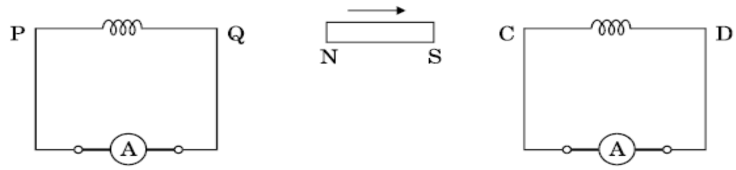


408. Predict the polarity of the capacitor in the situation described below : **CBSE (AI)-2017,2011**

[Ans. A – positive
B- negative



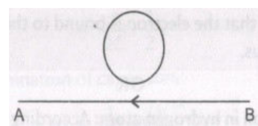
409. A bar magnet is moved in the direction indicated by the arrow between two coils PQ and CD. Predict the direction of the induced current in each coil. **CBSE (AI)-2017,2012**



[Ans. Q to P through ammeter and D to C through ammeter
(**Alternatively**: Anticlockwise as seen from left in coil PQ clockwise as seen from left in coil CD

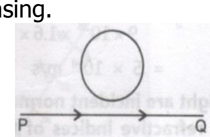
410. The electric current flowing in a wire in the direction from B to A is decreasing. Find out the direction of the induced current in the metallic loop kept above the wire as shown. **CBSE (AI)-2014**

[Ans. Clockwise



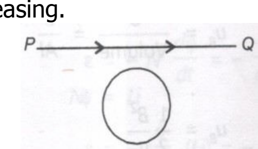
411. A conducting loop is held above a current carrying wire 'PQ'as shown in the figure. Depict the direction of the current induced in the loop when the current in the wire 'PQ'is constantly increasing. **CBSE (AI)-2014**

[Ans. Clockwise



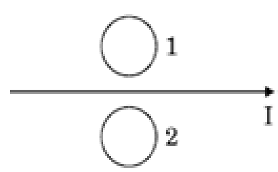
412. A conducting loop is held below a current carrying wire 'PQ'as shown in the figure. Predict the direction of the induced current in the loop when the current in the wire 'PQ'is constantly increasing. **CBSE (AI)-2014**

[Ans. Anticlockwise



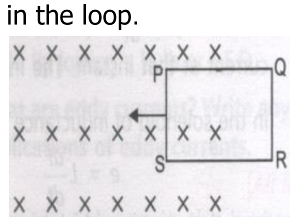
413. What is the direction of induced currents in metal rings 1 and 2 when current I in the wire is increasing steadily ? **CBSE (AI)-2017**

[Ans. Clockwise in loop 1, anticlockwise in loop 2



414. The closed loop (PQRS) of wire is moved in to a uniform magnetic field at right angles to the plane of the paper as shown in figure. Predict the direction of the induced current in the loop. **CBSE (F)-2012**

[Ans. Anticlockwise



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415. A long straight current carrying wire passes normally through the centre of circular loop. If the current through the wire increases, will there be any induced emf in the loop ? Justify **CBSE (D)-2017**

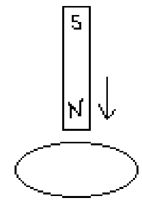
[Ans. No,

Reason : As the magnetic field due to current carrying wire will be in the plane of the circular loop, so magnetic flux will remain zero/ Magnetic flux does not change with the change of current

416. A bar magnet falls from height $'h'$ through a metal ring as shown in figure. **CBSE (AIC)-2001**

(i) Will its acceleration be equal to $'g'$?

(ii) What will happens if the ring in the above case is cut so as not to form a complete loop ? Justify your answer.



[**Ans. (i)** acceleration will be less than g ($a < g$)

Reason : as the magnet falls, magnetic flux inked with the metal ring increases. By the Lenz's law, induced current in the ring opposes the downward motion of the magnet

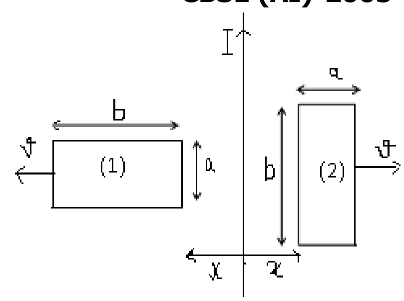
(ii) acceleration will be equal to g ($a = g$)

Reason : when the ring has a cut, emf will be induced but no induced current flows through it. Hence motion of the magnet is not opposed. Magnet will fall with acceleration equal to g

417. Figure shows two identical rectangular loops (1) and (2), placed on a table along with a straight long current carrying conductor between them. **CBSE (AI)-2005**

(i) What will be the direction of induced currents in the loops when they are pulled away from the conductor with the same velocity v ?

(ii) Will the emfs induced in the two loops be equal ? Justify your answer.



[**Ans. (i)** in loop (1) - Anticlockwise
in loop (2) – Clockwise

(ii) No, emf will not be equal because the rate of change of magnetic flux in the two loops are different

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418. What are eddy currents ? How are they produced ? **CBSE (AI)-2011,2009,(F)-2009,(AIC)-2006**

[**Ans. Eddy currents :** The induced circulating currents produced in the bulk piece of a conductor, when it is subjected to a changing magnetic flux, are known as eddy currents

Eddy currents are produced when a bulk conductor is placed in a changing magnetic field

419. Give two uses of eddy currents. **CBSE (AI)-2009**

[**Ans.** (i) magnetic braking in electric trains

(ii) to produce heat in induction furnaces

(iii) electro magnetic damping

420. Why eddy currents are considered undesirable ? **CBSE (AI)-2011,2009**

[**Ans.** Because (i) they heat up the metallic core and dissipate electrical energy in the form of heat.

(ii) they always oppose the motion.

421. How are eddy currents minimized ? **CBSE (AI)-2011,2009**

[**Ans.** (i) using laminating iron core

(ii) using slotted iron blocks

422. The motion of a copper plate is damped when it is allowed to oscillate between the two poles of a magnet. What is the cause of this damping ? **CBSE (AI)-2013**

[**Ans.** It is due to eddy currents produced in the plate

423. The motion of a copper plate is damped when it is allowed to oscillate between the two poles of a magnet. If the slots are cut in the plate, how will the damping be affected ? **CBSE (AI)-2013**

[**Ans.** The damping is due to eddy currents produced in the plate. Slots reduce eddy current hence damping will be less

424. A light metal disc on the top of an electromagnet is thrown up as the current is switched on. Why ? Give reason.

[**Ans.** Due to eddy currents set up in the disc **CBSE (AI)-2013**

Reason : As the current is switched on, eddy currents are set up in metal disc due to increasing magnetic flux. By Lenz's law lower face of the disc will have the same polarity as that on the top end of the Electromagnet, resulting in a repulsive force. Hence, it is thrown up

425. What is meant by self induction ?

[Ans. Self induction : When a changing current is passed through a coil, an emf is induced in the coil due to change in magnetic flux passing through it. This phenomenon is called self-induction.

426. Define self-inductance of a coil. Write its S.I. unit. **CBSE (AI)-2017,2015,2010,(D)-2009,(F)-2009**

[Ans. Self inductance : It is defined as the total magnetic flux linked with the coil, when unit current flows through it. Its S.I. unit is Henry (H)

427. What is meant by back emf ? When current in a coil changes with time, how is the back emf induced in the coil related to it ?

[Ans. Back emf :The self-induced emf in a coil due to changing current flowing through it, is called the back emf as it opposes any change in the current in a circuit ($e = -L\frac{dI}{dt}$) **CBSE (AI)-2008**

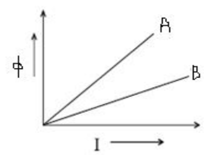
428. A plot of magnetic flux (ϕ) versus current (I) is shown in the figure for two inductors A and B, which of the two has larger value of self-inductance and why ? **CBSE (D)-2010**

[Ans. Inductor A

Reason : $\phi = L\,I$ ⇨ $L = \frac{\phi}{I} = \text{slope}$

As $(slope)_A > (slope)_B$

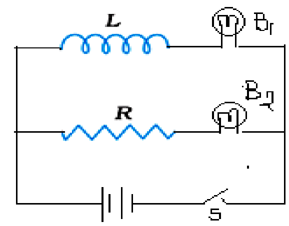
⇨ $(L)_A > (L)_B$



429. Figure shows an inductor L and a resistor R connected in parallel to a battery through a switch. The resistance R is same as that of coil that makes L. Two identical bulbs are put in each arm of the circuit. **CBSE (AI)-2003**

(i) Which of the bulbs lights up earlier when S is closed ?

(ii) Will the two bulbs be equally bright after some time ? Give reason for your answer.



[Ans. (i) Bulb B_2 lights up earlier

Reason : induced emf across L opposes growth of current in B_1

(ii) yes, after some time both bulbs will be equally bright

Reason : after some time current reached its maximum value in L and self-induction plays no role

430. What is meant by mutual induction ?

[Ans. Mutual induction : When a changing current is passed through a coil, an emf is induced in the neighbouring coil due to change in magnetic flux passing through it. This phenomenon is called mutual-induction.

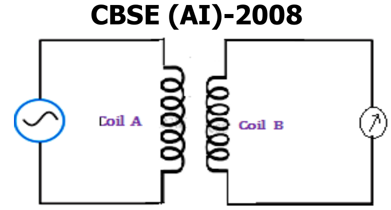
431. Define Mutual inductance of a coil. Write its S.I. unit. **CBSE (AI)-2015,2005,(D)-2009,(F)-2009**

[Ans. Mutual inductance : Mutual inductance of two coils may be defined as the total magnetic flux linked with one coil, when unit current flows through the other coil. Its S.I. unit is Henry (H)

432. The circuit arrangement given in the figure shows that when an a.c. passes through the coil A, the current starts Flowing in the coil B. **CBSE (AI)-2008**

(i) Name the underlying principle involved

(ii) Mention two factors on which the current produced in the coil B depends.



[Ans. (i) principle : Mutual induction

(ii) factors; (a) mutual inductance of two coils

(b) rate of change of current in coil A

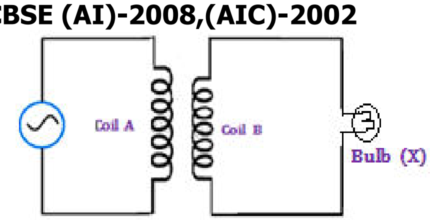
(c) resistance of coil B

433. Figure given below shows an arrangement by which current flows through the bulb (X) connected with coil B, when a.c. is passed through coil A. Explain the following observations : **CBSE (AI)-2008,(AIC)-2002**

(i) Bulb lights up

(ii) Bulb gets dimmer if coil B is moved upwards

(iii) If a copper sheet is inserted in the gap between the coils how the brightness of the bulb will change ?



[Ans. (i) bulb lights up due to induced current in coil B because of mutual induction

(ii) when coil B is moved upwards, flux linked with it decreases, induced current decreases so the bulb gets dimmer

(iii) eddy currents will be set up in the copper sheet, which will oppose the passage of magnetic flux. Induced emf in coil B de creases hence brightness s of bulb will decrease

435. The peak value of emf in an a.c. is E_0. Write its (a) rms and (b) average value over a complete cycle.

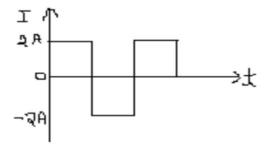
[**Ans. (a)** $E_{rms} = \frac{E_0}{\sqrt{2}}$ **(b)** Zero] **CBSE (F)-2001**

435. The instantaneous current from an a.c. source is $I = 5 \sin 314\, t$. What is the rms value of current ?

[**Ans.** $I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{5}{\sqrt{2}} = 0.707 \text{ X } 5 = 3.54 \ A$ **CBSE (DC)-2010**

436. Calculate the rms value of the alternating current shown in figure. **CBSE (D)-2001**

[**Ans.** $I_{rms} = \sqrt{\frac{I_1^2+I_2^2+I_3^2}{3}} = \sqrt{\frac{2^2+(-2)^2+2^2}{3}} = 2A$



437. (i) Define the term inductive reactance. Write its S.I. unit. **(AI)-2015,2011,(DC)-2008,(D)-2003**

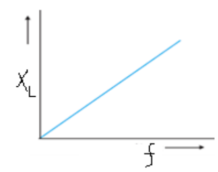
(ii) Show graphically the variation of inductive reactance with frequency of the applied alternating voltage.

[**Ans. Inductive reactance** (X_L) :

The obstruction offered by an inductor to the flow of alternating current through it, is called inductive reactance

$X_L = \omega L = 2\pi f L$ ⇨ $X_L \propto f$

Its S. I. unit is Ohm (Ω)



438. (i) Explain the term capacitive reactance. Write its S.I. unit. **CBSE (AI)-2015,2011,(DC)-2008,(D)-2003**

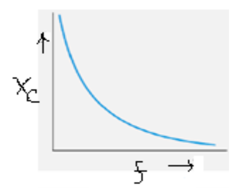
(ii) Show graphically the variation of capacitive reactance with frequency of the applied alternating voltage.

[**Ans. Capacitive reactance** (X_C) :

The obstruction offered by a capacitor to the flow of alternating current through it, is called capacitive reactance

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$ ⇨ $X_C \propto \frac{1}{f}$

Its S. I. unit is Ohm (Ω)



439. What is meant by impedance ? Write an expression for impedance of L-C-R circuit. What is it's S.I. unit ?

[**Ans. Impedance** (Z) :

The obstruction offered by the combination of resistance and effective reactance to the flow of alternating current through it, is called impedance

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

Its S. I. unit is Ohm (Ω)

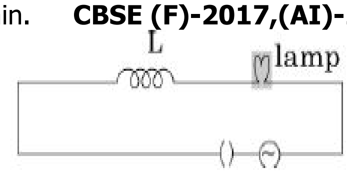
440. A lamp is connected in series with an inductor and an a.c. source. What happens to the brightness of the lamp when the key is plugged in and an iron rod is inserted inside the inductor ? Explain. **CBSE (F)-2017,(AI)-2016**

[**Ans. Brightness decreases**

Reason : When iron rod is inserted, inductance L increases

⇨ $X_L = \omega L$ & $Z = \sqrt{R^2 + X_L^2}$ also decreases and current increases

Hence brightness $(I^2 Z)$ *increases.*



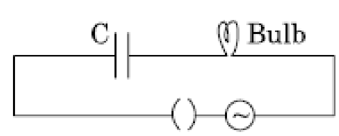
441. A bulb is connected in series with a variable capacitor and an a.c. source as shown. How the brightness of bulb changes on reducing the (a) capacitance and (b) frequency ? Justify your answer. **CBSE (AI)-2016,(D)-2010**

[**Ans. (a) Brightness will decreases**

Reason : When capacitance is reduced, reactance ($X_C = \frac{1}{\omega C}$) increases

⇨ $Z = \sqrt{R^2 + X_C^2}$ also increases and current decreases

Hence brightness $(I^2 Z)$ *decreases*



(b) Brightness will decreases

Reason : When frequency is reduced, reactance ($X_C = \frac{1}{2\pi f C}$) increase.

⇨ $Z = \sqrt{R^2 + X_C^2}$ also increases and current decreases

Hence brightness $(I^2 Z)$ *decreases*

442. Define quality factor (Q-factor) and give its significance. What is its S.I. unit ? **CBSE (D)-2016,2013,(AI)-2015**

[Ans. Quality factor: It is defined as the ratio of resonant frequency to the frequency band width of the resonant curve

i,e, $Q = \frac{\omega_0}{2\Delta\omega} = \frac{\omega_0 L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$

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

443. Name the factors on which Quality factors depends. **CBSE (D)-2009**

[Ans. Resonating frequency (ω_0) and band width ($2\Delta\omega$)

445. Why should the quality factor have high value in receiving circuits **CBSE (D)-2016,2013,(AI)-2015,(DC)-2014**

[Ans. For high value of Q, resonance will be sharper and consequently the circuit will be more selective

446. Define the term 'sharpness of resonance'. Under what condition, does a circuit become more selective ? **CBSE (F)-2016**

[Ans. Sharpness of resonance : The ratio of resonant frequency to the frequency band width of the resonant curve is the measure of sharpness of resonance (called Q-factor) and is given by

$$\frac{\omega_0}{2\Delta\omega} = \frac{\omega_0 L}{R} = Q$$

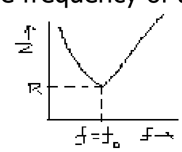
For high value of Q, resonance will be sharper and consequently the circuit will be more selective

447. (i) Mention the factors on which resonant frequency of a series LCR circuit depends. **CBSE (D)-2009,(AI)-2005**

(ii) Plot a graph showing the variation of impedance of a series LCR circuit with the frequency of applied a.c. source.

[Ans. (i) Factors : values of inductance L and capacitance C

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$



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448. Define the term power factor. State the condition under which it is (i) maximum and (ii) minimum. **CBSE (D)-2010**

[Ans. Power factor : It is the ratio of resistance to the impedance of an a.c. circuit

i,e, $\cos\phi = R/Z$

(i) when, $Z = R$, $\cos\phi = R/Z = 1 =$ maximum

i,e, when the circuit is purely resistive, power factor is maximum

(ii) when, $R = 0$, $\cos\phi = R/Z = 0 =$ minimum

i,e, when the circuit is purely inductive or capacitive, power factor is minimum]

449. Define the term 'Wattless current'. **CBSE (AI)-2015, (D)-2011**

[Ans. Wattless current : The current which flows in a circuit without consuming any electrical power is called Watt less current

In a purely inductive or capacitive circuit, $\cos\phi = R/Z = 0$

⇨ $\overline{P} = V_{rms} \, X \, I_{rms} \, X \cos 0 = 0$

450. The power factor of an a.c. circuit is 0.5. What is the phase difference between the voltage and current in the circuit ?

[Ans. 60^0 **Reason** : $\cos\phi = 0.5$ ⇨ $\phi = 60^0$ **CBSE (AI)-2016**

451. In a series LCR circuit, $V_L = V_C \neq V_R$. What is the value of power factor ? **CBSE (AI)-2015**

[Ans. $V_L = V_C$ ⇨ $IX_L = IX_C$ ⇨ $X_L = X_C$

⇨ $Z = \sqrt{(R)^2 + (X_C - X_L)^2} = R$ ⇨ Power factor, $\cos\phi = R/Z = 1$

452. In an a.c. circuit, the instantaneous voltage and current are $V = 200 \sin 300\, t$ Volt and $I = 8 \cos 300\, t$ Ampere respectively. Is the nature of the circuit is capacitive or inductive ? Give reason. **CBSE (AI)-2015**

[Ans. Capacitive, Reason : Given, $V = 200 \sin 300\, t$ & $I = 8 \cos 300\, t$ ⇨ $I = 8 \sin(300\, t + \pi/2)$

As the current leads voltage by phase angle $\pi/2$. Hence the circuit is Capacitive

453. Can the voltage drop across the inductor or the capacitor in a series LCR circuit be greater than the applied voltage of the a.c. source ? Justify your answer. **CBSE (D)-2005,2002**

[Ans. Yes, because in series LCR circuit, V_L or V_C are not in same phase, hence cannot be added like ordinary numbers

454. An a.c. source of voltage $V = V_0 \sin \omega t$ is connected one by one, to three circuit elements X, Y and Z. It is observed that the current flowing in them, **CBSE (AIC)-2008**
(i) is in phase with the applied voltage for element X
(ii) lags the applied voltage in phase by $\pi/2$, for element Y
(iii) leads the applied voltage in phase by $\pi/2$, for element Z.
Identify the three circuit elements.
[Ans. (i) X-Resistor (ii) Y- Inductor (iii) Z- capacitor

455. Write the principle of which a transformer works. **CBSE (AI)-2015,2014,2012,(F)-2008**
[Ans. It is based on the principle of **mutual induction**
i,e, whenever there is change in magnetic flux linked with a coil, an emf is induced in the neighbouring coil

456. Why cannot a transformer works on d.c. ? **CBSE (AI)-2015,(F)-2008, (DC)-2010**
OR
Why can not a transformer be used to step up d.c. voltage ?
[Ans. d.c. cannot produce a changing magnetic flux in the primary and hence no emf will be induced in the secondary

457. Why is the use of a.c. voltage is preferred over d.c. voltage ? Give two reasons. **CBSE (AI)-2014**
[Ans. 1. A.C. voltage can be steeped up & stepped down using a transformer, but same is not true for d.c. voltage
2. A.C. voltage can be converted in to d.c. voltage by using rectifier but d.c. voltage cannot be converted in to a.c. voltage

458. These days most of the electrical devices we use require a.c. voltage. Why ? **CBSE (AI)-2015**
[Ans. (a) It can be stepped up/ stepped down
(b) It can be converted in to d.c. (c) line loss can be minimized

459. In India, domestic power supply is at 220V,50Hz, while in U.S.A. it is 110V,50Hz. Give one advantage and one disadvantage of 220V supply over 110V supply. **CBSE (AI)-2004**
[Ans. Advantage – power loss at 220V supply is less than that at 110V.
Disadvantage- 220V is more dangerous than 110V because its peak value (311V) is more than peak value (155.5V) for 110V supply

460. Why is the core of a transformer is laminated ? **CBSE (DC)-2002**
[Ans. to minimize the energy losses due to eddy current

461. Mention the two characteristic properties of a material suitable for making core of a transformer. **CBSE (AI)-2012**
[Ans. (i) Low coercivity/ Low retentivity (ii) High permeability

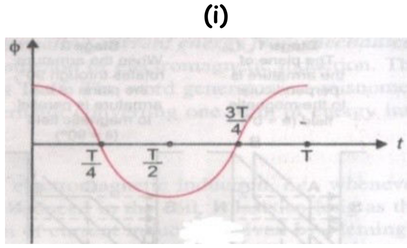
462. Why is the core of a transformer made of a magnetic material of high permeability ? **CBSE (DC)-2010**
[Ans. to increase the magnetic flux in the core, due to which flux leakage decreases & efficiency increases

463. Does a step up transformer violets the principle of conservation of energy ? **CBSE (D)-2011,(DC)-2009**
[Ans. No, In an ideal transformer input power is always equal to output power, due to which if voltage increases, current is reduced in same proportion

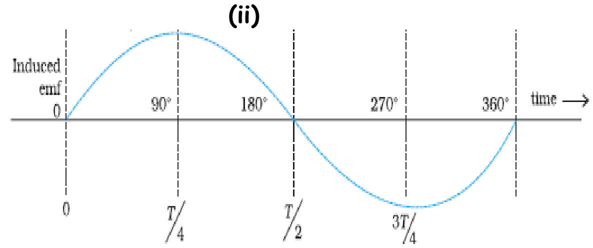
464. (i) What is the source of energy generation in an ac generator ? **CBSE (AI)-2011**
[Ans. Mechanical energy used in rotating the armature coil is the source of energy generation in an ac generator

465. (ii) Can the current produced by an ac generator be measured with a moving coil galvanometer ? **(D)-2007**
[Ans. No

465. 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 in an ac generator. **CBSE (D)-2014**
[Ans. **(i)**



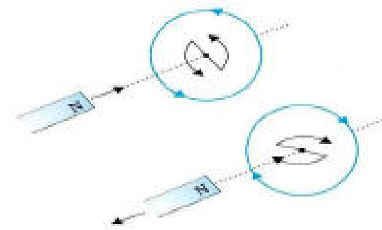
(ii)



466. Explain, with the help of a suitable example, how we can show that Lenz's law is a consequence of the principle of conservation of energy. **CBSE (F)-2017,(AI)-2015,(AIC)-2015,(D)-2009**

[**Ans. Lenz's is a consequence of law of conservation of energy :**

A bar magnet experiences a repulsive force when brought near a closed coil and attractive force when moved away from the coil, due to induced current. Therefore external work is required to be done in the process, which appears in the form of electrical energy.



In the absence of Lenz's law, no opposition by induced current and we would be obtaining electrical energy without doing any work, which is impossible. Thus, Lenz's law is in accordance with the principle of conservation of energy.

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467. What is motional electromotive force (motional emf) ?

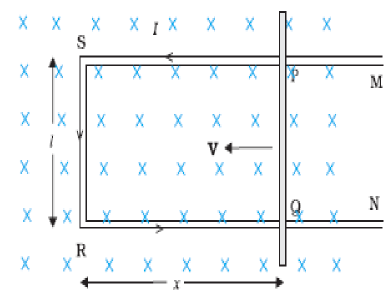
A rod of length l is moved horizontally with a uniform velocity $'v'$ in a direction perpendicular to its length through a region in which a uniform magnetic field is acting vertically downward. Derive the expression for the emf induced across the ends of the rod. **CBSE (D)-2014,2013**

[**Ans. Motional emf :** The emf induced across the ends of a conductor due to its motion in a magnetic field is called motional emf

Expression for motional emf :

Magnetic flux enclosed by loop PQRS

$\phi = BA = Blx$



Since X is changing with time, the rate of change of magnetic flux will induce an emf given by

$$e = -\frac{d\phi}{dt}$$

⇨ $$e = -\frac{d}{dt}(Blx) = Bl\left(-\frac{dx}{dt}\right)$$

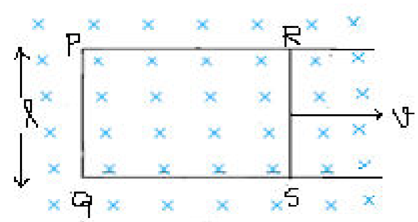
⇨ $e = Bl\,v$ Where $v = -\frac{dx}{dt}$, because velocity v is in decreasing direction of x

468. Figure shows a rectangular conducting loop $PQSR$ in which arm RS of length $'l'$ is movable. The loop is kept in a uniform magnetic field $'B'$ directed downwards perpendicular to the plane of the loop. The arm RS is moved with a uniform speed $'v'$. Deduce the expression for the : **CBSE (AI)-2009**

(a) emf induced across the arm $'RS'$

(b) external force required to move the arm, and

(c) power dissipated as heat.



[**Ans. (i) Induced emf :**

Magnetic flux enclosed by loop PQSR

$\phi = BA = Blx$

Since X is changing with time, the rate of change of magnetic flux will induce an emf given by

$$|e| = \frac{d\phi}{dt} = \frac{d}{dt}(Blx) = Bl\left(\frac{dx}{dt}\right)$$

⇨ $|e| = Bl\,v$

(ii) External force required to move the arm RS:

Induced current, $I = \frac{e}{R} = \frac{Blv}{R}$

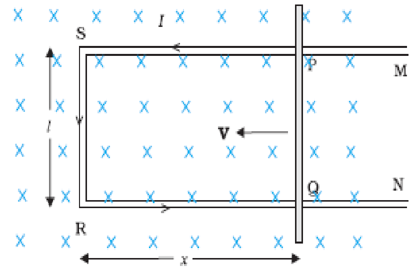
⇨ External force required, $F = BIl\,\sin 90 = B\left(\frac{Blv}{R}\right)l = \frac{B^2l^2v}{R}$

(iii) Power dissipated as heat :

$$P = I^2R = \left(\frac{Blv}{R}\right)^2 R = \frac{B^2l^2v^2}{R}$$

469. Use the expression for Lorentz force acting on the charge carriers of a conductor to obtain the expression for the induced emf across the conductor of length l moving with velocity v through a magnetic field B acting perpendicular to its length. **CBSE (AI)-2015**

[Ans. Motional emf by using Lorentz's force:



Lorenz's force on any charge q in the rod

$F_m = Bqv$

This force will be towards Q

work done in moving the charge from P to Q

$W = F_m \text{ X } l = Bqv\, l$

Now the induced emf = work done per unit charge

⇨ $e = \frac{W}{q} = \frac{Bqvl}{q}$

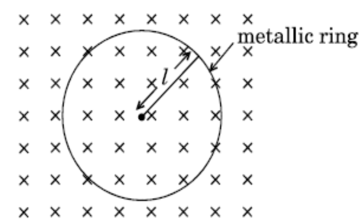
⇨ $e = Bl\, v$

470. A metallic rod of length $'l'$ is rotated with a frequency $'v'$, with one end hinged at the centre in a uniform magnetic field B as shown. Derive an expression for- **CBSE (AI)-2015, (AIC)-2014,(D)-2012,2008**

(a) induced emf and induced current in the rod

(b) magnitude and direction of the force acting on the rod

(c) power required to rotate the rod



[Ans. (a) As the rod is rotated, due to Lorentz force, free electrons in the rod move towards the outer end and get distributed over the ring. Thus, an emf is induced across the ends of the rod

induced emf across the length dl of the rod

$$de = Bv\, dl = B(l\omega)\, dl = B\omega\, ldl$$

⇨ $e = \int_0^l B\omega ldl = B\omega \int_0^l l\, dl\; e = B\omega \left[\frac{l^2}{2}\right]_0^l = \frac{1}{2}B\omega(l^2 - 0)$

⇨ $e = \frac{1}{2}B\omega l^2 = \frac{1}{2}B(2\pi v)l^2 = \pi v B l^2$

Induced current, $\mathrm{I} = \frac{e}{R} = \frac{1}{2}\frac{B\omega l^2}{R} = \frac{\pi v B l^2}{R}$

(b) Force on the rod, $F = BIl\, \sin 90 = B\left(\frac{1}{2}\frac{B\omega l^2}{R}\right) l = \frac{1}{2}\frac{B^2 l^3 \omega}{R} = \frac{\pi v B^2 l^3}{R}$

Direction of this force will be opposite to that of the Lorentz's force

(c) Power required to rotate the rod $P = \frac{e^2}{R} = \frac{\pi^2 v^2 B^2 l^4}{R}$

==

471. Describe briefly three main useful applications of eddy currents. **CBSE (F)-2015, (AI)-2010,2009**

[Ans. (i) Magnetic braking in trains:

In some electrically powered trains, strong electromagnets are situated above the rails. When the electromagnets are activated, the eddy currents induced in the rails oppose the motion of the train. As there are no mechanical linkages, the braking effect is smooth.

(ii) Electromagnetic damping:

Certain galvanometers have a fixed core made of nonmagnetic metallic material. When the coil oscillates, the eddy currents generated in the core oppose the motion and bring the coil to rest quickly.

(iii) Induction furnace: It is used to produce high temperatures and can be utilized to prepare alloys, by melting the constituent metals. A high frequency alternating current is passed through a coil which surrounds the metals to be melted. The eddy currents generated in the metals produce high temperatures sufficient to melt it.

(iv) Electric power meters: The shiny metal disc in the electric power meter rotates due to the eddy currents. Electric currents are induced in the disc by magnetic fields produced by sinusoidally varying currents in a coil

472. Derive the expression for the self-inductance of a long solenoid of cross sectional area A, length l, and having n turns per unit length. **CBSE (AIC)-13,(AI)-2005,(D)-2012,2009,2008**

[Ans. Self inductance of a long solenoid :

Let a current I is flowing through a long solenoid, then magnetic field at its centre

$$B = \mu_0 n I = \frac{\mu_0 N I}{l} \qquad [\because n = \frac{N}{l}]$$

⇨ magnetic flux linked with each turn of the solenoid

$$\phi = BA = \left(\frac{\mu_0 NI}{l}\right)A = \frac{\mu_0 N IA}{l}$$

⇨ $$L = \frac{N\phi}{I} = \frac{N}{I}\left(\frac{\mu_0 N IA}{l}\right) = \frac{\mu_0 N^2 A}{l}$$

⇨ $$L = \frac{\mu_0 (nl)^2 A}{l} = \mu_0 n^2 Al$$

If we fill the inside of the solenoid with a material of relative permeability μ_r, then

$$L = \mu_0 \mu_r n^2 Al = \mu_0 \mu_r n^2 \pi r^2 l$$

473. Derive an expression for the self-inductance of a circular aired coil. Name the three factors on which the self-inductance of a coil depends. **CBSE (AI)-2015**

[Ans. Self inductance of an aired coil :

magnetic field at the centre of circular coil

$$B = \frac{\mu_0 NI}{2r}$$

⇨ magnetic flux linked with each turn of the coil

$$\phi = BA = \left(\frac{\mu_0 NI}{2r}\right)\pi r^2 = \frac{1}{2}\mu_0 \pi NIr$$

⇨ Self inductance of the coil

$$L = \frac{N\phi}{I} = \frac{N}{I}\left(\frac{1}{2}\mu_0 \pi NIr\right) = \frac{1}{2}\mu_0 \pi N^2 r$$

Factors on which self inductance of a coil depends :

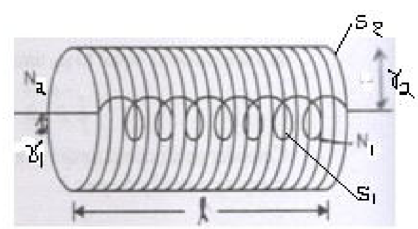
(a) the number of turns in the coil

(b) the area of cross section of the coil (c) the permeability of the core material

474. (i) Derive an expression for the mutual inductance of two long coaxial solenoids of same length wound one over the other. **CBSE (AI)-2017,2014,2009,(D)-2015,2012,2005,(F)-2013,2011**

(ii) Write the factors on which the mutual inductance of a pair of solenoids depends. **CBSE (AI)-2015**

[Ans. Mutual inductance between two co-axial long solenoids of same length wound over the other :



Magnetic field at the centre of solenoid S_2

$$B_2 = \mu_0 n_2 I_2 = \frac{\mu_0 N_2 I_2}{l}$$

Magnetic flux linked with each turn of inner solenoid S_1

$$\phi_1 = B_2 A_1 = \left(\frac{\mu_0 N_2 I_2}{l}\right) A_1 = \frac{\mu_0 N_2 I_2 A_1}{l}$$

Hence mutual inductance

⇨ $$M_{12} = \frac{N_1 \phi_1}{I_2} = \frac{N_1}{I_2}\left(\frac{\mu_0 N_2 I_2 A_1}{l}\right) = \frac{\mu_0 N_1 N_2 A_1}{l}$$

⇨ $$M_{12} = \frac{\mu_0 (n_1 l)(n_2 l) r_1^2}{l} = \mu_0 n_1 n_2 r_1^2 l$$

Similarly, $M_{21} = \mu_0 n_1 n_2 r_1^2 l$

⇨ $$M_{12} = M_{21} = M = \mu_0 n_1 n_2 r_1^2 l$$

If a medium of relative permeability μ_r is filled in between the solenoids then

$$M = \mu_0 \mu_r n_1 n_2 r_1^2 l$$

Factors on which mutual inductance of a pair of solenoids depends :

(i) number of turns and separation between two solenoids

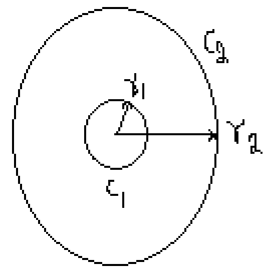
(ii) relative orientation of two solenoids

475. Two concentric circular coils, one of small radius r_1 and the other of large radius r_2 such that $r_1 \ll r_2$ are placed co-axially with centres coinciding. Obtain the mutual inductance of the arrangement. Give two factors on which the coefficient of mutual inductance between a pair of coils depends. **CBSE (AI)-2015,(D)-2015, (AIC)-2015**

[Ans. Mutual inductance between two co-axial with centres coinciding circular coils :

magnetic field at the centre of the outer coil

$$B_2 = \frac{\mu_0 N_2 I_2}{2r_2}$$



magnetic flux linked with inner coil

$$\phi_1 = B_2 A_1 = \left(\frac{\mu_0 N_2 I_2}{2r_2}\right) A_1$$

Hence mutual inductance

$$\Rightarrow \quad M_{12} = \frac{N_1\phi_1}{I_2} = \frac{N_1}{I_2}\left(\frac{\mu_0 N_2 I_2}{2r_2}\right) A_1 = \frac{\mu_0 N_1 N_2 A_1}{2r_2}$$

$$\Rightarrow \quad M_{12} = \frac{\mu_0 N_1 N_2 \pi r_1^2}{2r_2}$$

Factors on which mutual inductance of a pair of a coil depends :

(i) number of turns and geometrical shape of two coils
(ii) relative orientation of two coils

476. In an experimental arrangement of two coils C_1 and C_2 placed co-axially parallel to each other, find the expression for the emf induced in the coil C_1(of N_1 turns)corresponding to the change of current I_2 in the coil C_2 (of N_2 turns). **CBSE (AI)-2015, (D)-2015**

[Ans. Induced emf in coil C_1 due to change in current through C_2

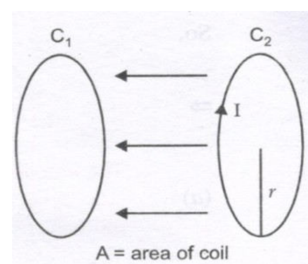
We have, $N_1\phi_1 = MI_2$

For varying currents,

$$N_1\left(\frac{d\phi_1}{dt}\right) = M\left(\frac{dI_2}{dt}\right)$$

$$\Rightarrow \quad -e = M\left(\frac{dI_2}{dt}\right)$$

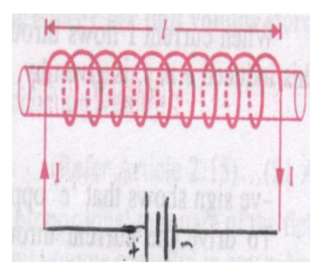
$$\Rightarrow \quad e = -M\left(\frac{dI_2}{dt}\right)$$]



477. Obtain an expression for the energy stored in an inductor/coil/ solenoid of self-inductance $'L'$ when the current through it grows from zero to $'I'$. **CBSE (AI)-2017,2015,2011,2008**

[Ans. <u>Energy stored in an inductor/coil/solenoid</u> :

When a current flows through an inductor/solenoid, work is done against back emf ($e = -L\frac{dI}{dt}$), which is stored as magnetic potential energy.



Rate of work done, when a current I is passing through the inductor

$$\frac{dW}{dt} = |e|\, I = \left(L\frac{dI}{dt}\right) I$$

$$\Rightarrow \quad W = \int_0^I L\, I\, dI = L\left[\frac{I^2}{2}\right]_0^I = \frac{1}{2} L\, I^2$$

$$\Rightarrow \quad \boxed{U = \frac{1}{2} L\, I^2}$$

But for a solenoid, $L = \frac{\mu_0 N^2 A}{l}$

$$\Rightarrow \quad U = \frac{1}{2}\left(\frac{\mu_0 N^2 A}{l}\right) I^2$$

478. An a.c. voltage $V = V_0 \sin\omega t$ is applied across a pure resistor of inductance R. Find an expression for the current flowing in the circuit and show mathematically that the current flowing through it is in phase with the applied voltage Also draw (a) phasor diagram (b) graphs of V and I versus ωt for the circuit. **CBSE (AIC)-2013**

[**Ans**. We have the applied a.c. voltage

$$V = V_0 \sin\omega t \qquad \text{-------(1)}$$

By Kirchhoff's loop rule,

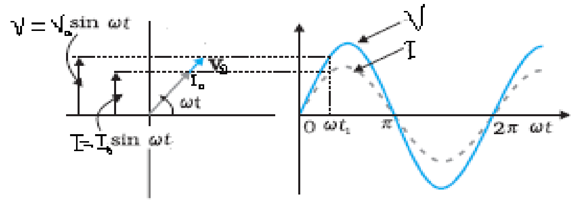
⇨ $IR = V_0 \sin\omega t$

⇨ $I = \frac{V_0}{R}\sin\omega t$

⇨ $I = I_0 \sin\omega t$ -------(2)

Where $I_0 = \frac{V_0}{R}$ is the peak value of a.c.

From (1) & (2) we conclude that voltage and current are in the same phase



Phasor diagram V-I graph

479. For a given alternating current, $I = I_0 \sin\omega t$, Show that the average power dissipated in a resistor R over a complete cycle is $\frac{1}{2} I_0^2 R$. **CBSE (AI)-2013**

[**Ans**. We have, $I = I_0 \sin\omega t$

Average power dissipated per cycle

$$\overline{P} = \frac{1}{T}\int_0^T I^2 \,\mathrm{R}\, dt = \frac{1}{T}\int_0^T (I_0 \sin\omega t)^2 \,\mathrm{R}\, dt = \frac{\mathrm{I_0}^2\mathrm{R}}{T}\int_0^T sin^2\omega t\, dt$$

⇨ $\overline{P} = \frac{\mathrm{I_0}^2\mathrm{R}}{T}\int_0^T \left(\frac{1-\cos 2\omega t}{2}\right) dt$

⇨ $\overline{P} = \frac{\mathrm{I_0}^2\mathrm{R}}{2T}\left[\int_0^T dt - \int_0^T \cos 2\omega t\, dt\right]$

⇨ $\overline{P} = \frac{I_0^2 R}{2T}[(T-0)]$ $\quad [\because \int_0^T \cos 2\omega t\, dt = 0]$

⇨ $\overline{P} = \frac{1}{2} I_0^2 R$

480. An a.c. voltage $V = V_0 \sin\omega t$ is applied across a pure inductor of inductance L. Find an expression for the current flowing in the circuit and show mathematically that the current flowing through it lags behind the applied voltage by a phase angle of $\frac{\pi}{2}$. Also draw (a) phasor diagram (b) graphs of V and I versus ωt for the circuit.

CBSE (F)-2017,(AI)-2015,2011,(DC)-2008,(D)-2003

[**Ans**. We have the applied a.c. voltage

$$V = V_0 \sin\omega t \qquad \text{-------(1)}$$

By Kirchhoff's loop rule,

$V - L\frac{dI}{dt} = 0$

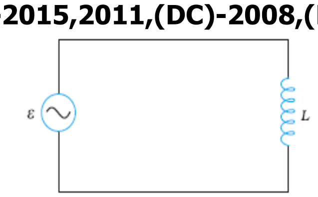
⇨ $\frac{dI}{dt} = \frac{V}{L} = \frac{V_0}{L}\sin\omega t$

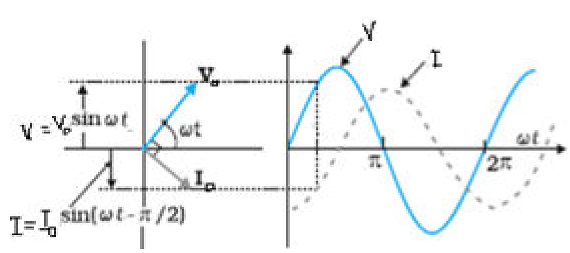
⇨ $\int dI = \frac{V_0}{L}\int \sin\omega t\, dt$

⇨ $\mathbf{I} = -\frac{V_0}{\omega L}\cos\omega t = -\mathbf{I_0}\cos\omega t$

⇨ $\mathbf{I} = \mathbf{I_0}\,\mathbf{sin}(\boldsymbol{\omega t} - \frac{\pi}{2})$ ------(2)

Where, $I_0 = \frac{V_0}{\omega L}$ ------(3)





Obviously, effective resistance of the circuit known as inductive reactance (X_L) given by $X_L = \omega L = 2\pi f L$

From (1) & (2) we conclude that current in the circuit lags behind the voltage in phase by $\frac{\pi}{2}$

481. An a.c. voltage $V = V_0 \sin \omega t$ is applied across a pure capacitor of capacitance C. Find an expression for the current flowing in the circuit and show mathematically that the current flowing through it leads the applied voltage by a phase angle of $\frac{\pi}{2}$. Also draw (a) phasor diagram (b) graphs of V and I versus ωt for the circuit.

CBSE (AI)-2015,2011,(D)-2015,2003,(F)-2014

[**Ans.** We have the applied a.c. voltage

$V = V_0 \sin \omega t$ -------(1)

By Kirchhoff's loop rule,

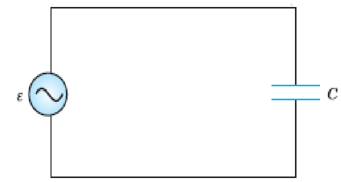
$\frac{q}{C} = V_0 \sin \omega t$

⇨ $\mathbf{I} = \frac{dq}{dt} = \frac{d}{dt}(CV_0 \sin \omega t)$

⇨ $\mathbf{I} = \omega C\ V_0 \cos \omega t = \frac{V_0}{1/\omega C} \cos \omega t$

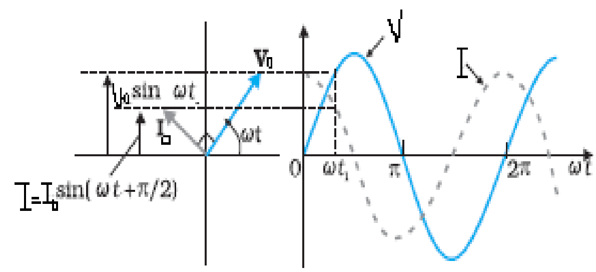
⇨ $\mathbf{I} = \mathbf{I_0} \cos \omega t = \mathbf{I_0} \sin(\boldsymbol{\omega t} + \frac{\pi}{2})$ ------(2)

Where, $I_0 = \frac{V_0}{1/\omega C}$ ------(3)



Obviously, effective resistance of the circuit known as capacitive reactance (X_C) given by

$$\boldsymbol{X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}}$$



Phasor diagram V-I graph

From (1) & (2) we conclude that current in the circuit Leads the voltage in phase by $\frac{\pi}{2}$

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482. When an a.c. source is connected to an ideal inductor show that the average power supplied by the source over a complete cycle is zero. Also plot a graph showing the variation of voltage, current, power and flux in one cycle.

CBSE (F)-2017,(D)-2016,(AI)-2015

[**Ans.** We have, $V = V_0 \sin \omega t$

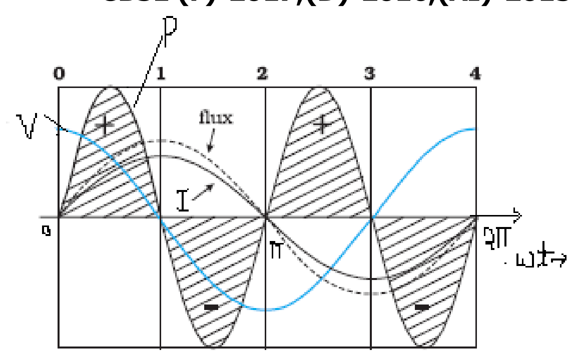
& $\mathrm{I} = \mathrm{I}_0 \sin(\omega t - \frac{\pi}{2}) = -\ \mathrm{I}_0 \cos \omega t$

Average power per cycle

$\bar{P} = \frac{1}{T}\int_0^T V\,\mathrm{X}\,I\ dt = \frac{1}{T}\int_0^T V_0\, I_0 \sin \omega t \cos \omega t\ dt$

⇨ $\bar{P} = \frac{V_0 I_0}{2T}\int_0^T \sin 2\omega t\ dt$

⇨ $\bar{P} = 0$ $[\because \int_0^T \sin 2\omega t\ dt = 0]$



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483. When an a.c. source is connected to a pure capacitor show that the average power supplied by the source over a complete cycle is zero. Also plot a graph showing the variation of voltage, current, power and flux in one cycle.

CBSE (AIC)-2017,(D)-2016,(AI)-2015

[**Ans.** We have, $V = V_0 \sin \omega t$

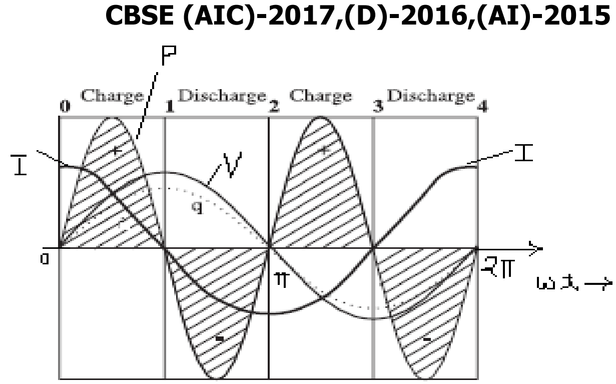
& $\mathrm{I} = \mathrm{I}_0 \sin(\omega t + \frac{\pi}{2}) = \mathrm{I}_0 \cos \omega t$

Average power per cycle

$\bar{P} = \frac{1}{T}\int_0^T V\,\mathrm{X}\,I\ dt = \frac{1}{T}\int_0^T V_0\, I_0 \sin \omega t \cos \omega t\ dt$

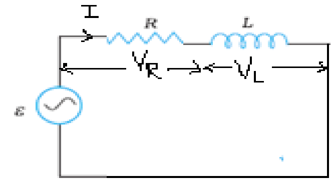
⇨ $\bar{P} = \frac{V_0 I_0}{2T}\int_0^T \sin 2\omega t\ dt$

⇨ $\bar{P} = 0$ $[\because \int_0^T \sin 2\omega t\ dt = 0]$



484. An alternating voltage $V = V_0 \sin \omega t$ is applied to a series combination of a resistor and an inductor. 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. **CBSE (AIC)-2014**

[***Ans. AC through LR circuit*** :



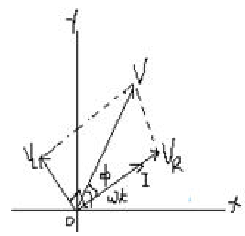
We have the applied voltage

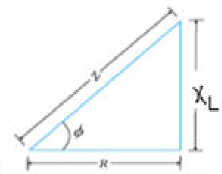
$$V = V_0 \sin \omega t \qquad \text{-------(1)}$$

From phasor diagram

$$\boldsymbol{V} = \sqrt{V_R^2 + V_L^2} = \sqrt{(IR)^2 + (I\,X_L)^2} = I\sqrt{(R)^2 + X_L^2}$$

$$\Rightarrow \boldsymbol{I} = \frac{\boldsymbol{V}}{\sqrt{R^2 + X_L^2}}$$





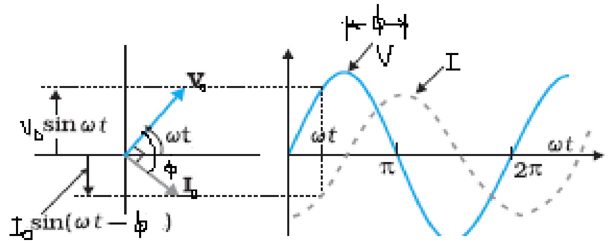
Obviously, effective resistance of the circuit, known as impedance is given by

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

Obviously, $\mathrm{I} = \mathrm{I}_0 \sin(\omega t - \phi)$ ----(2)

Where, $\tan\phi = \frac{V_L}{V_R} = \frac{I_0 X_L}{I_0 R} = \frac{X_L}{R} = \frac{\omega L}{R}$

$$\Rightarrow \phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$$



From (1) & (2) we conclude that current in the circuit lags behind the voltage in phase by ϕ.

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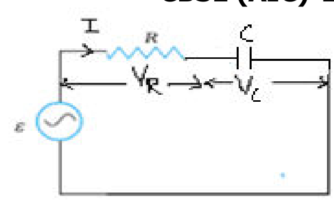
485. An alternating voltage $V = V_0 \sin \omega t$ is applied to a series combination of a resistor and a capacitor. Using phasor diagram, derive expressions for impedance, instantaneous current and its phase relationship to the applied voltage. Also draw graphs of V and I versus ωt for the circuit. **CBSE (AIC)-2014**

[***Ans. AC through CR circuit*** :



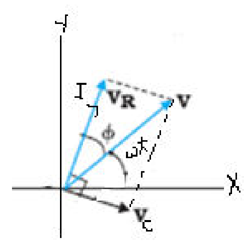
We have the applied voltage

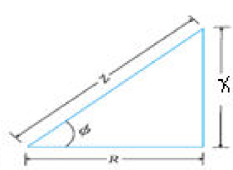
$$V = V_0 \sin \omega t \qquad \text{-------(1)}$$

From phasor diagram

$$\boldsymbol{V} = \sqrt{V_R^2 + V_C^2} = \sqrt{(IR)^2 + (I\,X_C)^2} = I\sqrt{(R)^2 + X_C^2}$$

$$\Rightarrow \boldsymbol{I} = \frac{\boldsymbol{V}}{\sqrt{R^2 + X_C^2}}$$





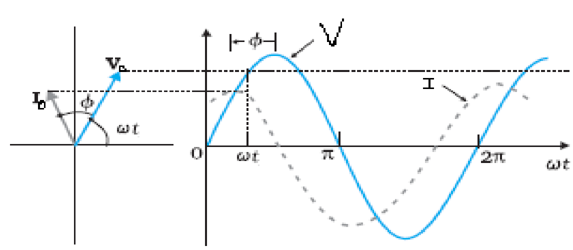
Obviously, effective resistance of the circuit, known as impedance is given by

$$Z = \sqrt{R^2 + X_C^2}$$

Obviously, $\mathrm{I} = \mathrm{I}_0 \sin(\omega t + \phi)$ ----(2)

Where, $\tan\phi = \frac{V_C}{V_R} = \frac{I_0 X_C}{I_0 R} = \frac{X_C}{R} = \frac{1/\omega C}{R}$

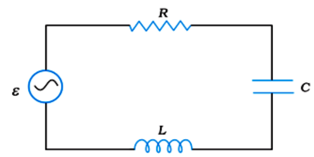
$$\Rightarrow \phi = \tan^{-1}\left(\frac{1}{\omega CR}\right)$$



From (1) & (2) we conclude that current in the circuit lags behind the voltage in phase by ϕ

486. A series LCR 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 **CBSE (AI)-2016**

[Ans. AC through LCR circuit :



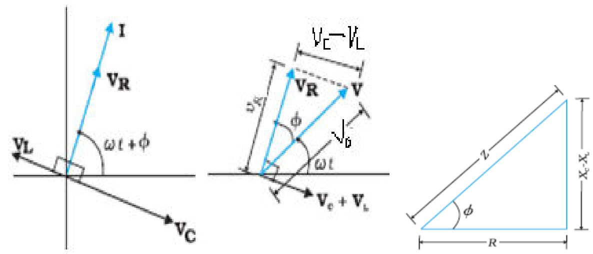
We have the applied a.c. voltage

$V = V_0 \sin \omega t$ -------(1)

From phasor diagram

$$\boldsymbol{V} = \sqrt{V_R^2 + (V_C - V_L)^2} = \sqrt{(IR)^2 + (IX_C - IX_L)^2} = I\sqrt{R^2 + (X_C - X_L)^2}$$

$$\Rightarrow \boldsymbol{I} = \frac{V}{\sqrt{R^2 + (X_C - X_L)^2}}$$



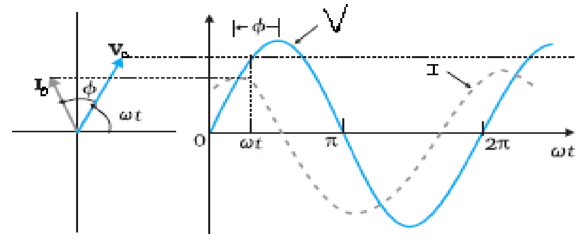
Obviously, effective resistance of the circuit, known as impedance is given by

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

Obviously, $I = I_0 \sin(\omega t + \phi)$ ----(2)

Where, $\tan \phi = \frac{V_C - V_L}{V_R} = \frac{I_0 X_C - I_0 X_L}{I_0 R} = \frac{X_C - X_L}{R}$

$$\Rightarrow \phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$$



From (1) & (2) we conclude that current in the circuit leads the voltage in phase by ϕ.

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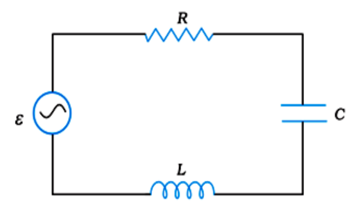
487. A voltage $V = V_0 \sin \omega t$ is applied to a series LCR circuit. Derive the expression for average power dissipated over a cycle. Under what condition is -

(i) no power is dissipated even though the current flows through the circuit,

(ii) maximum power dissipated in the circuit. **CBSE (AI)-2016,2015,2014,(D)-2016**

[Ans. We have the applied voltage



$V = V_0 \sin \omega t$

& $I = I_0 \sin(\omega t + \phi)$ Where, $\phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

$\Rightarrow P = V \text{ X } I = V_0 \sin \omega t \text{ X } I_0 \sin(\omega t + \phi)$

$\Rightarrow P = V_0 I_0 \sin \omega t \text{ X } (\sin \omega t \cos \phi + \cos \omega t \sin \phi)$

$\Rightarrow P = V_0 I_0 \left[sin^2 \omega t \cos \phi + \frac{1}{2} \sin 2\omega t \sin \phi\right]$

Average power per cycle

$$\overline{P} = \frac{1}{T}\int_0^T P\, dt = \frac{1}{T}\int_0^T V_0 I_0 \left[sin^2 \omega t \cos \phi + \frac{1}{2}\sin 2\omega t \sin \phi\right] dt$$

$$\Rightarrow \overline{P} = \frac{V_0 I_0 \cos \phi}{T}\int_0^T sin^2 \omega t\, dt + \frac{V_0 I_0 \sin \phi}{2T}\int_0^T \sin 2\omega t\, dt$$

$$\Rightarrow \overline{P} = \frac{V_0 I_0 \cos \phi}{T} \frac{T}{2} + 0 \qquad \left[\because \int_0^T sin^2 \omega t\, dt = \frac{T}{2} \;\&\; \int_0^T \sin 2\omega t\, dt = 0\right]$$

$$\Rightarrow \overline{P} = \frac{V_0 I_0}{2}\cos \phi = \frac{V_0}{\sqrt{2}} \text{ X } \frac{I_0}{\sqrt{2}} \text{ X } \cos \phi$$

$\Rightarrow$ $\boxed{\overline{P} = V_{rms} \text{ X } I_{rms} \text{ X} \cos \phi}$ Where, $\cos \phi = R/Z$ is called power factor

(i) For a pure inductive or capacitive circuit, $\phi = \frac{\pi}{2}$

$\Rightarrow \overline{P} = V_{rms} \, X \, I_{rms} \, X \cos \frac{\pi}{2} = 0$ which shows that, no power is dissipated even current flows through the circuit

(ii) at resonance when $X_L = X_C$, $\phi = 0$

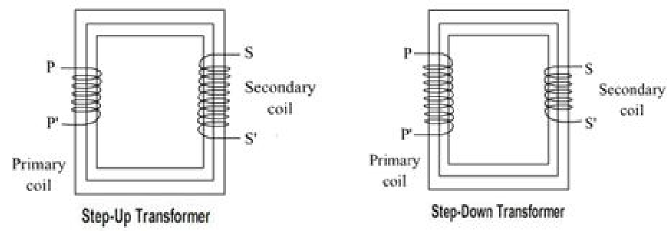
$\Rightarrow \overline{P} = V_{rms} \, X \, I_{rms} \, X \cos 0 = V_{rms} \, X \, I_{rms}$ = maximum Which shows that at resonance m ax power is dissipated

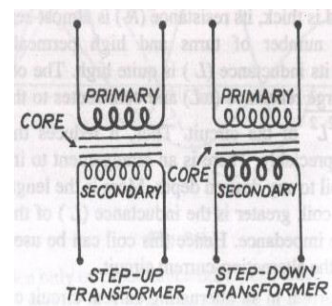
488. Draw a schematic diagram of a step up/step down transformer. Explain its working principle. Deduce the expression for the secondary to primary voltage in terms of the number of turns in the two coils. In an ideal transformer, how is this ratio related to the currents in the two coils ?

CBSE (F)-2017,2012,2009,(AI)-2015,2010,(D)-2016

[**Ans. Transformer :** It is an electrical device which, which is used to increase or decrease the voltage in a.c. circuits.

Principle : It is based on the principle of **mutual induction,** i,e, whenever there is change in magnetic flux linked with a coil, an emf is induced in the neighbouring coil





Working :

When an alternating voltage is applied to the primary, magnetic flux linked with it changes which links to the secondary and induces an emf in it due to mutual induction.

Back emf induced in Primary

$$e_p = -N_p \frac{d\phi}{dt}$$

Similarly, emf induced in the secondary

$$e_s = -N_s \frac{d\phi}{dt}$$

⇨ $\frac{e_s}{e_p} = \frac{-N_s\frac{d\phi}{dt}}{-N_p\frac{d\phi}{dt}} = \frac{N_s}{N_p}$ ---------(1)

As the primary has negligible resistance, $e_p = V_p$ and if secondary is in an open circuit then $e_s = V_s$, Then from (1) we have

$\frac{e_s}{e_p} = \frac{V_s}{V_p} = \frac{N_s}{N_p} = r$ --------(2)

Where, $r = \frac{N_s}{N_p}$, is called transformation ratio

Now, if the transformer is ideal, then

power input = power output

⇨ $V_P \times i_p = V_s \times i_s$

⇨ $\frac{i_s}{i_p} = \frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{1}{r}$

It shows that when voltage is stepped-up, the current is correspondingly reduced in the same ratio, and vice-versa

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489.(ii) Describe briefly any two energy losses, giving the reason of their occurrence in actual transformer. How are these reduced ?

CBSE (D)-2016, (AI)-2015, 2010, (F)-2012, 2009

[**Ans. Energy losses in a transformer :**

(i) Copper loss : Energy loss as heat due to resistance of primary and secondary is called copper loss and can be minimized by using thick copper wires

(ii) Iron loss : Energy loss as heat due to eddy currents in the iron core is called Iron loss and can be reduced by using a laminated iron core

(iii) Hysteresis loss: Magnetisation of iron core is repeatedly reversed by the alternating magnetic field and energy is lost in the form of heat in the core. This is called hysteresis loss and can be minimized by using a core of a material having low hysteresis loop.

(iv) Flux leakage : There is always some flux leakage; i,e, all of the flux due to primary does not passes through the secondary. It can be minimized by winding primary and secondary coils one over the other

490.(iii) How is the transformer used in large scale transmission and distribution of electrical energy over long distances ?

CBSE (AI)-2016,2010,2008,(AIC)-2014,(F)-2009

[**Ans.** (a) output voltage of the power generator is stepped-up so that current is reduced and as a result, line loss I^2R is also reduced

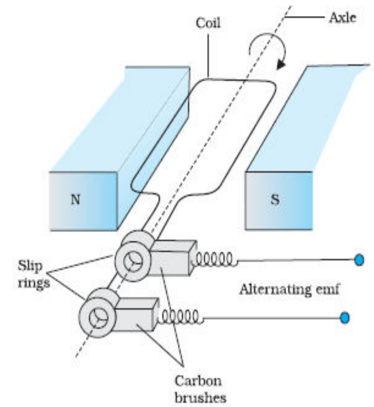
(b) It is then transmitted over long distances to an area sub-station, where voltage is stepped down.

491. (i) Explain with the help of a labelled diagram, the principle and working of an ac generator and obtain expression for the emf generated in the coil.
(ii) Draw a schematic diagram showing the nature of the alternating emf generated by the rotating coil in the magnetic field during one cycle. **CBSE (AI)-2016,2015,2011,(F)-2012,2009,(D)-2010,2007**

[Ans. **AC generator** : It is a device which converts mechanical energy in to electrical energy.

Principle : It is based on the principle of **electromagnetic induction**, i,e, whenever there is change in magnetic flux linked with a coil, an emf is induced in the coil

Working :



When the armature coil is rotated in a uniform magnetic field, effective area of coil $(A\ \cos\theta)$ changes continuously due to which magnetic flux linked with it changes. Hence an emf is induced in the circuit and a current flows through the coil

At any instant the magnetic flux linked with the coil
$\phi = B\ A\ \cos\theta = B\ A\ \cos\omega t$

⇨ Induced emf in the coil

$e = -N\frac{d\phi}{dt} = -N\frac{d}{dt}(BA\cos\omega t)$

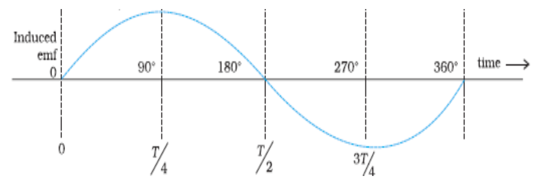
⇨ $e = -NBA\ (-\omega\ \sin\omega t) = NBA\ \omega\ \sin\omega t$

Obviously, when $\sin\omega t = 1$

$e = e_{max} = e_0 = NBA\ \omega$

⇨ $\boldsymbol{e = e_0\ \sin\omega t}$

& $I = \frac{e}{R} = \frac{e_0}{R}\sin\omega t = I_0\ \sin\omega t$



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492. In a series LCR circuit connected to an a.c. source of variable frequency and voltage $= V_0\ \sin\omega t$, 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: **CBSE (F)-2016,(AI)-2015,(DC)-2014,(D)-2013**
(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 ?

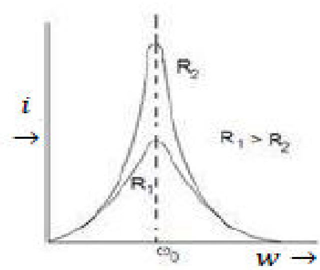
[Ans. Resonance condition : $X_L = X_C$ **or** $V_L = V_C$

(a) Sharper for R_2 **Reason** : Sharpness of resonance $= \frac{\omega_0 L}{R} \propto \frac{1}{R}$

(b) More power dissipation for R_2

Reason : At resonance, power dissipation$= \frac{V^2}{R} \propto \frac{1}{R}$ $(for\ same\ V)$

(c) for larger value of Q $\left(=\frac{\omega_0 L}{R} \propto \frac{1}{R}\right)$, resonance will be sharper hence circuit with resistance R_2 would be better suited for tuning the] receiver set



493. 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 P_1/P_2. **CBSE (D)-2016, (AI)-2015**

[**Ans. For LR circuit power factor**

$$P_1 = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + X_L^2}} = \frac{R}{\sqrt{R^2 + R^2}} = \frac{R}{R\sqrt{2}} = \frac{1}{\sqrt{2}}$$

When $X_L = X_C$ is put in series, for LCR circuit power factor

$$P_2 = \frac{R}{Z} = \frac{R}{\sqrt{(R)^2 + (X_C - X_L)^2}} = \frac{R}{R} = 1 \quad ⇨ \quad \frac{P_1}{P_2} = \frac{1/\sqrt{2}}{1} = 1\ ]$$

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Unit V: Electromagnetic waves **04 Periods**

Chapter–8: Electromagnetic Waves

Basic idea of displacement current, Electromagnetic waves, their characteristics, their Transverse nature (qualitative ideas only).

Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

501. What is meant by displacement current ? **CBSE (AIC)-2010**

[**Ans. Displacement current** : A current which comes in to existence due to time varying electric field, is known as displacement current

$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

502. In which situation there is a displacement current but no conduction current ? **CBSE (AI)-2016**

[**Ans.** Between the plates of capacitor during charging/discharging or in the regions of time varying electric field

503. The charging current for a capacitor is 0.25 A. What is the displacement current across its plates ? **CBSE (F)-2016**

[**Ans.** same as the convection current, i,e, I_D = 0.25 A

504. Why is the quantity $\varepsilon_0 \frac{d\phi_E}{dt}$ is called displacement current ? **CBSE (AIC)-2001**

[**Ans.** Because the quantity $\varepsilon_0 \frac{d\phi_E}{dt}$ has the dimensions of current and this current exists in a region between the two plates of a capacitor when displacement of charges occurs there ,i,e, during charging or discharging of capacitor

505. How does Ampere-Maxwell law explain the flow of current through a capacitor when it is being charged by a battery? Write the expression for displacement current in terms of the rate of change of electric flux. **CBSE (D)-2017**

[**Ans.** During charging, electric flux between the plates of capacitor keeps on changing; this results in the production of a displacement current between the plates

$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

506. Why does a galvanometer show a momentary deflection, at the time of charged or discharging a capacitor ? Write the necessary expression to explain this observation. **CBSE (AI)-2017,2016**

[**Ans.** During charging or discharging of the capacitor, displacement current between the plates is set up . Hence circuit becomes complete and galvanometer shows momentary deflection

$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

507. A capacitor has been charged by a d.c. source. What are the magnitudes of conduction and displacement currents, when it is fully charged ? **CBSE (D) -2013**

[**Ans.** when fully charged then both $I = I_D = 0$ and during charging $I = I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

508. What does the displacement current $I_D = \varepsilon_0 \frac{d\phi_E}{dt}$ signify ? **CBSE (D)-2012**

[**Ans.** It signifies that the changing electric field can give rise to a magnetic field

509. When an ideal capacitor is charged by a d.c. battery, no current flows. However, when an a.c. source is used, the current flows continuously. How does one explain this, based on the concept of displacement current ? **CBSE (AI)-2017,(D)-2012**

[**Ans.** In case of d.c. there is no change in electric flux and hence there is no displacement current. Circuit remains incomplete and capacitor does not conduct and no current flows

In case of a.c. source changing voltage causes change in electric flux and so displacement current ($I_D = \varepsilon_0 \frac{d\phi_E}{dt}$) is set up between the plates of capacitor. It completes the circuit and current flows continuously.

510. A capacitor made of two parallel plates each of plate area A and separation d, is being charged by an external a.c. source. Show that the displacement current inside the capacitor is same as the current charging the capacitor.

[**Ans.** Let applied alternating voltage **CBSE (AI)-2013**

$V = V_0 \sin\omega t$

At any instant, the conduction current

$$I = \frac{dq}{dt} = \frac{d}{dt}(CV) = \frac{d}{dt}(CV_0 \sin\omega t) = CV_0 \frac{d}{dt}(\sin\omega t) = \omega CV_0 \cos\omega t = I_0 \cos\omega t$$

Displacement current,

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}(E\,A) = \varepsilon_0 \frac{d}{dt}\left(\frac{q}{\varepsilon_0 A} A\right) = \frac{dq}{dt} = I = I_0 \cos\omega t$$

511. Write the expression for the generalized Ampere's circuital law. Through a suitable example, explain the significance of time dependent term. **CBSE (AI)-2015**

[**Ans. Generalized Ampere's circuital law** : $\oint \vec{B}.\vec{dl} = \mu_0 \left(I + \varepsilon_0 \frac{d\phi_E}{dt} \right)$

Significance : Time dependent term i,e, $\varepsilon_0 \frac{d\phi_E}{dt}$ is the displacement current and it signifies that the changing electric field can give rise to a magnetic field

512. What are electromagnetic waves ? Are these waves transverse or longitudinal ? **CBSE (AIC)-2011,(AI)-2001**

[**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

513. (i) How are electromagnetic waves produced ? Explain. **CBSE (F)-2017,(AI)-2016,2015**
(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

514. What oscillates in electromagnetic waves ? **CBSE (DC)-2010**

[**Ans.** Electric and magnetic vectors oscillates in an em wave

515. What is the phase relationship between oscillating electric and magnetic fields in an em wave ? **CBSE (AIC)-2010**

[**Ans.** They are in the same phase

516. What is the frequency of em waves produced by oscillating charge of frequency ? **CBSE (AI)-2015,2010**

[**Ans.** Frequency of em wave = frequency of oscillating charge = ν

517. When can a charge acts as a source of em wave ? **CBSE (D)-2013,2005,(AI)-2012,(AIC)-2004**

[**Ans.** when charge is either accelerated or oscillating

518. 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. **CBSE (AI)-2017**

$$c = \frac{E_0}{B_0}$$

519. Write the expression for speed of electromagnetic waves in a medium of electrical permittivity ε and magnetic permeability μ.

[**Ans.** $\boldsymbol{c = \frac{1}{\sqrt{\mu\,\varepsilon}} = \frac{1}{\sqrt{\mu_0\mu_r\varepsilon_0\varepsilon_r}}}$ **CBSE (F)-2017**

520. What is meant by the transverse nature of electromagnetic waves ? **CBSE (AI)-2016,2015**

[**Ans.** Transverse nature means, $\vec{E}$ & $\vec{B}$ are $\perp$ to each other as well as $\perp$ to the direction of propagation of the wave

530. How are the directions of the electric and magnetic field vectors in an em wave are related to each other and to the direction of propagation of the em waves ? **CBSE (F)-2012**

[**Ans.** $\vec{E}$ & $\vec{B}$ are $\perp$ to each other as well as $\perp$ to the direction of propagation of the wave

531. In which directions do the electric and magnetic field vectors oscillate in an electromagnetic wave propagating along the x-axis ?

[**Ans.** $\vec{E}$ along y-axis and $\vec{B}$ along z-axis **CBSE (AI)-2017**

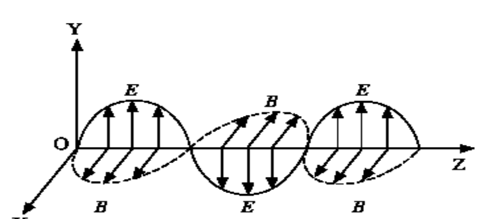
(Alternatively $\vec{E}$ along z-axis and $\vec{B}$ along y-axis

532. Write mathematical expression for electric and magnetic fields of an electromagnetic wave propagating along z-axis.

[**Ans.** $\overrightarrow{E_x} = E_0 \sin\,(Kz - \omega\, t)\,\hat{\imath}$ & $\overrightarrow{B_y} = B_0 \sin\,(Kz - \omega\, t)\,\hat{\jmath}$

533. Draw a sketch of linearly polarized em waves propagating in the Z-direction. Indicate the directions of the oscillating electric and magnetic fields. **CBSE (AI)-2016,2015,2010,(F)-2014,(D)-2009**

[**Ans.**



534.Write the expression for the energy density of an electromagnetic wave propagating in free space. **CBSE (AI)-2015**

[**Ans.** $u = u_E + u_B = \frac{1}{2}\,\varepsilon_0\,E^2 + \frac{B^2}{2\mu_0}$

535. State any four properties of electromagnetic waves. **CBSE (AI)-2016,2015**

[**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

536. Do the electromagnetic waves carry energy and momentum ? **CBSE (AI)-2017**

[**Ans. Yes**

537. How can we show that em waves carry momentum ? **CBSE (AI)-2016,2015**

[**Ans.** Electric charges present on a plane, normal to the direction of propagation of an em wave can be set and sustained in motion by the electric and magnetic fields of the electromagnetic wave. The charges thus acquire energy and momentum from the waves.

If the total energy transferred to a surface in time t is U, then the magnitude of the total momentum delivered to this surface (for complete absorption) is, $p = \frac{U}{c}$

538. Why is the amount of the momentum transferred by the EM waves incident on the surface so small ?

[**Ans.** momentum transferred by the em waves = energy/speed of light= $h\nu/c = 10^{-22}$ **CBSE (D)-2014,(AI)-2009**

Which is very small

539. An em wave exerts pressure on the surface on which it is incident. Justify. **CBSE (F)-2012**

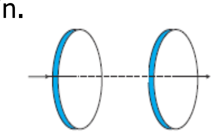
[**Ans.** em waves carry momentum $(p = \frac{U}{c})$ energy $(h\nu)$ hence they exert a radiation pressure $P = \frac{F}{A} = \frac{1}{A}\frac{dp}{dt}$

540. Figure shows a capacitor made of two circular plates. The capacitor is being charged by an external source. The charging current is constant and equal to 0.15 A. **NCERT-2017**

(a) What is the displacement current across the plates.

(b) Is Kirchhoff's first rule (junction rule) valid at each plate of the capacitor? Explain.

[**Ans.** (a) displacement current = charging current $= 0.15\ A$



(b) As $(I + I_D)$ is continuous so Kirchhoff's first rule (junction rule) valid at each plate of the capacitor

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541. Which physical quantity, if any, has the same value for the waves belonging to the different parts of the electromagnetic spectrum ? **CBSE (AI)-2012,(AIC)-2004**

[**Ans.** Velocity

542. Name the physical quantity which remains same for microwaves of wavelength 1mm and UV radiations of 1600 A^0 in vacuum.

[**Ans.** Velocity c= 3 X 10^8 m/s **CBSE (D)-2012**

543. What is the ratio of speed of infrared and ultraviolet rays in vacuum ? **CBSE (D)-2001**

[**Ans.** 1:1

544. Give the ratio of velocities of wavelengths 4000 A^0 and 8000 A^0 in vacuum ? **CBSE (AI)-2001**

[**Ans.** 1:1

545. 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. **CBSE (D)-2014,(AI)-2013,(F)-2010**

[**Ans.** Ultraviolet radiations, from 10^{14} Hz to 10^{16} Hz]

546. Why are microwaves found useful for the radar systems in aircraft navigation ?**CBSE (D) -2016,2004,(F)-2013**

OR

State the reason why microwaves are best suited for long distance transmission of signals ? **CBSE (F)-2008**

[**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

547. 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.

CBSE (AI)-2016,2009,(AIC)-2015,(D)-2014

[**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

548. 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. **CBSE (AI)-2016, (D)-2014,2011, (F) -2013,2010**

[**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

549. What role does infra radiation play in (i) maintain the Earth's warmth, and (ii) Physical therapy ?**CBSE (AI) -2015**

[**Ans.** (i) Infrared radiations are absorbed by the earth's surface and radiated as longer wavelength infrared radiations. These radiations are trapped by green house gases such as CO_2 and maintain the Earth's warmth.

(ii) Infrared radiations are easily absorbed by the water molecules present in the body. After absorption, their thermal motion increases causes heating which is used as physical therapy

550. If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now ? Explain.

[**Ans.** lower because of absence of green house gases **CBSE (D)-2014,(AI)-2009**

551. State clearly how a microwave oven works to heat up a food item containing water molecules? **CBSE (F) -2013**

[**Ans.** 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

552. Which segment of electromagnetic waves has highest frequency ? How are these waves produced ? Give one use of these waves. **CBSE (F)-2016**

[**Ans.** $\gamma - rays$,

Production : these are produced by Radioactive decay of the nucleus,

Use : used in medicine to destroy cancer cells

553. 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 ? **CBSE (F)-2016**

[**Ans.** $\boldsymbol{Ultra\ violet\ rays}$,
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

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554. Which of the following electromagnetic radiations has least frequency : **CBSE (AI)-2015**

UV radiations, X-rays, Microwaves

[**Ans.** Microwaves

555. Which of the following has the shortest wavelength : **CBSE (AI)-2010**

Microwaves, Ultraviolet rays, X-rays [**Ans.** X-rays

556. Arrange the following electromagnetic waves in order of increasing frequency : **CBSE (F)-2014,(D)-2009**

γ –rays, microwaves, infrared rays and Ultraviolet rays

[**Ans.** Microwaves, infrared rays, Ultraviolet rays, γ –rays

557. Arrange the following electromagnetic waves in order of decreasing frequency : **CBSE (F)-2014, (D)-2002**

x-rays, γ –rays, microwaves, UV rays and infrared rays

[**Ans.** γ –rays, x-rays, UV rays, infrared rays and Microwaves

558. Arrange the following em waves in order of their increasing wavelength : **CBSE (AI)-2015,(DC)-2001**

γ –rays, Microwaves, X-rays, U.V. rays and Radio waves

[**Ans.** γ –rays< X-rays ,UV rays < Microwaves < Radio waves

559. Arrange the following electromagnetic waves in decreasing order of wavelength : **CBSE (F)-2014**

γ –rays, infrared rays, x-rays and microwaves

[**Ans.** Microwaves, infrared rays, x-rays and γ –rays

560. Name the following constituent radiations of electromagnetic spectrum which- **CBSE (AI)-2016,2005**
(i) are used in satellite communication/in radar and geostationary satellite **CBSE (D) -2010, 2004**
(ii) are used for studying crystal structure of solids **CBSE (AI)-2007, (F)-2012,2005**
(iii) are similar to the radiations emitted during decay of radioactive nuclei **CBSE (AI)-2005, (AIC)-2005**
(iv) used for water purification/ are absorbed from sunlight by ozone layer **CBSE (AI)-2007, (F)-2005**
[**Ans**. (i) microwaves (ii) x- rays (iii) γ- rays (iv) UV rays

==

561. Name the following constituent radiations of electromagnetic spectrum which- **CBSE (AI)-2016,2005**
(i) has its wavelength range between 390 nm to 770 nm **CBSE (AI)-2005, (AIC)-2005**
(ii) produce intense heating effect/ used in warfare to look through fog **CBSE (AI)-2007, (F)-2005**
(iii) are used for radar systems used in aircraft navigation **CBSE (D)-2015,(F)-2012,(AI)-2007**
[**Ans**. (i) visible light (ii) Infrared rays (iii) microwaves

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562. Name the following constituent radiations of electromagnetic spectrum which-
(i) are adjacent to the low frequency end of electromagnetic spectrum **CBSE (F)-2010**
(ii) produced by nuclear reactions/used to destroy cancer cells/treatment of cancer **CBSE (F)-2010**
(iii) produced by bombarding a metal target by high speed electrons. **CBSE (AI)-2016, (F)-2009**
(iv) maintains the earth's warmth/ used in remote sensing **CBSE (F) -2012 ,(AI) -2007**
[**Ans**. (i) microwaves (ii) γ- rays (iii) x- rays (iv) Infrared rays

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563. Which constituent radiations of electromagnetic spectrum is used - **CBSE (F)-2004**
(i) in Radar
(ii) in photographs of internal parts of human body/as a diagnostic tool in medicine **CBSE (D) -2015**
(iii) for taking photographs of sky, during night and fog conditions. **CBSE (D)-2004**
(iv) has the largest penetrating power **CBSE (D) -2010, 2004**
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) $\boldsymbol{\gamma} - rays$ as they have the highest frequency and hence highest energy

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564. Electromagnetic waves with wavelengths- **CBSE (Sample Paper)-2009**
(i) λ_1 are used to treat muscular strain **CBSE (D) -2015**
(ii) λ_2 are used by a F.M. radio station for broadcasting
(iii) λ_3 are used to detect fractures in bones **CBSE (D) -2015**
(iv) λ_4 are absorbed by ozone layer of the atmosphere **CBSE (D) -2010, 2004**
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, $\lambda_2, > \lambda_1, > \lambda_4 > \lambda_3$

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565. Identify the electromagnetic waves whose wavelength vary as and also write one use for each. **CBSE (AI)-2017**
(i) $10^{-12}\,m < \lambda < 10^{-8}\,m$ (ii) $10^{-3}\,m < \lambda < 10^{-1}\,m$
[**Ans**. (i) X-rays/ $\boldsymbol{\gamma} - rays$ used for medical purposes/ nuclear reactions (ii) Microwaves used for radar systems

566. Identify the electromagnetic waves whose wavelength vary as and also write one use for each. **CBSE (AI)-2017**
(i) $10^{-11}\,m < \lambda < 10^{-14}\,m$ (ii) $10^{-4}\,m < \lambda < 10^{-6}\,m$
[**Ans**. (i) X-rays/ $\boldsymbol{\gamma} - rays$ used for medical purposes/ nuclear reactions
(ii) Infrared/ visible used for muscular treatment/ vision

567. Show that in the process of charging a capacitor, the current produced within the plates of the capacitor is

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

CBSE (D) -2016

where ϕ_E is the electric flux produced during charging of the capacitor plates.

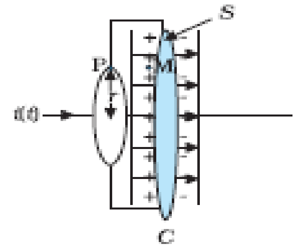
[**Ans**. Electric field between the plates of capacitor, $E = \frac{q}{\varepsilon_{0A}}$

⇨ electric flux, $\phi_E = E\,A = \frac{q}{\varepsilon_{0A}} A = \frac{q}{\varepsilon_0}$

⇨ $\frac{d\phi_E}{dt} = \frac{d}{dt}\left(\frac{q}{\varepsilon_0}\right) = \frac{1}{\varepsilon_0}\left(\frac{dq}{dt}\right)$

⇨ $\frac{dq}{dt} = \varepsilon_0 \frac{d\phi_E}{dt}$

⇨ $I_D = \varepsilon_0 \frac{d\phi_E}{dt}$



568. Show that in the process of charging a capacitor, displacement current is always equal to conduction current.

[**Ans**. Displacement current between the plates of capacitor, during charging **CBSE (AIC) -2010**

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}(E\,A) = \varepsilon_0 \frac{d}{dt}\left(\frac{q}{\varepsilon_{0A}} A\right) = \frac{dq}{dt} = I$$

==

569. Why does a galvanometer when connected in series with a capacitor show a momentary deflection, when it is Being charged or discharged ? How does this information lead to modify the Ampere's circuital law ? Hence write the generalized expression of Ampere's circuital law. **CBSE (F)-2015,(AI)-2014,2011**

[**Ans**. During charging or discharging of the capacitor, displacement current between the plates is set up . Hence circuit becomes complete and galvanometer shows momentary deflection

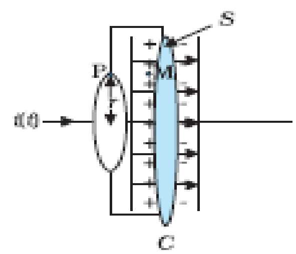
By Ampere's circuital law

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

Applying it to surface P, $\oint \vec{B}.\vec{dl} = \mu_0 I$

Applying it to surface S, $\oint \vec{B}.\vec{dl} = 0$

$\therefore \oint_p \vec{B}.\vec{dl} \neq \oint_s \vec{B}.\vec{dl}$.



This is in contradiction to Ampere's circuital law. Hence it needs modification.

In fact, during charging/ discharging of capacitor electric flux between the plates changes which produces current known as displacement current. Hence, there is a need to include displacement current.

Therefore, modified Ampere's circuital law is

$\oint \vec{B}.\vec{dl} = \mu_0 (I + I_D) = \mu_0 (I + \varepsilon_0 \frac{d\phi_E}{dt})$ Now for surface P, $\oint \vec{B}.\vec{dl} = (\mu_0 I + 0) = \mu_0 I$

For surface S, $\oint \vec{B}.\vec{dl} = (0 + I_D) = \mu_0 I_D = \mu_0 I$

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570. Write the generalized expression for Ampere's circuital law in terms of the conduction current and displacement current. Mention the situation when there is : **CBSE (F) -2013**

(i) only conduction current and no displacement current

(ii) only displacement current and no conduction current

[**Ans**. **Generalized Ampere's circuital law** : $\oint \vec{B}.\vec{dl} = \mu_0 (I + \varepsilon_0 \frac{d\phi_E}{dt})$

(i) In case of a steady current in conducting wire, electric field does not change with time, conduction current exists but displacement current is zero.

⇨ $\oint \vec{B}.\vec{dl} = \mu_0 I$

(ii) During charging of a capacitor displacement current flows in the space between the plates of capacitor but conduction current is zero.

⇨ $\oint \vec{B}.\vec{dl} = \mu_0 \varepsilon_0 \frac{d\phi_E}{dt} = \mu_0 I_D = \mu_0 I$

571. A plane electromagnetic wave of frequency 25 MHz travels in free space along the *x*-direction. At a particular point in space and time, $\vec{E}$ = 6.3 $\hat{j}$ V/m. What is $\vec{B}$ at this point ? **NCERT- 2017**

[**Ans.** $\frac{E}{B} = c \Rightarrow B = \frac{E}{c} = \frac{6.3}{3 X 10^8} = 2.1 \text{ X } 10^{-8}\ \hat{\boldsymbol{k}}$ Tesla]

572. In an electromagnetic wave the oscillating electric field having a frequency of 3 X 10^{10} H_Z and an amplitude of 30 V/m propagates in the positive x-direction. **CBSE (F)-2008**

(i) what is the wavelength of electromagnetic wave ?

(ii) write down the expression to represent the corresponding magnetic field.

[**Ans. (i)** $\lambda = \frac{c}{f} = \frac{3 X 10^8}{3 X 10^{10}} = 10^{-2}\ m$ **(ii)** $B_0 = \frac{E_0}{c} = \frac{30}{3 X 10^8} = 10^{-7}\ T$

$\omega = 2\pi f = 2\pi X 3 X 10^{10} = 6\pi X 10^{10}$ rad/s & $K = \frac{2\pi}{\lambda} = \frac{2\pi}{10^{-2}} = 2\pi \text{ X } 10^2\ m^{-1}$

$\Rightarrow B = B_0 \sin(\omega t - Kx) = 10^{-7} \sin(6\pi X 10^{10}\ t - 2\pi \text{ X } 10^2\ x)$]

573. In an electromagnetic wave propagating along x- direction, the magnetic field oscillates at a frequency of 3 X10^{10} H_Z and has an amplitude of 10^{-7} Tesla acting along the y-direction. **CBSE (F)-2008**

(i) what is the wavelength of electromagnetic wave ?

(ii) write the expression representing the corresponding oscillating electric field.

[**Ans. (i)** $\lambda = \frac{c}{f} = \frac{3 X 10^8}{3 X 10^{10}} = 10^{-2}\ m$ (ii) $\frac{E_0}{B_0} = c \Rightarrow E_0 = B_0\ c = 10^{-7} \text{ X } 3 X 10^8 = 30\ V/m$

$\omega = 2\pi f = 2\pi X 3 X 10^{10} = 6\pi X 10^{10}$ rad/s & $K = \frac{2\pi}{\lambda} = \frac{2\pi}{10^{-2}} = 2\pi \text{ X } 10^2\ m^{-1}$

$\Rightarrow E = E_0 \sin(\omega t - Kx)\ \hat{\boldsymbol{k}} = 30 \sin(6\pi X 10^{10}\ t - 2\pi \text{ X } 10^2\ x)\ \hat{\boldsymbol{k}}\ \ V/m$]

574. The oscillating magnetic field in a plane electromagnetic wave is given by **CBSE (D)-2008**

B_y = 8 X 10^{-6} sin (2 x 10^{11} t + 300 πx)] T

(i) calculate the wavelength of electromagnetic wave ?

(ii) write down the expression for the oscillating electric field.

[**Ans.** B_y = 8 X 10^{-6} sin (2 x 10^{11} t + 300 πx)] T Comparing with $B_y = B_0 \sin(\omega t + Kx)$

B_0 = 8 X10^{-6} T, ω = 2 x 10^{11} rad/s and K = 300 π

(i) $K = \frac{2\pi}{\lambda} \Rightarrow \frac{2\pi}{\lambda} = 300\,\pi \Rightarrow \lambda = \frac{1}{150}\ m = \frac{100}{150}\ cm = \frac{2}{3}\ cm$

(ii) $\frac{E_0}{B_0} = c \Rightarrow E_0 = B_0\ c = 8 X 10^{-6} \text{ X } 3 X 10^8 = 2400\ V/m$

$\Rightarrow E_z = E_0 \sin(\omega t + Kx)\ \hat{\boldsymbol{k}} = 2400 \sin(2 X 10^{11}\ t + 300\,\pi\, x)\ \hat{\boldsymbol{k}}\ \ V/m$]

575. The oscillating electric field of an electromagnetic wave is given by **CBSE (D)-2008**

E_y = 30 sin(2 x 10^{11} t + 300πx)] V/m

(i) obtain the value of the wavelength of electromagnetic wave ?

(ii) write down the expression for the oscillating magnetic field.

[**Ans.** E_Y = 30 sin(2 x 10^{11} t + 300πx)] Comparing with $E_y = E_0 \sin(\omega t + Kx)$

E_0 = 30 V/m, ω = 2 x 10^{11} rad/s and K = 300 π

(i) $K = \frac{2\pi}{\lambda} \Rightarrow \frac{2\pi}{\lambda} = 300\,\pi \Rightarrow \lambda = \frac{1}{150}\ m = \frac{100}{150}\ cm = \frac{2}{3}\ cm$

(ii) $\frac{E_0}{B_0} = c \Rightarrow B_0 = \frac{E_0}{c} = \frac{30}{3 X 10^8} = 10^{-7}\ T$

$\Rightarrow B_z = B_0 \sin(\omega t + Kx)\ \hat{\boldsymbol{k}} = 10^{-7} \sin(2 X 10^{11}\ t + 300\,\pi\, x)\ \hat{\boldsymbol{k}}\ \ T$]

576. In a plane em wave, the electric field oscillates sinusoidally at a frequency of 2.0 X 10^{10} H_Z and amplitude 48 V/m.

(i) what is the wavelength of the wave ? **NCERT- 2017,CBSE (AI)-2001,(AIC)-2002**

(ii) what is the amplitude of oscillating magnetic field ?

(iii) show that the average energy density of the $\vec{E}$ field equals the average energy density of the $\vec{B}$ field.

[**Ans.** (i) $\lambda = \frac{c}{f} = \frac{3 X 10^8}{2 X 10^{10}} = 1.5 X 10^{-2}\ m$ (ii) $\frac{E_0}{B_0} = c \Rightarrow B_0 = \frac{E_0}{c} = \frac{48}{3 X 10^8} = 1.6 X 10^{-7}\ T$

(iii) $u_E = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0 (Bc)^2 = \frac{1}{2}\varepsilon_0 B^2 (\frac{1}{\sqrt{\mu_0\varepsilon_0}})^2 = \frac{B^2}{2\mu_0} = u_B$]

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Unit VI: Optics **27 Periods**

Chapter–9: Ray Optics and Optical Instruments

Ray Optics: Reflection of light, spherical mirrors, mirror formula, refraction of light, total internal reflection and its applications, optical fibers, refraction at spherical surfaces, lenses, thin lens formula, lensmaker's formula, magnification, power of a lens, combination of thin lenses in contact, refraction of light through a prism.

Scattering of light - blue colour of sky and reddish appearance of the sun at sunrise and sunset.

Optical instruments: Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers.

601. When a wave is propagating from a rarer to a denser medium, which characteristic of the wave does not change and why ?
[**Ans.** frequency, as frequency is a characteristic of the source of waves **CBSE (AI)-2015**

OR

When monochromatic light travels from one medium to another, its wavelength changes but its frequency remains same. Why ?
[**Ans.** frequency is a characteristic of the source of waves. That is why it remains the same. **CBSE (AI)-2011**
But wavelength is characteristic of medium. So wavelength and velocity both change.

602. When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency. Why ? **CBSE (AI)-2016,2010,(D)-2011**
[**Ans.** Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of incident light. Hence frequency remains unchanged.

603. When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a reduction in the energy carried by the wave ? **CBSE (AI)-2016,2010**
[**Ans. No.** Energy carried out by a wave depends on the amplitude of the wave, not on the speed of wave propagation.

604. In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determine the intensity in the photon picture of light ? **CBSE (AI)-2016**
[**Ans.** In photon picture, intensity is determined by the number of photons incident normally on a unit area per unit time

605. When light comes from air to glass, the refracted ray is bent towards the normal. Why ? **CBSE (DC)-2004**
[**Ans.** $\mu = \frac{\sin i}{\sin r} = \frac{3}{2}$
⇨ $\sin r = \frac{2}{3}\sin i$ ⇨ $\sin r < \sin i$ ⇨ $r < i$ hence, refracted ray is bent towards the normal

606. For the same angle of incidence, the angle of refraction in to two media A and B are 25^0 and 35^0respectively. In which medium is the speed of light less ? **CBSE (AI)-2015,2012**
[**Ans. In medium A speed of light is less**
Reason : $\mu = \frac{\sin i}{\sin r} = \frac{c}{v}$ ⇨ $v = \frac{c\ X\ \sin r}{\sin i}$ ⇨ $v \propto \sin r$ [∵ angle of incidence is same
But $r_A < r_B$ ⇨ $v_A < v_B$

607. Define refractive index of a transparent medium. What is the minimum and maximum value of refractive index ?
[**Ans. Refractive index** : **CBSE (AIC)-2017,(AI)-2009**
Refractive index of a medium is defined as the ratio of velocity of light in vacuum to the velocity of light in that medium
i,e, $\mu = \frac{c}{v}$ Minimum value of refractive index is 1 for air and maximum is 2.42 for diamond

608. What is the ratio of the velocity of the wave in the two media of refractive indices μ_1 and μ_2 **CBSE (AI)-2015**
[**Ans.** $\frac{v_1}{v_2} = \frac{\mu_2}{\mu_1}$

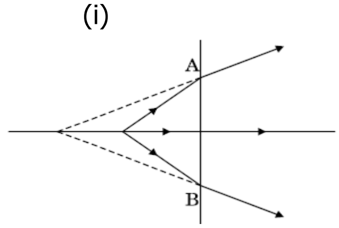
609. How does the refractive index of a transparent medium depend on wavelength of light used ? **CBSE (F)-2015**
[**Ans.** $\mu = a + \frac{b}{\lambda^2}$

610. When a glass slab is placed on an ink dot, ink dot appears to be raised. Why ? **BSE (AIC)-2010**
[**Ans.** due to refraction of light

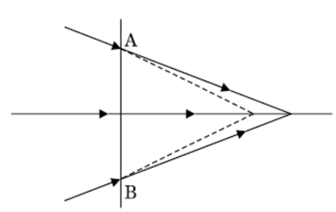
611. By how much would an ink dot appear to be raised, when covered by a glass plate of thickness $6.0\ cm$. Refractive index of glass is 1.5. **CBSE (AIC)-2010**
[**Ans.** $\Delta y = t\left(1 - \frac{1}{\mu}\right) = 6\left(1 - \frac{1}{1.5}\right) = 6\left(\frac{0.5}{1.5}\right) = 2.0\ cm$

612. The line AB in the ray diagram represents a lens. State whether the lens is convex or concave ? **CBSE (AI)-2015**

(i)



(ii)



[**Ans. (i) Convex lens, Reason** : refracted ray is bending towards the principal axis
(ii) Concave lens, Reason : refracted ray is bending away from the principal axis

613. What is total internal reflection of light ? **CBSE (AI)-2016,2001**

[Ans. Total internal reflection : When a ray of light travelling from denser to a rarer medium is incident on the interface at an angle greater than the critical angle, it is totally reflected back in to the denser medium. This phenomenon is called total internal reflection of light.

614. State the conditions for the phenomenon of total internal reflection to occur. **BSE (AI)-2016,(D)-2010**

[Ans. Conditions for TIR :

(i) light ray must travel from denser to a rarer medium

(ii) angle of incidence must be greater than the critical angle ($i > i_c$)

615. Name one phenomenon which is based on total internal reflection. **CBSE (AI)-2016**

[Ans. Mirage/ sparkling of diamond/ optical fibre/ totally reflecting prisms

616. Can total internal reflection occur when light goes from rarer to a denser medium ? **CBSE (D)-2007**

[Ans. No

617. Define critical angle.What is the relationbetween refractive index & critical angle for a given pair of optical media ?

[Ans. Critical angle : The angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90^0 is called critical angle. **CBSE (AI)-2009**

Relation : $\mu = \frac{1}{\sin i_c}$

618. When light travels from an optically denser medium to a rarer medium, why does the critical angle of incidence depend on the colour/wavelength of light ? **CBSE (AI)-2015,2009**

[Ans. $\mu = \frac{1}{\sin i_c}$ ⇨ $i_c = \sin^{-1}\left(\frac{1}{\mu}\right)$

As $\mu = a + \frac{b}{\lambda^2}$. Hence critical angle would also be different for different colours/wavelengths of light

619. What is the critical angle for a material of refractive index $\sqrt{2}$? **CBSE (AI)-2010**

[Ans. $\sin i_c = \frac{1}{\mu} = \frac{1}{\sqrt{2}}$ ⇨ $i_c = 45^0$

620. Velocity of light in glass is $2 \text{ X } 10^8$ m/s and in air is $3 \text{ X } 10^8$ m/s. If the ray of light passes from glass to air, calculate the value of critical angle. **CBSE (F)-2015**

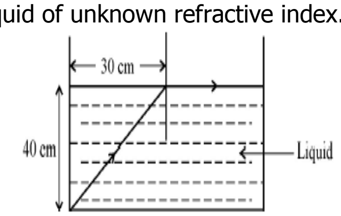
[Ans. $\mu = \frac{c}{v} = \frac{3\,X10^8}{2\,X10^8} = 1.5$

$\mu = \frac{1}{\sin i_c}$ ⇨ $i_c = \sin^{-1}\left(\frac{1}{\mu}\right) = \sin^{-1}\left(\frac{1}{1.5}\right) == \sin^{-1}\left(\frac{2}{3}\right) = 41.8^0$

621 Calculate the speed of light in a medium whose critical angle is 30^0. **CBSE (AI)-2012,2010**

[Ans. $\mu = \frac{1}{\sin i_c} = \frac{1}{\sin 30} = \frac{1}{1/2} = 2$ Now, $\mu = \frac{c}{v}$ ⇨ $v = \frac{c}{\mu} = \frac{3\,X10^8}{2} = 1.5\,X10^8$ m/s

622. In the following ray diagram, calculate the speed of light in the liquid of unknown refractive index. **CBSE (AIC)-2017**



[Ans. $\mu = \frac{c}{v} = \frac{1}{\sin i_c}$

⇨ $\frac{3 \text{ X } 10^8}{v} = \frac{1}{30/50}$

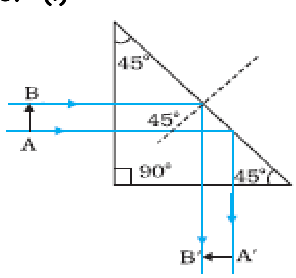
⇨ $v = \frac{30}{50} \text{ X } 3\,X10^8 = 1.8 \text{ X}10^8$ m/s

623. Draw a ray diagram to show how a right angled isosceles prism can be used to- **CBSE (AI)-2015,(DC)-2001**

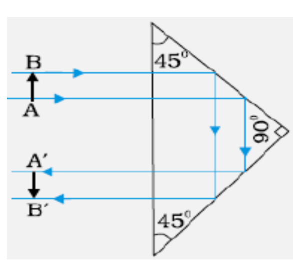
(i) deviate a light ray through (i) 90^0, (ii) deviate a light ray through 180^0/ to obtain the inverted image

(iii) to invert an image without the deviation of the rays ?

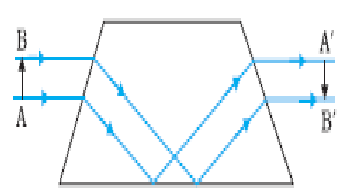
[Ans. (i)



(ii)



(iii)



624. Why does a diamond sparkle ? **CBSE (D)-2009,2002**

[Ans. The brilliance of diamond is due to total internal reflection of light

Refractive index of diamond is very large (2.42) so its critical angle is small (24.4^0). The faces of diamond are cut in such a manner that light entering diamond from any face suffers multiple total internal reflections and remains within the diamond but it comes out through only a few faces. Hence the diamond sparkles.

625. Find the relation between critical angle and refractive index. **CBSE (AI)-2016**

[Ans. By Snell's law, $\frac{\sin i}{\sin r} = \frac{1}{\mu}$

But when $i = i_c,\ r = 90^0$

⇨ $\frac{\sin\ i_c}{\sin 90} = \frac{1}{\mu}$ ⇨ $\mu = \frac{1}{\sin\ i_c}$

626. What is an optical fibre ? Name the phenomenon on which working of an optical fibre is based. Give any two uses of optical fibres. **CBSE (AI)-2016,(D)-2011**

[Ans. Optical fibre : An optical fibre is a fine strand of quality glass/quartz surrounded by a glass coating of slightly lower refractive index called cladding.

Phenomenon : Total internal reflection of light

Uses : (a) in transmission of optical signals

(b) as light pipe in medical examination of stomach etc.

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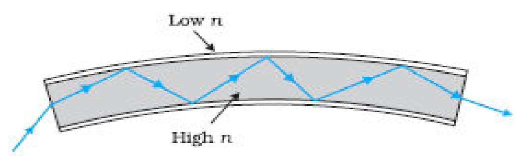
627. Draw a labelled diagram of an optical fibre. Explain how light propagates through the optical fiber.

[Ans. Phenomenon : Total internal reflection **CBSE (AI)-2016,(D)-2011**

Working :

When a signal in the form of light enters at one end of the fibre at suitable angle, it undergoes repeated total internal reflections and finally comes out at the other end.



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628 What is scattering light ? What is the condition for Rayleigh scattering to occur ? **CBSE (AIC)-2010**

[Ans. Scattering of light : This is the phenomenon in which light is deflected from its path due to its interaction with the particles of the medium through which it passes.

Condition : size of scatterer $a \ll \lambda$

629. Why cannot we see clearly through fog ? Name the phenomenon responsible for it. **CBSE (AI)-2016**

[Ans. Some light gets deviated/ scattered/ absorbed

Phenomenon- Scattering of light

630. Why does bluish colour predominate in the sky ? **CBSE (AI)-2015,2008,(D)-2010**

[Ans. due to most scattering of blue light

as blue light has the smallest wavelength and as per Rayleigh's law of scattering, intensity of scattered light $I \propto \frac{1}{\lambda^4}$

631. Why does Sun appears red at sunrise and sunset ? **CBSE (AI)-2016,(F)-2015**

[Ans. due to least scattering of red light

as red light has the longest wavelength and as per Rayleigh's law of scattering, intensity of scattered light $I \propto \frac{1}{\lambda^4}$

632. Clouds appear white. Why ? **CBSE (AIC)-2010**

[Ans. due to equal scattering of all colours of light

Large particles such as dust, raindrops, ice particle do not scatter light in accordance with Raleigh's law but scatters light of all colours almost equally

633 Give reasons for the following observations on the surface of the moon : **CBSE (AI)-2000**

(a) Sunrise and sunset are abrupt. (b) Sky appears dark (c) a rainbow is never formed.

[Ans. (a) Moon has no atmosphere. There is no scattering of light. Sunlight reaches the moon straight covering the short distance. Hence sunrise and sunset are abrupt.

(b) Moon has no atmosphere. There is nothing to scatter sunlight towards the moon. No skylight reaches moon surface. Hence sky appears black in the day time as it does at night.

(c) No water vapours are present at moon surface. No clouds are formed. There are no rains on the moon, so rainbow is never formed

634 Why is aperture of objective lens of a telescope is taken large ? **CBSE (AI)-2013**

[**Ans.** to increase the light gathering capacity and hence brightness of the image

635. State two main considerations taken into account while choosing the objective in optical telescopes with large diameters.

[**Ans.** (i) better light gathering power **CBSE (AI)-2015**

(ii) high resolving power

636. The objective of a telescope is of larger focal length and of larger aperture (as compared to eye piece). Why ?

[**Ans.** **(i)** Objective of larger focal length increases magnification ($m = -\frac{f_o}{f_e}$) **CBSE (AIC)-2013**

(ii) Objective of larger aperture has large light gathering capacity and hence increases the brightness of image/ have a high resolving power

637. Why is eye piece of a telescope is of short focal length, while objective of large focal length ? Explain.

[**Ans.** $m = -\frac{f_o}{f_e}$ **CBSE (F)-2013**

⇨ for large angular magnification, $f_o \gg f_e$

Hence, focal length of objective should be large, while focal length of eye piece should be small

638. State the condition under which a large magnification can be achieved in an astronomical telescope. **CBSE (F)-2017**

[**Ans.** $m = -\frac{f_o}{f_e}$

(i) By increasing f_o /decreasing f_e or $f_o \gg f_e$

(ii) Distance between two lenses $L > f_0 + f_e$

639. You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope ? Give reason. **CBSE (AI)-2017,(D)-2009**

Lenses	Power (D)	Aperture (cm)
L_1	3	8
L_2	6	1
L_3	10	1

[**Ans.** **Objective lens** : Lens L_1

& **Eye piece** : Lens L_3

Reason : $m = -\frac{f_o}{f_e}$

⇨ for higher magnification & brighter image, objective should have large aperture and large focal length & eye piece should have small aperture and small focal length

640. You are given three lenses of power $0.5\ D, 4\ D$ and $10\ D$ to design a telescope. Which lenses should you use as an objective and eyepiece of an astronomical telescope ? Justify your answer. **CBSE (AI)-2016**

[**Ans.** **Objective lens** : $0.5\ D$

& **Eye piece** : $10\ D$

Justification : $m = -\frac{f_o}{f_e}$

⇨ for higher magnification, objective should have large focal length & eye piece should have small focal length

641. Write two main limitations of refracting telescopes. Explain how these can be minimized in a reflecting telescope.

[**Ans.** **Limitations of refracting telescope**: **CBSE (F)-2016,2015,(AI)-2013**

(i) Suffers from spherical aberration . It can be corrected by using parabolic mirror objective

(ii) Suffers from chromatic aberration. It can be corrected by using mirror objective instead of spherical lens

(iii) Image is less bright/ small magnifying power/small resolving power

In reflecting telescope image is bright due to reflection and has high resolving power due to large aperture

642. Give two reasons to explain why a reflecting telescope is preferred over a refracting telescope. **CBSE (F)-2017**

OR

State the advantages of reflecting telescope over refracting telescope. **CBSE (AI)-2016,2015,(D)-2016,2009**

[**Ans.** (i) No chromatic/spherical aberration as mirror is used as objective in reflecting telescope

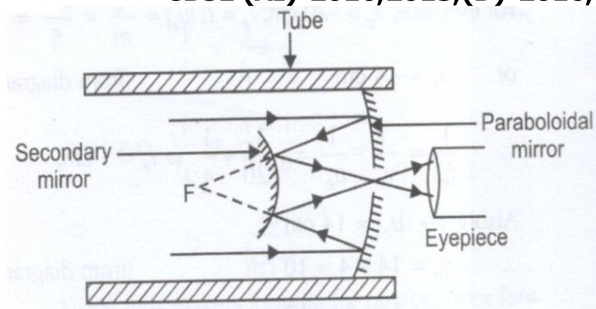
(ii) Brighter image/ high resolving power as mirror of large aperture is used as objective in reflecting telescope

643. (i) Draw a schematic diagram of a reflecting telescope. State the advantages of reflecting telescope over refracting telescope.
(ii) What is its magnifying power ? **CBSE (AI)-2016,2015,(D)-2016,2009**

[Ans. Advantages of reflecting telescope

(i) No chromatic aberration
(ii) No spherical aberration
(iii) Brighter image
(iv) large magnifying power
(v) High resolving power

$$m = \frac{angle\ subtended\ at\ the\ eye\ by\ image}{angle\ subtended\ at\ the\ eye\ by\ object} = \frac{f_o}{f_e}$$



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644. Does the magnifying power of a microscope depend on the colour of the light used ? Justify your answer.

[Ans. Yes Justification : $m \propto \frac{1}{f_o f_e}$ & focal length depends on colour/μ **CBSE (F)-2017**

645. Explain, why must both the objective and the eye piece of a compound microscope have short focal lengths ?

[Ans. $m = \frac{L}{f_o}$ X $\frac{D}{f_e}$ **CBSE (D)-2017,(D)-2009**

⇨ to increase magnifying power both the objective and the eye piece must have short focal lengths

646. Explain, why is the objective of a compound microscope be of short aperture ? **CBSE (AIC)-2014**

[Ans. to minimize spherical aberration and to collect all the reflected light from object to produce brighter image

647. Explain, While viewing through a compound microscope, why should our eyes be positioned not on the eye piece but a short distance away from it for best viewing ? **NCERT-2017**

[Ans. To collect complete light refracted by the objective and to increase field of view

648. You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct a compound microscope ? Give reason. **CBSE (AI)-2017**

Lenses	Power (D)	Aperture (cm)
L_1	3	8
L_2	6	1
L_3	10	1

[Ans. Objective lens : Lens L_3 **Eye piece** : Lens L_2

Reason : Objective of a microscope should have small aperture and smallest focal length eye piece of a microscope should have small aperture and small focal length (but longer focal length than aperture)

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649. What is dispersion of light ? What is its cause ? **CBSE (D)-2016**

[Ans. Dispersion of light : When a ray of white light is incident on a glass prism, it splits into its seven constituent Colours. This phenomenon is called dispersion of light.

Cause of dispersion : Refractive index of material of prism is different for different colours of light. Hence from $\delta = (\mu - 1)\,A$, different colour will deviate through different angles

650. How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced by red light ? Give reason.

[Ans. Decreases, Reason : $\delta = (\mu - 1)A$ & $\mu_{red} < \mu_{Violet}$ or $\lambda_{red} > \lambda_{Violet}$ **CBSE (AI)-2017**

651. Violet colour is seen at the bottom of the spectrum when white light is dispersed by a prism. Give reason

[Ans. $\delta = (\mu - 1)A$ & $\mu_{Violet} > \mu_{red}$ ⇨ $\delta_{Violet} > \delta_{red}$ **CBSE (D)-2010**

Hence, Violet colour is seen at the bottom of the spectrum when white light is dispersed by a prism

652. Out of blue and red light which is more deviate by prism ? Give reason. **CBSE (D)-2010**

[Ans. $\delta = (\mu - 1)A$ & $\mu_{blue} > \mu_{red}$ ⇨ $\delta_{blue} > \delta_{red}$ Hence, blue light deviates more than red light by a prism

653. For which colour the refractive index of prism material is maximum and minimum ? **CBSE (D)-2010**

[Ans. $\mu = a + \frac{b}{\lambda^2}$ & $\lambda_{Violet} < \lambda_{red}$ ⇨ $\mu_{Violet} > \mu_{red}$

Hence, refractive index of prism material is maximum for violet and minimum for red colour

654. How is the focal length of a spherical mirror affected, when the wavelength of light used is increased ?
[Ans. No change as focal length of a spherical mirror does not depend on wavelength **CBSE (AI)-2000**

655. How is the focal length of a spherical mirror is affected, when it is immersed in water/Glycerin ? **CBSE (F)-2010**
[Ans. No change as focal length of a spherical mirror does not depend on medium

657. How is the focal length of a spherical lens affected, when the wavelength of light used is increased ?
[Ans. Focal length of the lens increases **CBSE (AI)-2016,(F)-2010**

Reason : $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ & $\mu = a + \frac{b}{\lambda^2}$

658. How does focal length of a convex lens change, if violet light is used instead of red light ?
[Ans. Focal length of the lens decreases **CBSE (F)-2012,(AI)-2010**

Reason : $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ & $\mu = a + \frac{b}{\lambda^2}$

As $\lambda_{Violet} < \lambda_{red}$ ⇨ $\mu_{Violet} > \mu_{red}$ ⇨ $f_{Violet} < f_{red}$

659. Explain with reason, how the power of a diverging lens changes when incident red light is replaced by violet light.
[Ans. Power of the lens will increases **CBSE (AIC)-2017**

Reason : $\boldsymbol{P} = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ & $\mu = a + \frac{b}{\lambda^2}$

As $\lambda_{Violet} < \lambda_{red}$ ⇨ $\mu_{Violet} > \mu_{red}$ ⇨ $P_{Violet} > P_{red}$

660. What happens to the focal length of a convex lens when it is immersed in water ? Refractive index of the material of lens is greater than that of water . **CBSE (AI)-2016**
[Ans. Focal length will increase hence power will decrease

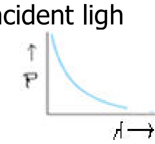
$P = \frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ As μ_1 increases f increases $(\mu_1\ for\ water > \mu_1\ for\ air)$

661. A lens of glass is immersed in water. What will be its effect on the power of lens ? **CBSE (AI)-2003**
[Ans. Power of the lens will decrease

$P = \frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ As μ_1 increases P decreases $(\mu_1\ for\ water > \mu_1\ for\ air)$

662. Draw a plot showing the variation of power of a lens with the wavelength of incident ligh **CBSE (D)-2008**
[Ans. Power of the lens decreases with increase in wavelength

Reason : $\boldsymbol{P} = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ & $\mu = a + \frac{b}{\lambda^2}$



663. A glass lens of refractive index 1.45 disappears when immersed in a liquid. What is the value of refractive index of the liquid ? **CBSE (D)-2010**
[Ans. The refractive index of the liquid should be equal to that of the lens, i,e, 1.45

664. What should be the value of the refractive index of the medium in which the lens should be placed so that it acts as a plane sheet of glass ? **CBSE (AI)-2015**

OR

Under what condition does a biconvex lens of glass having a certain refractive index acts as a plane glass sheet when immersed in a liquid ? **CBSE (D)-2012**
[Ans. The refractive index of the medium/liquid should be equal to that of the lens

665. Explain with reason, how the power of a diverging lens changes when it is kept in a medium of refractive index greater than that of the lens. **CBSE (AIC)-2017**
[Ans. Power will become positive, i,e, lens will behave as Converging lens.

Reason : $P = \frac{1}{f_m} = -\left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ As $\mu_m > \mu_g$ ⇨ $P = \frac{1}{f_m} =$ +ve

666. A biconcave lens made of transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave a converging or diverging lens ? Give reason. **CBSE (D)-2015,(AI)-2014**
[Ans. Converging lens.

Reason : $\frac{1}{f_m} = -\left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

As $\mu_m > \mu_g$ ⇨ $\frac{1}{f_m} =$ +ve ⇨ $f_m > 0$

667. A biconvex lens made of transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave a converging or diverging lens ? Give reason. **CBSE (AI)-2014**

[Ans. Diverging lens.

Reason : $\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ As $\mu_m > \mu_g$ ⇨ $\frac{1}{f_m} = -\text{ve}$ ⇨ $f_m < 0$

668. A biconvex lens made of transparent material of refractive index 1.5 is immersed in water of refractive index 1.33. Will the lens behave a converging or diverging lens ? Give reason. **CBSE (AI)-2014**

[Ans. Converging lens.

Reason : $\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ As $\mu_m < \mu_g$ ⇨ $\frac{1}{f_m} = +\text{ve}$ ⇨ $f_m > 0$

669. A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in **CBSE (AI)-2011**

(i) a medium of refractive index 1.65, (ii) a medium of refractive index 1.33

Will the lens behave a converging or diverging lens in the two cases ? Give reason.

[Ans. (i) Diverging lens.

Reason : $\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ As $\mu_m > \mu_g$ ⇨ $\frac{1}{f_m} = -\text{ve}$ ⇨ $f_m < 0$

(ii) Converging lens.

Reason : $\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ As $\mu_m < \mu_g$ ⇨ $\frac{1}{f_m} = +\text{ve}$ ⇨ $f_m > 0$

670. A converging lens is kept coaxially in contact with a diverging lens, both the lenses being of equal focal length. What is the focal length of the combination ? **CBSE (AI)-2016,2010**

[Ans. $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f} + \frac{1}{-f} = 0$

⇨ $F = \infty$ hence the combination will act as a plan e glass plate

671. Two thin lenses of power $+6\,D$ and $-2\,D$ are in contact. What is the focal length of this combination ?

[Ans. $P = P_1 + P_2 = +6 - 2 = +4\,D$ **CBSE (D)-2009**

⇨ $F = \frac{1}{P} = \frac{1}{4} = 0.25\ m = 25\ cm$

672. A convex lens of focal length $25\ cm$ is placed coaxially in contact with a concave lens of focal length $20\,cm$. Determine the power of the combination will the system be converging or diverging in nature ? **CBSE (AI)-2013**

[Ans. $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{25} + \frac{1}{-20} = \frac{4-5}{100} = -\frac{1}{100}$ ⇨ $F = -100\,cm = -1\ m$

⇨ $P = \frac{1}{F} = \frac{1}{-1} = -1$ hence the combination will be diverging in nature

673. The focal length of a convex lens made of glass($\mu = 1.5$) is 22 cm. What will be its new focal length when placed in a medium of refractive index 4/3 ? **CBSE (F)-2017,2016,(AI)-2015**

[Ans. $f_{medium} = \frac{({}_a\mu_g - 1)}{\left(\frac{{}_a\mu_g}{{}_a\mu_w} - 1\right)} \times f_{air} = \frac{(3/2-1)}{\left(\frac{3/2}{4/3} - 1\right)} \times 22 = 4 \times 22 = 88\,cm$

674. A double convex lens is made of a glass of refractive index 1.55, with both faces of the same radius of curvature. Find the radius of curvature required, if the focal length is 20 cm. **CBSE (AI)-2017,NCERT-2017**

[Ans. For biconvex lens, $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

⇨ $\frac{1}{20} = (1.55 - 1)\left(\frac{1}{R} + \frac{1}{R}\right)$ ⇨ $\frac{1}{20} = (0.55)\left(\frac{2}{R}\right)$ ⇨ $R = 2 \times 0.55 \times 20 = 22\ cm$

675. The focal length of an equiconvex lens is equal to the radius of curvature of either face. What is the refractive index of the material of the lens ? **CBSE (AI)-2015**

[Ans. $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} + \frac{1}{R}\right) = (\mu - 1)\left(\frac{2}{R}\right)$

But $f = R_1 = R_2 = R$ ⇨ $\frac{1}{R} = (\mu - 1)\left(\frac{2}{R}\right)$ ⇨ $\frac{1}{2} = (\mu - 1)$ ⇨ $\mu = \frac{1}{2} + 1 = \frac{3}{2}$

676. The radii of curvature of the faces of a double convex lens are $10\ cm$ and $15\ cm$. If the focal length of the lens is $12\ cm$, find the refractive index of the material of the lens ? **CBSE (D)-2010**

[Ans. $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ ⇨ $\frac{1}{12} = (\mu - 1)\left(\frac{1}{10} + \frac{1}{15}\right) = (\mu - 1)\left(\frac{3+2}{30}\right) = (\mu - 1)\left(\frac{1}{6}\right)$

⇨ $\mu - 1 = \frac{6}{12} = \frac{1}{2}$ ⇨ $\mu = 1 + \frac{1}{2} = \frac{3}{2}$

678. A concave mirror produces a real and magnified image of an object kept in front of it. Draw a ray diagram to show The image formation and use it to derive the mirror equation. **CBSE (AI)-2015**

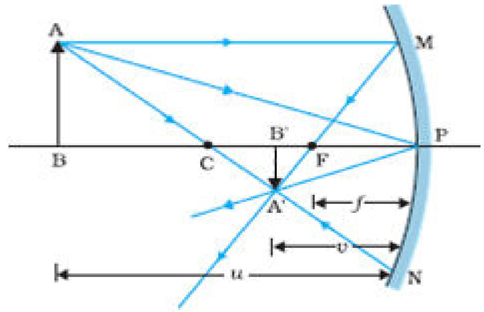
[Ans. Derivation of mirror formula:

ΔABC and $\Delta A'B'C$ are similar

$\therefore \quad \frac{B'A'}{BA} = \frac{B'C}{CB} = \frac{PC-PB'}{PB-PC}$ -----------(1)

ΔABP and $\Delta A'B'P$ are also similar

$\therefore \quad \frac{B'A'}{BA} = \frac{PB'}{PB}$ ----------(2)



⇨ from equation (1) and (2)

$$\frac{PC-PB'}{PB-PC} = \frac{PB'}{PB}$$

⇨ $\frac{-2f-(-v)}{-u-(-2f)} = \frac{-v}{-u}$ ⇨ $\frac{v-2f}{2f-u} = \frac{v}{u}$ ⇨ $uv - 2uf = 2vf - uv$

⇨ $2uv = 2vf + 2uf$

Dividing by $2uvf$ on both sides we get, $\frac{2uv}{2uvf} = \frac{2vf}{2uvf} + \frac{2uf}{2uvf}$

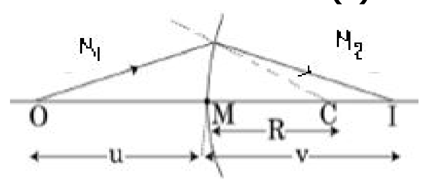
⇨ $$\boxed{\frac{1}{f} = \frac{1}{u} + \frac{1}{v}}$$

===

679. A point object O on the principal axis of a spherical surface of radius R separating two media of refractive indices μ_1 and μ_2 forms an image 'I' as shown in the figure. **CBSE (F)-2017,(AI)-2015**

Prove that

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2-\mu_1)}{R}$$



[Ans. By Snell's law, $\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$

For small angles, $\frac{i}{r} = \frac{\mu_2}{\mu_1}$

⇨ $\mu_1 i = \mu_2 r$ -----------(1)

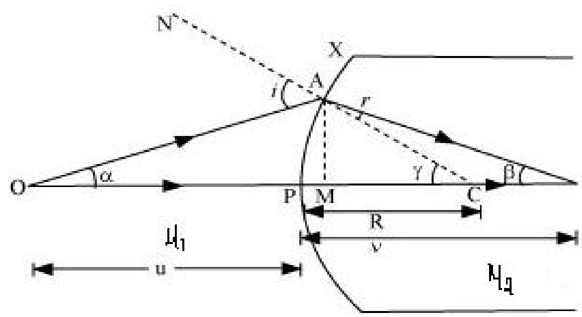
In Δ OAC and Δ IAC,

$i = \alpha + \gamma$ & $\gamma = r + \beta$

⇨ from (1),

$\mu_1(\alpha + \gamma) = \mu_2(\gamma - \beta)$

⇨ $\mu_1\alpha + \mu_2\beta = (\mu_2 - \mu_1)\gamma$ ----------(2)



let the aperture of the surface is also very small then we have

$\alpha \approx \tan\alpha = \frac{AM}{MO} \approx \frac{AM}{PO}$

$\beta \approx \tan\beta = \frac{AM}{MI} \approx \frac{AM}{PI}$ & $\gamma \approx \tan\gamma = \frac{AM}{MC} \approx \frac{AM}{PC}$

⇨ from equation (2)

$\mu_1\left(\frac{AM}{PO}\right) + \mu_2\left(\frac{AM}{PI}\right) = (\mu_2-\mu_1)\left(\frac{AM}{PC}\right)$

⇨ $\frac{\mu_1}{-u} + \frac{\mu_2}{+v} = \frac{(\mu_2-\mu_1)}{+R}$

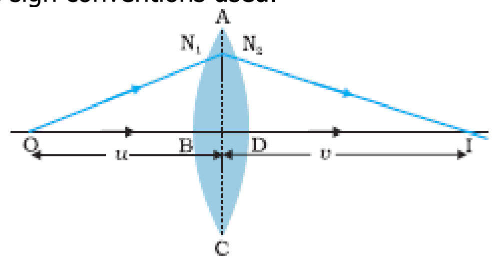
$$\boxed{\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2-\mu_1)}{R}}$$ Or $$\boxed{\frac{\mu}{v} - \frac{1}{u} = \frac{(\mu-1)}{R}}$$

680. Derive expression for the lens maker's formula using necessary ray diagrams. **CBSE (AI)-2016,2014,2012,2011**

$$\frac{1}{f} = (\mu_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Also state the assumptions in deriving the above relation and the sign conventions used.

[Ans. For the refraction at the interface ABC,

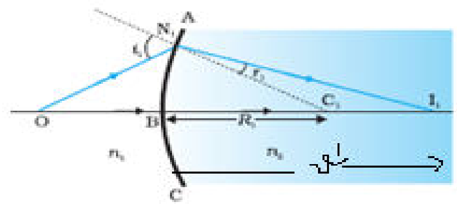


$$\frac{\mu_2}{v'} - \frac{\mu_1}{u} = \frac{(\mu_2 - \mu_1)}{R_1} \qquad \text{---------(1)}$$

For the refraction at ADC, image I_1 will act as an imaginary object and if the lens is very thin, then

$$\frac{\mu_1}{v} - \frac{\mu_2}{v'} = -\frac{(\mu_2 - \mu_1)}{R_2} \qquad \text{---------(2)}$$

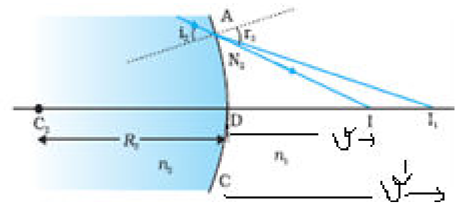
on adding (1) & (2) we get



$$\frac{\mu_1}{v} - \frac{\mu_1}{u} = (\mu_2 - \mu_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{v} - \frac{1}{u} = \frac{(\mu_2 - \mu_1)}{\mu_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{v} - \frac{1}{u} = (\mu_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$



But when $u = -\infty$ then $v = f$

$$\Rightarrow \frac{1}{f} - \frac{1}{-\infty} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\boxed{\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

Assumptions used :

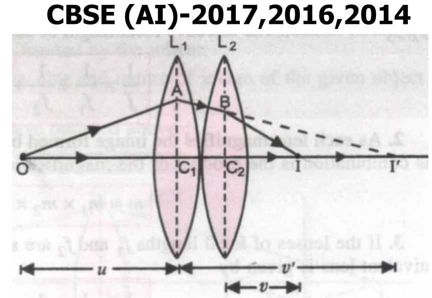
(i) lens used is very thin.
(ii) Aperture of the lens is very small
(iii) Object is a point object placed at the principal axis.
(iv) All the rays are paraxial.

New Cartesian sign conventions used :

(i) All distances are measured from the optical centre of the lens
(ii) Distances measured in the direction of incident ray are positive
(iii) Distances measured in the opposite direction of incident ray are negative.

==

681. Two thin convex lenses L_1 and L_2 of focal lengths f_1 and f_2 respectively, are placed coaxially in contact. An object is placed at a point beyond the focus of lens L_1. Draw a ray diagram to show the image formation and hence derive the expression for the focal length of the combined system. **CBSE (AI)-2017,2016,2014**



[Ans. For the refraction by lens L_1 we have

$$\frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1} \qquad \text{---------------(1)}$$

For the refraction by lens L_2, I' will act as an imaginary object,

$$\Rightarrow \frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2} \qquad \text{--------------(2)}$$

On adding equation (1) and (2) we get

$$\frac{1}{v'} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v'} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\Rightarrow \frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \qquad \text{------------(3)}$$

Let F be the focal length of this lens combination then we have

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{F} \qquad \text{-------------(4)}$$

From (3) and (4),

$$\boxed{\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}}$$

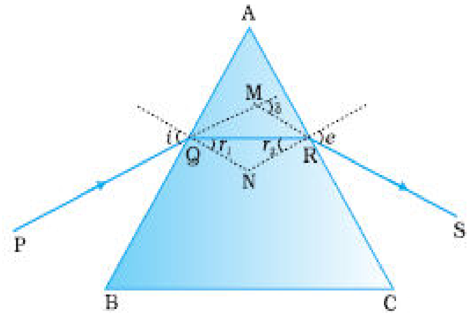
682. Draw a ray diagram to show the refraction of light through a glass prism. Hence derive the relation

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2}$$

CBSE (F)-2017,(AI)-2016,(D)-2016

[Ans. Refraction through a glass prism :

Let a light ray is incident on the principal section ABC of a glass prism as shown



In quadrilateral AQNR,

$\angle A + 90^0 + \angle QNR + 90^0 = 360^0$

⇨ $\angle A + \angle QNR = 180^0$ ----------(1)

In triangle QNR,

$r_1 + r_2 + \angle QNR = 180^0$ ----------(2)

From (1) and (2)

$r_1 + r_2 = A$ --------(3)

Now, total deviation

$\delta = (i - r_1) + (e - r_2) = (i + e) - (r_1 + r_2)$

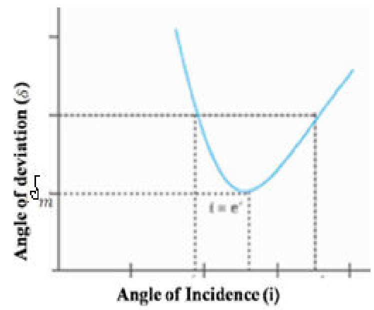
⇨ $\delta = i + e - A$ ---------(4)

But when $\delta = \delta_m$, $i = e$ hence $r_1 = r_2$

⇨ from (3), $2r = A$ ⇨ $r = A/2$

From (4), $\delta_m = 2i - A$ ⇨ $i = (A + \delta_m)/2$

⇨ $\mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2}$



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683. A ray of light incident on an equilateral glass prism propagates parallel to the base line of the prism inside it. Find the angle of incidence of this ray. Given refractive index of material of glass prism is $\sqrt{3}$. **CBSE (AI)-2016,2015**

[Ans. Given : $\mu_g = \sqrt{3}$, $A = 60^0$, i = ?

If the ray moves parallel to the base line, it means that, $r_1 = r_2 = r$

As $r_1 + r_2 = A$ ⇨ $2\,r = 60^0$ ⇨ $r = 30^0$

$\mu_g = \frac{\sin i}{\sin r}$ ⇨ $\sqrt{3} = \frac{\sin i}{\sin 30^0}$ ⇨ $\sin i = \sqrt{3} \times \sin 30^0 = \sqrt{3} \times 1/2 = \sqrt{3}/2$ ⇨ $i = 60^0$

==

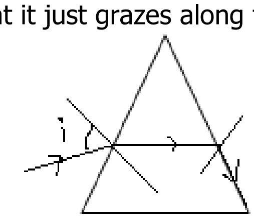
684. Determine the value of the angle of incidence for a ray of light travelling from a medium of refractive index $\mu_1 = \sqrt{2}$ into the medium of refractive index $\mu_2 = 1$, so that it just grazes along the surface of separation. CBSE (F)-2017

[Ans. From Snell's law,

$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$

⇨ $\frac{\sin i}{\sin 90} = \frac{1}{\sqrt{2}}$

⇨ $\sin i = \frac{1}{\sqrt{2}}$ ⇨ $i = 45^0$



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685. A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is 3/4 th of the angle of prism. Calculate the speed of light in the prism. **CBSE (AI)-2017**

[Ans. Given : $A = 60^0$, & $i = \frac{3}{4}A$ ⇨ $i = \frac{3}{4} \text{ X } 60 = 45^0$

At minimum deviation, $r = A/2 = 60/2 = 30^0$

⇨ $\mu = \frac{\sin i}{\sin r} = \frac{\sin 45}{\sin 30} = \frac{1/\sqrt{2}}{1/2} = \frac{2}{\sqrt{2}} = \sqrt{2}$

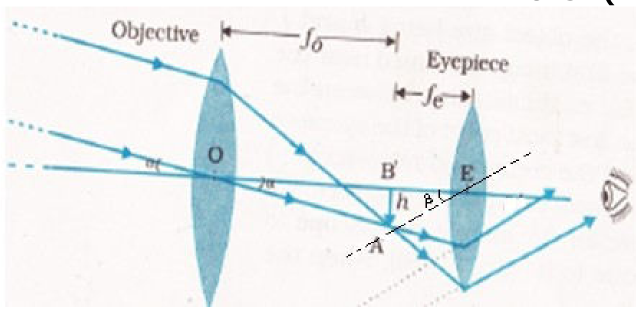
But, $\mu = \frac{c}{v}$ ⇨ $v = \frac{c}{\mu} = \frac{3 \text{ X } 10^8}{\sqrt{2}} = 2.1 \text{ X } 10^8\ m/s$

686. (i) Draw a labelled ray diagram to show the image formation by an astronomical telescope in normal adjustment.

(ii) Define magnifying power of an astronomical telescope in normal adjustment (i,e, when the final image is formed at infinity).

(iii) Derive the expression for its magnifying power in normal adjustment.

[**Ans.** **CBSE (AI)-2017,2016,(F)-2016,2009**



Magnifying power : It is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye by the object, when both are at infinity

$$m = \frac{\beta}{\alpha} \approx \frac{\tan\beta}{\tan\alpha} = \frac{B'A'/EB'}{B'A'/OB'} = \frac{OB'}{EB'} = \frac{f_0}{-f_e}$$

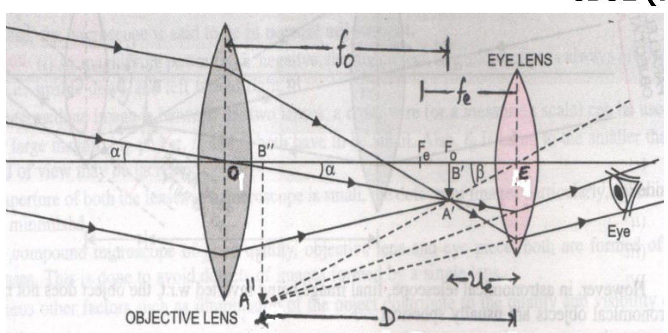
⇨ $m = -\frac{f_0}{f_e}$

===

687. (i) Draw a labelled ray diagram of an astronomical telescope when the final image is formed at least distance of distinct vision.

(ii) Define its magnifying power and deduce the expression for the magnifying power of telescope.

[**Ans.** **CBSE (F)-2015,2014,(AI)-2013**



Magnifying power : It is defined as the ratio of the angle subtended at the eye by the image at the least distance of the distinct vision to the angle subtended at the eye by the object at infinity, when seen directly

$$m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha} = \frac{A'B'/EB'}{A'B'/OB'} = \frac{OB'}{EB'} = -\frac{f_0}{u_e} \quad \text{-------(1)}$$

But for eye lens,

$$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{-D} + \frac{1}{u_e}$$

⇨ $\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D} = \frac{1}{f_e}\left(1 + \frac{f_e}{D}\right)$

⇨ from (1), $m = -\frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$

688. Write the main considerations required in selecting the objective and eye piece lenses in order to have large magnifying power and high resolution of the telescope **CBSE (AI)-2014**

[**Ans.** $m = -\frac{f_o}{f_e}$ & $R.P. = \frac{D}{1.22\ \lambda}$

(i) to have large magnifying power $f_o \gg f_e$

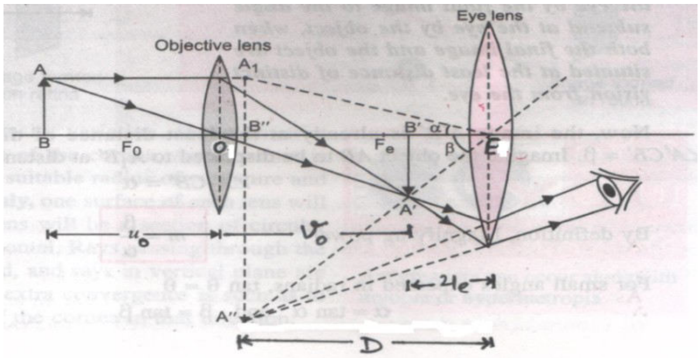
Hence, focal length of objective should be large, while focal length of eye piece should be small

(ii) to have high resolving power D should be large. Hence aperture of objective should be large

689. Draw a labelled ray diagram of a compound microscope when image is formed at least distance of distinct vision. Define its magnifying power and deduce the expression for the magnifying power of the microscope.

CBSE (AI)-2016,2010,(F)-2015,2013,(D)-2014

[Ans. ray diagram of a compound microscope when the final image is at least distance of distinct vision:



Magnifying power : It is defined as the ratio of the angle subtended at the eye by the image to the angle subtended at the eye by the object, when both lie at the least distance of distinct vision.

$$m = \frac{\beta}{\alpha} \approx \frac{\tan\beta}{\tan\alpha} = \frac{B'A'/EB'}{BA/EB} = \left(\frac{B'A'}{BA}\right)\left(\frac{EB}{EB'}\right) = \left(\frac{v_0}{-u_o}\right)\left(\frac{-D}{-u_e}\right)$$

$$\Rightarrow \quad m = -\frac{v_0}{u_o}\left(\frac{D}{u_e}\right) \qquad \text{------------(1)}$$

But for eye lens,

$$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{-D} + \frac{1}{u_e}$$

$$\Rightarrow \frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D} = \frac{1}{D}\left(1 + \frac{D}{f_e}\right)$$

⇨ from (1),

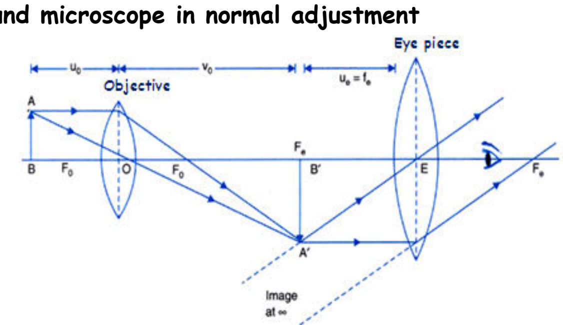
$$m = \frac{v_0}{u_o}\left(1 + \frac{D}{f_e}\right) = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

===

690. (i) Draw a labelled ray diagram for the formation of image by a compound microscope in normal adjustment.

(ii) Define magnifying power of a compound microscope in normal adjustment and derive an expression for it.

[Ans. ray diagram of a compound microscope in normal adjustment **CBSE (D)-2017,(AI)-2015**



[Ans. Magnifying power : Magnifying power of a compound microscope is defined as the angle subtended at the eye by the final image to the angle subtended (at the un aided eye) by the object

$m = m_0 \text{ X } m_e = \frac{v_0}{u_0} \text{ X } \frac{D}{fe}$

When the object is very close to f_o, and the image formed is very close to eye lens, then

$u_o \simeq f_o$ and $v_o \simeq$ L

$$\boldsymbol{m = -\frac{L}{f_o} \text{ X } \frac{D}{f_e}}$$

691. Three rays (1,2,3) of different colours fall normally on one of the sides of an isosceles right angled prism as shown. The refractive index of prism for these rays is 1.39, 1.47 and 1.52 respectively. Find which of these rays get internally reflected and which get only refracted from AC. Trace the path of rays. Justify your answer.

[Ans. **For TIR,** $i > i_c$ **CBSE (F)-2016,(AI)-2011,(D)-2009**

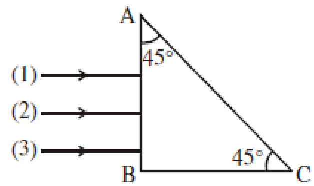
⇨ $\sin i > \sin i_c$

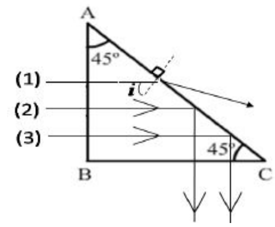
⇨ $\sin i > \frac{1}{\mu}$ $\quad [\because \mu = \frac{1}{\sin i_c}]$

⇨ $\mu > \frac{1}{\sin i} = \frac{1}{\sin 45} = \frac{1}{1/\sqrt{2}} = \sqrt{2}$

⇨ $\mu > \sqrt{2} = 1.414$

Hence rays (2) & (3) will go TIR





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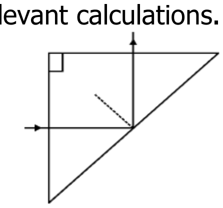
692. A ray of light incident normally on one face of a right isosceles prism is totally reflected as shown. What must be The minimum value of refractive index of glass ? Give relevant calculations. **CBSE (D)-2016**

[Ans. For TIR, $i \geq i_c$

⇨ $\sin i \geq \sin i_c$

⇨ $\sin 45 \geq \frac{1}{\mu}$ ⇨ $\frac{1}{\sqrt{2}} \geq \frac{1}{\mu}$

⇨ $\sqrt{2} \leq \mu$ ⇨ $\mu \geq \sqrt{2}$



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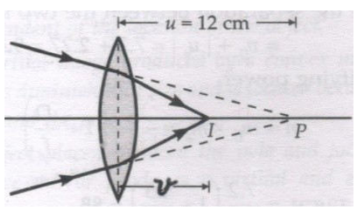
693. A beam of light converges at a point P. Now a lens is placed in the path of the convergent beam 12 cm from P. At what point does the beam converge if the lens is **CBSE (AI)-2015,NCERT-2017**

(i) a convex lens of focal length 20 cm,

(ii) a concave lens of focal length 16 cm ?

[Ans. u = + 12 cm, f = + 20 cm



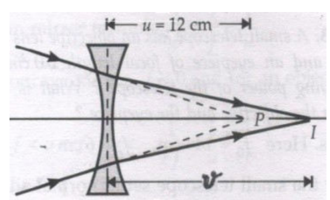
$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

⇨ $\frac{1}{20} = \frac{1}{v} - \frac{1}{12}$

⇨ $\frac{1}{v} = \frac{1}{20} + \frac{1}{12} = \frac{3+5}{60} = \frac{8}{60} = \frac{2}{15}$

⇨ $v = +7.5$ cm

u = + 12 cm, f = – 16 cm



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

⇨ $\frac{1}{-16} = \frac{1}{v} - \frac{1}{12}$

⇨ $\frac{1}{v} = \frac{1}{12} - \frac{1}{16} = \frac{4-3}{48} = \frac{1}{48}$

⇨ $v = +48$ cm

==

694. A ray of light incident on one of the faces of a glass prism of angle 'A' has angle of incidence 2A. The refracted ray in the prism strikes the opposite face which is silvered, the reflected ray from it retracing its path. Trace the ray diagram and find the relation between the refractive index of the material of the prism and the angle of the prism.

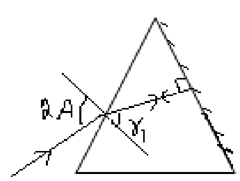
[Ans. We know **CBSE (AI)-2015**

$r_1 + r_2 = A$

But here, $r_2 = 0$

⇨ $r_1 = A$

⇨ $\mu = \frac{\sin i}{\sin r} = \frac{\sin 2A}{\sin A} = \frac{2 \sin A \cos A}{\sin A} = 2 \cos A$



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695. Using mirror formula, explain why does a convex mirror always produce a virtual image ? **CBSE (AI)-2016,2011**

[Ans. $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ ⇨ $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$ -------(1)

Hence from (1) v is always positive, hence image is always virtual

696. You are given two converging lenses of focal lengths 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, find out the separation between the objective and the eyepiece.

[Ans. $m = -\frac{L}{f_o}\left(1+\frac{D}{f_e}\right)$ **CBSE (AI)-2015**

⇨ $-30 = -\frac{L}{1.25}\left(1+\frac{25}{5}\right)$ ⇨ $-30 \text{ X } 1.25 = L \text{ X } 6$ ⇨ $L = 6.25\ cm$

697. (i) A small telescope has an objective lens of focal length 150 cm and eyepiece of focal length 5 cm. What is the magnifying power of the telescope for viewing distant objects in normal adjustment ? **CBSE (AI)-2015**

(ii) If this telescope is used to view a 100 m tall tower 3 km away, what is the height of the image of the tower formed by the objective lens ? **CBSE (AI)-2015**

[Ans. (i) $m = -\frac{f_0}{f_e} = -\frac{150}{5} = -30$

(ii) For objective lens, $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

⇨ $\frac{1}{1.5} = \frac{1}{v_o} - \frac{1}{-3000}$ ⇨ $\frac{1}{v_o} = \frac{1}{1.5} - \frac{1}{3000} = \frac{2000-1}{3000} = \frac{1999}{3000}$

⇨ $v_o = \frac{3000}{1999} \approx 1.5\ m$

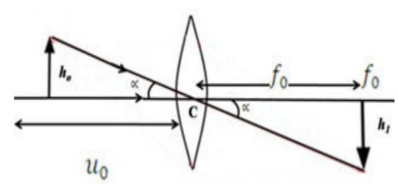
$h_2 = \frac{v_o}{u_o} \text{ X } h_1 = \frac{1.5}{3000} \text{ X } 100 = 0.05\ m$

698. (i) A giant refracting telescope has an objective lens of focal length 15 m. If an eye piece of focal length 1.0 cm is used, what is the angular magnification of the telescope ? **CBSE (D)-2015,(AI)-2011,NCERT-2017**

(ii) 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 $3.48 \times 10^6\ m$ and the radius of lunar orbit is $3.8 \text{ X } 10^8\ m$.

[Ans.(i) Angular magnification

$|m| = \frac{f_0}{f_e} = \frac{15}{1.0 \text{ X } 10^{-2}} = 1500$



(ii) Angle subtended by the moon

$\alpha = \frac{diameter\ of\ moon}{radius\ of\ lunar\ orbit} = \frac{3.48 \text{ X } 10^6}{3.8 \text{ X } 10^8} = \frac{3.48}{3.8} \text{ X } 10^{-2}$

Angle subtended by the image

$\alpha = \frac{diameter\ of\ image\ of\ moon}{f_0} = \frac{D}{f_o}$

⇨ $\frac{D}{f_o} = \frac{3.48}{3.8} \text{ X } 10^{-2}$ ⇨ $D = \frac{3.48}{3.8} \text{ X } 10^{-2} \text{ X } f_o = \frac{3.48}{3.8} \text{ X } 10^{-2} \text{ X } 15 = 13.73\ cm$

==

699. Monochromatic light of wavelength 589 nm is incident from air on a water surface. If μ for water is 1.33, find the wavelength, frequency and speed of the refracted light. **CBSE (AI)-2017,NCERT-2017**

[Ans. $\lambda' = \frac{\lambda}{\mu} = \frac{589}{1.33} = 442.89\ nm$

$\nu = \frac{c}{\lambda} = \frac{3 \text{ X } 10^8}{589 \text{ X } 10^{-9}} = 5.09 \text{ X} 10^{12} \text{ Hz}$

Speed $v' = \frac{c}{\mu} = \frac{3 \text{ X } 10^8}{1.33} = 2.25 \text{ X} 10^8\ m/s$

699*. Calculate the distance of an object of height h from a concave mirror of radius of curvature $20\ cm$, so as to obtain a real image of magnification 2. Also find the location of the image. **CBSE (D)-2016**

[Ans. Given, $R = -20\ cm$, $f = \frac{R}{2} = \frac{-20}{2} = -10\ cm$, $m = -2$, $u = ?$, $v = ?$

$m = -\frac{v}{u}$ ⇨ $-2 = -\frac{v}{u}$ ⇨ $v = 2u$ --------(1)

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ ⇨ $\frac{1}{-10} = \frac{1}{u} + \frac{1}{u}$ ⇨ $u = -15\ cm$

From (1) $v = 2 \text{ X} -15 = -30\ cm$

Chapter–10: Wave Optics

Wave optics: Wave front and Huygen's principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygen's principle. Interference, Young's double slit experiment and expression for fringe width, coherent sources and sustained interference of light, diffraction due to a single slit, width of central maximum, resolving power of microscope and astronomical telescope, polarisation, plane polarised light, Brewster's law, uses of plane polarised light and Polaroids.

601*. Define a wavefront. How is it different from a ray ? **CBSE (AI)-2017,2016,2015,2010,(D)-2013,2011**

[**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.

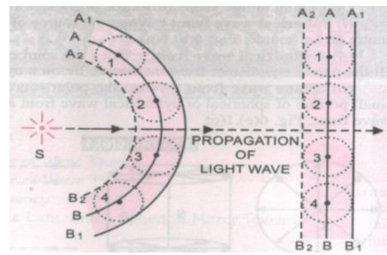
(ii) A ray gives the direction of propagation of light wave while the wavefront is the surface of constant phase

602*. State Huygen's principle. **CBSE (AI)-2016,2015,2010,2006,(D)-2013,2011,2008**

[**Ans. Huygen's Principle** :

(i) Each point on the wave front acts as a fresh source of new disturbance, called secondary wavelets, which spread out in all directions with the same velocity as that of the original wave

(ii) The forward envelope of these secondary wavelets drawn at any instant, gives the shape and position of new wave front at that instant



603*. (i) Sketch the wavefront that will emerge from a distance source of light like a star.

CBSE (F) -2010,(D)-2009,(AI)-2001,(AIC)-2004,2003

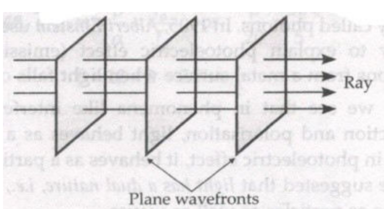
(ii) Sketch the shape of wavefront emerging/diverging from a point source of light and also mark the rays.

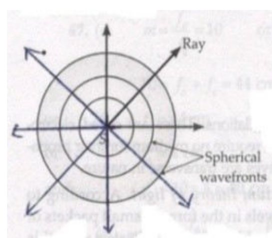
CBSE (F) -2009,2002,(D)-2009,2005, (AI)-2003,2001

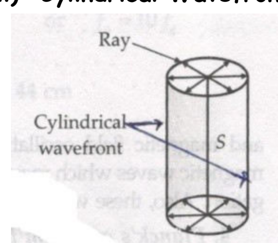
(iii) Sketch the wavefront that will emerge from a linear source of light like a slit.

CBSE (D)-2009,(F)-2002,(AI)-2001

[**Ans. (i) Plane wavefront** **(ii) Spherical wavefront** **(iii) Cylindrical Wavefront**







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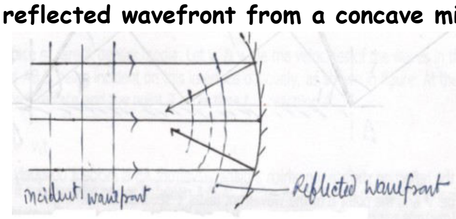
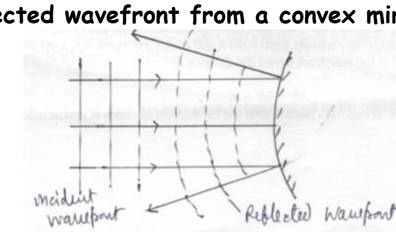
604*. Sketch the reflected wavefront emerging from a (i) concave mirror (ii) convex mirror, if plane wavefront is incident normally on it. **CBSE (AI)-2015,2006, (Sample Paper)-2011**

[**Ans. (i) reflected wavefront from a concave mirror** **(ii) reflected wavefront from a convex mirror**





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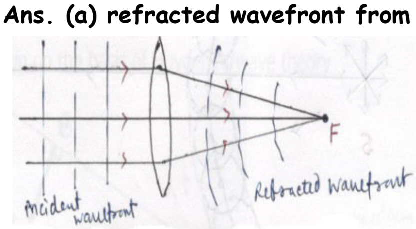
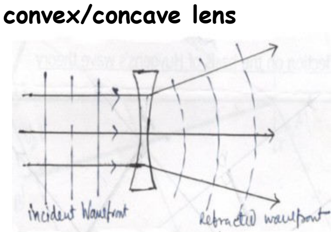
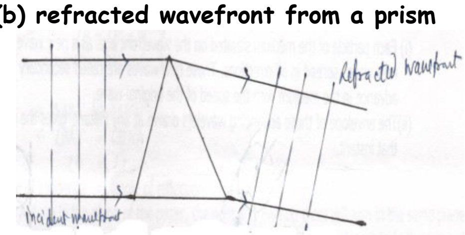
605*. Sketch the refracted wavefront emerging from a convex/concave lens/prism, if plane wavefront is incident normally on it.

CBSE (AI)-2016,2015,2006,2003,(AIC)-2004

[**Ans. (a) refracted wavefront from a convex/concave lens** **(b) refracted wavefront from a prism**







606*. What is interference of light ? Give one example of interference in daily life. **CBSE (AIC)-2012,(D)-2007**

[**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

607*. What are coherent sources of light ? Why are coherent sources necessary to produce a sustained interference pattern? **CBSE (D)-2012,2007,(F)-2009**

[**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

608*. What are the essential conditions for two light sources to be coherent ? **CBSE (AIC)-2004**

[**Ans.** (i) Two sources must produce waves of same frequency/ wavelength, and

(ii) phase difference between the waves must be zero or constant

609*. What happens to the interference pattern if phase difference between two light sources varies continuously ? **CBSE (AI)-2012,2009**

[**Ans.** Positions of bright and dark fringes would change rapidly hence the interference pattern shall not be sustained

610*. Why cannot two independent monochromatic sources produce sustained interference pattern ? **CBSE (AI)-2015, (D)-2015**

[**Ans.** Two independent sources do not maintain constant phase difference, therefore the interference pattern will also change with time

611*. 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 **CBSE (AIC)-2017**

[**Ans.** Interference pattern will not be observed as two independent lamps are not coherent sources

612*. Does the appearance of bright and dark fringes in the interference pattern violate, in any way, law of conservation of energy ? Explain. **CBSE (AIC)-2015**

[**Ans. No** , Appearance of the bright and dark fringes is simply due to a redistribution of energy

613*. Why does a soap bubble show beautiful colours when illuminated by white light ? Explain. **CBSE (AIC)-2004**

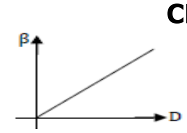
[**Ans. Due to Interference of light**

Reason : Light waves reflected from outer and inner surfaces of soap bubble interfere. For different wavelengths, conditions for constructive interference are satisfied at different positions. This is why beautiful colours are seen

614*. In Young's double slit experiment, plot a graph showing the variation of fringe width versus the distance of the screen from the plane of the slits keeping other parameters same. What information can one obtain from the slope of the curve ? **CBSE (AI)-2015**

[**Ans.** $\boldsymbol{\beta = \frac{D\lambda}{d}}$ ⇨ $\beta \propto D$

Slope $= \frac{\beta}{D} = \frac{\lambda}{d}$ ⇨ $\boldsymbol{\lambda} = (\text{Slope}) \times d$



615*. How would the angular separation of interference fringes in Young's double slit experiment change when the distance between the slits and screen is doubled/ halved ? **CBSE (AI)-2009**

[**Ans.** Angular separation ($\theta = \lambda/d$) remains unchanged as it does not depend on D

616*. In the Young's double slit experiment, how does the fringe width get affected if the entire experimental apparatus is immersed in water ? **CBSE (AI)-2011**

[**Ans.** fringe width will decrease, **Reason** : $\boldsymbol{\beta} = \frac{D\lambda}{d}$ & $\boldsymbol{\beta}_{water} = \frac{D\lambda/\mu_w}{d} = \frac{\beta}{\mu_w}$

617*. 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) ? **CBSE (D)-2011,2008**

[**Ans.** $\boldsymbol{\beta}_{water} = \frac{\boldsymbol{\beta}}{\mu_w} = \frac{\boldsymbol{\beta}}{4/3} = \frac{3}{4}\boldsymbol{\beta}$, so fringe width decreases to 3/4 times

618*. Two identical coherent waves each of intensity I_0 are producing interference pattern. What are the values of resultant Intensity at a point of (i) constructive interference (ii) destructive interference pattern ? **CBSE (DC)-2004**

[**Ans.** **(i)** $\mathbf{I}_{max} = (\sqrt{\mathbf{I_1}} + \sqrt{\mathbf{I_2}})^2 = (\sqrt{\mathbf{I_0}} + \sqrt{\mathbf{I_0}})^2 = (2\sqrt{\mathbf{I_0}})^2 = 4\,\mathbf{I_0}$

(ii) $\mathbf{I}_{min} = (\sqrt{\mathbf{I_1}} - \sqrt{\mathbf{I_2}})^2 = (\sqrt{\mathbf{I_0}} - \sqrt{\mathbf{I_0}})^2 = 0$

619*. What is diffraction of light ? State the essential condition for diffraction of light. **CBSE (F)-2016**

[**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, $a \approx \lambda$

620*. Why do secondary maxima get weaker in intensity with increasing the order ?Explain.**CBSE(AI)-2016,2014,2009**

OR

Explain how the intensity of diffraction pattern changes as the order (n) of the diffraction band varies. **CBSE(AIC)-2017**

[**Ans.** Intensity of diffraction pattern drops rapidly with order n because every higher order maxima gets intensity only from $\frac{1}{2n+1}$ part of the slit. The central maxima gets intensity from the whole slit $(n = 0)$

1st secondary maxima gets its intensity only from 1/3 of slit

2nd secondary maxima gets its intensity only from 1/5 of slit

and so on.

621*. Why do we not encounter diffraction effects of light in everyday observations ? **SE (AI)-2010,(F)-2009**

OR

Diffraction is common in sound but not common in light waves why ? **CBSE (D)-2002,(AI)-2000**

[**Ans.** This is because objects around us are much bigger in size as compared to the wavelength of visible light$(\simeq 10^{-6}m)$

622*. 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 ? **CBSE (F) -2009**

[**Ans.** $y_0 = 2D\lambda/a$ ⇨ Width of central maximum will be halved

623*. How is the width of central maxima in diffraction pattern due to a single slit affected if the entire apparatus is immersed in water. Justify your answer. **CBSE (F)-2009**

[**Ans.** $y'_0 = 2D\lambda'/a = \frac{2D\lambda/\mu}{a} = \frac{y_0}{\mu}$

624*. If the width of the slit is made double to original width in diffraction at a single slit, how does it affect the size and ntensity of the central band ? **CBSE (F) -2016,2012, (AI)-2012,2008, (D)-2012**

[**Ans.** $y_0 = 2D\lambda/a$ & $I \propto a^2$

Hence y_0 will become half and the intensity becomes 4 times

625*. How would the diffraction pattern due to a single slit be affected when the width of the slit is decreased ?

[**Ans.** $\theta_n = n\lambda/a$ **CBSE (F) -2013**

On decreasing a, θ_n will increase hence, diffraction pattern is spread out

626*. 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 ? **CBSE (F) -2009**

[**Ans.** $y_0 = 2D\lambda/a$ ⇨ Width of central maximum will be increased

627*. 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 ? **CBSE (AI) -2012**

[**Ans.** $\theta_n = n\lambda/a$, remains unchanged as it does not depend on D

628*. How would the diffraction pattern due to a single slit be affected when the monochromatic source of light is replaced by white light. **CBSE (F) -2013,2011, (AI)-2009**

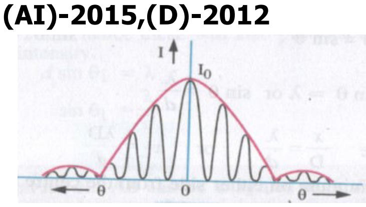
[**Ans.** (i) The diffraction pattern is coloured. As $\beta \propto \lambda$ so red fringe is wider than violet fringe

(ii) the central maxima is bright

(iii) more dispersion is obtained for higher order spectra, it causes an overlapping of different colours

629*. Show that the fringe pattern on the screen in Young's double slit experiment is actually a superposition of single slit diffraction from each slit. **CBSE (AI)-2015,(D)-2012**

[**Ans.** It is shown in figure, there is a broader diffraction peak in which there appear several fringes of smaller width due to double slit Interference pattern. In the limit of slit width 'a' becoming very small, the diffraction pattern become very flat and will observe the two slit interference pattern.

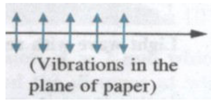


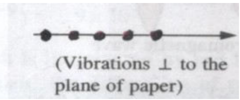
630*. What is polarization of light ? **CBSE (AI)-2013,2009,2008,(F)-2013,(D)-2010**

[**Ans. Polarization of light** : The phenomenon of restricting the vibrations of electric vectors in a plane perpendicular to the direction of propagation of light, is known as polarization of light

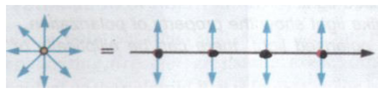
631. Define the term 'linearly polarised light' and 'unpolarised light'. **CBSE (AI)-2017,2013,2009,(F)-2013,(D)-2010**

[**Ans. Linearly Polarised light** : The light having vibrations of electric field vector in only one direction perpendicular to the direction of propagation of light is called plane or linearly polarised light





Unpolarised light : The light having vibrations of electric field vector in all possible directions perpendicular to the direction of propagation of light is called unpolarised light or ordinary light



632*. Which special characteristic of light is demonstrated only by the phenomenon of polarization ? **CBSE (AIC)-2004**

[**Ans.** Transverse nature of light

633*. Which type of waves show the property of polarization ? **CBSE (AIC)-2001**

[**Ans.** Transverse waves

634*. Name the phenomenon which proves transverse wave nature of **CBSE (Sample Paper)-2015**

[**Ans.** polarization

635*. Good quality sung-lasses made of polaroids are preferred over ordinary coloured glasses. Why ? Justify your answer.

CBSE (DC)-2015

[**Ans.** because they are more effective in reducing the glare due to reflections from horizontal surfaces/ provide better protection to our eyes / more effective in cutting off harmful UV rays of sun

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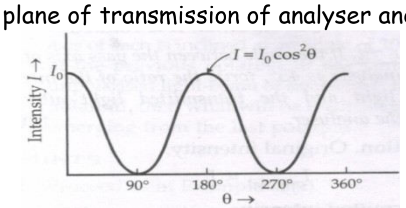
636*. (i) State law of Malus. **CBSE (AI)-2016**

(ii) Draw a graph showing the variation of intensity (I) of polarised light transmitted by an analyser with angle (θ) between polariser and analyser **CBSE (AI)-2017,2016**

[**Ans. Law of Malus** : When a beam of completely plane polarised light is incident on an analyser, intensity of transmitted light varies as the square of cosine of angle between plane of transmission of analyser and polariser

i,e, $I \propto cos^2\theta$

or $I = I_0 \ cos^2\theta$



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637*. Why does unpolarised light from a source show a variation in intensity when viewed through a Polaroid which is rotated ? **CBSE (AI)N-2016**

[**Ans.** By the law of Malus, $I = I_0 \ cos^2\theta$

Hence the transmitted intensity will show a variation as per $cos^2\theta$

638*. Does the intensity of polarised light emitted by a Polaroid depend on its orientation ? Explain briefly.

[**Ans. yes,** By Malus' law. transmitted intensity $I = I_0 \ cos^2\theta$ **CBSE (F)-2016**

639*. The vibrations in a beam of polarised light make an angle of 60^0 with the axis of the Polaroid sheet. What percentage of light is transmitted through the sheet ? **CBSE (F)-2016**

[**Ans.** $I = I_0 \ cos^2\theta = I_0 \ cos^2 60 = I_0 \ (1/2)^2 = \frac{I_0}{4}$ ⇨ $\frac{I}{I_0}$ X 100 = $\frac{1}{4}$ X 100 = 25%

640*. Unpolarised light of intensity I is passed through a Polaroid. What is intensity of light transmitted by the Polaroid ?

[**Ans.** $\frac{I}{2}$, as it will get polarised **CBSE (F)-2009**

641*. Unpolarized light is incident on a polaroid. How would the intensity of transmitted light change when the Polaroid is rotated ? **CBSE (AI)-2013**

[**Ans**. It will not change and remain $I_0/2$

642*. State Brewster's law. **CBSE (AI) -2016,(D)-2016,2002**

[**Ans**. **Brewster's law** : The refractive index of a refracting medium is numerically equal to the tangent of angle of polarization. i,e, $\mu = \tan i_\beta$

643*. What is Brewster's angle/Polarizing angle ? **CBSE (D)-2016,(F)-2013,(AIC)-2008**

[**Ans**. **Brewster's Angle** (i_β) : The angle of incidence of unpolarised light falling on a transparent surface, at which the reflected light is completely plane polarised light, is called Brewster's angle or polarizing angle i_β

644*. The value of Brewster angle for a transparent medium is different for light of different colours. Give reason

[**Ans**. We have $\mu = \tan i_\beta \Rightarrow i_\beta = \tan^{-1}\mu$ **CBSE (D)-2016,(F)-2013**

Since μ is different for different colours, hence Brewster's angle (i_β) is different for different colours

645*. Show that the Brewster angle i_B for a given pair of transparent media, is related to the critical angle i_c through the relation, $i_c = sin^{-1}(\cot i_B)$. **CBSE (AIC)-2008**

[**Ans**. $\mu = \tan i_B = \frac{1}{\cot i_B}$ Also $\mu = \frac{1}{\sin i_c}$ $\Rightarrow$ $\sin i_c = \cot i_B$ $\Rightarrow$ $i_c = sin^{-1}(\cot i_B)$

646*. When unpolarised light passes from air to a transparent medium, under what condition does the reflected light get plane polarised ? **CBSE (D)-2011**

[**Ans**. when unpolrised light is incident at Brewster's angle

647*. What is the value of refractive index of a medium of polarizing angle 60^0 ? **CBSE (AI)-2016,(D)-2016,2002**

[**Ans**. $\mu = \tan i_\beta = \tan 60 = \sqrt{3}$

648*. What is the value of polarizing angle of a medium of refractive index $\sqrt{3}$? **CBSE (F)-2008**

[**Ans**. $\mu = \tan i_\beta \Rightarrow \sqrt{3} = \tan i_\beta \Rightarrow i_\beta = \tan^{-1}\sqrt{3} = 60^0$

649*. Unpolarised light is incident on a plane glass surface. What should be the angle of incidence so that the reflected and refracted rays are perpendicular to each other ? **CBSE (AIC)-2010,NCERT-2017**

OR

Find the Brewster angle for air – glass interface, when the refractive index of glass = 1·5. **CBSE (AI)-2017**

[**Ans**. $\mu = \tan i_\beta \Rightarrow i_\beta = \tan^{-1}\mu = \tan^{-1}1.5 = 56.3^0$

650*. A ray of light falls on a transparent slab of μ = 1.732, if reflected and refracted rays are mutually perpendicular, what is the angle of incidence ? **CBSE (D)-2009**

[**Ans**. $\mu = \tan i_\beta \Rightarrow i_\beta = \tan^{-1}\mu = \tan^{-1}1.732 = 60^0$

651*. The refractive index of a material is $\sqrt{3}$. What is the angle of refraction if the unpolarised light is incident on it at the polarizing angle of the medium ? **CBSE (D)-2002**

[**Ans**. $\mu = \tan i_\beta = \Rightarrow i_\beta = \tan^{-1}\sqrt{3} = 60^0$ but $r + i_\beta = 90^0 \Rightarrow r = 90^0 - i_\beta = 90^0 - 60^0 = 30^0$

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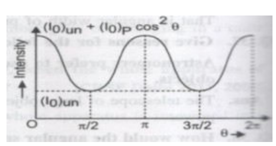
652*. A partially plane polarised beam of light passed through a Polaroid. Show graphically the variation of the transmitted light intensity with angle of rotation of Polaroid. **CBSE (F)-2014**

[**Ans**.



653*. If the angle between the pass axis of polarizer and analyser is 45^0, write the ratio of intensities of original light and the transmitted light after passing through the analyzer. **CBSE (D) -2009**

[**Ans**. $I_{original} = I_0$ & $I_{polariser} = I_1 = I_0 \overline{cos^2\theta} = \frac{I_0}{2}$

$I_{transmitted} = I_1\, cos^2 45 = \frac{I_0}{2}\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{I_0}{4}$ $\Rightarrow$ $\frac{I_{original}}{I_{transmitted}} = \frac{I_0}{I_0/4} = 4:1$

654*. 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. **CBSE (D)-2008,2003**

[**Ans.** <u>Explanation of reflection on the basis of Huygen's wave theory</u>

Let a plane wavefront AB is incident on a reflecting surface XY as shown. By the Huygens's principle, in the time disturbance reaches from B to C, secondary wavelets from A must have spread over a hemisphere of radius AD = BC = ct. Hence tangent CD be the reflected wavefront

In Δ ABC & Δ ADC,

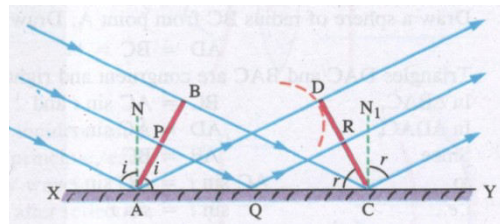
AC = common

$\angle B = \angle D = 90^0$

AD = BC = c t

⇨ Δ ABC ≅ Δ ADC

∴ $\angle i = \angle r$

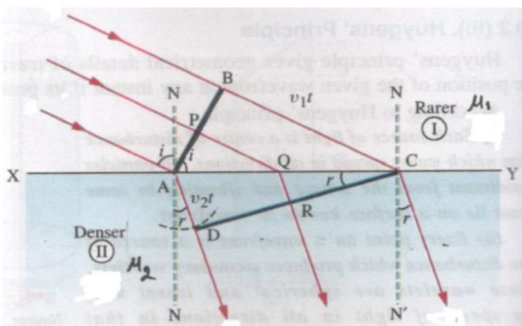


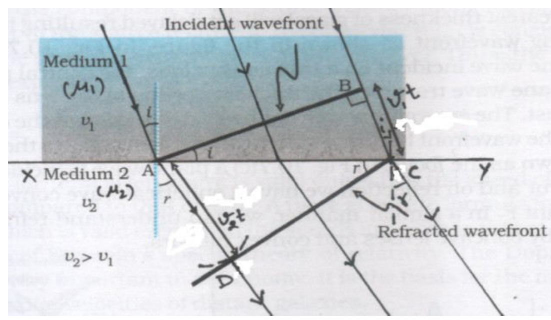
655*. Use Huygens' principle to verify the laws of refraction. **CBSE (AI)-2017**

OR

Derive Snell's law on the basis of Huygen's wave theory when light is travelling from a **rarer to a denser** medium/ **Denser to rarer** medium. **CBSE (AI)-2016,2015,2006,2002,(D)-2013,2011,2008,2005 (AIC)-2011**

[**Ans.** <u>Explanation of refraction on the basis of Huygen's wave theory</u>





Let a plane wavefront AB is incident on a refracting surface XY as shown. By the Huygens's principle, in the time $\left(t = \frac{BC}{v_1}\right)$ disturbance reaches from B to C, secondary wavelets from A must have spread over a hemisphere of radius $AD = v_2$t. Hence tangent CD be the refracted wavefront

Obviously, $\frac{\sin i}{\sin r} = \frac{BC/AC}{AD/AC} = \frac{BC}{AD} = \frac{v_1 t}{v_2 t} = \frac{v_1}{v_2}$ = constant

This is Snell's law of refraction

56*. Two harmonic waves of monochromatic light **CBSE (AI)S -2016,(AIC)-2015,2014,(D)-2014**

$\boldsymbol{y_1 = a\cos\omega t}$ and $\boldsymbol{y_1 = a\cos(\omega t + \phi)}$

are superimposed on each other. Show that the maximum intensity in interference pattern is four times the intensity due to each slit. Hence write the condition for constructive and destructive interference in terms of the phase angle ϕ.

[**Ans.** $y_1 = a\cos\omega t$ & $y_1 = a\cos(\omega t + \phi)$

⇨ $Y = Y_1 + Y_2 = a\cos\omega t + a\cos(\omega t + \phi) = 2a\cos\left(\frac{\phi}{2}\right)\cos\left(\omega t + \frac{\phi}{2}\right)$

⇨ $A = 2a\cos\left(\frac{\phi}{2}\right)$ ⇨ Resultant intensity,

$I = 4\,a^2\cos^2\left(\frac{\phi}{2}\right) = 4\,I_0\cos^2\left(\frac{\phi}{2}\right)$ where $I_0 = a^2$ is the intensity of each monochromatic wave

Obviously, $I_{max} = 4\,I_0 = 4$ X intensity due to one slit

For constructive interference, $\cos^2\left(\frac{\phi}{2}\right) = 1$

⇨ $\frac{\phi}{2} = n\pi$ or $\phi = 2n\pi$ where n = 0,1,2,3,------- and $I_{max} = 4\,I_0$

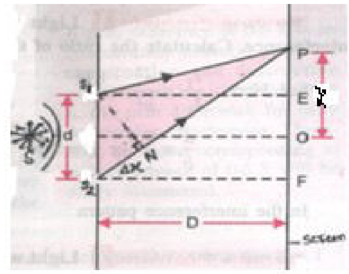
For destructive interference, $\cos^2\left(\frac{\phi}{2}\right) = 0$

⇨ $\frac{\phi}{2} = (2n-1)\frac{\pi}{2}$ or $\phi = (2n-1)\pi$ where n = 1,2,3,------- and $I_{min} = 0$

657*. Derive an expression for path difference in Young's double slit experiment and obtain the conditions for Constructive and destructive interference at a point on the screen. Hence find the expression for fringe width. Also draw a graph howing the variation of intensity in the interference pattern.

CBSE (AI)-2016,2015,2014,2012, (D)-2016,2012,2011, (F)-2015

[**Ans**. Let 'S ' be a monochromatic source of light of wavelength λ



The path difference

$\Delta x = S_2P - S_1P$

Now, $S_2P^2 - S_1P^2 = D^2 + \left(y + \frac{d}{2}\right)^2 - \left[D^2 + \left(y - \frac{d}{2}\right)^2\right]$

⇨ $(S_2P - S_1P)(S_2P + S_1P) = D^2 + y^2 + 2y\frac{d}{2} - D^2 - y^2 + 2y\frac{d}{2} = 2yd$

⇨ $\Delta x = \frac{2yd}{(S_2P + S_1P)}$

If point P is very close to point O then

$S_2P \simeq S_1P \simeq D$

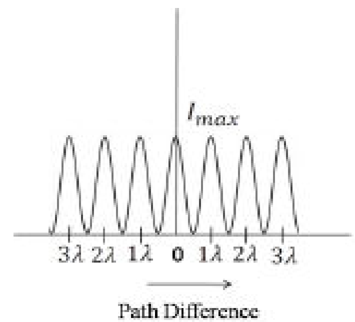
⇨ $\Delta x = \frac{2yd}{(D + D)} = \frac{2yd}{2D} = \frac{yd}{D}$

For constructive interference at P

$\Delta x = n\lambda$ where n = 0,1,2,3,------

⇨ $\frac{yd}{D} = n\lambda$

⇨ for n^{th} bright fringe, $y_n = \frac{nD\lambda}{d}$



For destructive interference at P

$\Delta x = (2n-1)\lambda/2$ where n = 1,2,3,---------

⇨ $\frac{yd}{D} = (2n-1)\lambda/2$

⇨ for n^{th} dark fringe, $y_n = \frac{(2n-1)D\lambda}{2d}$

Fringe width

Width of a dark fringe

$\beta = y_n - y_{n-1} = \frac{nD\lambda}{d} - \frac{(n-1)D\lambda}{d} = \frac{nD\lambda}{d} - \frac{nD\lambda}{d} + \frac{D\lambda}{d} = \frac{D\lambda}{d}$ ⇨ $\boxed{\beta = \frac{D\lambda}{d}}$

Width of a bright fringe

$\beta = y_n - y_{n-1} = \frac{(2n-1)D\lambda}{2d} - \frac{[2(n-1)-1]D\lambda}{d} = \frac{(2n-1)D\lambda}{2d} - \frac{(2n-3)D\lambda}{d}$

$\beta = \frac{(2n-1)D\lambda}{2d} - \frac{(2n-1)D\lambda}{d} + \frac{2D\lambda}{2d} = \frac{D\lambda}{d}$ ⇨ $\boxed{\beta = \frac{D\lambda}{d}}$

658*. (i) What is sustained interference pattern ? Write the necessary conditions to obtain sustained interference fringes.

[**Ans. Sustained interference pattern :** **CBSE (AI)-2015**

An interference pattern, in which the positions of maxima and minima on the screen does not change with time, is called sustained interference

Conditions : (i) Two sources must be coherent

(ii) Waves emitted by two sources should have same frequency and equal or nearly equal amplitude

(iii) Two sources should be quite narrow and the separation between them (d) should be small

(iv) Distance of screen (D) from the sources should be large

659*. (ii) What is the effect on interference fringes in a Young's double slit experiment when the monochromatic source of light is replaced by a source of white light ? Explain. **CBSE (F)-2012**

[**Ans**. The interference pattern consists of a central white fringe having on both sides a few coloured fringes and then a general illumination

Reason : Due to zero path difference, all the waves of different colour produce bright fringes at the centre which overlap and we get central white fringe.

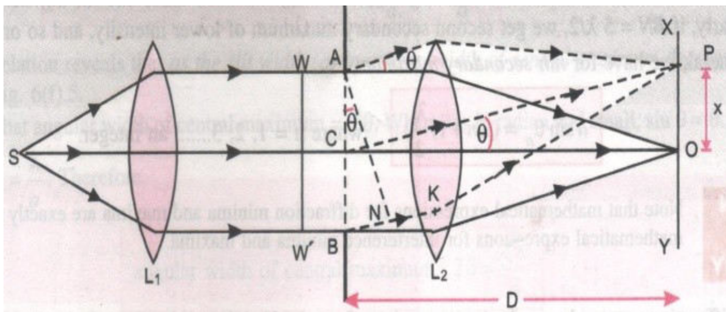
As, $\beta \propto D\lambda/d$, so closest fringe on either side of the central white fringe is violet and the farthest fringe is red. After a few fringes, the interference pattern is lost due to large overlapping of the fringes and uniform white illumination is seen on the screen.

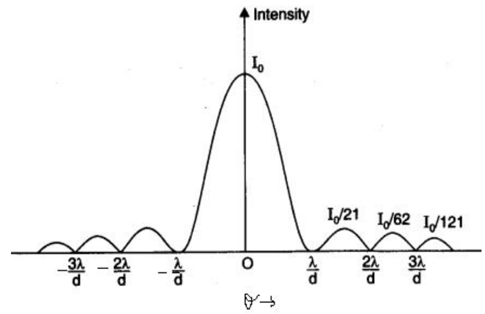
660*. When a parallel beam of monochromatic source of light of wavelength λ is incident on a single slit of width a, show how the diffraction pattern is formed at the screen by the interference of the wavelets from the slit.

(i) Show that, besides the central maximum at $\theta = 0$, secondary maxima are observed at $\theta_n = \left\{n + \frac{1}{2}\right\}\lambda/a$ & minima at $\theta_n = n\lambda/a$

(ii) Show that angular width of central maximum is twice the angular width of secondary maximum and hence find the relation for linear width of central maximum. **CBSE (F)-2017,2016,2013,2012,2011,(AI)-2016,2014,(D)-2012**

[**Ans.** When a parallel beam of monochromatic light is incident on a single slit, By the Huygen's principle, secondary wavelets from each point on the slit superpose on each other and diffraction pattern is obtained on the screen.





Central maximum : Wavelets from any two corresponding points of the two halves of the slit reach the central point in the same phase to produce maxima ($\theta = 0$). The entire incident wavefront contributes to this central maxima

Positions of minima :

Path difference, $\Delta x = BN = AB\ \sin\theta = a\sin\theta$

Wavelets from upper half of the slit and the corresponding points in the lower half is received with path difference $\frac{\lambda}{2}$ at P. Thus destructive interference takes place and we get first minimum.

i,e, for first secondary minimum

$$a\sin\theta_1 = \frac{\lambda}{2} + \frac{\lambda}{2} = \lambda$$

⇨ for n^{th} secondary minimum ,

$$a\sin\theta_n = n\lambda \qquad \text{where } n = 1,2,3,\text{-------}$$

If θ is very small then for n^{th} secondary minima

$$\theta_n = n\lambda/a$$

Positions of secondary maxima :

Dividing the slit in to three equal parts, wavelets from two parts will meet with phase difference $\frac{\lambda}{2}$ each and produce destructive interference and the wavelets from third part will produce first secondary maximum

i,e, for first secondary maximum

$$a\sin\theta_1 = \frac{3\lambda}{2}$$

⇨ for n^{th} secondary maximum

$$a\sin\theta_n = \left\{n + \frac{1}{2}\right\}\lambda \qquad \text{where } n = 1,2,3,\text{-------}$$

If θ is very small then for n^{th} secondary maxima

$$\theta_n = \left\{n + \frac{1}{2}\right\}\lambda/a$$

Width of central maximum :

for the first minima, $\theta_1 = \lambda/a$

& for the second minima, $\theta_2 = 2\lambda/a$

⇨ linear width of first minimum $y_1 = D\ \theta_1 = D\lambda/a$

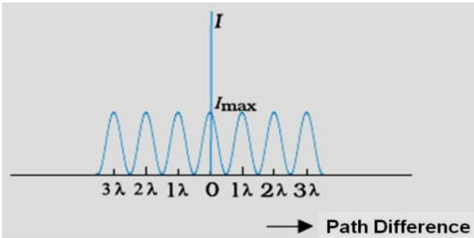
Angular width of central maximum $\theta_0 = \theta_1 - \theta_{-1} = \frac{\lambda}{a} - \left(-\frac{\lambda}{a}\right) = \frac{2\lambda}{a} = 2\theta_1$

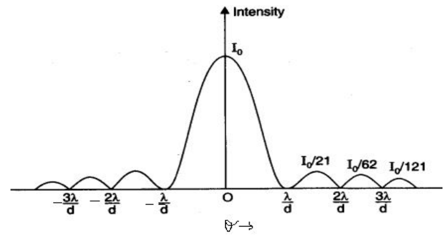
Angular width of secondary maxima $= \theta_2 - \theta_1 = \frac{2\lambda}{a} - \frac{\lambda}{a} = \frac{\lambda}{a} = \frac{1}{2}$X Angular width of central maxima

⇨ linear width of central maxima $\boldsymbol{y_0} = D\,(2\theta_1) = \boldsymbol{2D\lambda/a}$ ⇨ $\boxed{y_0 = 2D\lambda/a}$

661*. Draw the intensity pattern for single slit diffraction and double slit interference. **CBSE (AI)-2017,2004**

[**Ans.** **Interference** **Diffraction**





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662*. State two differences between interference and diffraction patterns. **CBSE (AI)-2017,(D)-2017**

[**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

===

663*. Explain with reason, how the resolving power of an astronomical telescope will change when - **CBSE (AI)-2002**
(i) frequency of the incident light on the objective lens is increased
(ii) the focal length of the objective lens is increased ?
(iii) aperture of the objective lens is halved
(iv) the wavelength of the incident light is increased ? Justify your answer in each case.

[**Ans.** R. P. of a Telescope $= \frac{D}{1.22\,\lambda} = \frac{D\,\nu}{1.22\,c}$

(i) R.P. increases as R.P. $\propto \nu$
(ii) R.P. does not change as it does not depend on focal length of the objective lens
(iii) R.P. is halved as R.P. $\propto D$
(iv) R.P. decreases as R.P. $\propto 1/\lambda$

664*. How does the resolving power of a microscope change when **CBSE (AI)-2015,2008,2005**
(i) the diameter/aperture of the objective lens is decreased,
(ii) the wavelength of the incident light is increased ?
(iii) refractive index of the medium between the object and the objective lens increases
(iv) the focal length of the objective lens is increased ? Justify your answer in each case.

[**Ans.** $\boldsymbol{R.P.} = \frac{2\,\mu\,sin\theta}{\lambda}$

(i) R.P. decreases because as D decreases, θ also decreases and R.P. $\propto sin\theta$
(ii) R.P. decreases as R.P. $\propto 1/\lambda$
(iii) R.P. increases as R.P. $\propto \mu$
(iv) R.P. does not change as it does not depend on focal length of the objective lens

665*. Why is no interference pattern is observed when two coherent sources are- **CBSE (AI)-2001**
(i) infinitely close to each other (ii) far apart from each other

[**Ans.** $\boldsymbol{\beta} = \frac{D\lambda}{d}$

(i) when sources are placed infinitely close to each other, $d \to 0$ ⇨ $\boldsymbol{\beta} \to \infty$
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

666*. Two slits are made $1\,mm$ apart and the screen is placed $1\,m$ away. What should be the width of each slit to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern ? **CBSE (AI)-2016,2015**

[**Ans.** $\boldsymbol{\beta} = \frac{D\lambda}{d}$ & $\boldsymbol{y_0} = \frac{2D\lambda}{a}$

Given, $\boldsymbol{y_0} = 10\beta$ ⇨ $\frac{2D\lambda}{a} = 10\,\frac{D\lambda}{d}$ ⇨ $a = \frac{d}{5} = \frac{1}{5}mm = 0.5\,mm$

667*. (i) What is a Polaroid ? What does a polaroid consist **CBSE (AI)-2015,(DC)-2013,(AIC)-2001**

(ii) How does one demonstrate, using a suitable diagram, that unpolrised light when passed through a polaroid gets polarized ? **CBSE (D)-2014, (AI)-2012,2010**

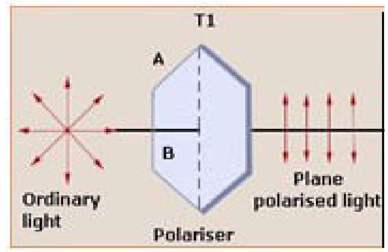
(iii) How will you use it to distinguish between unpolarised light and plane polarised light ? **CBSE (AI)-2015**

[**Ans. (i) Polaroid** : A Polaroid is a thin commercial sheet which makes use of the property of selective absorption to produce an intense beam of plane polarised light

A Polaroid consists of a long chain of molecules aligned in a particular direction

(ii) Plane Polarized light from Polaroid :

When an unpolarised light falls on it, the electric vectors oscillating along the direction of aligned molecules get absorbed and those oscillating in the direction perpendicular to the direction of alignment of molecules are passed through it. Hence the emergent light is plane polarised or linearly polarised



(iii) Distinction :

When unpolarised light is seen through a rotating Polaroid, intensity of transmitted light does not change, it remains $I_0/2$

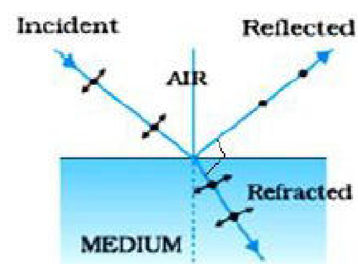
When plane polarised light is seen through a rotating Polaroid, the intensity of transmitted light varies. It becomes twice maximum and twice zero in each rotation

===

668*. When unpolarised light is incident on the boundary separating the two transparent media, explain, with the help of a suitable diagram, the conditions under which the reflected light gets polarised. Hence derive the relation of Brewster's angle in terms of the relative refractive index of the two media. **CBSE (AI)-2016,2014,2012,2008,(F)-2013,(D)-2014,2010**

[**Ans.** <u>**Polarization of light by reflection**</u>

When unpolarised light falls on a transparent surface, both the reflected and refracted light are found partially polarised. It is observed that, the degree of polarization of reflected light varies with angle of incidence. At Brewster's angle i_β, reflected light is completely plane polarised when the refracted and reflected rays make a right angle with each other.



i,e, when $i = i_\beta$, $i_\beta + r = 90$ ⇨ $r = 90 - i_\beta$

By Snell's law, $\mu = \frac{\sin i_\beta}{\sin r} = \frac{\sin i_\beta}{\sin(90 - i_\beta)} = \frac{\sin i_\beta}{\cos i_\beta} = \tan i_\beta$

⇨ $\boldsymbol{\mu = \tan i_\beta}$ This equation is called Brewster's law

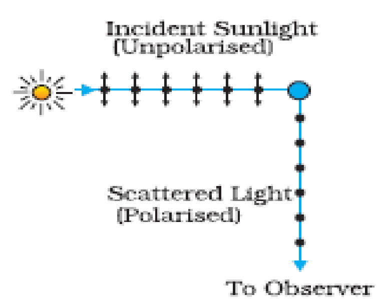
===

669*. Show, with the help of a suitable diagram, how unpolarized sunlight gets polarized due to scattering ? **CBSE (AI)-2017,2014,2013,(F)-2014**

[**Ans.** <u>**Polarization of sunlight due to scattering**</u>

Scattered light is found to be plane polarized perpendicular to the original direction.

Under the influence of electric field of incident wave, the electrons in the air molecules acquire components of motion in both the directions, parallel as well as perpendicular to the plane of paper (↕ as well as •). Charges accelerating parallel to ↕, do not radiates energy towards observer since their acceleration has no transverse component. Hence the radiation, scattered towards the observer gets linearly polarized.



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670*. The light from a clear blue portion of the sky shows a rise and fall in intensity when viewed through a polaroid which is rotated. Why ? **CBSE (AI)-2015**

[**Ans**. It is due to polarization of sunlight by scattering

Reason : When unpolarized sunlight falls on air molecules, it gets scattered and is found to be plane polarized ⊥ to the original direction hence shows rise & fall in intensity when viewed through a rotating polaroid.

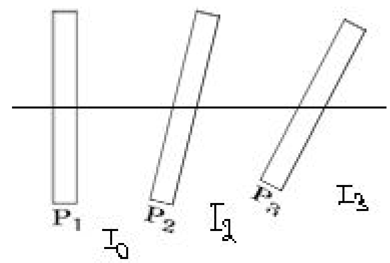
671*. Unpolarised light is passed through a polaroid P_1. When this polarised beam passes through another polaroid P_2 and if the pass axis of P_2 makes angle θ with the pass axis of P_1, then write the expression for the polarised beam passing through P_2. **CBSE (AI)-2017**

[**Ans**. $I = \frac{I_0}{2} cos^2\theta$

===

672*. Find an expression for intensity of transmitted light when a polaroid sheet is rotated between two crossed polaroids. In which position of the polaroid sheet will the transmitted intensity be maximum ? **CBSE (D)-2015,2010**

[**Ans**. Let I_0 = Intensity of polarised light passing through $\mathbf{P_1}$



⇨ Intensity of light after passing through second polarizer $\mathbf{P_2}$

$I_2 = I_0\ cos^2\theta$ Now, Intensity of light after passing through third polarizer $\mathbf{P_3}$

$I_3 = I_2\ cos^2(90-\theta) = I_0\ cos^2\theta\ cos^2(90-\theta)$

⇨ $I_3 = I_0\ cos^2\theta\ sin^2\theta = \frac{I_0}{4}(2\sin\theta\cos\theta)^2$

$$\mathbf{I_3 = \frac{I_0}{4}(\sin 2\theta)^2}$$

⇨ Transmitted intensity will be –

(i) minimum when $\sin 2\theta$ = 0 or $\theta = 0^0$ (ii) maximum when $\sin 2\theta$ = 1 or $2\theta = 90^0$ or $\theta = 45^0$

===

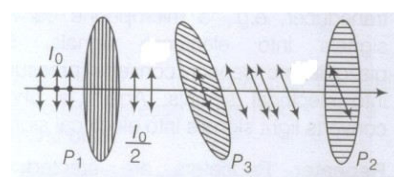
673*. A narrow beam of unpolarised light of intensity I_0 is incident on a Polaroid P_1. The light transmitted by it then incident on a second Polaroid P_2 with its pass axis making an angle of 60^0 with relative to the pass axis of P_1. Find the intensity of light transmitted by P_2. **CBSE (D)-2017**

[**Ans**. Intensity through P_1, $I_1 = I_0\ \overline{cos^2\theta} = \frac{I_0}{2}$ Intensity through P_2, $I_2 = I_1\ cos^2 60 = \frac{I_0}{2}(\frac{1}{2})^2 = \frac{I_0}{8}$

674*. Two Polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I_0 is incident on P_1. A third Polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 60^0 with that of P_1. Determine the intensity of light transmitting through P_1, P_2 and P_3. **CBSE (AI) -2014**

[**Ans**. Intensity through P_1, $I_1 = I_0\ \overline{cos^2\theta} = \frac{I_0}{2}$

Intensity through P_3, $I_3 = I_1\ cos^2 60 = \frac{I_0}{2}(\frac{1}{2})^2 = \frac{I_0}{8}$



Intensity through P_2,

$I_2 = I_3\ cos^2(90-60) = \frac{I_0}{8} cos^2 30 = \frac{I_0}{8}(\frac{\sqrt{3}}{2})^2 = \frac{3I_0}{32}$

675*. Light waves from two coherent sources arrive at two points on a screen with path differences of 0 and $\lambda/2$. Find the ratio of intensities at these points. **CBSE (AIC)-2017**

[**Ans**. **(i)** $\Delta x = 0$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \lambda = 0$ **(ii)** $\Delta x = \frac{\lambda}{2}$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$

⇨ $I_1 = 4I_0\ cos^2\left(\frac{\phi}{2}\right) = 4I_0\ cos^2 0 = 4I_0$

& $I_2 = 4I_0\ cos^2\left(\frac{\phi}{2}\right) = 4I_0\ cos^2\left(\frac{\pi}{2}\right) = 0$ ⇨ $\frac{I_1}{I_2} = \frac{4I_0}{0} = \infty$

676*. Find the intensity at a point on a screen in Young's double slit experiment where the interfering waves of equal intensity have a path difference of (i) λ /4, and (ii) λ /3. **CBSE (F)-2017**

[**Ans**. **(i)** $\Delta x = \frac{\lambda}{4}$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$ **(ii)** $\Delta x = \lambda/3$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \lambda/3 = 2\pi/3$

$I_1 = 4I_0\ cos^2\left(\frac{\phi}{2}\right) = 4I_0\ cos^2\left(\frac{\pi}{4}\right) = 4I_0\left(\frac{1}{\sqrt{2}}\right)^2 = 2I_0$ ⇨ $I_2 = 4I_0\ cos^2\left(\frac{\phi}{2}\right) = 4I_0\ cos^2(\pi/3) = 4I_0\ (1/2)^2 = I_0$

677*. In Young's double slit experiment, using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is $\lambda/3$.

[Ans. (i) $\Delta x = \lambda$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \lambda = 2\pi$ **CBSE (D)-2015,2012,NCERT-2017**

⇨ $I_1 = 4I_0 \cos^2\left(\frac{\phi}{2}\right) = 4I_0 \cos^2(\pi) = 4I_0 (-1)^2 = 4I_0 = K$ (given)

(ii) $\Delta x = \lambda/3$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \lambda/3 = 2\pi/3$ ⇨ $I_2 = 4I_0 \cos^2\left(\frac{\phi}{2}\right) = 4I_0 \cos^2(\pi/3) = 4I_0 (1/2)^2 = I_0 = K/4$

678*. Two coherent sources have intensities in the ratio 25 : 16. Find the ratio of intensities of maxima to minima after interference of light occurs. **CBSE (DC)-2003**

[Ans. Given, $\frac{I_1}{I_2} = \frac{25}{16}$ ⇨ $\frac{a_1^2}{a_2^2} = \frac{25}{16}$ ⇨ $\frac{a_1}{a_2} = \frac{5}{4}$ $\frac{I_{max}}{I_{min}} = ?$

⇨ $\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{(a_1/a_2+1)^2}{(a_1/a_2-1)^2} = \frac{\left(\frac{5}{4}+1\right)^2}{\left(\frac{5}{4}-1\right)^2} = 81:1$

679*. In Young's double slit experiment, two slits are $1\ mm$ apart and the screen is placed $1\ m$ away from the slits. Calculate the fringe width when light of wavelength $500\ nm$ is used. **CBSE (AI)E -2016**

[Ans. Given, $d = 1.mm = 1 X 10^{-3} m$, $D = 1\ m$, $\lambda = 500\ nm = 500 X 10^{-9} m$, $= ?$

fringe width, $\beta = \frac{D\lambda}{d} = \frac{1 X 500 X 10^{-9}}{1 X 10^{-3}} = 5X 10^{-4}\ m = 0.5\ mm$

680*.-A beam of light consisting of two wavelengths, $800\ nm$ and 600 nm, is used to obtain the interference fringes in a Young's double slit experiment on a screen is placed $1.4\ m$ away. If two slits are separated by $0.28\ mm$, Calculate the least distance from the central bright maximum where the bright fringes of the two wavelengths coincide.

[Ans. Given, $\lambda_1 = 800\ nm = 800 X 10^{-9} m$, $\lambda_2 = 600\ nm = 600 X 10^{-9} m$, $D = 1.4\ m$, **CBSE (AI)-2012**

$d = 0.28\ mm = 0.28 X 10^{-3} m$, Least distance of coincide $y = ?$

condition for coincide is

$\boldsymbol{n\beta_1} = (n+1)\boldsymbol{\beta_2}$ ⇨ $\boldsymbol{n} \frac{D\lambda_1}{d} = (n+1)\frac{D\lambda_2}{d}$ ⇨ $\boldsymbol{n}\ \lambda_1 = (n+1)\lambda_2$

⇨ $n X 800 X 10^{-9} = (n+1) X 600 X 10^{-9}$

⇨ $n X 8 = 6n + 6$ ⇨ $n = 3$ ⇨ Required least distance

$y = n\beta_1 = 3\frac{D\lambda_1}{d} = 3X \frac{1.4 X 800 X 10^{-9}}{0.28 X 10^{-3}} = \frac{3 X 1.4 X 8 X 10^{-3}}{2.8} = 1.2 X 10^{-2}\ m$

681*. A slit of width $'a'$ is illuminated by red light of wavelength $6500\ A^0$. For what value of $'a'$ will -
(i) the first minimum fall at an angle of diffraction of 30^0 **CBSE (AI)-2009, (F)-2006**
(ii) the first maximum fall at an angle of diffraction of 30^0

[Ans. Given, $\lambda = 6500\ A^0 = 6500 X 10^{-10} m$

(i) $a \sin\theta_1 = \lambda$

⇨ $a = \frac{\lambda}{\sin\theta_1} = \frac{6500 X 10^{-10}}{\sin 30} = \frac{6500 X 10^{-10}}{1/2} = 2 X 6500 X 10^{-10} = 1.3 X 10^{-6} m$

(ii) $a \sin\theta_1 = 3\lambda/2$

⇨ $a = \frac{3\lambda}{2\sin\theta_1} = \frac{3 X 6500 X 10^{-10}}{2 X \sin 30} = \frac{3 X 6500 X 10^{-10}}{2 x 1/2} = 3 X 6500 X 10^{-10} = 1.95 X 10^{-6} m$

682*.-The wavelengths of two Sodium light of $590\ nm$ and $596\ nm$ are used in turn to study the diffraction taking place at a single slit of aperture $2 X 10^{-6} m$. The distance between the slit and the screen is $1.5\ m$. Calculate the separation between the positions of first maxima of the diffraction pattern observed in the two cases.

CBSE (AIC)-2017,(AI)-2014,(D)-2013,(DC)-2006

[Ans. Given, $\lambda_1 = 590\ nm = 500 X 10^{-9} m$, $\lambda_1 = 596\ nm = 596 X 10^{-9} m$, $D = 1.5\ m$, $a = 2 X 10^{-6} m$, $\boldsymbol{y_2 - y_1} = ?$

for first maxima, $y_1 = \frac{3D\lambda}{2a}$

⇨ $\boldsymbol{y_2 - y_1} = \frac{3D}{2a}(\lambda_2 - \lambda_1) = \frac{3 X 1.5}{2X 2X 10^{-6}}(596 X 10^{-9} - 590 X 10^{-9}) = \frac{3X 1.5 X6 X10^{-3}}{4} = 6.75 X 10^{-3} m$

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Unit VII: Dual Nature of Radiation and Matter **08 Periods**

Chapter–11: Dual Nature of Radiation and Matter

Dual nature of radiation, Photoelectric effect, Hertz and Lenard's observations; Einstein's photoelectric equation-particle nature of light.

Matter waves-wave nature of particles, de-Broglie relation, Davisson-Germer experiment (experimental details should be omitted; only conclusion should be explained).

701. What is Photoelectric effect ? **CBSE (AI)-2007,2004,(D)-2002**

[**Ans. Photoelectric effect** : When an electromagnetic radiation (such as U.V rays, x-rays etc.) of suitable frequency is incident on a metal surface, electrons are emitted from the surface. This phenomenon is called photoelectric effect

702. Define the term Work function of a photoelectric surface. **CBSE (AI)-2007,2004,(D)-2002**

[**Ans. (i) Work function (W)** : The minimum energy required to by an electron to just eject out from the metallic surface is called work function of that surface

$$W = h\nu_0 = \frac{hc}{\lambda_0}$$

703. Define the term (i) cut off frequency & (ii) Threshold wavelength in photoelectric emission.
CBSE (F) -2016,2011,(D)-2004,(AI)-2002

[**Ans. (i) Cut off frequency (ν_0)** : The minimum frequency of incident radiation, **below which** photoelectric emission is **not** possible, is called cut off frequency or threshold frequency

(**ii) Threshold Wavelength (λ_0)**: The maximum wavelength of incident radiation, **above which** photoelectric emission is **not** possible, is called threshold wavelength

704. Define the term 'intensity of radiation' in photon picture and write its S.I. unit. **CBSE (AI)-2016,2015**

[**Ans. Intensity of radiation** : Number of photons incident per unit area per second normal to the surface, is defined as the intensity of radiation. Its S.I. unit is Watt/ m^2

705. Define the term "stopping potential" or "Cut-off Potential" in relation to photoelectric effect.

[**Ans. Stopping potential or Cut-off Potential (V_0)** : **CBSE (AI) -2011,2008,2002, (D) -2005,2002**

The minimum negative potential of anode at which photoelectric current becomes zero is called stopping potential

706. Name the phenomenon which shows the quantum nature of electromagnetic radiation. **CBSE (AI)-2017**

[**Ans.** Photoelectric effect

707. What is the stopping potential applied to a photocell if the maximum kinetic energy of a photoelectron is 5 eV ?

[**Ans.** $V_0 = -5\,V$] **CBSE (AI) -2009, 2008, (D)-2001**

708. The stopping potential in an experiment is 1.5 V. What is the maximum K.E. of photoelectrons emitted ?

[**Ans.** $E_{k_{max}} = 1.5$ eV] **CBSE (AI)-2009**

709. Two metals A and B have work functions 4 eV and 10 eV respectively. Which metal has the highest threshold wavelength ? **CBSE (AI) -2004, (F)-2005**

[**Ans. Metal A** has highest threshold wavelength as W= $\frac{hc}{\lambda_0}$

710. Two metals X and Y, when illuminated with appropriate radiations emit photoelectrons. The work function of X is higher than that of Y. Which metal will have higher value of cut off frequency & why ? **CBSE (AIC)-2001**

[**Ans. Metal X** has the higher cut off frequency because $\nu_0 = W/h$ & $W_X > W_Y$

711. 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. **CBSE (F)-2017**

[**Ans. Yes,** **Reason :** $\boldsymbol{\nu_{Blue} > \nu_{Red}}$ ⇨ $(h\boldsymbol{\nu})_{Blue} > (h\boldsymbol{\nu})_{Red}$

712. For a photosensitive surface, threshold wavelength is λ_0, Does photoemission occure, if the wavelength (λ) of the incident radiation is (i) more than λ_0 (ii) less than λ_0. Justify your answer. **CBSE (AI)-2010, (AIC)-2001**

[**Ans. (i) No (ii) yes** as for photoelectric emission $\frac{hc}{\lambda} \geq \frac{hc}{\lambda_0}$ hence $\lambda \leq \lambda_0$]

713. Electrons are emitted from a photosensitive surface when it is illuminated by green light but does not take place by yellow light. Will the electrons be emitted when the surface is illuminated by (i) red light, and (ii) blue light ?

[**Ans.(i) No (ii) yes** as λ_0 is for wavelength of green light] **CBSE (AI)-2012,2007, (D)-2005**

714. Red light however bright is it, cannot produce the emission of electrons from a clean zinc surface but even a weak Ultraviolet radiation can do so. Why ? **CBSE (AI)-2004, (AIC)-2003**

[**Ans.** The energy of photon of red light is less than work function of zinc surface and the energy of photon of Ultraviolet radiation is more than the work function of zinc surface

715. Work function of sodium is 2.3 eV. Does sodium show photoelectric emission for light of wavelength 6800 A^0 ?

[**Ans.** $E = \frac{hc}{\lambda} = \frac{6.6\,X10^{-34}\,X3\,X10^{8}}{6800\,X\,10^{-10}\,X\,1.6\,X\,10^{-19}}\,eV = 1.8\,eV$ **CBSE (D)-2001**

⇨ $E <$ W, Hence photoelectric emission will **not** take place

716. If the intensity of the incident radiation on a photosensitive surface is doubled, how does the kinetic energy of emitted electrons get affected ? **CBSE (F) -2005**

[**Ans**. **No change** as $E_{k_{max}}$ does not depend on intensity

717. Ultraviolet light is incident on two photosensitive materials having work functions W_1 and $W_2(W_1>W_2)$. In which case will the kinetic energy of the emitted electrons be greater ? Why ? **CBSE (AI)-2005**

[**Ans**. K.E. of electrons emitted by the metal having work function W_2 will be greater as $E_{k_{max}} = h\nu - W$]

718. Ultraviolet radiations of different frequencies ν_1 and ν_2 are incident on two photosensitive materials having work functions W_1 and $W_2(W_1>W_2)$ respectively. The kinetic energy of the emitted electrons is same in both the cases. Which one of the two radiations will be of higher frequency and why? **CBSE (AI)-2007**

[**Ans**. $\nu_1>\nu_2$ as $h\nu = E_{k_{max}} + W$

719. 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 theratiov_1:v_2. **CBSE (F)-2016, (D) -2004**

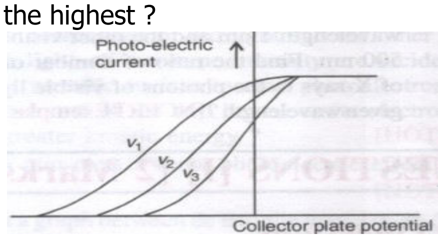
[**Ans**. $E_{K_{max}} = h\nu - W$ & $W = hf$

$$\Rightarrow \frac{\frac{1}{2}mv_1^2}{\frac{1}{2}mv_2^2} = \frac{h\nu_1 - W}{h\nu_2 - W} = \frac{h\,(2f) - hf}{h\,(5f) - hf} = \frac{hf}{4hf} = \frac{1}{4} \Rightarrow \frac{v_1^2}{v_2^2} = \frac{1}{4} \Rightarrow v_1:v_2 = 1:\ 2$$

720. The graph below shows variation of photocurrent with collector plate potential for different frequencies of incident radiation.

(i) Which physical parameter is kept constant for the three curves ? **CBSE (F) -2009**

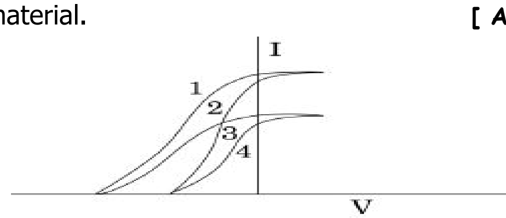
(ii) Which frequency (ν_1, ν_2 or ν_3) is the highest ? [**Ans**. (i) Intensity (ii) ν_1 is highest]



721. The given graph shows the variation of photoelectric current (I) with applied voltage (V) for two different materials and for two different intensities of the incident radiations. Identify the pair of curves that corresponds to

(i) different materials but same intensity of incident radiation **CBSE (AI)-2016,(D)-2013**

(ii) different intensities but same material. [**Ans**. (i) (1,2) and (3,4) (ii) (1,3) and (2,4)]



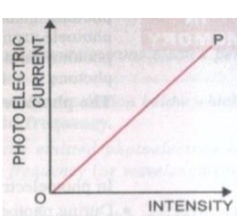
722. (i) Plot a graph showing the variation of photoelectric current with intensity of light.

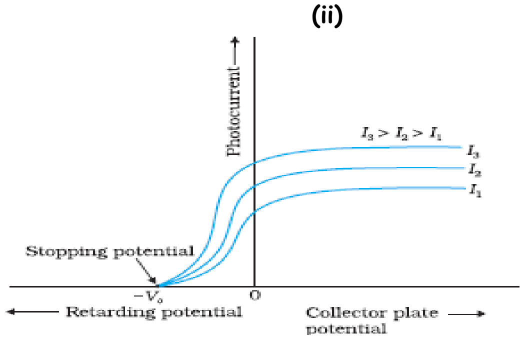
(ii) Show the variation of photocurrent with collector plate potential for different intensity but same frequency of incident radiation

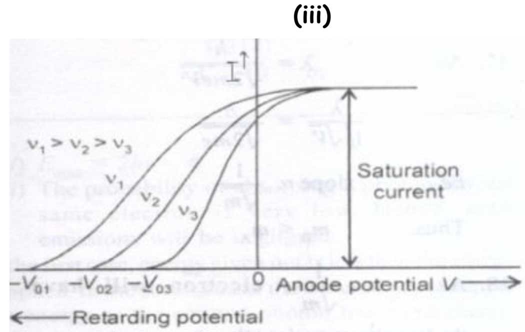
(iii) Show the variation of photocurrent with collector plate potential for different frequency but same intensity of incident radiation

[**Ans**. **CBSE (F) -2016,(D)-2014,(AI)-2010,(AIC)-2011**

(i) **(ii)** **(iii)**







723. Two monochromatic beams, one red and other blue, have the same intensity. In which case- **CBSE (AI)-2015**
(i) the number of photons per unit area per second is larger,
(ii) the maximum kinetic energy of the photoelectrons is more ? Justify your answer.
[Ans. (i) number of photons per unit area per second is same because both red and blue light has the same intensity
(ii) blue light, because $E_{k_{max}} = \frac{hc}{\lambda} - W$ & $\lambda_{blue} < \lambda_{red}$

724. How does the stopping potential in photoelectric emission depends upon- **CBSE (AI)-2011,2008,(D)-2005**
(i) intensity of the incident radiation
(ii) frequency of incident radiation
(iii) distance between light source and cathode in a photocell ?
[Ans. (i) stopping potential does not depend on intensity
(ii) stopping potential $\propto$ frequency
(iii) stopping potential does not depend on the distance between the light source and the cathode in a photocell

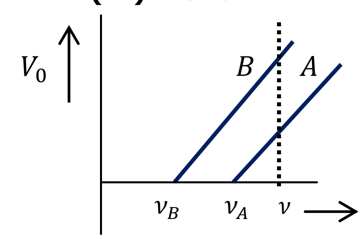
725. A beam of monochromatic radiation is incident on a photosensitive surface. Answer the following questions giving reasons :-
(i) Do the emitted photoelectrons have the same kinetic energy ? **CBSE (F)-2015**
(ii) Does the kinetic energy of the emitted electrons depend on the intensity of incident radiation ?
(iii) On what factors does the number of emitted photoelectrons depend ?
[Ans. (i) No, all the emitted photoelectrons do not have same K.E. The reason is that different electrons are bound with different forces in different layers of metals. More tightly bound electron will emerge with less K.E.
(ii) No, kinetic energy of the emitted electrons does not depend on the intensity of incident radiation.
(iii) number of emitted photoelectrons depends on intensity of incident radiation provided that energy $h\nu > W$

726. Write two characteristic features observed in photoelectric effect which support the photon picture of electromagnetic radiation.
[Ans.(i) number of photoelectrons emitted is proportional to the intensity of incident radiation **CBSE (F) -2012**
(ii) maximum kinetic energy of photoelectrons increases with frequency of incident radiation

727. State three important properties of photon which are used to write Einstein's photoelectric equation.
[Ans. (i) for a radiation of frequency v , the energy of each photon is hv. **CBSE (AI)-2016,2013, (D)-2013**
(ii) During the collision of a photon, with an electron, the total energy of photon gets absorbed by the electron
(iii) Intensity of light depends on the number of photons crossing per unit area per unit time

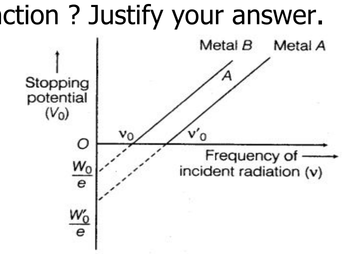
728. Write three characteristic features in photoelectric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation. **CBSE (AI)-2017,(D)-2016**
[Ans. (i) Instantaneous emission of photoelectrons
(ii) Existence of threshold frequency
(iii) Maximum Kinetic energy of emitted photoelectrons is independent of intensity of incident light

729. Sketch the graphs showing variation of stopping potential with frequency of incident radiations for two Photosensitive materials A and B having threshold frequencies $\nu_A > \nu_B$. **CBSE (AI) -2016**
(i) in which case is the stopping potential more and why ?
(ii) Does the slope of graph depend on the nature of material used ? Explain.



[Ans. (i) V_0 is more for material B
Reason : $eV_0 = h(\nu - \nu_0)$ ⇨ $V_0 = \frac{h}{e}(\nu - \nu_0)$
V_0 is more for lower value of ν_0
(ii) No, slope = h/e, which is constant

730. The graph shows the variation of stopping potential with frequency of incident radiation for two photosensitive metals A and B. Which of the two has higher value of work function ? Justify your answer. **(AI) -2014**



[Ans. Metal A has higher work function
Justification : As $(\nu_0)_A > (\nu_0)_B$
⇨ $(h\nu_0)_A > (h\nu_0)_B$
⇨ $W_A > W_B$

731. State de-Broglie hypothesis. **CBSE (D)-2012**

[**Ans**. **de-Broglie hypothesis** : Whenever a material particle such as electron, proton etc is in motion, a wave is always associated with it, known as de-Broglie wave or matter wave and has the wavelength

$\lambda = \frac{h}{p} = \frac{h}{mv}$

732. What reasoning led de-Broglie to put forward the concept of matter waves ? **CBSE (Sample Paper)-2012**

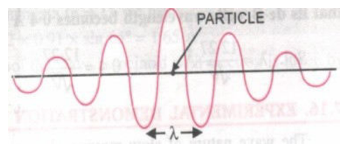
[**Ans**. Nature is symmetrical and that the two basic physical entities, matter and energy, must have symmetrical character So, if radiation shows dual nature, matter should also show it

733. Name the two quantities which determine the wavelength and frequency of de-Broglie wave associated with moving electron.

[**Ans**. Energy and momentum **CBSE (D)-2003**

734. Draw a schematic diagram of a localized wave describing the wave nature of moving electron. **CBSE (F)-2009**

[**Ans**.



734. Why are de-Broglie waves associated with a moving football not visible ? **CBSE (D)-2003**

[**Ans**. Since mass of a football is quite large, hence de-Broglie wave length ($\lambda = \frac{h}{mv}$) associated with it is quite small and is not visible

735. In what manner wave velocity of matter waves is different from that of light ? **CBSE (D)-2003**

[**Ans**. Wave velocity of matter waves ($v_w = \frac{h}{2\,m\lambda}$) depends upon the wavelength even if the particle is moving in vacuum. But light waves which moves in vacuum with the same velocity regardless of wavelength

736. de-Broglie waves are also called matter waves. Why ? **CBSE (AIC)-2004**

[**Ans**. because to be associated with a de-Broglie wave, a particle need not have a charge

737. de-Broglie waves cannot be electromagnetic waves. Why ? **CBSE (AIC)-2009**

[**Ans**. because de-Broglie waves are associated with every moving material particle whether charged or uncharged, whereas electromagnetic waves are associated with accelerated charged particles only

738. In what way wave nature of electrons helps us to increase the resolving limit of electron microscope ? **CBSE (D)-2003**

[**Ans**. An electron accelerated through a potential difference of 50KV will have a de-Broglie wavelength of 0.0055nm, which is about 10^5 times smaller than that of visible light. In this way wave nature of electron helps us to increase the resolving limit of electron microscope up to 0.0055 nm

739. (i) Name an experiment which shows wave nature of electrons. **CBSE (F)-2011, (AIC)-2006,2004**

(ii) Which phenomenon was observed in this experiment using electron beam ?

(iii) Also name the important hypothesis that was confirmed by this experiment.

[**Ans**. **(i)** Davison- Germer experiment

(ii) Diffraction

(iii) de-Broglie hypothesis

740. Write briefly the underlying principle used in Davison-Germer experiment to verify wave nature of electrons experimentally. **CBSE (AI)-2016**

[**Ans**. Diffraction effects are observed for beams of electrons scattered by the crystals using Bragg's diffraction law

741. Mention the significance of Davisson and Germer experiment. **CBSE (F)-2008, (AI)-2005**

OR

With what purpose was famous Davisson- Germer experiment with electrons performed ? **CBSE (D) -2006**

[**Ans**. This experiment proves existence of de-Broglie waves associated with electrons in motion. Which proves the wave nature of material particles

742. Write the expression for the de-Broglie wavelength associated with a charged particle having charge q and mass m, when it is accelerated by potential V. **CBSE (AI)-2013,2006,2004,(F)-2009**

[**Ans**. $\lambda = \frac{\mathrm{h}}{\sqrt{2\,m\,\mathrm{qV}}}$

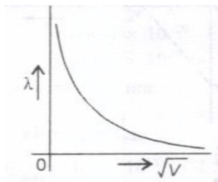
743. If the potential difference used to accelerate electrons is doubled, by what factor does the de-Broglie wavelength associated with the electron changed ? **CBSE (AI)-2013,2006,2004**

[**Ans**. becomes $\frac{1}{\sqrt{2}}$ times as $\lambda = \frac{\mathrm{h}}{\sqrt{2\,m\,\mathrm{qV}}}$ ⇨ $\lambda \propto \frac{1}{\sqrt{\mathrm{V}}}$

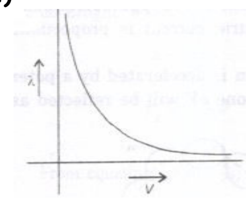
744. (i) Show on a graph the variation of the de-Broglie wavelength (λ) associated with an electron with the square root of accelerating potential V. **CBSE (F)-2012**

(ii) Show graphically the variation of the de-Broglie wavelength (λ) with the potential (V) through which an electron is accelerated from rest. **CBSE (D) -2011**

[**Ans**. **(i)**



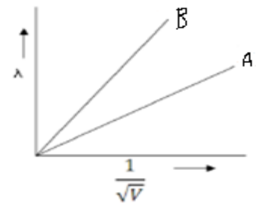
(ii)



745. (i) Plot a graph showing variation of de-Broglie wavelength λ versus $\frac{1}{\sqrt{V}}$, where V is accelerating potential for two particles A and B carrying same charge but of masses m_1, $m_2 (m_1 > m_2)$.

(ii) Which one of the two graphs represents a particle of smaller mass and why ? **CBSE (D)-2016,(AI)-2008**

[**Ans**. **(ii) B** represents smaller mass ($\boldsymbol{m_2}$) because its slope is more



slope = $\frac{\lambda}{1/\sqrt{V}} = \lambda\sqrt{V} = \frac{\mathrm{h}}{\sqrt{2\,m\,\mathrm{q}}}$ [$\because\ \lambda = \frac{\mathrm{h}}{\sqrt{2\,m\,\mathrm{qV}}}$]

⇨ slope $\propto \frac{1}{\sqrt{m}}$

746. 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 ?

[**Ans**. $\lambda = \frac{12.27}{\sqrt{\mathrm{V}}} A^0 = \frac{12.27}{\sqrt{100}} A^0 = 1.227 A^0$, X-rays **CBSE (D)-2010,(F)-2006**

747. What is the de-Broglie wavelength of an electron with kinetic energy (K.E.) 120 eV ? **CBSE (AI)-2016,(F)-2015**

[**Ans**. $E_K = 120$ eV ⇨ $V = 120$ Volts

⇨ $\lambda = \frac{12.27}{\sqrt{\mathrm{V}}} A^0 = \frac{12.27}{\sqrt{120}} A^0 = 1.12 A^0$

748. An α –particle and a proton are accelerated from rest through the same potential difference V. Find the ratio of Their de-Broglie wavelengths associated with them. **CBSE(AI)-2010,2005,(F)-2008**

[**Ans**. $\lambda = \frac{\mathrm{h}}{\sqrt{2\,m\,\mathrm{qV}}}$ & V = same

⇨ $\frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{m_p}{m_\alpha}} \times \sqrt{\frac{q_p}{q_\alpha}} = \sqrt{\frac{m_p}{4m_p}} \times \sqrt{\frac{q_p}{2q_p}} = \frac{1}{2\sqrt{2}}$

749. A proton and electron have same kinetic energy. Which one has greater de-Broglie wavelength and why ?

[**Ans**. $\lambda = \frac{\mathrm{h}}{\sqrt{2\,m\,E_k}}$ & E_k = same **CBSE (AI) -2012, (AIC)-2005**

⇨ $\lambda \propto \frac{1}{\sqrt{m}}$ as $m_e < m_p$ hence $\lambda_e > \lambda_p$

Thus electron will have the greater de-Broglie wavelength

750. An electron, an alpha particle and a proton have the same kinetic energy. Which one of these particles has the largest/ shortest de-Broglie wavelength ? **CBSE (D) -2007, (DC) -2003**

[**Ans**. $\lambda = \frac{\mathrm{h}}{\sqrt{2\,m\,E_k}}$ & E_k = same

⇨ $\lambda \propto \frac{1}{\sqrt{m}}$ as $m_e < m_p < m_\alpha$ hence $\lambda_e > \lambda_p > \lambda_\alpha$

Thus electron will have the largest de-Broglie wavelength & alpha particle has shortest de-Broglie wavelength

751. An electron and alpha particle have the same de-Broglie wavelength associated with them. How are their kinetic energies related to each other ? **CBSE (D) -2008**

[**Ans**. $\lambda = \frac{\mathrm{h}}{\sqrt{2\,m\,E_k}}$ & $\lambda =$ same

⇨ $E_k \propto \frac{1}{m^2}$ as $m_e < m_\alpha$ hence $E_{k_{electron}} > E_{k_{alpha\ particle}}$

752. Matter waves are associated with the material particles only if they are in motion. Why ? **CBSE (DC)-2008**

[Ans. If v = 0, $\lambda = \infty$, it means, matter waves are associated with the material particles only if they are in motion

753. State the laws of photoelectric emission. **CBSE (AI)-2010,(AIC)-2012**

[Ans. (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 ($\boldsymbol{\nu_0}$) below which no photoelectric emission takes place, whatever may be the intensity of incident radiation

(iv) The photoelectric emission is an instantaneous process

754. Why photoelectric effect cannot be explained on the basis of wave nature of light ? Give reasons.**CBSE (D) -2013**

[Ans.(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 $\nu < \nu_0$, no emission of photo electrons takes place, whatever may be the intensity

(iii) According to wave theory, the electron should take appreciable time before it acquires sufficient energy to come out from the metal surface. But, experimental observations show that, there is no time lag between the incidence of radiation and emission of photoelectrons

755. (i) Using photon picture of light, show how Einstein's photoelectric equation can be established.

(ii) Write three salient features observed in photoelectric effect which can be explained using this equation.

CBSE (AI)-2017,2013,(D)-2012

[Ans. **(i)** In the photon picture, energy of light is assumed to be in the form of photons, each carrying an energy $\mathrm{h}\nu$ Einstein assumed that-

(a) Photoelectric emission is the result of interaction of a photon of incident radiation and a bound electron of metal surface

(b) When a photon falls on a metal surface, the energy hv of a photon is completely absorbed by an electron and is partly used as work function and rest is carried as its kinetic energy

i,e, ,$\mathrm{h}\nu = \mathrm{W} + E_{K_{max}}$

⇨ $E_{K_{max}} = \mathrm{h}\nu - \mathrm{W} = \mathrm{h}\nu - \mathrm{h}\nu_0$ [$\because \mathrm{W} = \mathrm{h}\nu_0$]

⇨ $E_{K_{max}} = \mathrm{h}\,(\nu - \nu_0)$ This is Einstein's photoelectric equation

(ii) Three salient features explained by the Einstein's photoelectric equation

(a) Existence of threshold frequency In the equation $\mathrm{E}_{k_{max}} = \mathrm{h}\,(\nu - \nu_0)$

If $\nu < \nu_0$, $\mathrm{E}_{k_{max}}$ will be negative, which is not possible. Hence ν must be greater than ν_0.

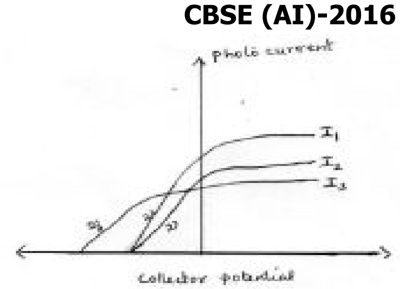
(b) The K.E. of photoelectrons is independent of intensity of incident light.

(c) The K.E. of photoelectrons increases with the frequency of incident light

756. (i) Plot a graph showing the variation of photocurrent versus collector potential for three different intensities $\mathrm{I}_1 > \mathrm{I}_2 > \mathrm{I}_3$, two of which ($\mathrm{I}_1$ and I_2) have the same frequency ν and the third has frequency $\nu_1 > \nu$.

(ii) Explain the nature of curves on the basis of Einstein's equation. **CBSE (AI)-2016**

[Ans. (i) graph is shown below



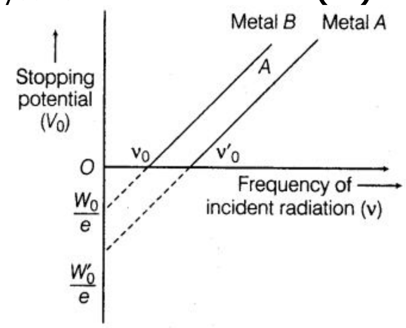
(ii) as per the Einstein's equation

$eV_0 = \mathrm{h}\,(\nu - \nu_0)$ which concludes

(a) the stopping potential is same for I_1 and I_2 as they have the same frequency.

(b) the saturation currents are as shown, because $\mathrm{I}_1 > \mathrm{I}_2 > \mathrm{I}_3$.

757. The graph shows the variation of stopping potential with frequency of incident radiation for two photosensitive Metals A and B. Which of the two has higher threshold frequency ? Justify your answer. **CBSE (AI) -2014**



[Ans. Metal A has higher threshold frequency

Justification : $eV_0 = h\nu - W$

⇨ $\frac{V_0}{e} = \left(\frac{h}{e}\right)\nu - \frac{W}{e}$

⇨ $\frac{W}{e}$ = Intercept on y-axis

But, $(\text{Intercept})_A > (\text{Intercept})_B$

⇨ $W_A > W_B$ ⇨ $(h\nu_0)_A > (h\nu_0)_B$

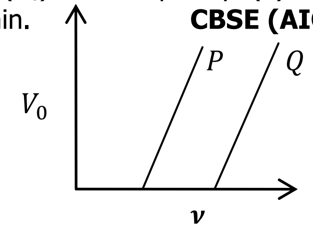
⇨ $(\nu_0)_A > (\nu_0)_B$

==

758. In a photoelectric effect experiment, the graph between the stopping potential (V_0) and frequency (ν) of the incident radiation on two different metal plates P & Q are shown in figure. Explain. **CBSE (AIC)-2005**

(i) Which of the metal plates P & Q has greater value of work function ?

(ii) What does the slope of lines depict ?



[Ans. (i) Metal Q has greater work function

Reason : As, $(\nu_0)_Q > (\nu_0)_P$

⇨ $(h\nu_0)_Q > (h\nu_0)_P$

⇨ $W_Q > W_P$

(ii) slope $= \left(\frac{h}{e}\right)$

Reason : $eV_0 = h\nu - W$

⇨ $\frac{V_0}{e} = \left(\frac{h}{e}\right)\nu - \frac{W}{e}$

On comparing with $y = mx + c$ ⇨ slope $= \left(\frac{h}{e}\right)$

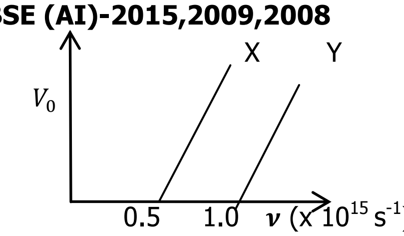
==

759. The following graph shows the variation of stopping potential (V_0) with frequency (ν) of the incident radiation for two photosensitive surfaces X and Y. **CBSE (AI)-2015,2009,2008**

(i) Which of the metals has larger threshold wavelength ? Give reason.

(ii) Explain giving reason, which metal gives out electrons having larger kinetic energy, for the same wavelength of incident radiation ?

(iii) If the distance between the light source and metal X is halved, how will the kinetic energy of emitted from it change ? Give reason.



[Ans. (i) Metal X has larger threshold wavelength

Reason : $(\nu_0)_X < (\nu_0)_Y$

⇨ $\left(\frac{c}{\lambda_0}\right)_X < \left(\frac{c}{\lambda_0}\right)_Y$

⇨ $(\lambda_0)_X > (\lambda_0)_Y$

(ii) Metal X will emit electrons of larger kinetic energy

Reason : $(\nu_0)_X < (\nu_0)_Y$

⇨ $(h\nu_0)_X < (h\nu_0)_Y$

⇨ $W_X < W_Y$

Hence from, $E_{k_{max}} = \frac{hc}{\lambda} - W$

metal X will emit electrons of larger kinetic energy

(iii) K.E. will not change as it does not depend on the distance between light source and metal surface

760. An electron is accelerated from rest through a potential V. Obtain the expression for the de-Broglie wavelength.

[**Ans.** As the electron is accelerated through a potential V **CBSE (F)-2014,(AI)-2012,2010,2007,(D)-2005**

⇨ $E_k = e\,V = \frac{1}{2}mv^2$

⇨ $v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2\,e\,V}{m}}$

de-Broglie wavelength,

$\lambda = \frac{\text{h}}{mv} = \frac{\text{h}}{m\sqrt{\frac{2\,e\,V}{m}}} = \frac{\text{h}}{\sqrt{2meV}}$

⇨ $\lambda = \frac{\text{h}}{\sqrt{2meV}} = \frac{6.6\,X\,10^{-34}}{\sqrt{2X\,9.1\,X\,10^{-31}X1.6\,X10^{-19}V}} = \frac{12.27\,X\,10^{-10}}{\sqrt{V}}$

⇨ $\boldsymbol{\lambda = \frac{12.27}{\sqrt{V}}}\,A^0$

761. Describe briefly how Davisson-Germer experiment demonstrated the wave nature of electrons. **CBSE (F)-2014**

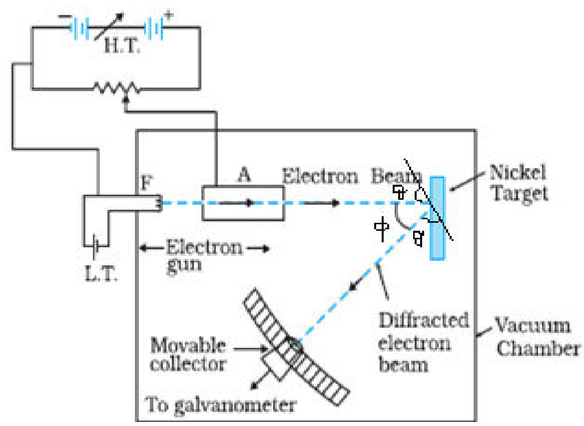
[**Ans. Davisson – Germer experiment** : It provides first experimental proof of concept of wave nature of electrons

Principle : Electron beam can be diffracted through crystal lattice, using Bragg's diffraction condition,

$2d\ \sin\theta = n\lambda$

Working:

Maximum intensity of scattered electron beam is obtained at 54 V and $\phi = 50^0$. This is due to the constructive interference of electron beams scattered from different layers of the regularly spaced atoms of the crystals.



We have, $\theta + \phi + \theta = 180^0$

⇨ $\theta = \frac{1}{2}(180^0 - \phi) = \frac{1}{2}(180^0 - 50^0) = 65^0$

From Bragg's diffraction condition,

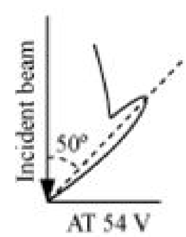
$2d\ \sin\theta = n\lambda$

$2\ X\ 0.91\ X\ \sin 65^0 = 1\lambda$

⇨ $\lambda = 1.65\ \ A^0$ -----------(1)

Now the de-Broglie wavelength

$\lambda = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{54}} = 1.66\ \ A^0$ -----------(2)



From (1) & (2) it is obvious that theoretical and the experimental value of λ are same. Hence, this experiment confirms the wave nature of electrons and the de Broglie hypothesis.

==

762. 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 $(2\lambda mc/\text{h})$ times the kinetic energy of electron. Where m, c and h have their usual meaning.

[**Ans.** Energy of photon, $E = \text{h}\nu = \frac{\text{h}\,c}{\lambda}$ **CBSE (F) -2016, (D)-2003**

de-Broglie wavelength of electron, $\lambda = \frac{\text{h}}{p}$ ⇨ $p = \frac{\text{h}}{\lambda}$

Kinetic energy of electron $E_k = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$

⇨ $\frac{E}{E_k} = \frac{hc/\lambda}{\text{h}^2/2m\lambda^2} = \frac{2m\lambda c}{h}$

⇨ $E = \left(\frac{2m\lambda c}{h}\right)E_k$

763. X-rays of wavelength 'λ' 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 $\sqrt{\frac{h\lambda}{2mc}}$ **CBSE (AIC)-2017,(AI)-2004**

OR

An electromagnetic wave of wavelength λ is incident on a photosensitive surface of negligible work function. If the photoelectrons emitted from this surface have the de-Broglie wavelength λ_1, Prove that, $\lambda=(\frac{2mc}{h})\ \lambda_1^2$ **CBSE (D)-2008**

[Ans. As, W is negligible

⇨ $E_{K_{max}} = h\nu - W = h\nu - 0 = h\nu = \frac{hc}{\lambda}$

Now de-Broglie wavelength,

$\lambda_1 = \frac{h}{\sqrt{2\,m\,E_k}} = \frac{h}{\sqrt{2\,m \times \frac{hc}{\lambda}}} = \sqrt{\frac{h\,\lambda}{2mc}}$ ⇨ $\lambda_1^2 = \frac{h\,\lambda}{2mc}$ ⇨ $\lambda=(\frac{2mc}{h})\ \lambda_1^2$

764. A proton and an $\alpha-$ particleare accelerated through the same potential difference. Which on of the two has
(i) greater de-Broglie wavelength, and **CBSE (AI)-2016,(D)-2014,2010,2009**
(ii) less kinetic energy ? Justify your answer.

[Ans. (i) $\lambda = \frac{h}{\sqrt{2\,m\,qV}}$ & V = same

⇨ $\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_p}} \times \sqrt{\frac{q_\alpha}{q_p}} = \sqrt{\frac{4\,m_p}{m_p}} \times \sqrt{\frac{2e}{e}} = 2\sqrt{2}$ ⇨ $\lambda_{proton} > \lambda_{\alpha-particle}$

(ii) $E_k = qV$ ⇨ $E_k \propto q$

As $q_{proton} < q_{\alpha-particle}$ ⇨ $E_{k_{proton}} < E_{k_{\alpha-particle}}$

765. A deuteron and an $\alpha-particle$ are accelerated with the same accelerating potential. Which one of the two has -
(i) greater value of de-Broglie wavelength associated with it, it, and **CBSE (AI)-2015,(D) -2014**
(ii) less kinetic energy ? Explain.

[Ans. (i) $\lambda = \frac{h}{\sqrt{2\,m\,qV}}$ & V = same

⇨ $\frac{\lambda_d}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_d}} \times \sqrt{\frac{q_\alpha}{q_d}} = \sqrt{\frac{4\,m_p}{2\,m_p}} \times \sqrt{\frac{2e}{e}} = 2{:}1$ ⇨ $\lambda_{deutron} > \lambda_{\alpha-particle}$

(ii) $E_k = qV$ ⇨ $E_k \propto q$

As $q_{deutron} < q_{\alpha-particle}$ ⇨ $E_{k_{deutron}} < E_{k_{\alpha-particle}}$

766. A proton and an $\alpha-particle$ have the same de-Broglie wavelength. Determine the ratio of-
(i) their accelerating potentials, and (ii) their speeds. **CBSE (D) -2015, (DC)-2009**

[Ans. (i) $\lambda = \frac{h}{\sqrt{2\,m\,qV}}$ ⇨ $V = \frac{h^2}{2mq\,\lambda^2}$ & λ = same

⇨ $\frac{V_P}{V_\alpha} = \frac{m_\alpha}{m_P} \times \frac{q_\alpha}{q_P} = \frac{4\,m_P}{m_P} \times \frac{2q_P}{q_P} = 8 : 1$

(ii) $\lambda = \frac{h}{m\,v}$ ⇨ $v = \frac{h}{m\,\lambda}$ ⇨ $v \propto 1/m$

⇨ $\frac{v_P}{v_\alpha} = \frac{m_\alpha}{m_P} = \frac{4\,m_p}{m_P} = 4{:}1$

767. A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has –
(i) greater value of de-Broglie wavelength associated with it, it, and **CBSE (D)-2014**
(ii) less momentum ? Give reasons to justify your answer.

[Ans. (i) $\lambda = \frac{h}{\sqrt{2\,m\,qV}}$ & V = same

⇨ $\frac{\lambda_p}{\lambda_d} = \sqrt{\frac{m_d}{m_p}} \times \sqrt{\frac{q_d}{q_p}} = \sqrt{\frac{2\,m_p}{m_p}} \times \sqrt{\frac{2\,e}{e}} = 2$

⇨ $\lambda_{proton} > \lambda_{deutron}$ thus proton has the greater de-Broglie wavelength

(ii) $\lambda = \frac{h}{p}$ ⇨ $p = \frac{h}{\lambda}$ ⇨ $p \propto \frac{1}{\lambda}$

As $\lambda_{proton} > \lambda_{deutron}$ hence $p_{proton} < p_{deutron}$ Thus proton has less momentum

768. Two metals X and Y have work functions 2 eV & 5 eV respectively. Which metal will emit electrons, when it is radiated with light of wavelength 400 nm & why ? **CBSE (AIC)-2010**

[**Ans**. **metal X**, as $E = \frac{hc}{\lambda} = \frac{6.6 \text{ X } 10^{-34} \text{ X } 3 \text{ X } 10^{8}}{400 \text{ X } 10^{-9} \text{ X } 1.6 \text{ X } 10^{-19}}\ eV = 3.09$ eV ⇨ $E > W_X$ & $E < W_Y$

769. Monochromatic light of frequency 6.0 X 10^{14} Hz is produced by a laser. The power emitted is 2.0 X 10^{-3} W.
(a) What is the energy of a photon in the light beam ? **NCERT-2017**
(b) Estimate the number of photons emitted per second on an average by the source. **CBSE (AI)-2015,(D)-2014**

[**Ans**. **(a)** $E = h\nu = 6.6 \text{ X } 10^{-34} \text{ X } 6 \text{ X } 10^{14} = 3.98 \text{ X } 10^{-19}$ J

(b) number of photons, $n = \frac{P}{E} = \frac{P}{h\nu} = \frac{2 \text{ X } 10^{-3}}{6.6 \text{ X } 10^{-34} \text{ X } 6 \text{ X } 10^{14}} = \frac{100 \text{ X } 10^{15}}{6.6 \text{ X } 3} = 5 \text{ X } 10^{15}$

770. The work function for the following metals is given : **CBSE (F)-2016**

Na : 2.75 eV and Mo : 4.175 eV

(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 ?

[**Ans**. (i) for $\lambda = 3300$ A^0, energy of photon, $\frac{hc}{\lambda} = \frac{6.6 X10^{-34}\ X3\ X10^{8}}{3300\ X\ 10^{-10}\ X\ 1.6\ X\ 10^{-19}}\ eV = 3.75\ eV < 4.175$ eV

Hence **Mo will not** give photoelectric emission as $\frac{hc}{\lambda} <$ W

(ii) In case of Na, photocurrent will increase but in case of Mo no effect

771. The work function of Cesium metal is 2.14 eV. When light of frequency 6.0 X 10^{14} Hz is incident on metal surface, photoemission of electron occurs. What is the **CBSE (AIC)-2010,NCERT-2017**
(i) maximum kinetic energy of emitted electrons
(ii) stopping potential, and
(iii) maximum speed of emitted photoelectrons

[**Ans**. **(i)** $E_{k_{max}} = h\nu - W = 6.6 \text{ X } 10^{-34} \text{ X } 6 \text{ X } 10^{14} - 2.14 \text{ X } 1.6 \text{ X} 10^{-19} = 1.6 \text{ X } 10^{-19}\ (2.48 - 2.14)$ J = 0.34 eV

(ii) $eV_0 = E_{k_{max}} = 0.34$ eV ⇨ $V_0 = 0.34\ V$

(iii) $\frac{1}{2} m v_{max}{}^2 = E_{k_{max}} = 0.34$ eV = 0.34 X 1.6 X 10^{-19} J ⇨ $V_{max} = 345.8 \text{ X } 10^3\ m/s$

772. Light of wavelength 2000 A^0 falls on a metal surface of work function 4.2 eV. **CBSE (F)-2011**
(i) What is the kinetic energy (in eV) of the (a) fastest and (b) slowest electrons emitted from the surface ?
(ii) What will be the change in the energy of the emitted electrons if the intensity of light with same wavelength is doubled ?
(iii) If the same light falls on another surface of work function 6.5 eV, what will be the energy of emitted electrons ?

[**Ans**. (i) (a) K.E. of fastest electron

$$E_{k_{max}} = \frac{hc}{\lambda} - W = \frac{6.6\ X\ 10^{-34}\ X3\ X\ 10^{8}}{2000\ X\ 10^{-10}} - 4.2 \text{ X } 1.6 \text{ X } 10^{-19} = 1.6 \text{ X } 10^{-19}\ (6.2 - 4.2) \text{ J} = 2.0 \text{ eV}$$

(b) K.E. of slowest electron = 0 eV (ii) **No change** in the energy of emitted electrons as it does not depend on intensity
(iii) **no emission** as E(6.2 eV) < W (6.5 eV)]

773. Ultraviolet light of wavelength 2271 A^0 from a 100W mercury source irradiated a photocell made of Molybdenum metal. If the stopping potential is −1.3 V, estimate the work function of the metal. How would the photocell respond when the source is replaced by another source of high intensity (10^5 W/m^2) red light of wavelength 6328 A^0. Justify your answer. **CBSE (AI)-2015,(F)-2013,(D)-2005**

[**Ans**. $eV_0 = \frac{hc}{\lambda} - W$

⇨ $W = \frac{hc}{\lambda} - eV_0 = \frac{6.6 \text{ X } 10^{-34} \text{ X } 3 \text{ X } 10^{8}}{2271\ X\ 10^{-10}} - 1.3 \text{ X } 1.6 \text{ X} 10^{-19} = 1.6 \text{ X } 10^{-19}\ (5.5 - 1.3)$ J = 4.2 eV

Also, $W = \frac{hc}{\lambda_0}$ ⇨ $\lambda_0 = \frac{hc}{W} = \frac{6.6 \text{ X } 10^{-34} \text{ X } 3 \text{ X } 10^{8}}{1.6\ X4.2\ X\ 10^{-19}} = 2.977 \text{ X } 10^{-7}\ m = 2977\ A^0$

As $\lambda\ (= 6328\ A^0) > \lambda_0 (= 2977\ A^0)$

Hence, photocell **will not respond** to source of high intensity (10^5 W/m^2) red light of wavelength 6328 A^0

774. Calculate the- **NCERT-2017**
(a) momentum, and
(b) de Broglie wavelength of the electrons accelerated through a potential difference of 56 V.

[**Ans**. (a) $p = \sqrt{2\,m\,E_k} = \sqrt{2\,m\,eV} = \sqrt{2\ \text{X}\ 9.1\ \text{X}\ 10^{-31}\ \text{X}\ 1.6\ \ \text{X}10^{-19}\text{X}\ 56} = 4.04\ \text{X}\ 10^{-24}\ Kg\ m/s$

(b) $\lambda = \frac{h}{p} = \frac{6.6\ \text{X}\ 10^{-34}}{4.04\ X\ 10^{-24}} = 0.164\ \text{X}\ 10^{-9} m$

775. The wavelength of light from the spectral emission line of Sodium is 589 nm. Find the kinetic energy of electron for which it would have the same de-Broglie wavelength. **CBSE (AI)-2015**

[**Ans**. $\lambda = \frac{\text{h}}{\sqrt{2\,m\,E_k}}$ ⇨ $E_K = \frac{\text{h}^2}{2m\lambda^2} = \frac{(6.6\ X\ 10^{-34})^2}{2\ X\ 9.1\ X\ 10^{-31} X\ (589\ X\ 10^{-9})^2} = 6.96\ \text{X}\ 10^{-25}$ J

776. An electron and a photon each have a wavelength 2.00 nm. Find- **CBSE (D)-2011**
(i) their momenta
(ii) the energy of photon, and
(iii) the kinetic energy of electron

[**Ans**. (i) momentum of electron = momentum of photon = $\frac{\text{h}}{\lambda} = \frac{6.6\ \text{X}\ 10^{-34}}{2.0\ X\ 10^{-9}} = 3.3\ \text{X}\ 10^{-25}$ kgm/s

(ii) energy of photon $= \frac{\text{h}c}{\lambda} = \frac{6.6\ X\ 10^{-34}\ X 3\ X\ 10^{8}}{2.0\ X\ 10^{-9}} = 9.945\ \text{X} 10^{-17}$ J.

(iii) K.E. of electron $= \frac{p^2}{2m} = \frac{(3.3\ \text{X}\ 10^{-25})^2}{2\ X\ 9.1\ X\ 10^{-31}} = 6.0314\ \text{X}\ 10^{-20}$ J

777. An electron and a proton each has de-Broglie wavelength of 1.6 nm. **CBSE (F)-2013**
(i) write the ratio of their linear momenta
(ii) compare the kinetic energy of the proton with that of the electron.

[**Ans**. (i) momentum of electron = momentum of proton = $\frac{\text{h}}{\lambda}$ ⇨ $\frac{momentum\ of\ electron}{momentum\ of\ photon} = 1:1$

(ii) $\lambda = \frac{\text{h}}{\sqrt{2\,m\,E_k}}$ ⇨ $E_K = \frac{\text{h}^2}{2m\lambda^2}$ ⇨ $E_K \propto \frac{1}{m}$ As $m_e < m_p$ ⇨ $E_{K_e} > E_{K_p}$

778. Given the ground state energy $E_0 = -13.6$ eV and Bohr radius a_0 = 0.53 A^0. Find out how the de-Broglie wavelength associated with the electron orbiting in the ground state would change when it jump in to the first excited state ?

[**Ans**. $E_{K_n} = \frac{13.6}{n^2} eV$ & for ground state $n = 1$, for first excited state $n = 2$ **CBSE (AI)-2015**

Now, as $\lambda = \frac{h}{mv}$ ⇨ $\lambda \propto \frac{1}{v}$ but $v \propto \frac{1}{n}$ ⇨ $\lambda \propto n$

⇨ $\frac{\lambda_2}{\lambda_1} = \frac{n_2}{n_1} = \frac{2}{1}$ ⇨ $\lambda_2 = 2\,\lambda_1$

Hence, de-Broglie wavelength will become double

779. When an electron orbiting in hydrogen atom in its ground state moves to third excited state, show how the de-Broglie wavelength associated with it would be affected ? **CBSE (AI)-2015**

[**Ans**. for ground state $n = 1$, for third excited state $n = 4$

Now, as $\lambda = \frac{h}{mv}$ ⇨ $\lambda \propto \frac{1}{v}$ but $v \propto \frac{1}{n}$ ⇨ $\lambda \propto n$

⇨ $\frac{\lambda_2}{\lambda_1} = \frac{n_2}{n_1} = \frac{4}{1}$ ⇨ $\lambda_2 = 4\,\lambda_1$

Hence, de-Broglie wavelength will become four times

780. 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. **CBSE (AI)-2015**

[**Ans**. for third excited state $n = 4$, for ground state $n = 1$

Now, as $\lambda = \frac{h}{mv}$ ⇨ $\lambda \propto \frac{1}{v}$ but $v \propto \frac{1}{n}$ ⇨ $\lambda \propto n$

⇨ $\frac{\lambda_2}{\lambda_1} = \frac{n_2}{n_1} = \frac{1}{4}$ ⇨ $\lambda_2 = \lambda_1/4$

Hence, de-Broglie wavelength will decrease to one fourth of its value in third excited state

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Unit VIII: Atoms and Nuclei **15 Periods**

Chapter–12: Atoms

Alpha-particle scattering experiment; Rutherford's model of atom; Bohr model, energy levels, hydrogen spectrum.

Chapter–13: Nuclei

Composition and size of nucleus, Radioactivity, alpha, beta and gamma particles/rays and their properties; radioactive decay law.

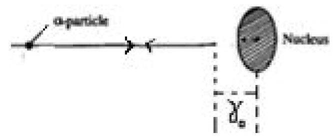
Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

801. Define the distance of closest approach. **CBSE (D)-2017**

[Ans. Distance of closest approach : The minimum distance up to which an α-particle can approach the nucleus just before retracing its path, is known as distance of closest approach

$$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{E_K}$$

$= 2.5 \times 10^{-14}$ m



802. The K. E. of α –particle incident on gold foil is doubled. How does the distance of closest approach change?

[Ans. $r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{E_K}$ ⇨ $r_0 \propto \frac{1}{E_K}$ **CBSE (D)-2017,(AI)-2015,2012**

hence, distance of closest approach will be halved when K.E. is doubled

803. In the Rutherford's scattering experiment the distance of closest approach for an α –particle is d_0. If α –particle is replaced by a proton, how much kinetic energy in comparison to α –particle will it require to have the same distance of closest approach d_0 ? **CBSE (F)-2009**

[Ans. $E_{K_\alpha} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{d_0}$ & $E_{K_p} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{d_0}$ ⇨ $E_{K_p} = \frac{1}{2}E_{K_\alpha}$

804. Determine the distance of closest approach when an alpha particle of kinetic energy 4.5 MeV strikes a nucleus of $Z = 80$, stops and reverses its direction. **CBSE (AI)-2015, 2012, (AIC)-2015**

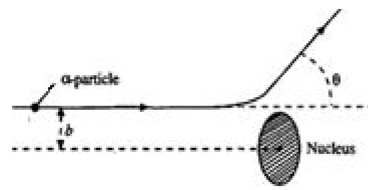
[Ans. $r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{E_K} = 9 \times 10^9 \times \frac{2 \times 80 \times (1.6 \times 10^{-19})^2}{4.5 \times 10^6 \times 1.6 \times 10^{-19}}$ = 5.12 x 10^{-14} m

805. (i) What is Impact parameter ? **CBSE (AIC)-2015**

(ii) What is the significance of impact parameter ?

[Ans. (i) Impact parameter (b) :

It is the perpendicular distance of the initial velocity vector of the α-particle from the



(ii) Significance : It gives an estimate of size of nucleus

806. The trajectories, traced by different α –particles, in Geiger-Marsden experiment were observed as shown in figure. (a) What names are given to the symbols 'b' and 'θ' shown here ? **CBSE (DC)-2008**

(b) What can we say about values of b for (i) $\theta = 0^0$ (ii) $\theta = \pi$ radians ?

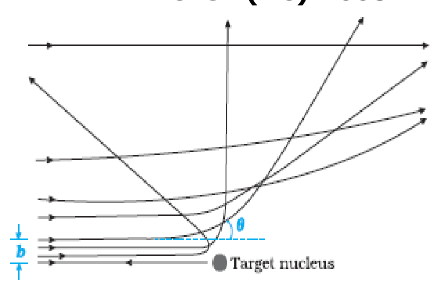
[Ans. (a) symbol **'b'** represents **impact parameter**

& '**θ**' represents **scattering angle**

(b) $b = \frac{Ze^2 \cot\theta/2}{4\pi\varepsilon_0 (\frac{1}{2}m u^2)}$

(i) **when $\theta = 0^0$**, **b** is maximum & represent the **atomic size**

(ii) **When $\theta = \pi$ radians, b** is minimum & represent **nuclear size**



807. State Bohr's quantization condition for defining stationary orbits. **CBSE (D)-2016,(D)-2012,(F)-2010**

[Ans. Bohr's quantization condition : electrons can revolve only in those orbits in which their angular momentum is an integral multiple of $\frac{h}{2\pi}$

i, e, $m v r = n\frac{h}{2\pi}$ where $n = 1,2,3, -------$

These orbits are called stationary orbits and electrons do not radiate energy while revolving in these orbits

908. State Bohr postulate of hydrogen atom that gives the relationship for the frequency of emitted photon in a transition. **OR** **CBSE (F)-2016**

State Bohr's postulate of hydrogen atom which successfully explains emission lines in the spectrum of hydrogen atom.

[Ans. Bohr's postulate of transition : **CBSE (AI)-2015, (D)-2013**

When an electron makes a transition from higher (E_2) to lower energy level (E_1), a photon is emitted which have the energy equal to the energy difference of two levels.

i, e, $h\nu = E_2 - E_1$ This equation is called Bohr's frequency condition

809. The ground state energy of hydrogen atom is −13.6 eV. What are the kinetic and potential energies of electron in this state ? **CBSE (AI)-2014, 2011,(AIC)-2002**

[Ans. $E_K = +13.6\ eV$ & $P.E. = 2\ X\ (-13.6) = -27.2\ eV$

810. The total energy of an electron in the first excited state of hydrogen atom is $-3.4\ eV$. What is the kinetic and potential energy of the electron in this state ? **CBSE (DC)-2010,(D)-2001**

[Ans. $E_K = +3.4\ eV$ & $P.E. = 2\ X\ (-3.4) = -6.8\ eV$

811. Given the value of the ground state energy of hydrogen atom as −13.6 eV. Find out its kinetic and potential energy in the ground and second excited states. **CBSE (AI)-2015,2008**

[Ans. $\boldsymbol{E_n} = -\frac{13.6}{n^2}$ eV

For ground state $n = 1$, ⇨ $E_1 = -13.6\ eV$ ⇨ $E_K = +13.6\ eV$ & $P.E. = 2\ X\ (-13.6) = -27.2\ eV$

For II excited state $n = 3$, ⇨ $E_3 = -\frac{13.6}{3^2} = -1.51\ eV$ ⇨ $E_K = +1.51\ eV$ & $P.E. = 2\ X\ (-1.51) = -3.02\ eV$

812. The value of ground state energy of hydrogen atom is −13.6 eV. **CBSE (AI)-2008, 2001, (F)-2009**

(i) what does the negative sign signify ?

(ii) How much energy is required to take an electron in this atom from the ground state to the first excited state ?

[Ans. (i) Negative sign shows that electron is bound with the nucleus by electrostatic force

(ii) $\boldsymbol{E_n} = -\frac{13.6}{n^2}$ eV & For ground state n =1 and for first excited state n =2

⇨ $\Delta E = E_2 - E_1 = -\frac{13.6}{2^2} - \left(-\frac{13.6}{1^2}\right) = -3.4 + 13.6 = 10.2$ eV

813. In the ground state of hydrogen atom, its Bohr radius is given as 5.3 X $10^{-11}\ m$. The atom is excited such that the radius becomes 21.2X $10^{-11}\ m$. Find - **CBSE (AI)-2016**

(i) the value of principal quantum number and

(ii) the total energy of the atom in this excited state.

[Ans. (i) $\boldsymbol{r = n^2\ r_0}$ ⇨ $\boldsymbol{n^2 = \frac{r}{r_0}}$ ⇨ $\boldsymbol{n^2} = \frac{21.2\ X\ 10^{-11}}{5.3\ X\ 10^{-11}} = 4$ ⇨ $n = 2$

(ii) $\boldsymbol{E_n} = -\frac{13.6}{n^2}$ e ⇨ $\boldsymbol{E_2} = -\frac{13.6}{2^2}$ eV $= -3.4$ eV

814. Calculate the de-Broglie wavelength of the electron orbiting in the $n = 2$ state of hydrogen atom.

[Ans. $\boldsymbol{E_k} = \frac{13.6}{n^2}$ eV $= \frac{13.6}{2^2}$ eV $= \frac{13.6}{4}$ eV $= 3.4$ eV $= 3.4\ X\ 10^{-19}$J **CBSE (AI)-2016**

de-Broglie wavelength, $\lambda = \frac{h}{\sqrt{2mE_k}} = \frac{6.6\ X\ 10^{-34}}{\sqrt{2X\ 9.1\ X\ 10^{-31}\ X3.4\ X\ 1.6\ X10^{-19}}} = 0.6\ X\ 10^{-10}\ m$

815. What is the longest wavelength of photon that can ionize a hydrogen atom in its ground state ? Specify the type of radiation. **CBSE (D)-2007**

[Ans. $\Delta E = \frac{hc}{\lambda}$ ⇨ $\lambda = \frac{hc}{\Delta E} = \frac{6.6\ X\ 10^{-34}\ X\ 3\ X\ 10^8}{13.6\ X\ 1.6\ X\ 10^{-19}} = 0.910\ X\ 10^{-10}\ m$, Ultraviolet region

816. Write the expression for Bohr's radius in hydrogen atom. **CBSE (D)-2010**

[Ans. $r_0 = \frac{\varepsilon_0 h^2}{\pi m e^2} = 0.53\ A^0$

817. In hydrogen atom, if the electron is replaced by a particle which is 200 times heavier but have the same charge, How would its radius change ? **CBSE (F)-2008**

[Ans. radius will be 1/200 times, **Reason :** $r = \frac{\varepsilon_0\ n^2\ h^2}{\pi\ m\ Ze^2}$ ⇨ $\boldsymbol{r \propto \frac{1}{m}}$

818. What is the ratio of radii of the orbits corresponding to first excited state and ground state in a hydrogen atom ?

[Ans. 4:1 as $\boldsymbol{r \propto n^2}$ **CBSE (D)-2010**

819.The radius of innermost electron orbit of a hydrogen atom is 5.3 X 10^{-11} m. What is the radius of orbit in the second excited state ? **CBSE (D)-2010**

[Ans. For II excited state $n = 3$ $\boldsymbol{r = n^2\ r_0} = \boldsymbol{3^2}$ X 5.3 X 10^{-11} = 47.7 X $10^{-11}\ m$

820. Find out the wavelength of the electron orbiting in the ground state of hydrogen atom. **CBSE (D)-2017**

[Ans. $r_0 = 0.53\ A^0$ & For ground state $n = 1$

By the de-Broglie relation,

$2\pi r = n\lambda$ ⇨ $2\ X\ 3.14\ X\ 0.53\ X\ 10^{-10} = 1\ X\ \lambda$ ⇨ $\lambda = 3.32\ X\ 10^{-10}\ m = 3.32\ A^0$

821. Use Bohr model of hydrogen atom to calculate the speed of the electron in the first excited state.

[Ans. For first excited state, n = 2 **CBSE (AI)-2016**

$v_n = \frac{1}{137}\frac{c}{n}$ ⇨ $v_2 = \frac{1}{137} X \frac{3 X 10^8}{2} = 1.09 X 10^6$ m/s

822. Use Rydberg formula to determine the wavelength of H_α line. (Given : Rydberg's constant R =1.03 X 10^7 m^{-1})

[Ans. For H_α line, n_1=2 and n_2=3 **CBSE (AI)-2015, (D)-2012**

⇨ $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$ ⇨ $\lambda = \frac{36}{5R} = \frac{36}{5 X 1.03 X 10^7} = 6990 A^0$

823. When H_α line in the emission spectrum of hydrogen atom obtained ? Calculate the frequency of photon emitted during this transition. **CBSE (AI)-2016**

[Ans. for H_α line/first line in Balmer series transition is from $n = 3$ to $n = 2$

$\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$

⇨ $\nu = \frac{c}{\lambda} = c X \frac{5R}{36} = \frac{3X10^8 X 5 X 1.09 X 10^7}{36} = 4.7 X 10^{14}$ Hz

824. Calculate the shortest wavelength of the spectral lines emitted in Balmer series. (Rydberg constant, $R = 10^7 m^{-1}$)

[Ans. $\frac{1}{\lambda_{min}} = R\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] = R\left[\frac{1}{4} - 0\right] = \frac{R}{4}$ ⇨ $\lambda_{min} = \frac{4}{R} = \frac{4}{10^7}$ m = 4000 A^0 **CBSE (AI)-2016**

825. Calculate the wavelength of radiation emitted when electron in a hydrogen atom jumps from $n = \infty$ to $n = 1$.

[Ans. $\frac{1}{\lambda} = R\left[\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right] = R\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] = R\,[1 - 0] = R$ **CBSE (AI)-2016**

⇨ $\lambda = \frac{1}{R} = \frac{1}{1.09 X 10^7} m = 912 A^0$

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826. (i) Write the relation between mass number and radius of a nucleus. **CBSE (F)-2012,(AI)-2011**

(ii) Show that nuclear density in a given nucleus is independent of mass number A. **CBSE (D)-2015,2013,2012**

[Ans. (i) $\boldsymbol{R} = R_0\, A^{1/3}$ where R_0 is constant

(ii) nuclear density $\rho = \frac{M}{V} = \frac{A}{\frac{4}{3}\pi r^3} = \frac{A}{\frac{4}{3}\pi(R_0 A^{1/3})^3} = \frac{3}{4\pi R_0^3}$

827. Compare the radii of two nuclei with mass numbers 1 and 27 respectively. **CBSE (AI)-2012,2010,(D)-2011**

[Ans. $\boldsymbol{R} \propto A^{1/3}$ ⇨ $\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{27}\right)^{1/3} = \frac{1}{3}$

828. What is the nuclear radius of ^{125}Fe, if that of ^{27}Al is 3.6 Fermi ? **CBSE (AI)-2008**

[Ans. $\boldsymbol{R} \propto A^{1/3}$ ⇨ $\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{125}{27}\right)^{1/3} = \frac{5}{3}$

⇨ $R_1 = R_2 X \frac{5}{3} = 3.6 X \frac{5}{3} = 6$ Fermi

829. Two nuclei have mass numbers in the ratio 1:2. What is the ratio of their nuclear densities ? **CBSE (D)-2009**

[Ans. 1:1 as nuclear density does not depend on mass number

830. What are nuclear forces ? State any two characteristic properties of nuclear forces.

CBSE (AIC)-2017,(AI)-2015,2012,2011,2008,2007

[Ans. Nuclear Forces ; Very short range strongest attractive forces, which firmly hold the nucleons together inside a nucleus, are called nuclear forces.

Properties: (i) very short range, strongest attractive forces.

(ii) charge independent.

(iii) non-central forces

(iv) do not obey inverse square law

831. Define the term mass defect. **CBSE (AIC)-2014,2001**

[Ans. Mass defect $(\Delta \boldsymbol{m})$**:** The difference in mass of a nucleus and its constituents, is called the mass defect.

Δm = [Zm_p + (A – Z) m_n] $- M_N$

832. Define binding energy of a nucleus. **CBSE (AIC)-2002**

[Ans. Binding Energy (BE) : It is defined as the minimum energy required to separate its nucleons and place them at rest at infinite distance apart

It is the equivalent energy of mass defect, i,e, $BE = \Delta m \text{ X } c^2$

833. What is meant by the term binding energy per nucleon **CBSE (DC)-2010**

[Ans. Binding Energy per nucleon (E_{bn}) : It is the average energy per nucleon needed to separate a nucleus in to its individual nucleons

$$E_{bn} = \frac{E_b}{A} = \frac{\Delta m\, c^2}{A}$$

834. The binding energies of deuteron $({}_1^2\text{H})$ and $\alpha - particle$ $({}_2^4\text{He})$ are 1.25 and 7.2 MeV/ nucleon respectively. Which nucleus is more stable ? **CBSE (AIC)-2001**

[Ans. $\alpha - particle$ $({}_2^4\text{He})$ is more stable as BE per nucleon of ${}_2^4\text{He}$ is more than that of ${}_1^2\text{H}$

835. Which out of two nuclei ${}_3^7X$ & ${}_3^4Y$ is more stable ? **CBSE (AI)-2004**

[Ans. Nucleus ${}_3^7X$ is more stable because n/p ratio for ${}_3^7X$ is more than that for ${}_3^4Y$

Reason : A nucleus is more stable if, it has -(a) high value of B.E./A (b) greater n/p ratio, or (c) even-even nucleus.

836. Why is mass of a nucleus is always less than the sum of the masses of its constituent, neutrons & protons ? **CBSE (AI)-2004**

[Ans. When nucleons approach each other to form a nucleus, they strongly attract each other. Hence their potential energy decreases and becomes negative. This decrease in P.E. results in the decrease in the mass of the nucleons

837. If the nucleons of a nucleus are separated far apart from each other, the sum of the masses of all these nucleons is larger than the mass of the nucleus. Why ? **CBSE (AIC)-2003**

[Ans. For the separation of nucleons to a distance far apart from each other, an energy equal to B.E. of the nucleus is given to these nucleons. From E = $\Delta m\ c^2$, thus mass difference comes

838. If the total number of neutrons & protons in a nuclear reaction is conserved, how is then the energy is absorbed or evolved in the reaction ? **CBSE (AI)-2015**

OR

In a nuclear reaction,

$$, {}_2^3\text{He} + {}_2^3\text{He} \longrightarrow {}_2^4\text{He} + {}_1^1\text{H} + 12.86 \text{ MeV}$$ **CBSE (D)-2013**

though the number of nucleons is conserved on both sides of the reaction, yet the energy is released. How ? Explain.

[Ans. Since certain mass disappears in the formation of a nucleus (mass defect), it appears in the form of energy E = Δmc^2. Thus the difference of B.E. of the two sides appear as energy released or absorbed in a nuclear reaction

839. A nucleus with mass number A = 240 and BE/A = 7.6 MeV breaks in to two fragments each of A = 120 with BE/A = 8.5 MeV. Calculate the energy released. **CBSE (D)-2016**

[Ans. Energy released = BE of two fragments $-$ BE of nucleus

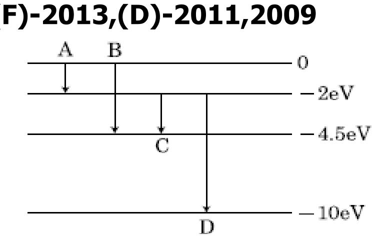
= 2 X 120 X 8.5 – 240 X 7.6 = 240 (8.5 – 7.6) = 240 X 0.9 = 216 MeV

840. Calculate the energy released in the fusion reaction : **CBSE (D)-2016**

${}_1^2\text{H} + {}_1^2\text{H} \longrightarrow {}_2^3\text{He} + n,$ where BE of ${}_1^2\text{H} = 2.23\ MeV$ and of ${}_2^3\text{He} = 7.73\ MeV$

[Ans. Energy released = BE of ${}_2^3\text{He} - BE$ of $({}_1^2\text{H} + {}_1^2\text{H}) = 7.73 - (2.23 + 2.23) = 3.73$ MeV

841. The energy levels of a hypothetical atom are shown below. Which of the shown transitions will result in the emission of photon of wavelength $275\ nm$? **[Ans.** B] **CBSE (F)-2013,(D)-2011,2009**



[Ans. $\lambda = 275 \text{ nm} = 275 \text{ X } 10^{-9}\ m$

$$\Delta E = \frac{hc}{\lambda} = \frac{6.6\ X\ 10^{-34}\ X\ 3\ X\ 10^8}{2.75 \text{ X } 10^{-7} \text{ X } 1.6\text{X } 10^{-19}} = 4.5 \text{ eV}$$

For transition B

$\Delta E = 0 - (-4.5) = 4.5$ eV

842. Calculate the binding energy per nucleon of ${}_{20}^{40}Ca$ nucleus. **CBSE (AI)-2007,2004,2002,(D)-2002**

(Given, Mass of ${}_{20}^{40}Ca$ = 39.962589 u, Mass of proton= 1.007825 u, Mass of neutron =1.008665 u & 1u= 931 MeV/c^2)

[Ans. mass defect, Δm = [Zm_p + (A – Z) m_n] $-M_N$ = [20(1.007825) + 20(1.008665)]−39.962589 =0.367211

⇨ B.E. = 0.367211 X 931 = 341.87 MeV ⇨ B.E. per nucleon = $\frac{341.87}{40}$ = 8.547 MeV

843. What is radioactivity ? **CBSE (AIC)-2001**

[**Ans**. **Radioactivity** : The phenomenon of spontaneous and continuous emission of radiations such as α or β and γ –rays from the nucleus of heavy elements is called radioactivity

844. When a radioactive radiation is placed in an electric or magnetic field it divides in to three parts. Why ? **CBSE (AIC)-2014**

[**Ans**. Radioactive decay occurs in series where daughter product give rise to grand daughter product and so on. Some of them emit α –particles while others emit β –particles. If after α- emission or β- emission, nucleus is left in the excited state it may emit γ –rays. Therefore radioactive sample give out α –particle, β –particles and γ –rays together

845. Why do α –particles have high ionising power ? **CBSE (F)-2010**

[**Ans**. Because of their large mass & large nuclear cross section α –particles have highest ionizing power

846. Which of the following radiations α-rays, β-rays, γ-rays **CBSE (AI)-2001**

(i) are similar to X-rays
(ii) are easily absorbed by the matter
(iii) travel with greatest speed
(iv) are similar in nature to cathode rays.

[**Ans**. (i) $\gamma - rays$ (ii) α-rays (iii) γ-rays (iv) β-rays

847. What is the difference between an electron and a $\beta - particle$? **CBSE (AIC)-2001**

[**Ans**. Both are essentially the same. In fact an electron of nuclear origin is called $\beta - particle$

848. A nucleus contains no electrons, yet it ejects them. How ? **CBSE (AIC)-2003**

[**Ans**. A neutron in a nucleus decays in to a proton and an antineutrino. It is this electron which is emitted as $\beta - particle$

$$n \longrightarrow p + {}_{-1}^{0}e + \overline{\nu}$$

849. A nucleus undergoes $\boldsymbol{\beta}^{-} decay$. How does its (i) mass number (ii) atomic number change ? **CBSE (D)-2011**

[**Ans**. During $\boldsymbol{\beta}^{-} decay$ (i) mass number remains same (ii) atomic number increases by one

850. What is β-decay ? **CBSE (F)-2002**

[**Ans**. $\boldsymbol{\beta - decay}$: The process of spontaneous emission of β –particle from a radioactive nucleus is called β –decay

851. (i) Write the nuclear decay process of β-decay ${}_{15}^{32}P$ **CBSE (AI)-2010,2004,(D)-2004**

(ii) Write the β –decay of tritium in symbolic form. **CBSE (F) -2015,(AI)-2013**

[**Ans**. (i) ${}_{15}^{32}P \longrightarrow {}_{16}^{32}\mathrm{S} + {}_{-1}^{0}e + \overline{\nu}$

(ii) ${}_{1}^{3}\mathrm{H} \longrightarrow {}_{2}^{3}\mathrm{He} + {}_{-1}^{0}e + \overline{\nu}$

852. Write the basic nuclear process involved in the emission of (a) β^{-} decay and (b) β^{+} decay in a symbolic form, by a radioactive nucleus. **CBSE (D)-2017,(AI)-2016,2013,(F)-2015,(AIC)-2015**

[**Ans**. (a) β^{-} decay, $n \longrightarrow p + {}_{-1}^{0}e + \overline{\nu}$

(b) β^{+} decay, $p \longrightarrow n + {}_{+1}^{0}e + \nu$

853. Why is the detection of neutrinos found very difficult ? **CBSE (AI)-2016,2013,(F)-2015,(AIC)-2015**

[**Ans**. Because neutrinos have no charge, almost no mass and their interaction with matter is very weak

854. Why the mass number of a nuclide undergoing β-decay does not change? **CBSE (DC)-2003**

OR

In both β-decay process, the mass number of the nucleus remains same, whereas the atomic number Z increases by one in β^{-}decay and decreases by one in β^{+}decay. Explain giving reason. **CBSE (F)-2014**

[**Ans**. In both β-decay process, the conversion of neutron to proton or proton to neutron inside the nuleus. These nucleons have nearly equal masses. Hence mass number does not change and

In $\boldsymbol{\beta}^{-}$ decay $n \longrightarrow p + {}_{-1}^{0}e + \overline{\nu}$

or ${}_{Z}^{A}\mathrm{X} \longrightarrow {}_{Z+1}^{A}\mathrm{Y} + {}_{-1}^{0}e + \overline{\nu}$

In $\boldsymbol{\beta}^{+}$ decay $p \longrightarrow n + {}_{+1}^{0}e + \nu$

or ${}_{Z}^{A}\mathrm{X} \longrightarrow {}_{Z+1}^{A}\mathrm{Y} + {}_{+1}^{0}e + \nu$

855. Write the nuclear reactions for the following- **CBSE (DC)-2005**

(i) α-decay of $^{242}_{94}Pu$ (ii) β-decay of $^{32}_{15}P$ (iii) β^{+}decay of $^{11}_{6}\mathrm{C}$ (iv) α-decay of $^{226}_{88}Ra$

[Ans. (i) $^{242}_{94}Pu \longrightarrow {}^{238}_{92}U + {}^{4}_{2}\mathrm{He}$

(ii) $^{32}_{15}P \longrightarrow {}^{32}_{16}\mathrm{S} + {}^{0}_{-1}e + \overline{\nu}$

(iii) $^{11}_{6}\mathrm{C} \longrightarrow {}^{11}_{5}\mathrm{C} + {}^{0}_{+1}e + \nu$

(iv) $^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}\mathrm{He}$

856. In the reactions given below, find the values of x, y & z and a, b & c. **CBSE (AI)-2016**

(a) $^{12}_{6}\mathrm{C} \longrightarrow {}^{y}_{z}\mathrm{B} + x + \nu$ **[Ans.** (a) x = $_{+1}^{0}e$, y =5, z =11 (b) a=10, b=2, c= 4]

(b) $^{12}_{6}\mathrm{C} + {}^{12}_{6}\mathrm{C} \longrightarrow {}^{20}_{a}\mathrm{Ne} + {}^{c}_{b}\mathrm{He}$

857. In the following nuclear reaction assign the value of Z and A. **[Ans.** (a) Z = 56, *A* = 89] **CBSE (AI)-2015**

$$n + {}^{235}_{92}U \longrightarrow {}^{144}_{Z}Ba + {}^{A}_{36}X + 3\,n$$

858. Identify the nature of the radioactive radiations emitted in each step of the decay process given below:

$^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y \longrightarrow {}^{A-4}_{Z-1}W$ **CBSE (AI)-2015**

[Ans. $^{A}_{Z}X \xrightarrow{\alpha} {}^{A-4}_{Z-2}Y \xrightarrow{\beta^{-}} {}^{A-4}_{Z-1}W$

859. Give the mass number and atomic number of elements on the right hand side of the decay process. **CBSE (D)-2004**

$^{220}_{86}Ru \longrightarrow Po + \mathrm{He}$

[Ans. $^{220}_{86}Ru \longrightarrow {}^{216}_{84}Po + {}^{4}_{2}\mathrm{He}$

==

860. A radioactive nucleus 'A' undergoes series of decays shown in the following scheme : **CBSE (AI)-2015**

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\gamma} A_3$$

If mass number and atomiv number of A_3 are 176 and 69 respectively, find the mass number and atomic number of A

[Ans. $^{180}_{70}A \xrightarrow{\alpha} {}^{176}_{68}A_1 \xrightarrow{\beta} {}^{176}_{69}A_2 \xrightarrow{\gamma} {}^{176}_{69}A_3$

861. A radioactive nucleus 'A' undergoes a series of decays according to the following scheme- **CBSE (D)-2017,(D)-2009,(AIC)-2002**

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

If the mass number and atomic number of A are 180 & 72 respectively, What are these numbers for A_4?

[Ans. $^{180}_{72}A \xrightarrow{\alpha} {}^{176}_{70}A_1 \xrightarrow{\beta} {}^{176}_{71}A_2 \xrightarrow{\alpha} {}^{172}_{69}A_3 \xrightarrow{\gamma} {}^{172}_{69}A_4$

862. A radioactive isotope D decays according to the sequence - **CBSE (AI)-2002**

$$D \xrightarrow{{}^{1}_{0}n} D_1 \xrightarrow{\alpha} D_2$$

If the mass number & atomic number for D_2 are 176 & 71 respectively, find the mass number and atomic number of D

[Ans. $^{181}_{69}D \xrightarrow{{}^{1}_{0}n} {}^{180}_{69}D_1 \xrightarrow{\alpha} {}^{176}_{67}D_2$]

863. The sequence of stepwise decays of a radioactive nucleus is - **CBSE (D)-2010**

$$D \xrightarrow{\alpha} D_1 \xrightarrow{\beta^{-}} D_2$$

If the atomic number and mass number of D_2 are 71 & 176 respectively, What are their corresponding values for D ?

[Ans. $^{180}_{72}D \xrightarrow{\alpha} {}^{176}_{70}D_1 \xrightarrow{\beta^{-}} {}^{176}_{71}D_2$

864. (a) Write two important limitations of Rutherford nuclear model of the atom. **CBSE (D)-2017,(AIC)-2015**
(b) How these were explained in Bohr's model of hydrogen atom ? **CBSE (AIC)-2015**

[Ans. (a) Limitations of Rutherford nuclear model of the atom :

(i) Electron moving in a circular orbit around the nucleus would get accelerated. Therefore it looses its energy and hence it would spiral into the nucleus

(ii) Due to continuously changing radii of orbits, electron will emit em waves of all frequencies. Hence atom should emit continuous spectrum

(b) Explanation according to Bohr's model of hydrogen atom :

(i) Electron in an atom can revolve in certain stable orbits without the emission of radiant energy, in which

$$m\,v\,r = n\frac{h}{2\pi} \quad \text{Where } n = 1,2,3,\text{--------}$$

(ii) Energy is released/ absorbed only, when an electron jumps from one stable orbit to another stable orbit. This results in a discrete spectrum

865. How does de-Broglie explain the stationary orbits for revolution of electrons using Bohr's quantization condition ?

[Ans. d<u>e-Broglie's explanation of Stationary orbits</u> **CBSE (D)-2016,(D)-2012,(F)-2010**

According to de- Broglie hypothesis,

$\lambda = \frac{h}{p} \quad ⇨ \quad p = \frac{h}{\lambda}$

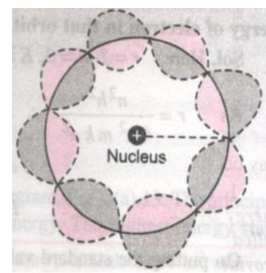
But for circular orbits,

$L = m\,v\,r = r_n\,p$ where r_n is the radius of quantized orbits

⇨ $n\,\frac{h}{2\pi} = r_n\,\frac{h}{\lambda}$ [$\because L = n\frac{h}{2\pi}$]

⇨ $2\,\pi\,r_n = n\,\lambda$

⇨ Circumference of permitted orbits are integer multiples of wavelength λ



866. Derive the Bohr's quantization condition for angular momentum of the orbiting of electron in hydrogen atom, Using de-Broglie's hypothesis. **CBSE (AIC)-2017,(AI)-2016,2015,2011**

[Ans. de-Broglie wavelength

$$\lambda = \frac{h}{mv}$$

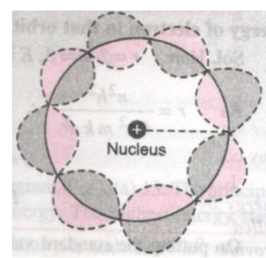
For electron moving in n^{th} orbit,

$2\pi r = n\,\lambda$

⇨ $2\pi r = n\frac{h}{mv}$

⇨ $m\,v\,r = n\,\frac{h}{2\pi}$

This is Bohr's postulate of quantization of angular momentum



867. Use de-Broglie's hypothesis to write the relation for the n^{th} radius of Bohr orbit interms of Bohr's quantization condition of orbital angular momentum. **CBSE (F)-2016**

[Ans. de Broglie Wavelength associated with electron in its orbit

$$\lambda = \frac{h}{p} = \frac{h}{m\,v_n}$$

Only those waves survive which form standing waves. For electron moving in n^{th} circular orbit of radius r_n

$2\pi r_n = n\,\lambda$ where n = 1,2,3,-------------

⇨ $2\pi r_n = n\frac{h}{m\,v_n}$

⇨ $r_n = n\frac{n\,h}{2\,\pi\,m\,v_n}$

868. (i) Define Ionization energy. What is its value for hydrogen atom ? **CBSE (AI)-2016,2010**
(ii) How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron but having the same charge ?

[Ans. (i) **Ionization Energy** : It is the minimum energy required to just remove an electron from the atom

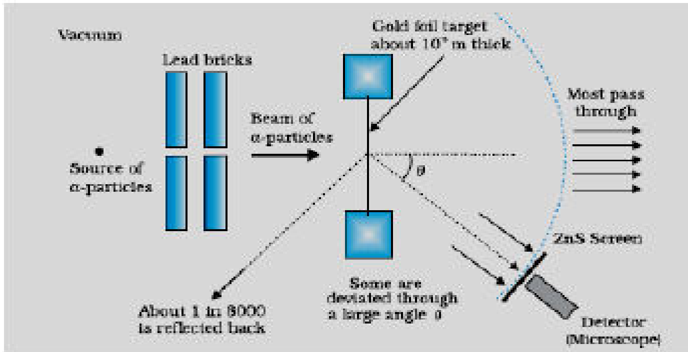
for H- atom ionization energy is $E_0 = \frac{m\,e^4}{8\,\varepsilon_0^2 h^2} = 13.6$ eV

(ii) As $E_0 \propto m$, hence ionization energy becomes 200 times

869. Draw a schematic arrangement of the Geiger – Marsden experiment for studying α –particle scattering by a thin foil of gold. Describe briefly, by drawing trajectories of the scattered α –particles, how this study can be used to estimate the size of the nucleus ? Draw a plot showing the number of particles scattered versus scattering angle θ.

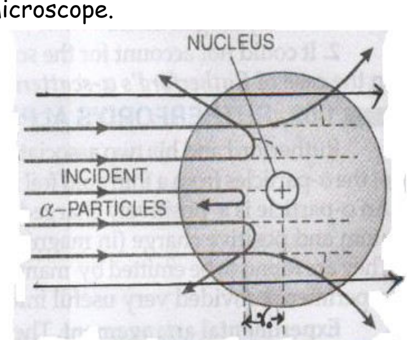
CBSE (F)-2013,2010,2008,2003 (AI)-2009,(D)-2005

[Ans. Geiger-Marsden experiment (Rutherford's α-Particle scattering experiment) :



High energetic collimated beam of α-Particles is allowed to fall on a very thin gold foil as shown. The scattered α-particles are observed through a rotating detector consisting of ZnS screen and microscope.

Observations and Conclusions :



(i) most of the α–Particles passed un deflected through the foil.

It indicates that most of the space in an atom is empty.

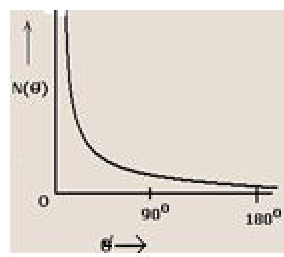
(ii) some α–Particles were deflected through small angles and only a few (1 in 8000) were deflected through large angles (> 90^0) to return back

It concludes that whole of the positive charge and almost whole mass is concentrated in a tiny central core known as nucleus.

(iii)The number of α–Particles at a scattering angle θ is

$$N(\theta) \propto \frac{1}{sin^4(\theta/2)}$$

It is due to the fact that, scattering of α-particles is in accordance with Coulomb's force.



Size of nucleus : It can be estimated by distance of closest approach

$$\frac{1}{2} m v^2 = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{r_0}$$

$$\Rightarrow \quad r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{\frac{1}{2} m v^2} = 2.5 \times 10^{-14} \text{ m}$$]

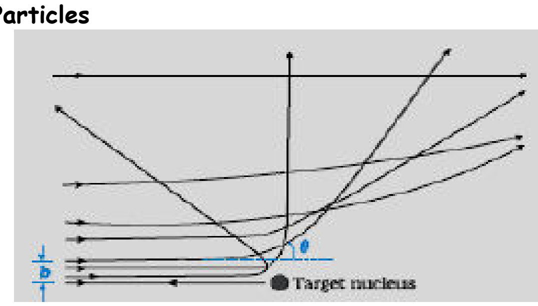
==

870. In Geiger- Marsden experiment, why is the most of the α–Particles go straight through the foil and only a small fraction gets scattered at large angles ? **CBSE (AIC)-2015**

[Ans. for most of the α–Particles, impact parameter is large, hence they suffer very small repulsion due to nucleus and go straight (right) through the foil

871. In Geiger-Marsden experiment, draw the trajectories traced by α–Particles in the Coulomb's field of target.

[Ans. Trajectories traced by α–Particles **CBSE (AIC)-2015**



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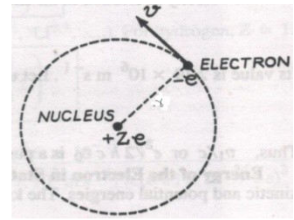
872. Using Bohr's postulates, derive the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence, derive the expression for the orbital velocity and orbital period of the electron moving in the n^{th} orbit of hydrogen atom. **CBSE (F)-2017,2014,2012,2011,(AI)-2015,2014,2013,(D)-2013**

[Ans. Bohr's theory of H-atom :

As the electrostatic force of attraction between electron and nucleus provides the necessary centripetal force



i,e, $\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{r^2}$

⇨ $mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}$ ------------(1)

According to Bohr's quantum condition

$m\,v\,r = n\frac{\mathrm{h}}{2\pi}$ -----------(2)

on squaring eqn (2) and dividing by eqn (1) we get

$$\frac{m^2v^2r^2}{m\,v^2} = \frac{n^2\mathrm{h}^2/\,4\pi^2}{\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}}$$

⇨ $\boldsymbol{r = \frac{\varepsilon_0\, n^2\, \mathrm{h}^2}{\pi\, m\, Ze^2}}$ ⇨ $\boldsymbol{r_n \propto n^2}$

For H-atom $Z = 1$ & for innermost orbit $n = 1$,

⇨ $r_0 = \frac{\varepsilon_0 \mathrm{h}^2}{\pi\, m\, e^2}$ = 0.53 A^0. This is called **Bohr's orbit**

<u>Energy of electron in stationary orbits</u>

K.E. of electron, $E_K = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right)$ $\left[\because mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right]$

& P.E. $\mathrm{U} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(-e)}{r} = -\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r}$

⇨ total energy of electron $E = E_K + \mathrm{U} = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right) - \frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r} = -\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r}$

⇨ $E_n = -\frac{1}{2}\,\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{\frac{\varepsilon_0\, n^2\, \mathrm{h}^2}{\pi\, m\, Z\, e^2}} = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,h^2}\left(\frac{1}{n^2}\right)$

⇨ $E_n = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,h^2}\left(\frac{1}{n^2}\right) \times \frac{ch}{ch} = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,c\,h^3}\left(\frac{ch}{n^2}\right) = -\boldsymbol{\frac{Z^2Rch}{n^2}}$

For H- atom $Z = 1$

⇨ $\boldsymbol{E_n = -\frac{Rch}{n^2} = -\frac{13.6}{n^2}}\,\mathrm{eV}$

Where, $R = \frac{m\,e^4}{8\varepsilon_0^2\,ch^3}$ = 1.097 X 10^7 m^{-1} and is called Rydberg's constant.

<u>Orbital velocity & time period of electron in stationary orbits</u>

dividing by eqn (1) by (2)

$$\frac{m\,v^2}{m\,v\,r} = \frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r} \times \frac{2\pi}{n\mathrm{h}}$$

⇨ $v = \frac{Ze^2}{(2\,\varepsilon_0)n\,\mathrm{h}} = \frac{Ze^2}{(2\,\varepsilon_0)c\,h} \times \frac{c}{n} = \alpha\,\frac{c}{n} = \frac{1}{137}\,\frac{c}{n}$ ⇨ $\boldsymbol{v \propto \frac{1}{n}}$

where $\alpha = \frac{Ze^2}{(2\,\varepsilon_0)c\,h} = \frac{1}{137}$ and is called fine structure constant

Orbital period of electron in H-atom :

$$T = \frac{2\pi r}{v} = \frac{2\pi(mvr)}{mv^2} = \frac{2\pi\left(\frac{nh}{2\pi}\right)}{m\left(\frac{e^2}{2\varepsilon_0 n\,\mathrm{h}}\right)^2}$$

⇨ $T = \frac{4\varepsilon_0^2\,n^3h^3}{me^4}$

873. (a) Explain the origin of spectral series/ lines of hydrogen atom using Bohr's atomic model.

(b) Draw the energy level diagram showing how the line spectra corresponding to Lyman/Balmer series occur due to transition between energy levels in a hydrogen atom. **CBSE (AI)-2015,(D)-2013**

[Ans. (a) Spectral series of hydrogen atom :

According to Bohr's frequency condition, if an electron makes a transition from higher energy level E_2 to lower energy level E_1, then

$$\mathrm{h}\frac{c}{\lambda} = E_2 - E_1 = -\frac{Rch}{n_2{}^2} - \left[-\frac{Rch}{n_1{}^2}\right] = Rch\left[\frac{1}{n_1{}^2} - \frac{1}{n_2{}^2}\right]$$

⇨ $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{n_1{}^2} - \frac{1}{n_2{}^2}\right]$ where $\bar{\nu}$ is called wave number

Where $\bar{\nu}$ is called wave number (number of waves per unit distance), & R is the Rydberg's constant ($R = 1.097 \times 10^7$ m^{-1})

(i) Lyman Series

When an electron jumps from any higher energy level to the first level, we get Lyman series. This series lies in ultraviolet region $(912 - 1215\ \mathrm{A}^0)$ and hence not visible. It is given by

$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{n_2{}^2}\right]$ where n_2 = 2,3,4,5,---------

(ii) Balmer Series

When an electron jumps from any higher energy level to the second level, we get Balmer series. This series lies in visible region $(3646 - 6563\ \mathrm{A}^0)$ and is given by

$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n_2{}^2}\right]$ where n_2 = 3,4,5,6,---------

(iii) Paschen Series

When an electron jumps from any higher energy level to the third level, we get Paschen series. This series lies in infrared region, $(8204 - 18752\ \mathrm{A}^0)$ hence not visible and is given by

$\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n_2{}^2}\right]$ where n_2 = 4,5,6,7,---------

(iv) Brackett Series

When an electron jumps from any higher energy level to the fourth level, we get Brackett series. This series lies in infrared region, $(14576 - 40589\ \mathrm{A}^0)$ hence not visible & is given by

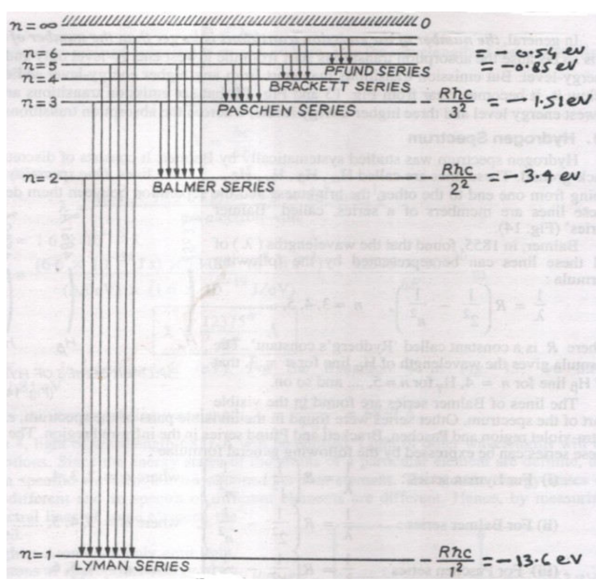
$\frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{n_2{}^2}\right]$ where n_2 = 5,6,7,8,--------

(v) Pfund Series

When an electron jumps from any higher energy level to the fifth level, we get Pfund series. This series also lies in infrared region, $(22775 - 74536\ \mathrm{A}^0)$ hence not visible & is given by

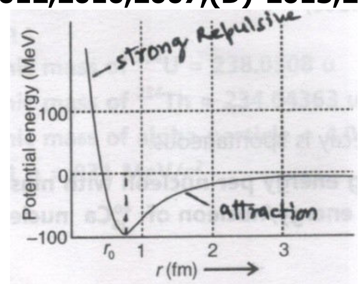
$\frac{1}{\lambda} = R\left[\frac{1}{5^2} - \frac{1}{n_2{}^2}\right]$ where n_2 = 6,7,8,9,--------

(b) Hydrogen spectrum :



874. Draw a plot of potential energy of a pair of nucleons as a function of their separations.
(i) Write two important conclusions that can be drawn from the graph.
(ii) What is the significance of negative potential energy in the graph drawn ?

[Ans. Graph : **CBSE (AIC)-2017,(AI)-2015,2012,2010,2007,(D)-2013,2007**



(i) Conclusions :

(a) For $r < r_0$, P.E. increases rapidly with the decrease in r.
This indicates strong repulsion between the nucleons

(b) For $r > r_0$, P.E. is negative which falls to zero for a separation more than a few Fermi. It indicates attractive force between the nucleons

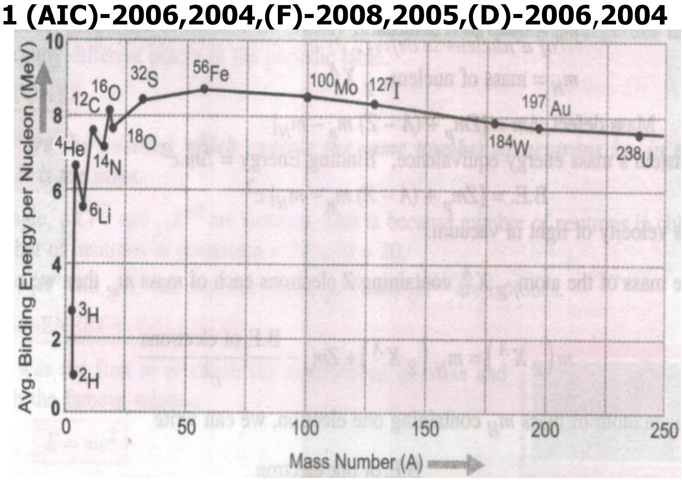
(ii) Significance :

Negative potential energy shows that binding force between the nucleons is strong.

875. Draw a plot of binding energy per nucleon (B.E/A) as a function of mass number A.
(a) Write salient features of this curve.
(b) Write two important conclusions that can be drawn regarding the nature of nuclear force.
(c) Use this graph to explain the release of energy in both the processes of nuclear fission and fusion.

CBSE (AI)-2016,2013,2011,2009,2004,2001 (AIC)-2006,2004,(F)-2008,2005,(D)-2006,2004

[Ans. Binding energy curve :



(a) Salient features :

(i) BE per nucleon (E_{bn}) is practically constant (independent of A) for the nuclei of middle mass number (30 <A<170).

Maximum E_{bn} is about 8.75 MeV for $A = 56$, thus Fe^{56} is most stable.

For A = 238 E_{bn} drops to 7.6 MeV.

(ii) Average B.E. per nucleon is very small for both light nuclei $(A < 30)$ and heavy nuclei$(A > 170)$, so these nuclei are less stable.

(b) Conclusions/Importance of BE curve :

(i) Nuclear force is attractive and sufficiently strong to produce BE of a few MeV per nucleon

(ii) Constancy of BE curve in the range 30 <A <170 is a due to the fact that nuclear force is short – ranged.

(c) Release of energy in fission & fusion :

(i) When a heavy nucleus undergoes nuclear fission, the BE per nucleon of product nuclei is more than that of the original nucleus. This means that the nucleons get more tightly bound. Hence, there is release of energy.

(ii) When two very light nuclei (A ≤10) undergoes nuclear fusion, the BE per nucleon of product nucleus becomes more than that of the original lighter nuclei. This means that the nucleons in the final nucleus get more tightly bound. Hence, there is release of energy.

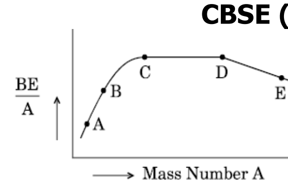
876. What characteristic property of nuclear force explains the consistency of binding energy per nucleon (BE/A) in the range of mass number 'A' lying 30< A< 170 ? **CBSE (AI)-2015**

[Ans. Nuclear force is short ranged or saturated

877. Give the reason for the decrease of binding energy per nucleon for nuclei with high numbers.

[Ans. This is due to increase in Coulomb repulsive force between protons **CBSE (DC)-2006,(D)-2004**

878. The figure shows the plot of binding energy (BE) per nucleon as a function of mass number A. Point out, giving reasons, the two processes (in terms of A,B,C,D and E) , one of which can occur due to nuclear fission and the other due to nuclear fusion. **CBSE (AI)-2015**



[Ans. (i) Nuclear fission of E in to D and C,
as there is increase in binding energy per nucleon

(ii) Nuclear fusion of A and B in to C,
as there is an increase in binding energy per nucleon

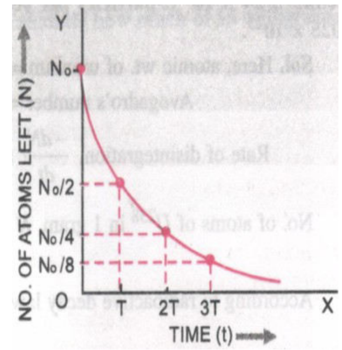
879. State the law of radioactive decay.
(i) Derive the mathematical expression for law of radioactive decay for a sample of radioactive nucleus.
(ii) Plot a graph showing the number (N) of undecayed nuclei as a function of time (t) for a given radioactive sample having half-life T. **CBSE (AI) -2016, 2015, 2006, 2004, (D)-2014, 2011,2005, CBSE (F)-2013,2007**

[**Ans. Law of radioactive decay :** The rate of decay of a given radioactive sample is directly proportional to the total number of undecayed nuclei present in the sample

i,e, $-\frac{dN}{dt} \propto N$

⇨ $\frac{dN}{dt} = -\lambda N$

⇨ $\frac{dN}{N} = -\lambda\, dt$ ------------(1)



Where λ is constant of proportionality & is called decay constant

Let, when $t = 0,\ N = N_0$, Integrating (1) on both sides

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_0^t dt$$

$$[\log_e N]_{N_0}^{N} = -\lambda\, [t]_0^t$$

$$\log_e N - \log_e N_0 = -\lambda\,(t-0)$$

$$\log_e \frac{N}{N_0} = -\lambda\, t$$

⇨ $\frac{N}{N_0} = e^{-\lambda t}$

⇨ $\mathbf{N = N_0\, e^{-\lambda t}}$

==

880. Define the terms half-life period & decay constant of a radioactive substance. Write their S.I. units. Establish the relation between them. **CBSE (AI)-2015,2006,2004,(F)-2007,(D)-2005,2001**

[**Ans. Half-life (T) :** It is defined as the time taken to decay one-half of the initial number of nuclei present in a radioactive sample

Its S.I. unit is second (s)

Decay constant (λ) : It is defined as the reciprocal of the time in which the number of nuclei left undecayed reduces to $\frac{1}{e}$ times of its initial value

Its S.I. unit is second (s^{-1})

Relation : We have, $N = N_0 e^{-\lambda t}$

But when $t = T, N = \frac{N_0}{2}$

⇨ $\frac{N_0}{2} = N_0 e^{-\lambda T}$

$\frac{1}{2} = e^{-\lambda T}$

⇨ $2 = e^{\lambda T}$

$\lambda T = \log_e 2$

$\lambda = \frac{\log_e 2}{T} = \frac{0.6931}{T}$

==

881. Define the term **mean life** of a radioactive nuclide. How is the mean life of a given radioactive nucleus related to the decay constant and Half-life ? **CBSE (AI) -2016, 2015, (F)-2014**

[**Ans. Average or Mean life (τ) :** mean life of a radioactive substance is defined as the sum of life time of all the nuclei divided by the number of all nuclei

i,e, Mean life (τ) = $\frac{sum\ of\ life\ time\ of\ all\ the\ nuclei}{total\ number\ of\ nuclei} = \frac{\int_0^{N_0} t\, dN}{N_0} = \frac{1}{\lambda}$

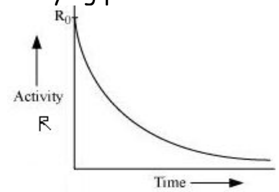
Relation : $\tau = \frac{1}{\lambda} = \frac{T}{0.6931} = 1.44\ T$

882. Define activity of a radioactive substance and write its S.I. unit. Plot a graph showing variation of activity of a given radioactive sample with time **CBSE (F)-2016,(AI)-2015,2009,(D)-2010,2005,(F)-2008**

[Ans. Activity (R) : It is defined as the number of radioactive nuclei decaying per second at any time

i,e, $R = -\frac{dN}{dt}$

S.I. unit of Activity is Becquerel (Bq)



883. Show that the decay rate 'R' of a sample of a radioactive nuclide is related to the number of radioactive nuclei 'N' at the same instant by the expression $R = \lambda N$ & $\frac{dR}{dt} \propto \frac{1}{T^2}$ **CBSE (AIC)-2010**

[Ans. $R = -\frac{dN}{dt} = -\frac{d}{dt}\left(N_0 e^{-\lambda t}\right) = -N_0\left(-\lambda e^{-\lambda t}\right) = \lambda\left(N_0 e^{-\lambda t}\right) = \lambda N$ ⇨ $R = \lambda N$

Now, $R = \lambda N$

⇨ $\frac{dR}{dt} = \frac{d}{dt}(\lambda N) = \lambda \frac{dN}{dt} = \lambda (R) = \lambda(\lambda N) = \lambda^2 N = \left[\frac{\log_e 2}{T}\right]^2 N$

⇨ $\frac{dR}{dt} \propto \frac{1}{T^2}$

884. A radioactive sample having N nuclei has activity R. Write down an expression for its half-life in terms of R and N

[Ans. Activity $R = \lambda N$ ⇨ $\lambda = \frac{R}{N}$ **CBSE (AIC)-2011**

Half-life, $T = \frac{0.6931}{\lambda} = \frac{0.6931\,N}{R}$

==

885. What is nuclear fission and fusion ? Give one representative equation of each. **CBSE (AIC)-2005**

[Ans. **Nuclear fission :** When a heavy nucleus is bombarded with slow neutrons it splits in to two or more light nuclei and a very large amount of energy is released. This phenomenon is called nuclear fission

$${}^{235}_{92}U + {}^{1}_{0}\mathrm{n} \longrightarrow {}^{236}_{92}U \longrightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,{}^{1}_{0}\mathrm{n} + Q$$

Nuclear reactor and atom bomb are based on nuclear fission

Nuclear fusion : When two light nuclei are combined to form a heavy nucleus, a tremendous amount of energy is released. This phenomenon is called nuclear fission

$${}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \longrightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + 3.27\ \mathrm{MeV}$$

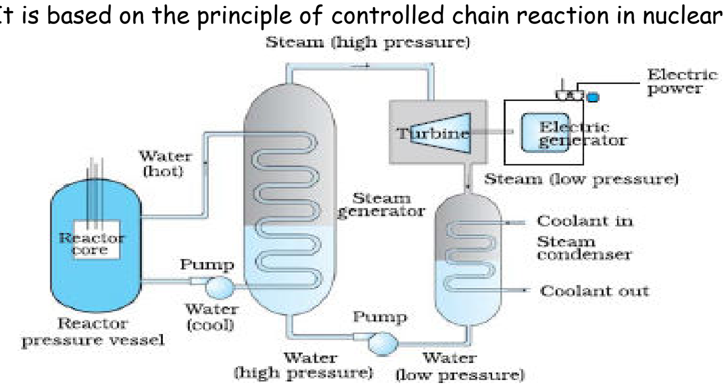
Source of energy in Sun is nuclear fusion. Hydrogen bomb is based on nuclear fusion

==

886. What is nuclear reactor ? Draw a labelled diagram of a nuclear reactor. Write its principle and explain its working.

[Ans. **Nuclear Reactor** : It is device used to convert nuclear energy it to electric energy.

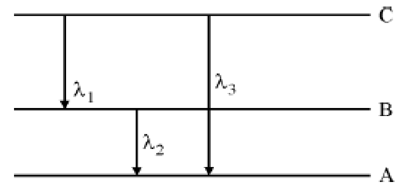
Principle : It is based on the principle of controlled chain reaction in nuclear fission.



Working : In a nuclear reactor, ${}^{235}_{92}U$ is used as a fuel, cadmium rods are used as control rods and graphite or heavy water as moderator. The entire set up is shielded with a heavy thick lead sheets and then with a thick concrete walls. The energy obtained from fission is used to heat up the water to produce steam. This steam is then used to rotate the turbines to produce electricity

887. Find the relation between the three wavelengths λ_1, λ_2 and λ_3 from the energy level diagram shown below.

CBSE (D)-2016



[**Ans**. $E_c - E_B = \frac{hc}{\lambda_1}$ ------(1)

$E_B - E_A = \frac{hc}{\lambda_2}$ ------(2)

$E_c - E_A = \frac{hc}{\lambda_3}$ ------(3)

Adding (1) and (2)

$E_c - E_A = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$

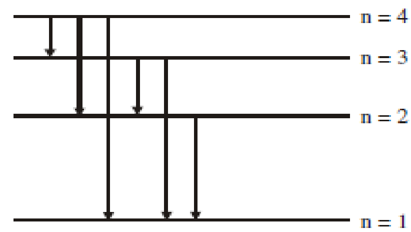
⇨ $\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$ ⇨ $\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

==

888 . The figure shows energy level diagram of hydrogen atom. **CBSE (AIC)-2015**

(i) Find out the transition which results in the emission of a photon of wavelength $496\ nm$

(ii) Which transition corresponds to the emission of radiation of maximum wavelength ? Justify your answer.



[**Ans**. (i) $\lambda = 496$ nm $= 496 \times 10^{-9}\ m$

$$\Delta E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{4.96 \times 10^{-7} \times 1.6 \times 10^{-19}} \text{ eV} \cong 2.5 \text{ eV}$$

For hydrogen atom, $E_n = -\frac{13.6}{n^2}$eV

⇨ $E_1 = -13.6$, $E_2 = -3.4$, $E_3 = -1.51$, $E_4 = -0.85$ eV

$E_4 - E_2 \cong 2.5$ eV hence transition n= 4 to n=1 will give radiation of wavelength 496 nm

(ii) $\Delta E = \frac{hc}{\lambda}$ ⇨ $\lambda \propto \frac{1}{\Delta E}$ for transition n= 4 to n=3 ΔE is minimum hence λ will be maximum

889. A hydrogen atom initially in its ground state absorbs a photon and is in the excited state with energy 12.5 eV. Calculate the longest wavelength of the radiation emitted and identify the series to which it belongs .
(Rydberg constant, $R = 1.1 \times 10^7 m^{-1}$) **CBSE (AI)-2016**

[**Ans**. ΔE = −13.6 + 12.5 = −1.1 eV

$E_n = -\frac{13.6}{n^2}$eV ⇨ $-1.1 = -\frac{13.6}{n^2}$ ⇨ n = 3

⇨ $\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$ ⇨ $\lambda_{max} = \frac{36}{5R} = \frac{36}{5 \times 1.1 \times 10^7} = 6563\ A^0$ It belongs to Balmer series

890 . Using Rydberg's formula, calculate the longest wavelengths belonging to Lyman and Balmer series. In which region f hydrogen spectrum do these transmission lie ? (Given, $R = 1.1 \times 10^7 m^{-1}$) **CBSE (F)-2015**

[**Ans**. $\frac{1}{\lambda} = R\left[\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right]$

For Lyman series, $\frac{1}{\lambda_{max}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = R\left[1 - \frac{1}{4}\right] = \frac{3R}{4}$

⇨ $\lambda_{max} = \frac{4}{3R} = \frac{4}{3 \times 1.1 \times 10^7} = 1210\ A^0$. It lies in Ultraviolet region

For Balmer series $\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$

⇨ $\lambda_{max} = \frac{36}{5R} = \frac{36}{5 \times 1.1 \times 10^7} = 6563\ A^0$. It lies in visible region

891. The ground state energy of hydrogen atom is −13.6 eV. **CBSE (AI)-2008**

(i) what is the kinetic energy of an electron in the 2nd excited state ?

(ii) If the electron jumps to the ground state from 2nd excited state, calculate the wavelength of the spectral line emitted.

[**Ans**. (i) $E_{kn} = \frac{13.6}{n^2}$ eV & $U_n = -2 \times \frac{13.6}{n^2}$ eV

For ground state n =1 and for second excited state n = 3,

$E_{k3} = \frac{13.6}{3^2} = \frac{13.6}{9} = 1.51$ eV & $U_3 = -2 \times \frac{13.6}{3^2} = -\frac{27.2}{9} = 3.02$ eV

(ii) $\Delta E = E_3 - E_1 = -\frac{13.6}{3^2} - \left(-\frac{13.6}{1^2}\right) = -1.51 + 13.6 = 12.09$ eV $= 12.09 \times 1.6 \times 10^{-19}$ J

⇨ $\frac{hc}{\lambda} = \Delta E$ ⇨ $\lambda = \frac{hc}{\Delta E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{12.09 \times 1.6 \times 10^{-19}} = 1.02 \times 10^{-7}$ m

892. Two different radioactive elements with half lives T_1 and T_2 have N_1 and N_2 undecayed atoms respectively present at a given instant. Derive an expression for the ratio of their activities at this instant in terms of N_1 & N_2

[Ans. $R = -\frac{dN}{dt} = -\frac{d}{dt}\left(\mathrm{N}_0 e^{-\lambda t}\right) = -\mathrm{N}_0\ \left(-\lambda\, e^{-\lambda t}\right) = \lambda\left(\mathrm{N}_0\, e^{-\lambda t}\right) = \lambda\, N$ **CBSE (DC)-2012**

⇨ $R = \lambda\, N$ ⇨ $R_1 = \lambda_1 N_1 = \frac{\mathbf{0.6931}}{\boldsymbol{T_1}} N_1$ & $R_2 = \lambda_2 N_2 = \frac{\mathbf{0.6931}}{\boldsymbol{T_2}} N_2$

⇨ $\frac{R_1}{R_2} = \frac{N_1}{N_2} \times \frac{T_2}{T_1}$

893. Half life of ${}^{238}_{92}U$against $\alpha - decay$ is 4.5 X 10^9years. Calculate the activity of 1 g sample of ${}^{238}_{92}U$.
(Given Avogadro's number = 6 X 10^{26} atoms/ Kmol) **CBSE (AI) E-2016,(F)-2006, (D)-2005**

[Ans. Half-life T $= 4.5 \times 10^9$years $= 4.5\ X\ 10^9 \times 365 \times 24 \times 60 \times 60$ s = 1.42 X 10^{17}s

Number of atoms present in 1 g sample of ${}^{238}_{92}U$, $N = \frac{6 \times 10^{23}}{238}$

Activity, $R = \lambda N = \frac{0.6931}{T} \times N = \frac{0.6931}{1.42\ X\ 10^{17}} \times \frac{6 \times 10^{23}}{238}$ = 1.23 X $10^4\ Bq$

894. A radioactive sample contains 2.2 mg of pure ${}^{11}_{6}$C which has half-life period of 1224 seconds. Calculate :
(i) the number of atoms present initially. **CBSE (AI)-2005**
(ii) the activity when 5 μg of the sample will be left.

[Ans. Given $T = 1224$ s

(i) Number of atoms present initially in 2.2 mg of ${}^{11}_{6}$C

$N_0 = \frac{6 \times 10^{23}\ X\ 2.2\ X\ 10^{-3}}{11}$ = 1.2 X 10^{20}

(ii) Number of atoms present in 5 μg of ${}^{11}_{6}$C

$N = \frac{6 \times 10^{23}\ X\ 5\ X\ 10^{-6}}{11}$ = 2.74 X 10^{17}

$R = \lambda N = \frac{0.6931}{T} \times N = \frac{0.6931}{1224} \times 2.74 \times 10^{17}$ = 1.55 X 10^{14} Bq

===

895. The half life of a certain radioactive material against α –decay is 100 days. After how much time, will the Undecayed fraction of the material be 6.25 % ? **CBSE (AI)-2015**

[Ans. Given : $T = 100$ days & $\frac{N}{N_0}$ = 6.25 % $= \frac{6.25}{100} = \frac{1}{16}$

$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$ ⇨ $\frac{1}{16} = \left(\frac{1}{2}\right)^n$ ⇨ $n = 4$

⇨ $t = n\, T$ = 4 X 100 = 400 days

896. The half life of radioactive substance is 20s. calculate- **CBSE (F)-2009**
(i) The decay constant, and
(ii) time taken for the sample to decay 7/8th of the initial value.

[Ans. Given $T = 20$ s & $\frac{N}{N_0} = 1 - \frac{7}{8} = \frac{1}{8}$

(i) $\lambda = \frac{0.6931}{T} = \frac{0.6931}{20} = 0.0346\ s^{-1}$

(ii) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$ ⇨ $\frac{1}{8} = \left(\frac{1}{2}\right)^n$ ⇨ $n = 3$

⇨ $t = n\, T$ = 3 X 20 = 60 s

897. The activity of a radioactive element drops to $\frac{1}{16}$th of its initial value in 32 Years. Find the mean life of the sample.

[Ans. Given, $\frac{R}{R_0} = \frac{1}{16}$ & $t = 32$ years **CBSE (AIC)-2010**

$\frac{R}{R_0} = \left(\frac{1}{2}\right)^n$ ⇨ $\frac{1}{16} = \left(\frac{1}{2}\right)^n$ ⇨ $n = 4$ & $T = \frac{t}{n} = \frac{32}{4}$ = 8 years

⇨ τ = 1.44 T = 1.44 x 8 = 11.52 yrs

898. Calculate the energy release in MeV in the deuterium-tritium fusion reaction **CBSE (D)-2015,2010, (AI)-2009,(DC)-2008,2003**

$${}_{1}^{2}\mathrm{H} + {}_{1}^{3}\mathrm{H} \longrightarrow {}_{2}^{4}\mathrm{He} + {}_{0}^{1}\mathrm{n}$$

Given $m({}_{1}^{2}\mathrm{H})$ = 2.014102 u, $m({}_{1}^{3}\mathrm{H})$ = 3.016049 u, $m({}_{2}^{4}\mathrm{He})$ = 4.002603 u, m_n = 1.008665 u & 1u = 931.5 MeV/c²

[**Ans**. $\Delta m = [m({}_{1}^{2}\mathrm{H}) + m({}_{1}^{3}\mathrm{H})$ –{ $m({}_{2}^{4}\mathrm{He}) + m_n$}]= [2.014102 + 3.016049 –{ 4.002603 +1.008665 }]

⇨ $\Delta m = 0.018883\ u$ ⇨ Q = 0.018883 X 931.5 = 17.59 MeV

899. Calculate the energy released if, U^{238} , emits an α-particle. **CBSE (AI)-2007**

OR

Calculate the energy released in MeV in the following nuclear reaction. **CBSE (AI)-2008,(D)-2007**

$${}_{92}^{238}\mathrm{U} \longrightarrow {}_{90}^{234}\mathrm{Th} + {}_{2}^{4}\mathrm{He} + Q$$

[**Ans**. 4.25

[Given, mass of ${}_{92}^{238}\mathrm{U}$ = 238.05079 u, mass of ${}_{90}^{234}\mathrm{Th}$ = 234.043630 u, mass of ${}_{2}^{4}\mathrm{He}$ =4.002600 u & 1u = 931.5 MeV/c²]

[**Ans**. $\Delta m = [m({}_{92}^{238}\mathrm{U}) - \{m({}_{90}^{234}\mathrm{Th}) + m({}_{2}^{4}\mathrm{He})\}]$= [238.05079 –{234.043630+ 4.002600}]

⇨ $\Delta m = 0.0456\ u$ ⇨ Q = 0.0456 X 931.5 = 4.25 MeV

899a. A neutron is absorbed by a ${}_{3}^{6}\mathrm{Li}$ nucleus with the subsequent emission of an alpha particle. Write the corresponding nuclear reaction. Calculate the energy released in this nuclear reaction. **CBSE (AI)-2006,(D)-2005**

OR

Calculate the energy released in the following nuclear reaction **CBSE (AI)-2006,2002,(D)-2005,2003**

$${}_{3}^{6}\mathrm{Li} + {}_{0}^{1}\mathrm{n} \longrightarrow {}_{2}^{4}\mathrm{He} + {}_{1}^{3}\mathrm{H} + Q$$

[**Ans**. 4.78 MeV]

[mass of ${}_{0}^{1}\mathrm{n}$ = 1.008665 u, mass of ${}_{3}^{6}\mathrm{Li}$ = 6.015126 u, mass of ${}_{2}^{4}\mathrm{He}$= 4.002603 u, mass of ${}_{1}^{3}\mathrm{H}$ = 3.016049 u]

[**Ans**. $\Delta m = [m({}_{3}^{6}\mathrm{Li}) + m({}_{0}^{1}\mathrm{n}) - \{m({}_{2}^{4}\mathrm{He}) + ({}_{1}^{3}\mathrm{H})\})]$= [6.015126 + 1.008665 – {4.002603 + 3.016049}]

⇨ Δm = 0.005138 u

⇨ Q = 0.005138 X 931 = 4.78 MeV

899b. (i) Write symbolically the nuclear β^{+} decay process of ${}_{6}^{11}\mathrm{C}$. Is the decayed product X an isotope or isobar of ${}_{6}^{11}\mathrm{C}$?
(ii) Given tha mass value of $m({}_{6}^{11}\mathrm{C})$ = 11.011434 u and $m(X)$ = 11.00935 u. Estimate the Q value in this process.

[**Ans**. (i) ${}_{6}^{11}\mathrm{C} \longrightarrow {}_{5}^{11}\mathrm{C} + {}_{+1}^{0}e + \nu$, X is an isobar **CBSE (AI)-2015**

(ii) $\Delta m = [m({}_{6}^{11}\mathrm{C}) - m(X)]$ = [11.011434– 11.00935] = 0.002129 u

⇨ Q = 0.002129 X 931.5 = 1.98 MeV

899c. A nucleus ${}_{10}^{23}\mathrm{Ne}$, β-decays to give the nucleus of ${}_{11}^{23}\mathrm{Na}$. Write down the β-decay equation. Calculate the kinetic energy of electron emitted. (Rest mass of electron may be ignored.) **CBSE (D)-2008,(AI)-2004**

(Given, $m({}_{10}^{23}\mathrm{Ne}) = 22.994466\ u$ & $m({}_{11}^{23}\mathrm{Na}) = 22.989770\ u$)

[**Ans**. ${}_{10}^{23}\mathrm{Ne} \longrightarrow {}_{11}^{23}\mathrm{Na} + {}_{-1}^{0}e + \overline{\nu}$

⇨ $\Delta m = [m({}_{10}^{23}\mathrm{Ne}) - \{m({}_{11}^{23}\mathrm{Na})] = [22.994466 - 22.989770]$ = 0.004696 u

⇨ Energy released or the K.E. of emitted electron Q = Δm X c^2 = 0.004696 X 931.5 = 4.374 MeV

899d. When a deuteron of mass $2.0141\ u$ and negligible kinetic energy is absorbed by a Lithium (${}_{3}^{6}\mathrm{Li}$) nucleus of mass $6.0155\ u$, the compound nucleus disintegrates spontaneously in to two alpha particles each of mass $4.0026\ u$. Calculate the energy in Joules carried by each alpha particle. $(1\ u = 1.66\ X\ 10^{-27}\ \mathrm{Kg})$ **CBSE (AI)-2004**

[**Ans**. ${}_{3}^{6}\mathrm{Li} + {}_{1}^{2}\mathrm{H} \longrightarrow {}_{2}^{4}\mathrm{He} + {}_{2}^{4}\mathrm{He} + Q$

⇨ $\Delta m = [m({}_{3}^{6}\mathrm{Li}) + m({}_{1}^{2}\mathrm{H}) - 2\ X\ m({}_{2}^{4}\mathrm{He})]$ = [6.0155 + 2.0141 – 4 X 4.0026] = 8.0296 –8.0052

⇨ Δm = 0.0244 u = 0.0244 X 1.66 X 10^{-27} Kg

⇨ Q = Δm X c^2 = 0.0244 X 1.66 X 10^{-27}X $(3\ X\ 10^8)^2$ = 3.645 X 10^{-12} J

Hence energy carried by each alpha particle = 3.645 X 10^{-12}/2 = 1.8225 X 10^{-12} J

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Unit IX: Electronic Devices 12 Periods

Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuits

Energy bands in conductors, semiconductors and insulators (qualitative ideas only)

Semiconductor diode - I-V characteristics in forward and reverse bias, diode as a rectifier;

Special purpose p-n junction diodes: LED, photodiode, solar cell and Zener diode and their characteristics, zener diode as a voltage regulator.

901. Give the ratio of the number of holes and number of conduction electrons in an intrinsic semiconductor.
[Ans. $n_h / n_e = 1$ **CBSE (F)-2003**

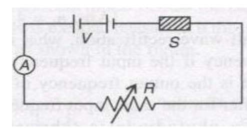
902. What is meant by the term doping of an intrinsic semiconductor ? How does it affect the conductivity of a semiconductor ?
[Ans. Doping : **CBSE (AIC)-2001**
Deliberate adding of desired impurity to a semiconductor to increase its conductivity is called doping.
Conductivity of a semiconductor increases due to doping

903. How does the energy gap of an intrinsic semiconductor vary, when doped with a trivalent impurity/ pentavalent impurity?
[Ans. Decreases **CBSE (AI)-2002,(D)-2002**

904. How does the forbidden energy gap of an intrinsic semiconductor vary with increase in temperature?
[Ans. no effect **CBSE (AI)-2002,(D)-2002**

905. Name the two factors on which electrical conductivity of a pure semiconductor at a given temperature depends.
[Ans. (i) The width of the forbidden band **CBSE (AIC)-2005**
(ii) Intrinsic charge carrier concentration

906. The diagram shows a piece of pure semiconductor 'S' in series with variable resistor R and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter (A) constant when semiconductor 'S' is heated ? Give one reason. **CBSE (DC)-2005**
[Ans. Increase the value of R
Reason : on heating, conductivity of the semiconductor increases



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907. Give reason, why, a p-type semiconductor crystal is electrically neutral, although $n_h >> n_e$
[Ans. because impurity atoms added to the semiconductor are electrically neutral **CBSE (F)-2013,(D)-2008**

908. An n-type semiconductor has a large number of electrons but still it is electrically neutral. Explain the reason.
[Ans. because impurity atoms added to the semiconductor are electrically neutral] **CBSE (AI)-2008**

909. Is the ratio of the number of holes and number of electrons in a p-type semiconductor more than, less than or equal to 1 ?
[Ans. $n_h / n_e > 1$ **CBSE (AIC)-2003**

910. Why is the conductivity of n-type semiconductor greater than that of the p-type semiconductor even when both of these have same level of doping ? **CBSE (AIC)-2005**
[Ans. because mobility of electrons is higher than that of holes

911. How does the conductivity of a semiconductor change with the rise in its temperature ? **CBSE (DC)-2010**
[Ans. Conductivity of a semiconductor increases exponentially with the temperature

912. Why does the conductivity of a semiconductor increase with the rise in its temperature ? **CBSE (DC)-2005**
[Ans. $\boldsymbol{\sigma = e\,[\,n_e\mu_e + n_h\mu_h\,]}$
On increasing the temperature μ_e & μ_h decreases (due to increase in the collision frequency). But n_e& n_h increases (as $n \propto e^{-\frac{E_g}{KT}}$). Since n_e & n_h is so large that decrease of μ_e & μ_h does not affect too much. So overall conductivity of the semiconductor increases

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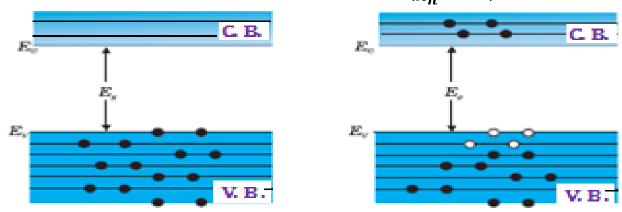
913. What are energy bands ? How are these formed ? **CBSE (AI)-2016,2008,2006,(D)-2010,2006,2005,(F)-2003**
[Ans. Energy bands : A group of large number of closely spaced energy levels spread in a very short energy range, is called an energy band
Formation of energy bands :
Due to interaction of electrons in outermost orbits of atoms in a crystal, different energy levels with continuous energy variation splits and energy bands are formed.

914. What is a valance band & conduction band ?
[Ans. **Valence Band :** The highest energy band filled with valence electrons is called the valence band
Conduction Band : The lowest unfilled allowed energy band above the valence band is called conduction band

915. Define forbidden energy gap ?
[Ans. Forbidden energy gap (E_g) **:** The energy gap between the valence band and the conduction band in which no allowed energy levels can exists is called the energy band gap (E_g)

916. Draw the energy band diagram of an intrinsic semiconductor. **CBSE (AIC)-2006,2005,2003**

[Ans. Energy band diagrams of an intrinsic semiconductor $\left(\frac{n_e}{n_h} = 1\right)$



(a) at T = 0 K **(b) at T > 0 K**

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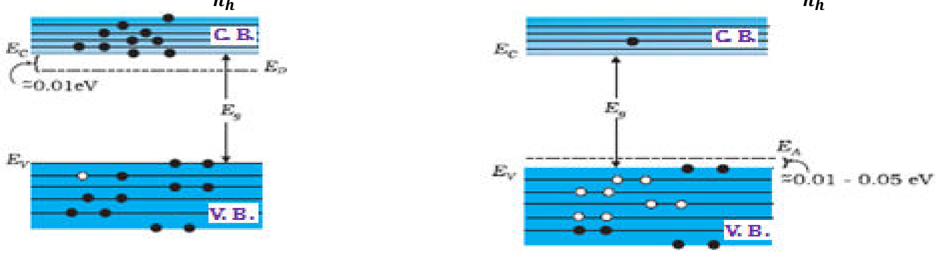
917. Draw the energy band diagram of $n-type$ & $p-type$ semiconductor.

[Ans. **CBSE (AI)-2012,2006,2005,2003,2001,(D)-2005,2004,2002**

n-type semiconductor ($\frac{n_e}{n_h}$ >1) p-type semiconductor ($\frac{n_e}{n_h}$ <1)



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918. Distinguish between intrinsic and extrinsic semiconductors. **CBSE (F)-2017,(D)-2015,2008**

[Ans.

Intrinsic Semiconductor	Extrinsic Semiconductor
1. It is a pure semiconductor.	1. It is a semiconductor with added impurity.
2. $n_e = n_h$	2. $n_e \neq n_h$
3. Low conductivity at room temperature	3. High conductivity at room temperature
4. Its electrical conductivity depends on temperature only.	4. Its electrical conductivity depends on temperature and the amount of doping.

919. Distinguish between intrinsic and a p-type semiconductor. **CBSE (F)-2013**

[Ans.

n-type semiconductor	p-type semiconductor
1. It is obtained by adding controlled amount of pentavalent impurity to a pure semiconductor.	1. It is obtained by adding controlled amount of trivalent impurity to a pure semiconductor.
2. $n_e \gg n_h$	2. $n_h \gg n_e$
3. Its electrical conductivity is due to free electrons.	3. Its electrical conductivity is due to holes.

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920. Name the two important processes that occur during the formation of a p-n junction. **CBSE (AI)-2016,(D)-2017**

[Ans. (i) Diffusion (ii) drift

921. What happens when a forward bias is applied to a p-n junction ? **CBSE (AI)-2015**

[Ans. p-n junction conducts current when a forward bias is applied to it

922. Name any semiconductor device which operates under the reverse bias in the breakdown region. **CBSE (AI)-2013**

[Ans. Zener diode

923. Name the p-n junction diode, which emits spontaneous radiation when forward biased. **CBSE (DC)-2004**

[Ans. Light Emitting Diode (LED)

924. Why is the current under reverse bias almost independent of the applied potential up to a critical voltage ? **CBSE (AI)-2013**

[Ans. As the number of minority charge carriers is very small, so the current is almost independent of the applied voltage up to reverse breakdown voltage

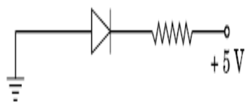
925. Why does the reverse current shows a sudden increase at the critical voltage ? **CBSE (AI)-2013**

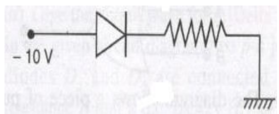
[Ans. At the critical voltage, i,e, reverse breakdown voltage, the applied voltage is large enough to break covalent bonds producing more minority charge carriers which conduct causing a sudden increment in the current

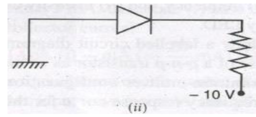
926. Explain how the width of depletion region in a p-n junction diode change, when the junction is- (i) forward biased (ii) reverse biased. **CBSE (AI)-2011, 2002,(D)-2010,2003**

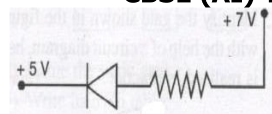
[Ans. (i) decreases (ii) increases

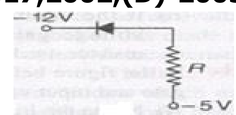
927. In the following circuit diagram, is the junction diode forward biased or reverse biased ? **CBSE (AI)-2017,2002,(D)-2005**











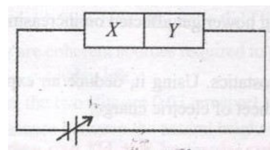
[Ans. (i) reverse bias (ii) reverse bias (iii) Forward bias (iv) forward bias (v) forward bias

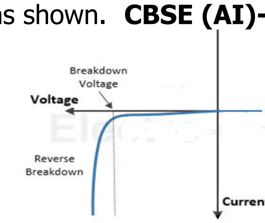
928. Two semiconductor materials X and Y shown in given figure are made by doping germanium crystal with Indium and Arsenic respectively. The two are joined end to end and connected to a battery as shown. **CBSE (AI)-2007**

(i) Will the junction be forward biased or reverse biased ?

(ii) sketch V-I graph for this arrangement.

[Ans. (i) Reverse bias



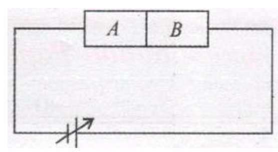


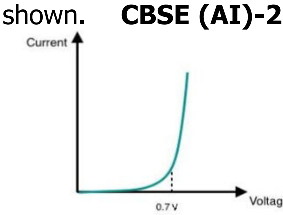
929. Two semiconductor materials A and B shown in given figure are made by doping germanium crystal with Arsenic and Indium respectively. The two are joined end to end and connected to a battery as shown. **CBSE (AI)-2007**

(i) Will the junction be forward biased or reverse biased ?

(ii) sketch V-I graph for this arrangement.

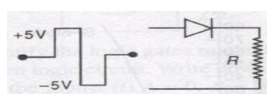
[Ans. (i) Forward bias

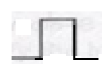




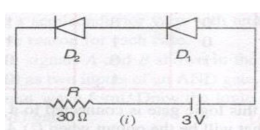
930. Draw and explain the output wave forms across the load resistor R, if the input waveform is as shown in the figure.

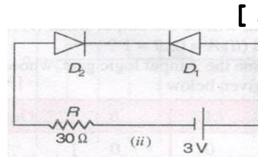
[Ans. **CBSE (D)-2006**



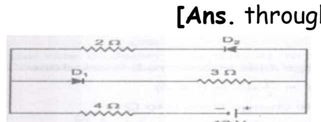


931. Determine the currents through the resistance R of the circuits (i) and (ii), when similar diodes D_1 and D_2 are connected as shown. **[Ans. (i)** $0.1\,A$ **(ii) zero** **CBSE (DC)-2002**

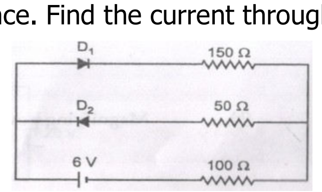


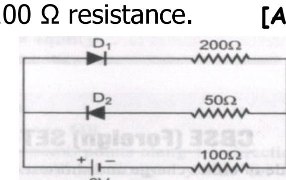


932. The circuit shown in the figure has two oppositely connected ideal diodes connected in parallel. Find the current flowing through each diode in the circuit. **[Ans.** through D_1, I=0, through D_2, I = 2A] **CBSE (F)-2013**



933. The circuit shown in the figure consists of two diodes each with a forward resistance of 50 Ω and infinite backward resistance. Find the current through 100 Ω resistance. **[Ans.** 6/300 A, 6/350 A] **CBSE (F)-2013**

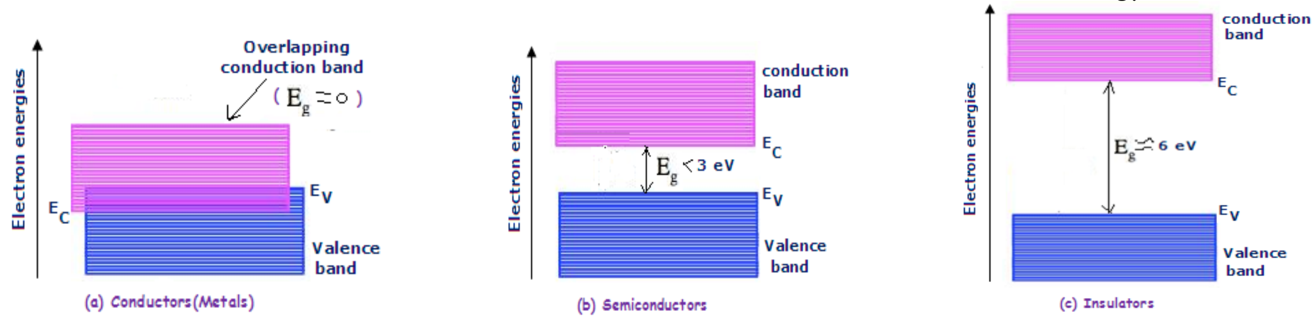




934. Distinguish between a conductor, an insulator and a semiconductor on the basis of energy band diagrams.

CBSE (AI)-2016,2008,2006,(D)-2010,2006,2005,(F)-2003

[Ans. Distinction between Conductors (metals), insulators and semiconductors on the basis of Energy bands



1. **Conductors (Metals) :**

In conductors either conduction and valence band partly overlap each other or the conduction band is partially filled. Forbidden energy gap does not exists ($E_g \approx 0$). This makes a large number of free electrons available for electrical conduction. So the metals have high conductivity.

2. **Semiconductors :**

In semiconductors, conduction band is empty and valance band is totally filled. E_g is quite small (< 3 eV). At $0\ K$, electrons are not able to cross this energy gap and semiconductor behaves as an insulator. But at room temperature, some electrons are able to jump to conduction band and semiconductor acquires small conductivity

3. **Insulators**

In insulators, conduction band is empty and valance band is totally filled. E_g is very large (≈ 6 eV). It is not possible to give such large amount of energy to electrons by any means. Hence conduction band remains total empty and the crystal remains as insulator

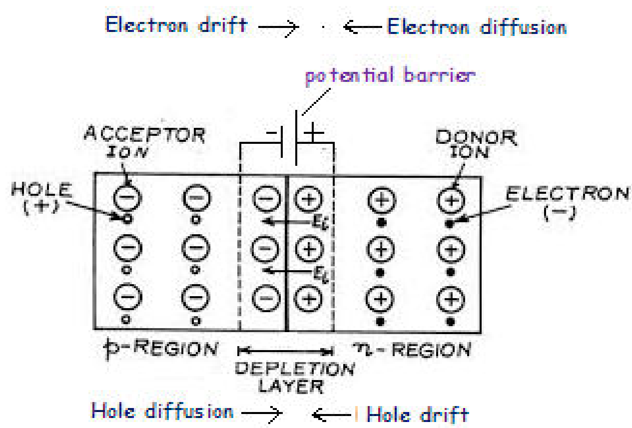
935. What is p-n junction ? Explain briefly, with the help of suitable diagram, how a p-n junction is formed. Define the term Potential barrier and depletion region.

CBSE (D)-2017,2014,2010,2006,(AI)-2016,2015,2012,2009,2003,(F)-2015,2009,2006

[Ans. p-n junction : When a semiconductor crystal is so prepared that, it's one half is p-type and other is n-type, then the contact surface dividing the two halves, is called p-n junction

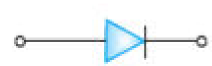
Formation of p-n junction : potential barrier & depletion region

Diffusion and drift are the two important processes involved during the formation of a p-n junction



Due to different concentration gradient of the charge carriers on two sides of the junction, electrons from $n-side$ starts moving towards $p-side$ and holes start moving from $p-side$ to $n-side$. This process is called ***Diffusion***.

Due to diffusion, positive space charge region is created on the $n-side$ of the junction and negative space charge region is created on the $p-side$ of the junction. Hence an electric field called Junction field is set up from $n-side$ to $p-side$ which forces the minority charge carriers to cross the junction. This process is called **Drift**.



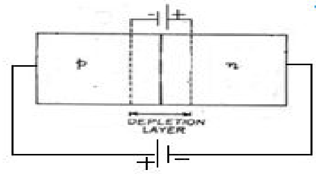
The potential difference developed across the p-n junction due to diffusion of majority charge carriers, which prevents the further movement of majority charge carriers through it, is called potential barrier. For Si, V_B = 0.7 V and for Ge, V_B =0.3 V

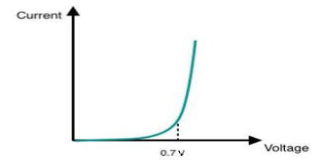
The small space charge region on either side of the p-n junction, which becomes depleted from mobile charge carriers is known as depletion region (10^{-6}m)

936. What is meant by forward and reverse biasing of a p-n junction ? Draw the circuit diagram of a forward and reverse biasing of a p-n junction. **CBSE (AIC)-2010**

[Ans. (i) Forward biasing :

When the positive terminal of external battery is connected to p-side and negative terminal to the n-side, then the p-n junction is said to be forward biased





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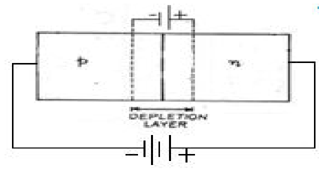
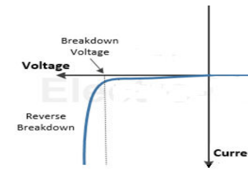
(ii) Reverse biasing :

When the positive terminal of external battery is connected to n-side and negative terminal to the p-side, then the p-n junction is said to be reverse biased





937. Describe briefly: (i) 'minority carrier injection' in forward bias (ii) 'Breakdown voltage' in reverse bias. **CBSE (AI)-2015**

[Ans. (i) Minority carrier injection in forward bias :

During forward bias, electrons from n-side cross the junction and reach p-side. (where they are minority carries). Similarly, holes from p-side cross the junction and reach the n-side (where they are minority carries). This process is known as minority carrier injection

(ii) Breakdown voltage in reverse bias : At very high reverse voltage, the current suddenly increases and becomes independent of applied voltage. This critical voltage is called breakdown voltage

938. Define the terms 'depletion region' and 'potential barrier' in a p-n junction. Explain how the width of depletion region in a p-n junction diode change, when the junction is- (i) forward biased (ii) reverse biased. **CBSE (AI)-2016,2011,2010,2002**

[Ans. Depletion region : The small space charge region on either side of the p-n junction which becomes depleted from mobile charge carriers. is known as depletion region

Potential barrier : The potential difference developed across the p-n junction due to diffusion of majority charge carriers, which prevents the further movement of these charge carriers through it, is called potential barrier

(i) Width of depletion region decreases in forward bias

Reason : In the forward bias, external battery pushes the majority charge carriers towards the junction.

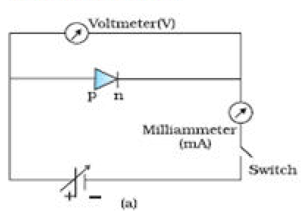
(ii) Width of depletion region increases in reverse bias

Reason : In the reverse bias, external battery attracts the majority charge carriers away from the junction.

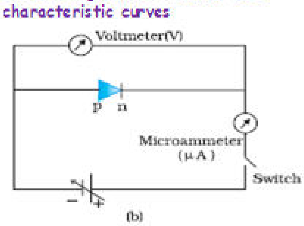
939. Draw the circuit diagram for studying the V-I characteristics of a p-n junction diode in (i) forward bias and (ii) reverse bias. Draw the typical V-I characteristics of a silicon diode. **SE (AI)-2015,2014,2013,2010,2009,(D)-2014**

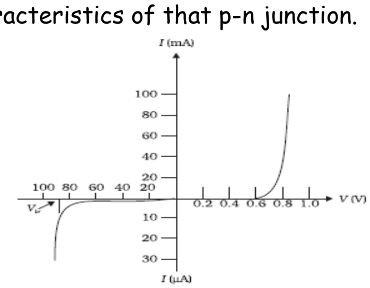
[Ans. V-I characteristics : A graph showing the variation of current through a p-n junction with the voltage applied across it, is called the voltage – current (V-I) characteristics of that p-n junction.

Circuit diagram for forward bias characteristic curves



Circuit diagram for reverse bias characteristic curves





For different values of voltages, the value of the current is noted. A graph between *V* and **I** is obtained as in fig. This V-I graph shows that -

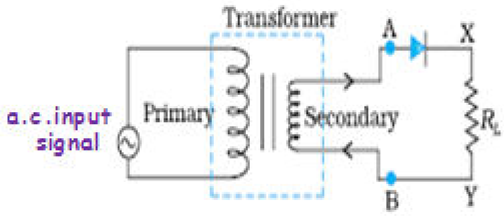
(i) At a certain forward bias voltage, current increases rapidly showing the linear variation. This voltage is known as knee voltage or threshold voltage or cut-in voltage.

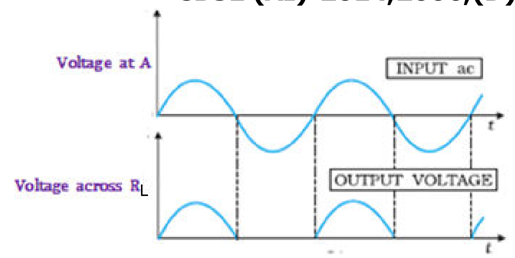
(ii) The ratio of change in forward voltage to the change in forward current is called dynamic resistance (r_d)

i,e, $r_d = \frac{\Delta V}{\Delta I}$ Ω

(iii) Under reverse bias, the current is very small (~μA) and remains almost constant. However, when reverse bias voltage reaches a high value, reverse current suddenly increases. This voltage is called Zener breakdown voltage.

940. Explain with the help of a circuit diagram, the working of p-n junction diode as half wave rectifier.
[Ans. Half wave rectifier : **CBSE (AI)-2014,2006,(D)-2009**





During the positive half cycle of ac input signal, the diode is forward biased and it conducts. Hence, there is current in the load resistance R_L and we get an output voltage.

During the negative half cycle of ac input signal, diode is reverse-biased and it does not conduct. Hence, there is no current in the load resistance and there is no output.

Thus, we get the output only for half cycle of a.c. input signal.

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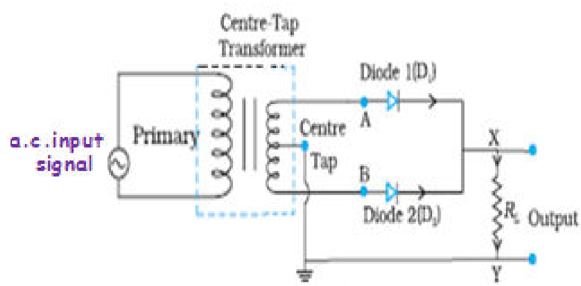
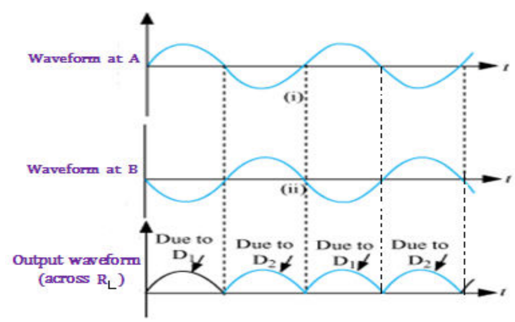
941. Draw a labelled circuit diagram of a junction diode as a full wave rectifier. Explain its underlying principle and working. Depict the input and output wave forms. **CBSE (AI)-2017,2015,2011,2006,(D)-2012,2009,(F)-2009,2005**

[Ans. Full wave rectifier





During the positive half cycle of a.c. input signal, diode D_1 gets forward biased and conducts while D_2 being reverse biased does not conducts. Hence, there is a current in R_L due to diode D_1 and we get an output voltage.

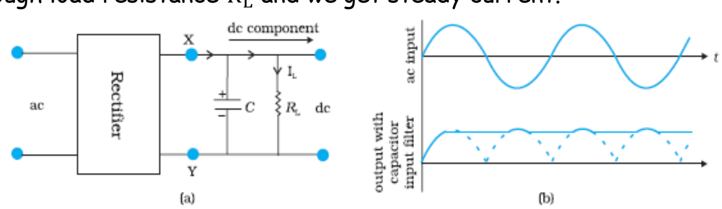
During the negative half cycle of ac input signal, diode D_1 gets reverse biased and does not conduct while D_2 being forward biased conducts. Hence, now there is a current in R_L due to diode D_2 and again we get an output voltage.

Thus, we get output voltage for complete cycle of a.c. input signal in the same direction

942. Which characteristic property makes the junction diode suitable for rectification ? **CBSE (AI)-2015**
[Ans. A p-n junction diode allows current to pass only when it is forward biased

943. Frequency of an a.c. input signal is 50 Hz. What is the output frequency of a - **CBSE (AIC)-2010**
(i) Half wave rectifier (ii) Full wave rectifier
[Ans. (i) 50 Hz **(ii)** 100 Hz

947. Describe briefly the role of a capacitor in filtering. **CBSE (AI)-2015**
[Ans. A capacitor connected across the output terminals of a rectifier offers a low resistance path for a.c. and blocks dc. So all dc will pass through load resistance R_L and we get steady current.



948. How are the V-I characteristics of a p-n junction diode made use of in rectification ? **CBSE (D)-2014**
[Ans. It is obvious from V-I characteristics that diode allows the current to pass only when it is forward biased. So, when an alternating voltage is applied across a junction diode, the current will flow only in that part of the cycle when diode is forward biased. This property is used to rectify the alternating voltages

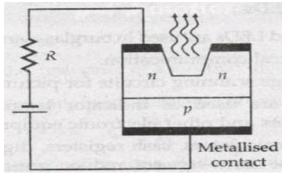
949. What is a light emitting diode ? How is a light emitting diode fabricated ? Draw a circuit diagram showing the biasing of a LED. Explain briefly the process of emission of light by a light emitting diode (LED).

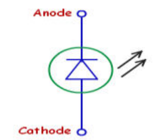
CBSE (D)-2016,2004,(AI)-2015, 2010,(F)-2008,(DC)-2005

[Ans. Light Emitting Diode (LED) : It is a special heavily doped p-n junction diode, which emits spontaneous light, when forward biased. It converts electrical energy in to light energy.

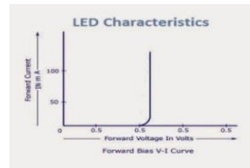
LED is fabricated by- (i) heavily doped p-n junction made from a semiconductor like GaAs having $E_g \approx 1.8$ eV.

(ii) Providing a transparent cover so that light can come out





Symbol of LED



Working : When p-n junction is forward biased, electrons and holes moves across the junction from n to p and p to n-side respectively. As a result, the concentration of minority carriers increases rapidly at the junction. These excess minority carriers on either side of the junction, recombine with majority carriers and energy is released in the form of photons ($h\nu = E_g$)

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981. Give two advantages of using LEDs over conventional incandescent lamps. **CBSE (AI)-2015,2007,2004**

[Ans. low operational voltage/less power consumption/Long life/ fast on-off switching capability/no warm-up time required

982. Mention two uses of LEDs. **CBSE (AIC)-2010,2004**

[Ans. in remote controls/in electronic watches & calculators /in burglar alarm systems/ in optical communication

983. Which semiconductors are preferred to make LEDs and why ? **CBSE (AI)-2015,2010**

[Ans. GaAs and GaAsP

Reason: these materials have energy gap $E_g \geq 1.8$ eV which is suitable to produce visible light of desired wavelengths

984. What criterion is kept in mind while choosing the semiconductor material for a LED ? **CBSE (D)-2013,2007**

[Ans. semiconductor used must have an energy band gap of 1.8 eV

985. The band gap of the semiconductor used for fabrication of visible LED's must at least be 1.8 eV. Why ? **CBSE (SP)-2015**

[Ans. The photon energy of visible light photons varies about 1.8 eV to 3 eV. Hence for visible LED's the semiconductor used must have a band gap of at least 1.8 eV

986. State the factor which controls (i) wavelength/frequency of light (ii) intensity of light emitted by LED. **CBSE (F)-2008**

[Ans. (i) nature of material of diode/band gap (ii) forward biasing of LED

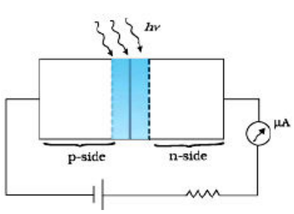
===

987. What is Photodiode ? How is photodiode fabricated ? Describe the working of photodiode by drawing the circuit diagram. Also draw the characteristics of a photodiode for different illumination intensities.

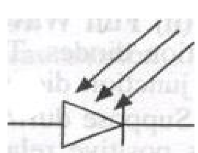
CBSE (AI)-2016,2015,2005,(D)-2015,2012,2005,(F)-2014,2010,2005

[Ans. Photodiode : It is a reverse biased p-n junction diode, in which current carriers are generated by photons through photoconduction by light

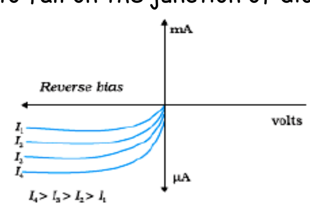
Fabrication of Photodiode : It is a special reverse biased p-n junction diode fabricated with a transparent window to allow the light of suitable frequency ($h\nu > E_g$) to fall on the junction of diode



Biasing of a photodiode



Symbol of a photodiode



Characteristics of a photodiode

Working : (i) when light of energy ($h\nu > E_g$) falls on photodiode, electron-holes pairs are generated in the depletion region due to absorption of photons

(ii) due to electric field at the junction, electrons and holes are separated before they recombine

(iii) electrons are collected on n-side and holes are collected at p-side, giving rise to an emf and current flows in the load. Photocurrent is proportional to the incident light intensity

988. Give any two uses of photodiode. **CBSE (DC)-2010**

[Ans. in detection of optical signals / in light operated switches/ in electronic counters

989. A photodiode is operated under reverse bias although in the forward bias the current is known to be more than the current in the reverse bias. Explain giving reason. **CBSE (D)-2015,2012,2005,(F)-2010,2005,(AI)-2005**

[Ans. The fractional change, due to photo effects, in the reverse bias current, is much more than the fractional change in the forward bias current. Hence, photodiode is used in reverse bias.

Explanation : Let us consider n-type semiconductor ($n \gg p$).

When illuminated with light, both type of carriers increase equally in number.

⇨ $n' = n + \Delta n$ & $p' = p + \Delta p$

Now as $n \gg p$ & $\Delta n = \Delta p$, ⇨ $\frac{\Delta n}{n} \ll \frac{\Delta p}{p}$

990. Write briefly how a photodiode can be used as a photo detector to detect optical signals. **CBSE (D)-2013**

[Ans. It is easier to observe change in the current, with change in the light intensity, when reverse bias is applied. Hence photodiode can be used as a photo detector to detect optical signals

991. A photodiode is fabricated from a semiconductor with a band gap of 2.8eV.Can it detect a wavelength of 6000nm? Justify. **CBSE (AI)-2005,(D)-2005,(F)-2005**

[Ans. $E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{6000 \times 10^{-9}} = 0.207\ eV$

As $E < E_g$, photodiode **cannot** detect the radiation of wavelength 6000 nm

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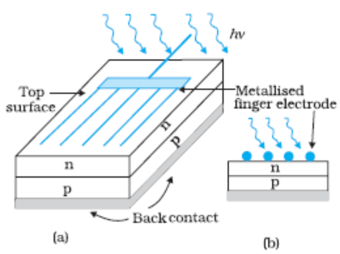
992. What is a Solar Cell ? How a solar cell is fabricated ? State the working principle of a solar cell. Mention three Basic processes involved in the generation of emf. **CBSE (F)-2016,(AI)-2015,2008**

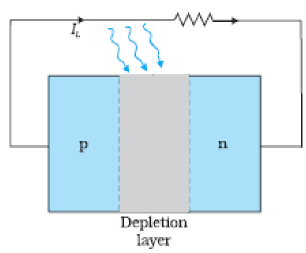
[Ans. Solar Cell : It is a p-n junction diode, which converts light energy in to electrical energy.

Principle : It is based on the principle of **photovoltaic effect**

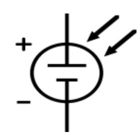
Fabrication : A simple p-n junction solar cell consists of a very thin p-Si wafer. On one side of this wafer, a thin layer of n-Si is grown by diffusion process and on the other side there is a metal coating which acts as back contact. On the top of n-Si layer, metallic grid is deposited, which acts as a front contact.



Solar cell



Circuit diagram



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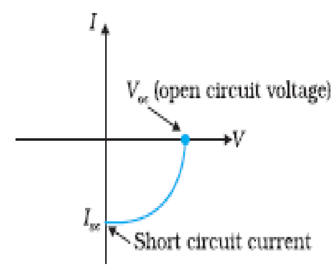

characteristic curve

Working : Generation of emf by a solar cell, when light falls on, it is due to the following three basic processes:

(i) generation of electron hole pairs due to incident light (with $h\nu > E_g$) close to the junction

(ii) separation of electrons and holes due to electric field of the depletion region

(iii) the electrons reaching the n-side are collected by the front contact and holes reaching p-side are collected by the back contact. Thus p-side becomes positive and n-side becomes negative giving rise to photo voltage.

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993. Write any two uses of solar cells. **CBSE (AIC)-2010**

[Ans. (i) to power electronic devices in satellites and space vehicles

(ii) in power supply for watches, calculators

(iii) in charging solar batteries

994. Why are Si and GaAs preferred materials for solar cells ? **CBSE (F)-2016, (AI)-2008**

[Ans. Solar radiation has maximum intensity of photons of energy = 1.5 eV. Hence, semiconducting materials Si and GaAs, with $E_g \approx 1.5$ eV, are preferred materials for solar cell

995. Write two important criteria required for the selection of a material for solar cell fabrication. **CBSE (AI)-2015**

[Ans. (i) Band energy gap E_g must be of range 1.0 to 1.8 eV (ii) strong electrical conductivity

(iii) high optical absorption ($\approx 10^4 cm^{-1}$) (iv) availability and low cost of the raw material

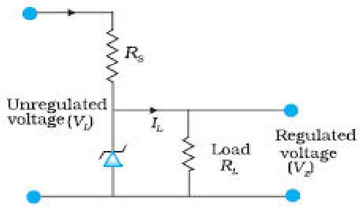
996. What is Zener diode ? How is a Zener diode fabricated ? What causes the setting up of high electric field even for small reverse bias voltage across the diode ? With the help of a circuit diagram explain the use of a Zener diode as a voltage stabilizer. **CBSE (AI)-2015,2009,2008,2004,(F)-2007,2001**

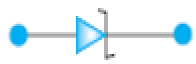
[Ans. Zener Diode: It is a heavily doped p-n junction diode specially designed to operate in the reverse breakdown region Continuously

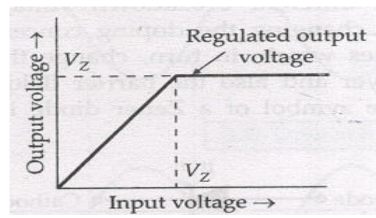
Principle : At reverse breakdown voltage, the voltage across Zener diode remains constant for a large change in reverse current.

Fabrication : Zener diode fabricated by heavily doping both p and n- side of the junction. Heavy doping makes the depletion region very thin. This makes the electric field of the junction extremely high ($\approx$5 X 10^6 V/m), even for a small reverse voltage ($\approx$ 5V). This in turn helps the Zener diode to act as voltage regulator

Zener diode as a Voltage stabilizer :




Symbol of Zener diode



Working :

If input voltage increases/ decreases, current through Zener diode will also increase/ decreases. It increases/ decreases voltage drop across Rs without any change in voltage across R_L as potential across Zener diode does not change in breakdown region giving the regulated output voltage

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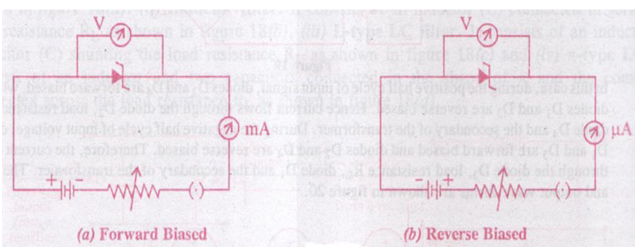
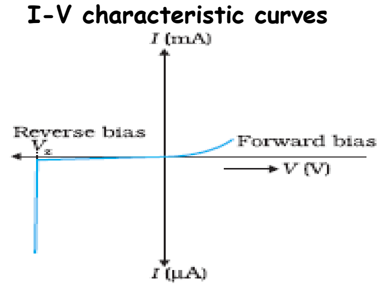
997. Draw the circuit diagram to study the characteristic curves of a Zener diode and draw its typical I-V characteristics. **CBSE (F)-2012,2010**

[Ans. Circuit diagram to draw characteristic curves :



(a) Forward Biased (b) Reverse Biased

I-V characteristic curves



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997a. Write two important considerations used while fabricating a Zener diode. **CBSE (AI)-2015,2012**

[Ans. (i) heavily doping of both p and n-sides of the junction (ii) Proper breakdown voltage under reverse biasing

997b. Why Zener diode is called a special purpose diode ?

[Ans. Because operates in reverse breakdown region and acts as a voltage regulator

997c. Why is Zener diode fabricated by heavily doping both p and n- side of the junction ? **CBSE (F)-2014**

OR

How is a Zener diode fabricated ? What causes the setting up of high electric field even for small reverse bias voltage across the diode ? **CBSE (AI)-2015**

[Ans. Zener diode fabricated by heavily doping both p and n- side of the junction. Heavy doping makes the depletion region very thin. This makes the electric field of the junction extremely high ($\approx$5 X 10^6 V/m), even for a small reverse voltage ($\approx$5V). This in turn helps the Zener diode to act as voltage regulator

998. Zener diodes have higher dopant densities as compared to ordinary p-n junction diodes. How does it affect the- (i) width of depletion layer (ii) junction field ? **CBSE (Sample Paper)-2010**

[Ans.(i) width of depletion layer decreases (ii) junction field increases

999. How the reverse current suddenly increases at the breakdown voltage ? Explain. **CBSE (F)-2012,2010**

[Ans. At V = V_Z, electric field is high enough (10^6 V/m) to pull valence electrons from the host atoms on the p-side which are accelerated to n-side. These electrons account for high current observed at the breakdown. The emission of electrons from the host atoms due to the high electric field is known as internal field emission or field ionization. The breakdown of diode due to internal field emission is called Zener breakdown

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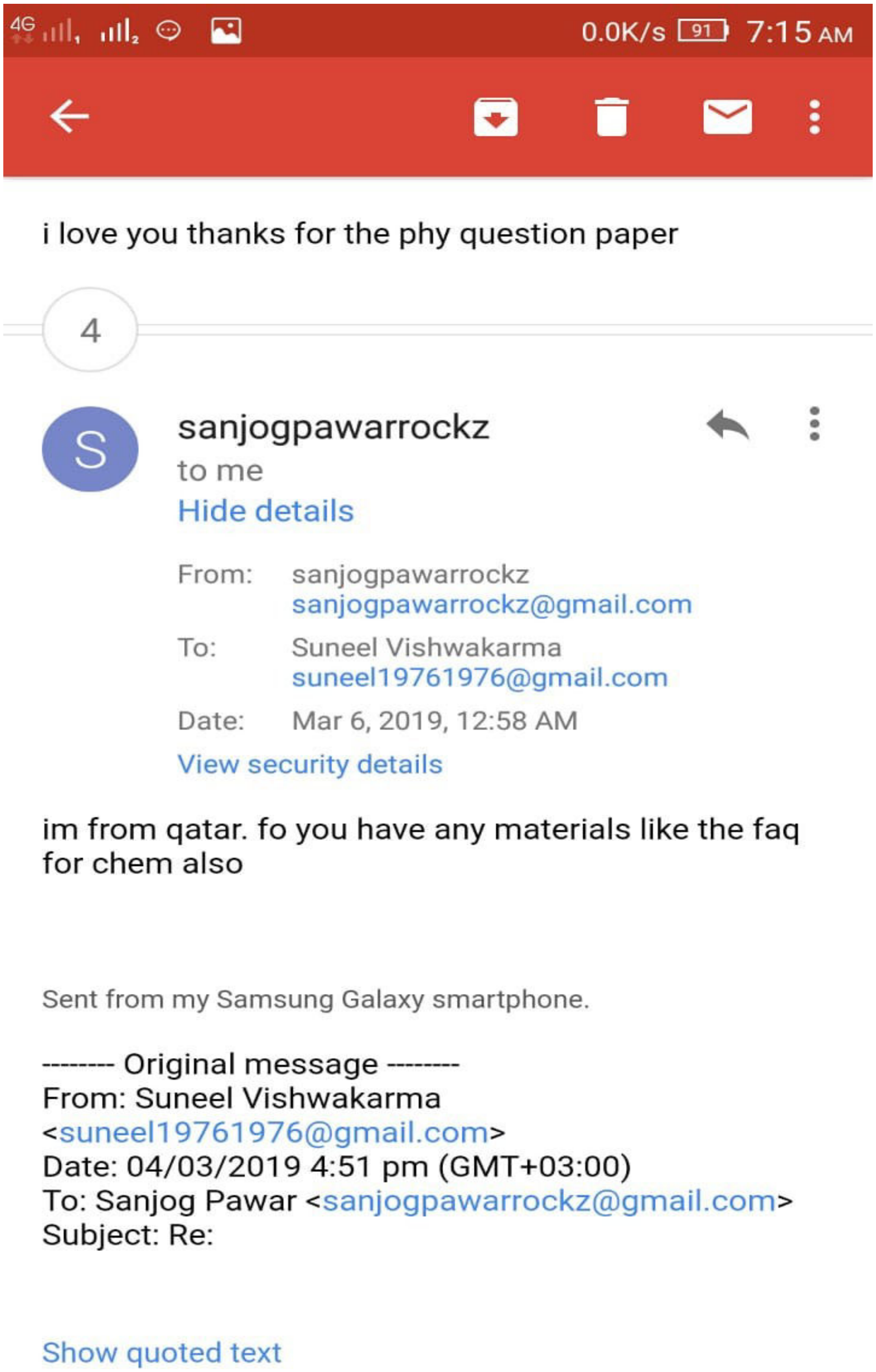

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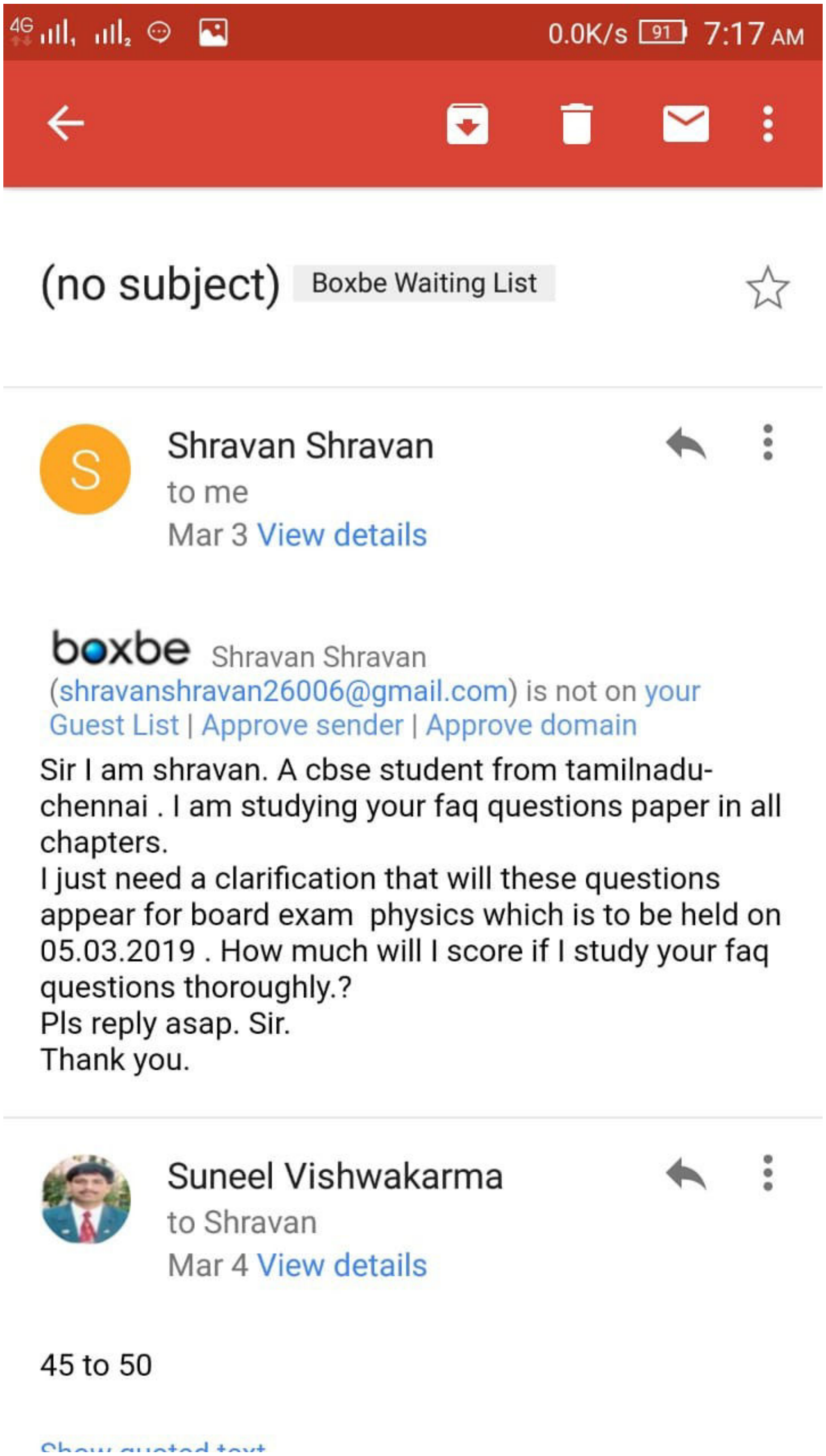

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to me
Mar 9 View details

Dear Sir,

I am Dr. Ashish Kashyap working as Physics facilitator at Ecole Globale International Girl's School, Dehradun. I would like to express my gratitude to you for your valuable Physics notes (FAQ) which you have made for grade 12. They helped a lot.
Sir it is my humble request that If you have same physics material for grade 10. Then please share with me if you don't mind. I will be highly grateful to you for this kind favour.

Thanks & Best Regards
Dr. Ashish Kashyap
Dehradun
9634230068

A

Ashish Shivakumar

to me

Jun 16 View details

Dear Sir

I am Ashish.S student of Air Force School Hebbal, through my physics teacher I got a pdf copy of your class 12 FAQ revision document PDF which proved helpful to me to the greatest extent with regards to the board exam preparation. I thank you wholeheartedly for that. I wanted to ask you if created a similar version for 11th std physics or have any other related similar material's PDF, if so could you please send me a PDF copy of the same. It would be my humble request for the same.
This would help me a lot.
Thanks a lot for the class 12 FAQ revision document PDF Sir, that helped me a lot.
With regards
Ashish.S
the great

S

Sachin Kumar

to me

Nov 6 View details

Hello Sir
I am Sachin. PGT physics at KV Barwaha, MP. I got the Physics FAQ prepared by you last year from a senior teacher. I used it last year and found it really helpful for revision. I would like to thank you for the effort you have put in to make this. Also I request you to send me the updated version of it (if you have added more questions to it after it was made) and other such useful materials that you can share.
Thank you once again sir.

Sachin

“Success is not permanent and failure is not final, so never stop working after success and never stop trying after failure”


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MASTER RESOURCE PERSONS WORKSHOP
15th MAY to 24th MAY 2019
IIT KANPUR
केन्द्रीय विद्यालय संगठन

THANKS