Physics 2011 (Outside Delhi) SET I

Time allowed : 3 hours

Maximum marks : 70

1. Define electric dipole moment. Write its S.I. unit. [1]

Answer : Electric dipole moment : Dipole moment is a measure of strength of electric dipole. It is vector quantity whose magnitude is equal to product of magnitude of charge and the distance between them.

$$p = q \times 2d$$

SI unit of dipole moment is coulomb-metre (Cm).

2. Where on the surface of Earth is the angle of dip 90° ? [1]

Answer : Magnetic dip is the angle made by a compass needle with the horizontal point on earth's surface. The angle of dip is 90° at the poles.

3. A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. What is potential at the centre of the sphere ? [1]

Answer : Potential inside the charged sphere is constant and equal to potential on the surface of the conductor. So, potential at the centre of sphere is 10 V.

4. How are radiowaves produced ? [1]

Answer : Radiowaves are produced by :

(i) Rapid acceleration and deceleration of electrons.

(ii) Using tuning circuits like LCR, LC and RC.

(iii) Accelereted motion of charges in conducting wires.

(iv) They are also given off by stars, sparks and lightning.

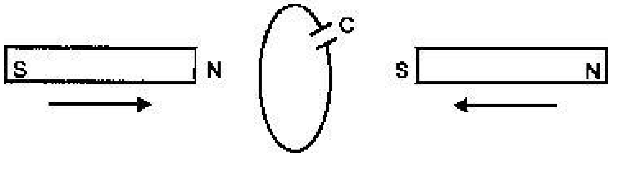
5. Write any two characteristic properties of nuclear force. [1]

Answer : Characteristic properties of nuclear forces are :

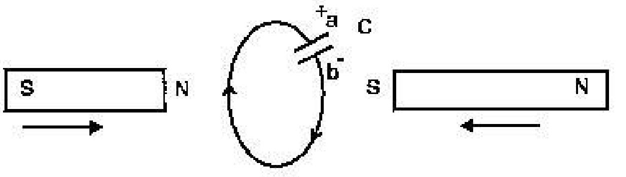
(i) Nuclear forces are strongest forces in nature.

(ii) Nuclear forces are charge independent.

6. Two bar magnets are quickly moved towards a metallic loop connected across a capacitor 'C' as shown in the figure. Predict the polarity of the capacitor. [1]



Answer : In this situation, *a* will become positive with respect to *b*, as current induced is in clockwise direction.



7. What happens to the width of depletion layer of a *p-n* junction when it is (i) forward biased, (ii) reverse biased ? [1]

Answer : (i) Forward biased : Potential drop across the junction decreases and diffusion of holes and electrons across the junction increases. It makes the width of the depletion layer smaller.

(ii) Reverse biased : Potential drop across the junction increases and diffusion of holes and electrons across the junction decreases. It makes the width of the depletion layer larger.

8. Define the term 'stopping potential' in relation to photoelectric effect. [1]

Answer : Stopping potential is the minimum negative (retarding) potential of anode for which photocurrent stops or becomes zero. It is denoted by V_s. The value of stopping potential is different for different metals but it is independent of the intensity of incident light and depends on the frequency of the incident light.

9. A thin straight infinitely long conducting wire having charge density λ is enclosed by a cylindrical surface of radius *r* and length *l*, its axis coinciding with the length of the wire. Find the expression for the electric flux through the surface of the cylinder. [2]

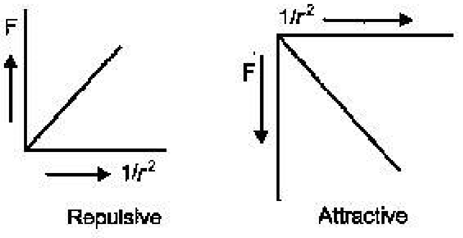
Answer : Charge enclosed by the cylindrical surface $q = \lambda l$

$$\text{Flux, } \phi = \frac{q}{\varepsilon_0}$$

$$\phi = \frac{\lambda l}{\varepsilon_0}$$

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

Answer : The following graph shows the variation of Coulomb force (F) versus *r*.



According to Coulomb's law,

$$F \propto q_1 q_2$$

$$F \propto \frac{1}{r^2}$$

$\therefore$ For both pair of charges, graph between F and $\frac{1}{r^2}$ is a straight line.

Between (1 μC, 2 μC), force is positive/repulsive.

Value of slope, $m = \frac{2}{4\pi\varepsilon_0}$

Between (2μC, – 3μC), force is negative/attractive.

Value of slope, $m = \frac{-6}{4\pi\varepsilon_0}$.

11. Write the expression for Lorentz 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. [2]

Answer : Magnetic Lorentz force is given by

$$\vec{f_m} = q(\vec{v} \times \vec{B})$$

$$\text{Work done} = \vec{f_m} \cdot \vec{S} = f_m S \cos\theta$$

$\vec{f_m}$ is always perpendicular to $\vec{v}$ *i.e.,* perpendicular to the direction of motion of the charge.

$\therefore$ Work done $= f_m S \cos\theta = f_m S \cos 90° = 0$

12. What are eddy currents ? Write any two applications of eddy currents. [2]

Answer : When a bulk piece of conductor is subjected to changing magnetic flux, the induced current developed in it is called eddy current.

Applications of eddy currents :

(i) Magnetic brakes in trains.

(ii) Electromagnetic damping.

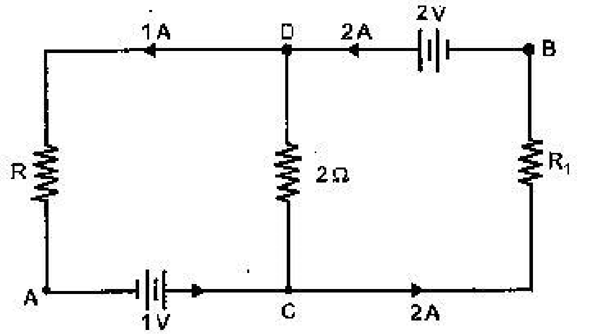
(iii) Induction furnaces.

(iv) Electric power meter.

13. What is sky wave communication ? Why is this mode of propagation restricted to the frequencies only upto few MHz ? [2]**

**Answer is not given due to the change in present syllabus.

14. In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B. [2]



Answer : $V_D - V_C = 2 \times 1 = 2\text{ V}$ ...(i)

$\because$ $V_A = 0$

$\therefore$ $V_C - V_A = 1\text{ V}$

$\Rightarrow$ $V_C = 1\text{ V}$ ...(ii)

From (i) and (ii),

$V_D = 2 + V_C = 3\text{ V}$ ...(iii)

Now $V_D - V_B = 2\text{ V}$

$\Rightarrow$ $3 - V_B = 2\text{ V}$

$\Rightarrow$ $V_B = 1\text{ V}$

15. A parallel plate capacitor is being charged by a time varying current. Explain briefly how Ampere's circuital law is generalized to incorporate the effect due to the displacement current. [2]

Answer : Gauss' law states that the electric flux ϕ_E of a parallel plate capacitor having an area A, and a total charge Q is given by

$$\phi_E = EA = \frac{1Q}{A\varepsilon_0} \times A \quad \left[\because E = \frac{Q}{A\varepsilon_0}\right]$$

$$= \frac{Q}{\varepsilon_0}$$

As the charge Q on the capacitor plates change with time, so current is given by

$$i = \frac{dQ}{dt}$$

$$\therefore \quad \frac{d\phi_E}{dt} = \frac{d}{dt}\left(\frac{Q}{\varepsilon_0}\right) = \frac{1}{\varepsilon_0}\frac{dQ}{dt}$$

$$\Rightarrow \quad \varepsilon_0 \frac{d\phi_E}{dt} = \frac{dQ}{dt} = i$$

This is the missing term in Ampere's Circuital law.

So, the total current through the conductor is

i = Conduction current (i_c) + Displacement current (i_d)

$$i = i_c + \epsilon_0 \frac{d\phi_E}{dt} \quad ...(i)$$

Ampere's circuital law states that

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 i \quad ...(ii)$$

Putting equation (i) in (ii), we get

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 i_c + \mu_0\epsilon_0 \frac{d\phi_E}{dt}$$

This is the required generalized form of Ampere's circuital law.

16. Net capacitance of three identical capacitors in series is 1 μF. What will be their net capacitance if connected in parallel ?

Find the ratio of energy stored in the two configurations if they are both connected to the same source. [2]

Answer : Net capacitance in series = 1 μF

If $C_1 = C_2 = C_3 = C$

Let C be the capacitance of each of three capacitors and C_S and C_P be the capacitance of series and parallel combination respectively.

Then, $$\frac{1}{C_S} = \frac{1}{C}+\frac{1}{C}+\frac{1}{C} = \frac{3}{C}$$

$$C_S = \frac{C}{3}$$

$$1\,\mu F = \frac{C}{3}$$

∴ $$C = 3\,\mu F$$

Also $$C_P = C + C + C$$

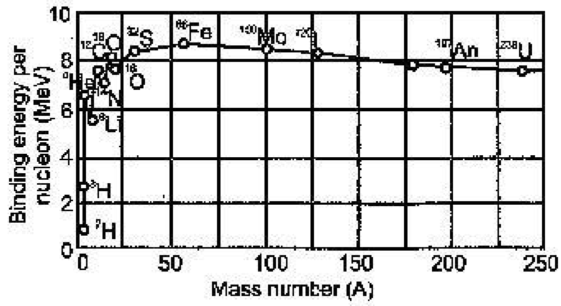
$$= 3 + 3 + 3 = 9\,\mu F$$

Energy stored in capacitor

$$E = \frac{1}{2}CV^2$$

∴ $$\frac{E_S}{E_P} = \frac{\frac{1}{2}C_S V^2}{\frac{1}{2}C_P V^2} = \frac{C_S}{C_P} = \frac{1}{9}$$

17. Using the curve for the binding energy per nucleon as a function of mass number A, state clearly how the release in energy in the processes of nuclear fission and nuclear fusion can be explained. [2]



Answer : The above curve shows that :

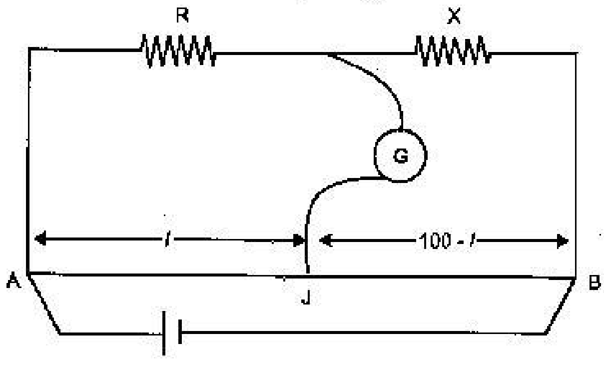
(i) When a heavy nucleus breaks into two medium sized nuclei (in nuclear fission), the BE/nucleon increases resulting in the release of energy.

(ii) When two small nuclei combine to form a relatively bigger nucleus in nuclear fusion, BE/nucleon increases, resulting in the release of energy.

18. In the meter bridge experiment, balance point was observed at J with AJ = l. [2]

(i) The values of R and X were doubled and then interchanged. What would be the new position of balance point ?

(ii) If the galvanometer and battery are interchanged at the balance position, how will the balance point get affected ?



Answer : (i) Initially, balanced condition will be given as

$$\frac{R}{X} = \frac{l}{100-l} \quad ...(i)$$

By doubling and interchanging R and X. Let the new balance point be obtained at l'.

Then,

$$\frac{2X}{2R} = \frac{l'}{100-l'}$$

$$\Rightarrow \quad \frac{X}{R} = \frac{l'}{100-l'} \quad ...(ii)$$

From equations (i) and (ii),

$$l' = 100 - l$$

(ii) By interchanging galvanometer and battery, there will be no change in the balance point position.

19. A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in (i) a medium of refractive index 1.65, (ii) a medium of refractive index 1.33. [3]

(a) Will it behave as a converging or a diverging lens in the two cases ?

(b) How will its focal length change in the two media ?

Answer : (a) Here ${}^a\mu_g = 1.5$

Let f_{air} be the focal length of lens in air, then

$$\frac{1}{f_{air}} = ({}^a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

or $$\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f_{air}(1.5-1)}$$

$$\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{2}{f_{air}} \quad \text{...(i)}$$

(i) When lens is dipped in medium A.

Here $${}^a\mu_A = 1.65$$

Let f_A be focal length of lens, when dipped in medium A, then

$$\frac{1}{f_A} = ({}^A\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

or $$\frac{1}{f_A} = \left(\frac{{}^a\mu_g}{{}^a\mu_A} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using equation (i), we have

$$\frac{1}{f_A} = \left(\frac{1.5}{1.65} - 1\right) \times \frac{2}{f_{air}}$$

$$= -\frac{0.15}{1.65} \times \frac{2}{f_{air}}$$

or $$f_A = -5.5 f_{air} \quad \text{...(ii)}$$

As sign of f_A is opposite to that of f_{air}, the lens will behave as a diverging lens.

(ii) When lens is dipped in medium B.

Here, $${}^a\mu_B = 1.33.$$

Let f_B be the focal length, when dipped in medium B, then

$$\frac{1}{f_B} = ({}^B\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= \left(\frac{{}^a\mu_g}{{}^a\mu_B} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using equation (i), we have

$$\frac{1}{f_B} = \left(\frac{1.5}{1.33} - 1\right) \times \frac{2}{f_{air}}$$

$$\therefore \quad f_B = 3.9 f_{air} \quad \text{...(iii)}$$

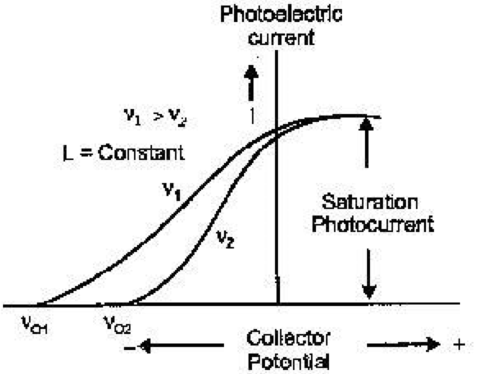
As sign of f_B is same as that of f_{air}, the lens will behave as converging lens.

(b) (i) As seen from equation (ii), focal length becomes negative and increases in magnitude.

(ii) As seen from equation (ii), focal length remains positive and increases in magnitude.

20. Draw a plot showing the variation of photoelectric current with collector plate potential for two different frequencies, $\nu_1 > \nu_2$, of incident radiation having the same intensity. In which case will be stopping potential be higher ? Justify your answer. [3]

Answer :



Stopping potential is more for the curve corresponding to the frequency ν_2. ($\because \nu_1 > \nu_2$)

This is due to the fact that with increase in the frequency, the kinetic energy of emitted photoelectrons also increases. Therefore, we need more negative potential to stop these electrons.

21. Write briefly any two factors which demonstrate the need for modulating a signal. Draw a suitable diagram to show amplitude modulation using a sinusoidal signal as a modulating signal. [3]**

22. Use the mirror equation to show that [3]

(a) an object placed between f and $2f$ of a concave mirror produces a real image beyond $2f$.

(b) a convex mirror always produces a virtual image independent of the location of the object.

****Answer is not given due to the change in present syllabus.**

(c) an object placed between the pole and focus of a concave mirror produces a virtual and enlarged image.

Answer : Mirror equation is given as,

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

For concave mirror, $f < 0$ or $f = -ve$

For convex mirror, $f > 0$ or $f = +ve$

Concave Mirror

Let $f = -c$

Also, let $u = nf = -nc$

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

$$\frac{1}{v} = \frac{1}{-c}-\frac{1}{-nc}$$

$$v = \frac{nc}{(1-n)}$$

(a) When object is between f and $2f$: We have $1 < n < 2$.

In this case, v is $-ve$ *i.e.* real image.

(For $n = 1$ and $n = 2$), magnitude of v becomes ∞ and $-2c$, respectively.

Therefore, real image is formed beyond $2f$.

(b) Convex Mirror : As we know $f = +d$

Let $u = -pd$ (p can have any value)

$$\frac{1}{v} = \frac{1}{d}+\frac{1}{pd}=\frac{(1+p)}{pd}$$

$$v = \frac{pd}{(p+1)}$$

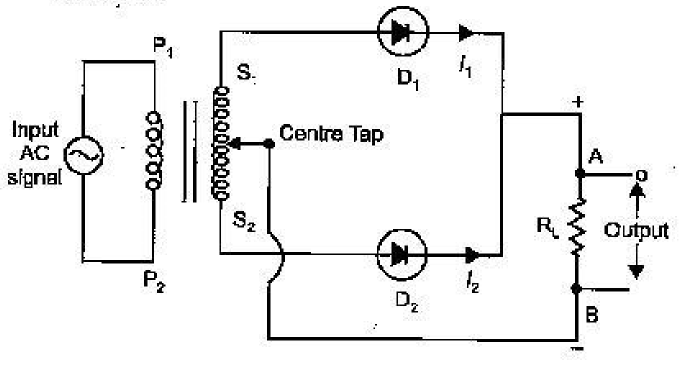
Therefore, v is always $+ve$ and always less than d, so we can say that convex mirror always produces a virtual image between pole and focus.

(c) Object between pole and F : We have $0 < n < 1$. In this case, v is +ve (virtual image) and $|v| > c$.

Therefore, we get a virtual and enlarge image.

23. Draw a labelled diagram of a full wave rectifier circuit. State its working principle. Show the input-output waveforms. [3]

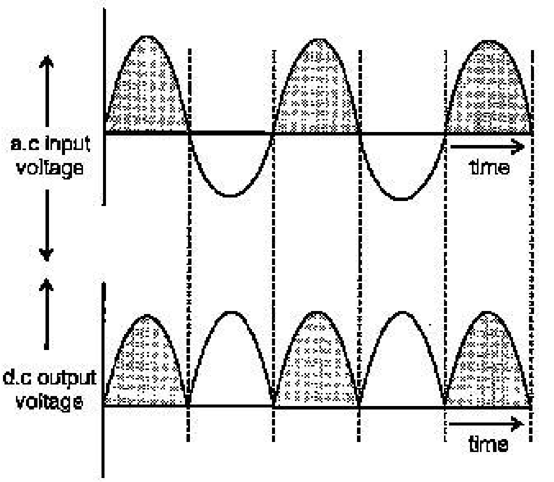
Answer :



Rectification : Rectification means conversion of ac into dc. A *p-n* diode acts as a rectifier because an ac changes polarity periodically and a *p-n* diode conducts only when it is forward biased; it does not conduct when it is reverse biased.

Working : The ac input voltage across secondary S_1 and S_2 changes polarity after each half cycle. Suppose during the first cycle of input ac signal, the terminal S_1 is positive relative to centre tap and S_2 is negative relative to it. Then diode D_1 is forward biased and D_2 is reverse biased. Therefore, diode D_1 conducts while D_2 does not. Thus, the current in load resistance R_L is in the same direction for both half cycles of input ac signal and the output current is a continuous series of unidirectional pulses.

In a full wave rectifier, if input frequency is f Hertz, then output frequency will be $2f$ Hertz because for each cycle of input, two positive half cycles of output are obtained.



24. (a) Using de-Broglie's hypothesis, explain with the help of a suitable diagram, Bohr's second postulate of quantization of energy levels in a hydrogen atom.

(b) The ground state energy of hydrogen atom is −13.6 eV. What are the kinetic and potential energies of the electron in this state ? [3]

Answer : (a) The second postulate of Bohr atom model says that angular momentum of electron orbiting around the nucleus is quantized, *i.e.*, $mvr = \frac{nh}{2\pi}$, where $n = 1, 2, 3, ...$

According to de-Broglie, a stationary orbit is that which contains an integral number of de-Broglie waves associated with the revolving electron.

For an electron revolving in the n^{th} circular orbit of radius r_n, total distance covered = circumference of the orbit = $2\pi r_n$

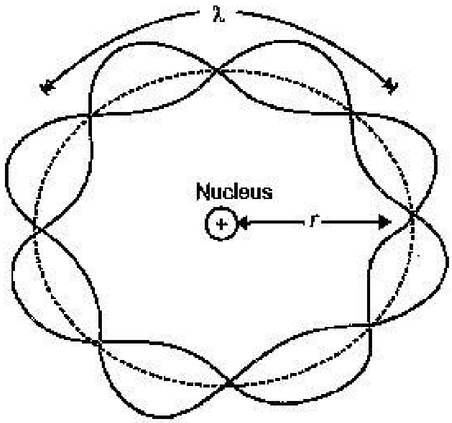
$$2\pi r_n = n\lambda$$

According to de-Broglie, $\lambda = \frac{h}{mv_n}$

Where v_n is speed of electron revolving in n^{th} orbit.

$$2\pi r_n = \frac{nh}{mv_n} \text{ or } mv_n r_n = \frac{nh}{2\pi}$$

i.e., angular momentum of electron revolving in n^{th} orbit must be an integral multiple of $\frac{h}{2\pi}$, which is the quantum condition proposed by Bohr in second postulate.



(b) The kinetic and the potential energies of electron in the hydrogen atom (Z = 1) are given by

$$K = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r} \text{ and } U = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r},$$

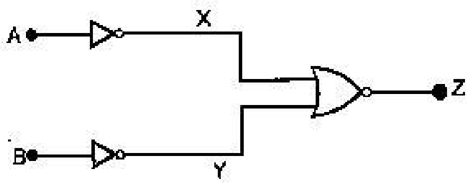
where r is the radius of the orbit in the given energy state. The total energy is

$$E = K + U = \frac{1}{4\pi\varepsilon_0}\left(\frac{e^2}{2r} - \frac{e^2}{r}\right) = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r}$$

Thus, $K = -E = -(-13.6 \text{ eV}) = +13.6 \text{ eV}$

$U = 2E = 2 \times (-13.6 \text{ eV}) = -27.2 \text{ eV}$

25. You are given a circuit below. Write its truth table. Hence, identify the logic operation carried out by this circuit. Draw the logic symbol of the gate it corresponds to.** **[3]**



****Answer is not given due to the change in present syllabus.**

26. A compound microscope uses an objective lens of focal length 4 cm and eyepiece lens of focal length 10 cm. An object is placed at 6 cm from the objective lens. Calculate the magnifying power of the compound microscope. Also calculate the length of the microscope. **[3]**

OR

A giant refracting telescope at an observatory has an objective lens of focal length 15 m. If an eyepiece lens of focal length 1.0 cm is used, find the angular magnification of the telescope.

If this telescope is used to view the moon, what is the diameter of the image of the moon formed by the objective lens ? The diameter of the moon is 3.42×10^6 m and the radius of the lunar orbit is 3.8×10^8 m.

Answer : Focal length of objective, $f_o = 4$ cm

Focal length of eyepiece, $f_e = 10$ cm

Object distance, $u_o = 6$ cm

By lens formula, for objective lens,

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$$

$$\frac{1}{v_o} = \frac{1}{f_o} + \frac{1}{u_o}$$

$$\frac{1}{v_o} = \frac{1}{4} - \frac{1}{6} = \frac{1}{12}$$

$$\Rightarrow \quad v_0 = 12 \text{ cm}$$

Magnification by objective,

$$m_0 = \frac{v_o}{|u_o|}$$

$$= \frac{12}{6} = 2$$

Magnification by eyepiece,

$$m_e = \left(1 + \frac{D}{f_e}\right) \text{ or } \frac{D}{f_e}$$

[$\therefore$ D = 25 cm for compound microscope]

$$= \left(1 + \frac{25}{10}\right) \text{ or } \frac{25}{10}$$

$$= 3.5 \text{ or } 2.5$$

Magnification power of the microscope,

$$m = m_o \times m_e$$

$$= 2 \times 3.5 \text{ or } 2 \times 2.5$$

$$= 7 \text{ or } 5$$

For eyepiece, by lens formula

$$\frac{1}{v_e}-\frac{1}{u_e} = \frac{1}{f_e}$$

For image to be formed at least distance of distinct vision, $v_e = 25$ cm.

$$\therefore \quad -\frac{1}{25}-\frac{1}{u_e} = \frac{1}{10}$$

$$\Rightarrow \quad \frac{1}{u_e} = -\frac{1}{25}-\frac{1}{10}=\frac{-7}{50}$$

$$\Rightarrow \quad u_e = \frac{-50}{7}\text{ cm} = -7.14\text{ cm.}$$

Length of the microscope,

$L = v_o + |u_e|$ or $L = v_o + |f_e|$

$L = 12 + 7.14$ or $L = 12 + 10$

$L = 19.14$ cm or $L = 22$ cm

OR

(a) Angular magnification, $m = \frac{f_o}{f_e} = \frac{15}{1\times10^{-2}}$
$= 1500$

(b) Diameter of moon $= 3.42 \times 10^6$ m

And radius of lunar orbit $= 3.8 \times 10^8$ m

Let d be diameter of the image.

We know,

$$d = \alpha f_o$$

Where $\alpha = \frac{\text{Diameter of moon}}{\text{Radius of lunar orbit}}$

$$\therefore \quad d = \frac{3.42\times10^6}{3.8\times10^8}\times15$$

$$= 0.135\text{ m or }13.5\text{ cm}$$

27. Two heating elements of resistances R_1 and R_2 when operated at a constant supply of voltage V, consume powers P_1 and P_2 respectively. Deduce the expressions for the power of their combination when they are, in turn, connected in (i) series and (ii) parallel across the same voltage supply. **[3]**

Answer : (i) In series,

Net resistance, $R = R_1 + R_2$ ...(i)

The heating elements are operated at same voltage.

$$\therefore \quad P = \frac{V^2}{R}; P_1 = \frac{V^2}{R_1}; P_2 = \frac{V^2}{R_2}$$

From equation (i)

$$\frac{V^2}{P} = \frac{V^2}{P_1}+\frac{V^2}{P_2}$$

$$\Rightarrow \quad \frac{1}{P} = \frac{1}{P_1}+\frac{1}{P_2}$$

(ii) In parallel combination,

Net resistance can be calculated as,

$$\frac{1}{R} = \frac{1}{R_1}+\frac{1}{R_2}$$

$$\Rightarrow \quad \frac{1}{\frac{V^2}{P}} = \frac{1}{\frac{V^2}{P_1}}+\frac{1}{\frac{V^2}{P_2}}$$

$$\Rightarrow \quad P = P_1 + P_2$$

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

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

(c) How is the magnetic field inside a given solenoid made strong ? **[5]**

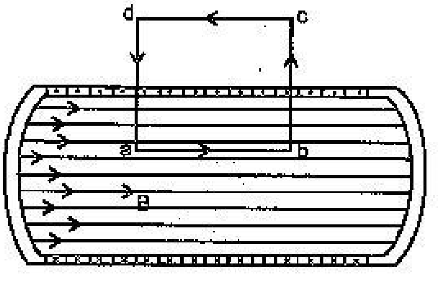
OR

(a) State the principle of the working of a moving coil galvanometer, giving its labelled diagram.

(b) "Increasing the current sensitivity of a galvonometer may not necessarily increase its voltage sensitivity." Justify this statement.

(c) Outline the necessary steps to convert a galvanometer of resistance R_G into an ammeter of a given range.

Answer : (a) Magnetic field inside a long solenoid is uniform every where and approximately zero outside it. Fig. shows a sectional view of long solenoid current coming out of the plane of the papers at points marked ⊙ and current entering the plane of the paper at points marked ⊗. To find the magnetic field $\vec{B}$ at any point inside the solenoid, consider a rectangular loop *abcd* as Amperian loop. According to Ampere's circuital law,



$$\oint \vec{B}\cdot\vec{dl} = \mu_0 \times \text{Total current through the loop}$$

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 \Sigma I$$

$$\oint \vec{B}\cdot\vec{dl} = \int_a^b \vec{B}\cdot\vec{dl} + \int_b^c \vec{B}\cdot\vec{dl} + \int_c^d \vec{B}\cdot\vec{dl} + \int_d^a \vec{B}\cdot\vec{dl}$$

$$= \int_a^b B\cdot dl\cos 0^\circ + \int_b^c B\cdot dl\cos 90^\circ + \int_c^d B\cdot dl\cos 180^\circ + \int_d^a B\cdot dl\cos 90^\circ$$

$$= B\int_a^b dl + 0 + 0 + 0 \quad \left[\begin{array}{l} \because \int B\,dl\cos 180^\circ = 0 \\ \because B = 0 \text{ outside the solenoid} \end{array}\right]$$

$$= B \times l + 0 + 0 + 0$$

$$\oint \vec{B}\cdot\vec{dl} = Bl$$

Where, l = length of the loop *abcd*

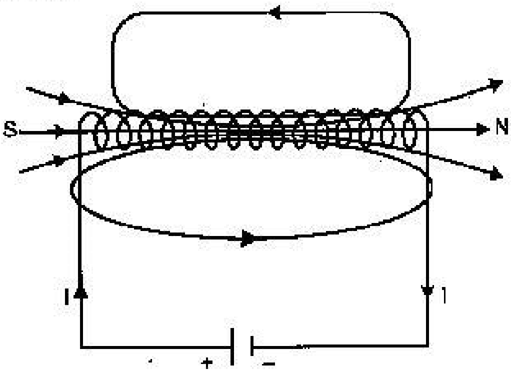
$\Sigma I = nlI$ [where I is the current passing through the solenoid]

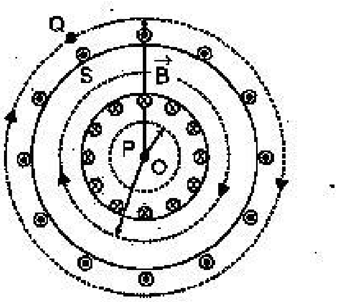
$\therefore$ $Bl = \mu_0 nlI$

$\Rightarrow$ $B = \mu_0 nI$

(b) Difference : In a toroid, magnetic lines do not exist outside the body. Toroid is closed whereas the solenoid is open on both sides.

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





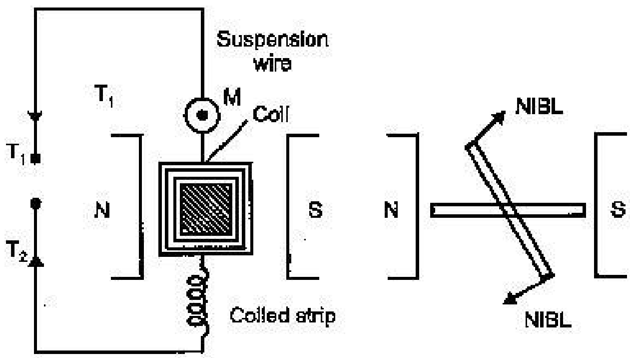
(c) Strength of magnetic field :

(1) By inserting the ferromagnetic substance inside the solenoid.

(2) By increasing the current through the solenoid.

OR

(a)



Principle : Its working is based on the fact that when a current carrying coil is placed in a magnetic field, it experiences a torque.

Working : When current (I) is passed in the coil, torque τ acts on the coil, given by

$$\tau = NIAB\sin\theta$$

where, θ = Angle between normal to plane of coil

B = Magnetic field of strength

N = No. of turns in a coil.

For equilibrium,

deflecting torque = restoring torque

$$NIAB = C\theta$$

$$\Rightarrow \quad \theta = \frac{NAB}{C} I$$

where, C = Torsional rigidity of the wire

$\Rightarrow$ $\theta \propto I$

The deflection of coil is directly proportional to the current flowing in the coil.

(b) Due to deflecting torque, the coil rotates and suspension wire gets twisted. A restoring torque is set up in the suspension wire.

$$NIBA = C\theta \qquad (\because \text{In equilibrium})$$

$$I = \frac{C}{NBA}\theta$$

$$I = G\theta$$

where, $G = \dfrac{C}{NBA}$

It is known as galvanometer constant.

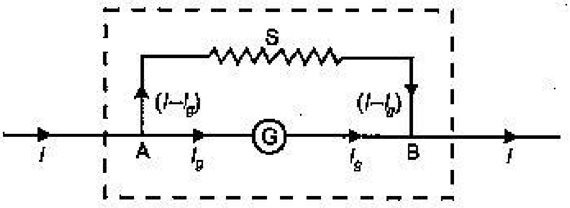
Current sensitivity, $S_C = \dfrac{\theta}{I} = \dfrac{NAB}{C}$

and voltage sensitivity, $S_V = \frac{\theta}{V} = \left(\frac{NAB}{C}\right)\frac{1}{R}$

$$= \frac{S_C}{R}$$

It means voltage sensitivity is dependent on current sensitivity and resistance of galvanometer, R. If we increase current sensitivity and galvanometer resistance is high, then it is not certain that voltage sensitivity will be increased. Thus, the increase of current sensitivity does not imply the increase of voltage sensitivity.

(c) Conversion of a galvanometer to ammeter :



A galvanometer can be converted into ammeter by connecting a shunt (low resistance) in parallel with the galvanometer and its value is given by

$$S = \left[\frac{I_g}{I - I_g}\right] G$$

29. State the working of a.c. generator with the help of a labelled diagram.

The coil of an a.c. generator having N turns, each of area A, is rotated with a constant angular velocity ω. Deduce the expression for the alternating e.m.f. generated in the coil. What is the source of energy generation in this device ? [5]

OR

(a) Show that in an a.c. circuit containing a pure inductor, the voltage is ahead of current by π/2 in phase.

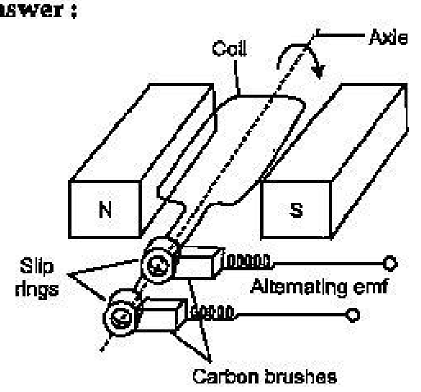
(b) A horizontal straight wire of length L extending from east to west is falling with speed v at right angles to the horizontal component of Earth's magnetic field B.

(i) Write the expression for the instantaneous value of the e.m.f. induced in the wire.

(ii) What is the direction of the e.m.f. ?

(iii) Which end of the wire is at the higher potential ?

Answer :



Working : When a coil (armature) rotates inside a uniform magnetic field, magnetic flux linked with the coil changes w.r.t. time. This produces an e.m.f. according to Faraday's law.

For first half of the rotation, the current will be from one end (first ring) to the other end (second ring). For second half of the rotation, it is in opposite sense.

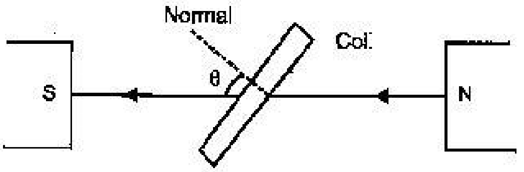
To calculate the magnitude of e.m.f. induced, Suppose

N = number of turns in the coil.

A = area enclosed by each turn of coil.

$\vec{B}$ = strength of magnetic field.

θ = angle which normal to the coil makes with $\vec{B}$ at any instant t,



∴ Magnetic flux linked with the coil in this position

$$\phi = N(\vec{B} \cdot A) = NBA \cos\theta$$

$$= NBA \cos \omega t \qquad ...(i)$$

where is the angular velocity of the coil. At this instant t, if e is the e.m.f. induced in the coil, then

$$e = \frac{-d\phi}{dt} = \frac{-d}{dt}(NAB \cos \omega t)$$

$$= -NAB \frac{d}{dt}(\cos \omega t)$$

$$= -NAB\,\omega\,(-\sin \omega t)$$

∴ $$e = NAB\,\omega \sin \omega t \qquad ...(ii)$$

The induced e.m.f. will be maximum, when $\sin \omega t$ is maximum *i.e.*, 1

∴ $$e_{max} = NAB\,\omega \times 1 \qquad ...(iii)$$

Put in (ii), if we denote NABω as e_0, then

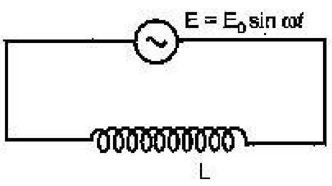
$$e = e_0 \sin \omega t$$

Source of energy : Mechanical energy.

The word generator is a misnomer, because nothing is generated by the machine, it is an alternator converting one form of energy to another.

OR

(a) Circuit containing inductance only : Let an alternating emf given by $E = E_0 \sin \omega t$, ...(i)



be applied across a pure (zero resistance) coil of inductance L. As the current i in the coil grow continuously, an opposing emf is induced in the coil whose magnitude is $L\frac{di}{dt}$, where $\frac{di}{dt}$ is the rate of change of current. But this should be zero because there is no resistance in the current. Thus,

$$E_0 \sin \omega t - L\frac{di}{dt} = 0$$

$$\Rightarrow \quad \frac{di}{dt} = \frac{E_0}{L}\sin \omega t$$

$$\Rightarrow \quad di = \frac{E_0}{L}\sin \omega t \, dt$$

Integrating both sides, we have

$$\int di = \frac{E_0}{L}\int \sin \omega t \, dt$$

$$i = \frac{E_0}{L}\left(-\frac{\cos \omega t}{\omega}\right) = \frac{E_0}{\omega L}(-\cos \omega t \, dt)$$

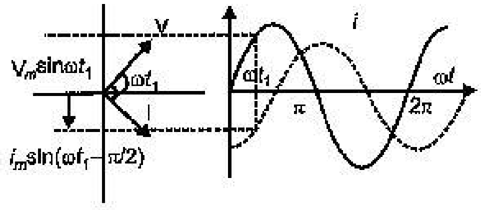
$$\Rightarrow \quad i = \frac{E_0}{\omega L}\sin(\omega t - \pi/2)$$

The maximum value of $\sin(\omega t - \pi/2)$ is 1.

Therefore, $\frac{E_0}{\omega L}$ is the maximum current in the circuit. Thus,

$$i = i_0 \sin(\omega t - \pi/2) \quad ...(ii)$$

From equations (i) and (ii), it is proved that voltage is ahead of current by $\frac{\pi}{2}$.



(b) (i) $e = BLv$

(ii) Direction of e.m.f is from west to east.

(iii) Wire 1 is at greater potential than wire 2.

30. State the importance of coherent sources in the phenomenon of interference.

In Young's double slit experiment to produce interference pattern, obtain the conditions for constructive and destructive interference. Hence deduce the expression for the fringe width.

How does the fringe width get affected, if the entire experimental apparatus of Young is immersed in water ? [5]

Answer : Two sources of light which continuously emit light waves of same frequency with a zero or constant phase difference between them are called coherent sources. They are necessary to produce sustained interference pattern.

A thin film of oil spread over water shows beautiful colours due to interference of light.

If coherent sources are not taken, the phase difference between the two interfering waves will change continuously and a sustained interference pattern will not be obtained.

$$y_1 = a \cos \omega t$$

$$y_2 = a[\cos(\omega t + \phi)]$$

According to principle of superposition, the resultant wave is given by

$$y = y_1 + y_2$$

$$\Rightarrow \quad y = a[\cos\omega t + \cos(\omega t + \phi)]$$

$$\Rightarrow \quad y = 2a \cos \phi/2 \cos(\omega t + \phi/2)$$

Resultant amplitude $= 2a \cos(\phi/2)$

The intensity is directly proportional to the square of the amplitude. $I \propto a^2$

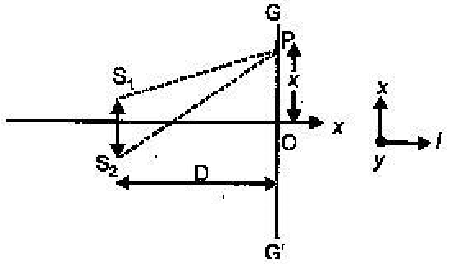
$$\therefore \quad I = 4I_0 \cos^2(\phi/2)$$

Condition for constructive interference

$\phi = 0, 2\pi, 4\pi, \ldots\ldots$ or $= \pm 2n\pi$ ($n = 0, 1, 2, \ldots\ldots\ldots$)

Condition for destructive interference

$\phi = \pm \pi, \pm 3\pi, \pm 5\pi, \ldots\ldots$ or $= \pm (2n+1)\pi$ ($n = 0, 1, 2, \ldots$)



We have, $(S_2P)^2 - (S_1P)^2$

$$= \left[D^2 + \left(x + \frac{d}{2}\right)^2\right] - D^2\left[x - \frac{d}{2}\right]^2 = 2xd$$

$$\therefore \quad S_2P - S_1P = \frac{2xd}{S_2P + S_1P} = \frac{2xd}{2D} = \frac{xd}{D}$$

Constructive interference : The intensity of light will be maximum at those places where the path difference between the interfering light waves is zero or an integral multiple of λ, *i.e.*, $\lambda, 2\lambda, \ldots\ldots$

Hence for maximum intensity, we have

$$\frac{xd}{D} = n\lambda$$

$$\Rightarrow \qquad x = \frac{nD\lambda}{d}$$

Destructive interference : The intensity of light will be minimum at those places where the path difference between the interfering light-waves is an old integral multiple of $\frac{\lambda}{2}\left(\frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, \ldots\ldots\right)$.

Hence for minimum intensity, we have

$$\frac{D\lambda}{d} = (2n-1)\frac{\lambda}{2} = (n - \frac{1}{2})\lambda$$

$$x = (n - \frac{1}{2})\frac{D\lambda}{d}$$

Fringe width, $\beta = x_{n+1} - x_n = (n+1)\frac{D\lambda}{d} - \frac{nD\lambda}{d}$

$\beta = \frac{D\lambda}{d}$, which will be same for constructive and destructive interference.

So fringe width is directly proportional to λ. On immersing the apparatus in water, the wavelength of light decreases $(\lambda_\omega = \lambda/n)$.

Therefore, fringe width will decrease in water.

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Physics 2011 (Outside Delhi) SET II

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

1. **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 ?** **[1]**

   Answer : Potential inside the charged sphere is constant and equal to potential on the surface of conductor.

   Therefore, potential at the centre of sphere is 5 V.

2. **How are X-rays produced ?** **[1]**

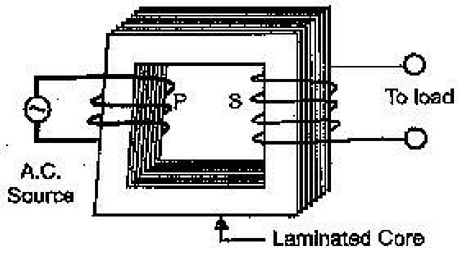
   Answer : X-rays are produced when electron strike a metal target. The electrons are liberated from the heated filament and accelerated from the high voltage towards the metal target. X-rays are also produced when electrons collide with the atom and nuclei of metal target.

4. **Where on the surface of Earth is the angle of dip zero ?** **[1]**

   Answer : At magnetic equator angle of dip is zero.

12. **State the principle of working of a transformer. Can a transformer be used to step up or step down a d.c. voltage ? Justify your answer.** **[2]**

    Answer : Transformer principle : It is a device which converts high voltage a.c. into low voltage a.c. and *vice-versa*.



It is based upon the principle of mutual induction. When alternating current is passed through a coil, an induced e.m.f. is set up in the neighbouring coil.

Working : When an alternating current is passed through the primary, the magnetic flux through the iron core changes which does two things. It produces e.m.f. in the primary and an induced e.m.f. is also set up in the secondary. If we assume that the resistance of primary is negligible, the back e.m.f. will be equal to the voltage applied to the primary.

$$\therefore \quad V_P = -N_P \frac{d\phi}{dt}$$

and $$V_S = -N_S \frac{d\phi}{dt}$$

where N_P and N_S are number of turns in the primary and secondary respectively. V_P and V_S are their respective voltages.

$$\therefore \quad \frac{V_S}{V_P} = \frac{N_S}{N_P}$$

The ratio $\frac{N_S}{N_P}$ is called the turns ratio.

In a step-up transformer : $N_S > N_P$

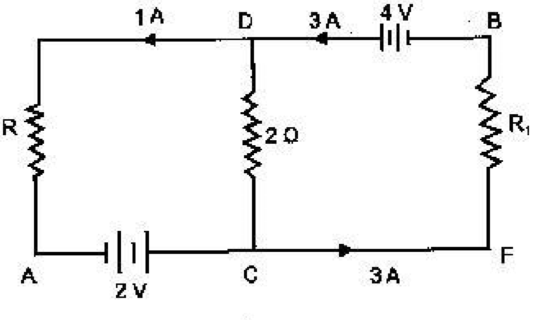
So $V_S > V_P$

In a step-down transformer : $N_S < N_P$

So $V_S < V_P$

A transformer can not be used to step up or step down a d.c. voltage because d.c. can not produce a changing magnetic flux in the core of the transformer and no emf will be induced.

14. In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B. [2]



Answer : $V_D - V_C = 2 \times 2 = 4$ V ...(i)

$$V_C - V_A = 2 \text{ V}$$

$$\because \quad V_A = 0 \Rightarrow V_C = 2 \text{ V} \quad ...(ii)$$

Now, from equations (i) and (ii),

$$V_D = 6 \text{ V} \quad ...(iii)$$

Thus, $V_D - V_B = 4 \text{ V} \Rightarrow V_B = 2$ V

17. What is ground wave communication ? On what factors does the maximum range of propagation in this mode depend ? [2]**

22. A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in (i) a medium of refractive index 1.6, (ii) a medium of refractive index 1.3. [3]

(a) Will it behave as a converging or a diverging lens in two cases ?

(b) How will its focal length change in the two media ?

Answer : (a) Here $^a\mu_g = 1.5$

Let f_{air} be the focal length of lens in air, then

$$\frac{1}{f_{air}} = (^a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

or $$\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f_{air}(1.5-1)}$$

$$\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{2}{f_{air}} \quad ...(i)$$

(i) When lens is dipped in medium A.

Here $^a\mu_A = 1.6$

Let f_A be focal length of lens, when dipped in medium A, then $\frac{1}{f_A} = (^A\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

or $$\frac{1}{f_A} = \left(\frac{^a\mu_g}{^a\mu_A} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using equation (i), we have

$$\frac{1}{f_A} = \left(\frac{1.5}{1.6} - 1\right)\frac{2}{f_{air}} = \frac{-0.1}{1.6}\,\frac{2}{f_{air}}$$

or $$f_A = -8 f_{air} \quad ...(ii)$$

As sign of f_A is opposite to that of f_{air}, the lens will behave as a diverging lens.

**Answer is not given due to the change in present syllabus.

(ii) When lens is dipped in medium B:

Here, $^{a}\mu_B = 1.3$

Let f_B be the focal lens, when dipped in medium B, then

$$\frac{1}{f_B} = \left({}^{B}\mu_g - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= \left(\frac{^{a}\mu_g}{^{a}\mu_B} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using equation (i) we have,

$$\frac{1}{f_B} = \left(\frac{1.5}{1.3} - 1\right) \times \frac{2}{f_{air}}$$

or $\quad f_B = 3.25 f_{air} \quad$ (iii)

As sign of f_B is same as that of f_{air}, the lens will behave as converging lens.

(b) (i) As seen from equation (ii),

$$f_A = -f_{air},$$

∴ Focal length increases in magnitude and becomes negative.

(ii) As seen from equation (iii),

$$f_B = 3.25 f_{air}$$

∴ Focal length increases in magnitude and remains positive.

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Physics 2011 (Outside Delhi) SET III

Time allowed : 3 hours Maximum marks : 70

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

1. **A hollow metal sphere of radius 6 cm is charged such that the potential on its surface is 12 V. What is the potential at the centre of sphere ? [1]**

Answer : Potential inside the charged sphere is constant and equal to potential on the surface of conductor. So therefore, potential at the centre of sphere is 12 V.

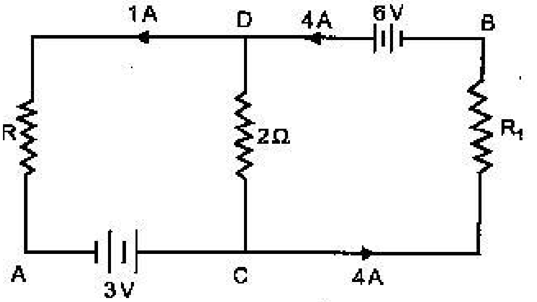
3. **How are microwaves produced ? [1]**

Answer : Microwaves are electromagnetic waves with wavelength ranging from as long as metre to as short as one millimetre, or equivalently with frequencies between 300 MHz and 300 GHz. Microwaves are produced by vacuum tubes devices that operate on the ballistic motion of electron controlled by magnetic or electric fields. Some different kinds of microwaves emitters are the cavity magnetron, the klystron, the traveling wave tube (TWT), the gyrotron and all stars.

12. **Mention various energy losses in transformer. [2]**

Answer : Magnetic core losses are exaggerated with higher frequencies, eddy currents in the iron core, resistance of windings or copper loss, hysteresis loss and flux leakage are energy losses in transformers. Transformers energy losses tend to worsen with increasing frequency.

14. **In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B. [2]**



Answer : $V_D - V_C = 2 \times 3 = 6$ V ...(i)

then, $\quad V_C - V_A = 3$ V

∵ $\quad V_A = 0$

⇒ $\quad V_C = 3$ V ...(ii)

From equations (i) and (ii),

$$V_D - 3 = 6 \text{ V}$$

⇒ $\quad V_D = 9$ V ...(iii)

Now, $\quad V_D - V_B = 6$ V

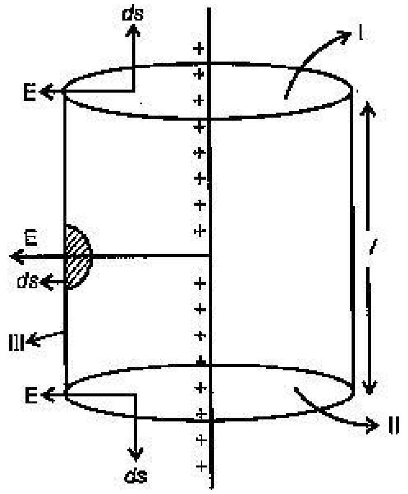
⇒ $\quad 9 - V_B = 6$ V

⇒ $\quad V_B = 3$ V

18. **A thin straight infinitely long conducting wire having charge density λ is enclosed by a cylindrical surface of radius r and length l, its**

axis coinciding with the length of the wire. Find the expression for the electric flux through the surface of the cylinder. [2]

Answer :



There will be no electric flux through the circular ends of the cylinder.

So, according to Gauss's law,

Flux, $\phi = \frac{q}{\varepsilon_0}$

Since, charge enclosed by gaussian surface

i.e. $q = \lambda \times l,$

$\therefore \quad \phi = \frac{\lambda l}{\varepsilon_0}$

20. A converging lens has a focal length of 20 cm in air. It is made of a material of refractive index 1.6. It is immersed in a liquid of refractive index 1.3. Calculate its new focal length. [3]

Answer : If f_a be the focal length of glass lens in air, then.

$$\frac{1}{f_a} = ({}^a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{... (i)}$$

If f_l be the focal length of glass lens in liquid. Then

$$\frac{1}{f_l} = ({}^l\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{...(ii)}$$

Dividing equation (i) by (ii),

$$\frac{f_l}{f_a} = \frac{{}_a\mu_g - 1}{{}_l\mu_g - 1}$$

$$\frac{f_l}{20} = \frac{1.6 - 1}{\frac{1.6}{1.3} - 1}$$

or $\quad f_l = 52$ cm.

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Physics 2011 (Delhi) SET I

Time allowed : 3 hours **Maximum marks : 70**

1. A point charge is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero, if Q is (i) positive (ii) negative ? [1]

Answer : If Q is positively charged, $V_A - V_B$ = positive.

If Q is negatively charged, $V_A - V_B$ = negative.

2. A plane electromagnetic wave travels in vacuum along Z-direction. What can you say about the direction of electric and magnetic field vector ? [1]

Answer : In electromagnetic wave, the electric field vector $\vec{E}$ and magnetic field vector $\vec{B}$ show their variations perpendicular to the direction of propagation of wave as well as perpendicular to each other. As the electromagnetic wave is travelling along Z-direction, hence $\vec{E}$ and $\vec{B}$ show their variation in XY-plane.

3. A resistance R is connected across a cell of emf ε and internal resistance r. A potentiometer now measures the potential difference between the terminals of the cell as V. Write the expression for 'r' in terms of ε, V and R. [1]

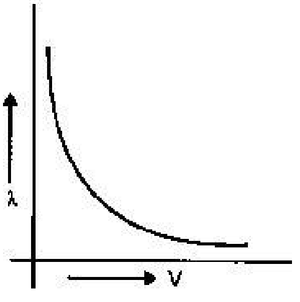
Answer : $r = \left(\frac{\varepsilon}{V} - 1\right) \times R$

4. The permeability of magnetic material is 0.9983. Name the type of magnetic materials it represents. [1]

Answer : Diamagnetic material.

5. **Show graphically, the variation of the de-Broglie wavelength (λ) with the potential (V) through which an electron is accelerated from rest.** **[1]**

Answer :



6. **In a transistor, doping level in base is increased slightly. How will it affect (i) collector current and (ii) base current ?**** **[1]**

7. **Define the term 'wattless current'.** **[1]**

Answer : Current flowing in a circuit without any net dissipation of power is called wattless current.

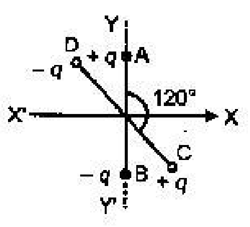
8. **When monochromatic light travels from one medium to another its wavelength changes but frequency remains the same. Explain.** **[1]**

Answer : Atoms (of the second medium) oscillate with the same (incident light) frequency and in turn, emit light of the same frequency.

9. **Two Uniformly large parallel thin plates having charge densities $+\sigma$ and $-\sigma$ are kept in the X-Z plane at a distance 'd' apart. Sketch an equipotential surface due to electric field between the plates. If a particle of mass m and charge '$-q$' remains stationary between the plates, what is the magnitude and direction of this field ?** **[2]**

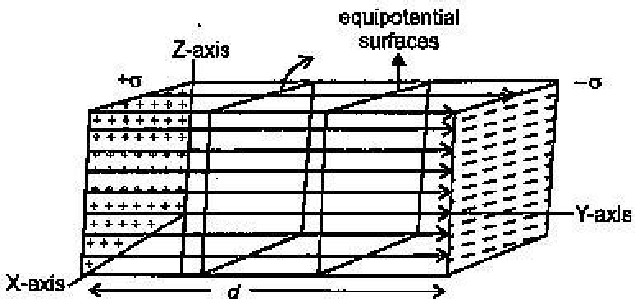
OR

Two small identical electrical dipoles AB and CD, each of dipole moment 'p' are kept at an angle of 120° as shown in the figure. What is the resultant dipole moment of this combination ? If this system is subjected to electric field $\vec{E}$ directed along +X direction, what will be the magnitude and direction of the torque acting on this ?

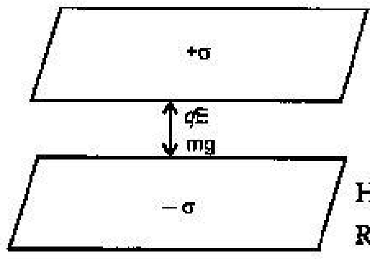


**Answer is not given due to the change in present syllabus.

Answer :



Downward force due to gravity is balanced by upward force due to electric field



$i.e., \; mg = qE$

$\therefore \quad E = \dfrac{mg}{q}$

OR

Here $p_{AB} = p_{CD} = p$

Resultant dipole moment

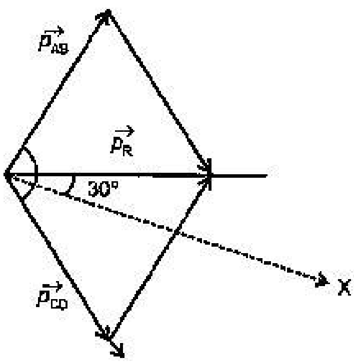
$$p_R = \sqrt{p^2 + p^2 + 2p^2 \cos 120°}$$

$$= \sqrt{2p^2 + 2p^2\left(-\frac{1}{2}\right)}$$

$$= \sqrt{2p^2 - p^2} = \sqrt{p^2}$$

$$= p$$

When this dipole is placed in an electric field along + X-axis, it will experience a torque.



$$\tau = pE \sin 30° = pE \times \frac{1}{2} = \frac{1}{2}pE$$

$$= \frac{pE}{2}$$

According to right hand thumb rule, torque will be into the plane of the paper $i.e.,$ along Z-axis.

10. **A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its north tip down at 60° with the horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.4 G. Determine the magnitude of the earth's magnetic field at the place. [2]**

Answer : Given, angle of dip, $\delta = 60°$

$$H = 0.4\text{ G}$$

$$R = ?$$

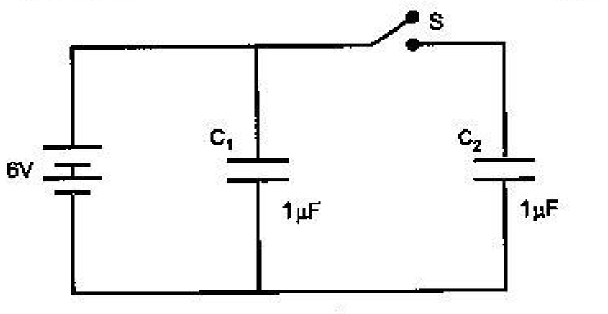
We know, $H = R\cos\delta$

or $R = \dfrac{H}{\cos\delta} = \dfrac{0.4}{\cos 60°}$

$= \dfrac{0.4}{1/2} = 0.4 \times 2$

$\therefore$ $R = 0.8\text{ G}$

11. **Figure shows two identical capacitors, C_1 and C_2, each of 1μF capacitance connected to a battery of 6 V. Initially switch 'S' is closed. After sometime 'S' is left open and dielectric slabs of dielectric constant K = 3 are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted ? [2]**



Answer : When S is closed :

P.d. across C_1 = P.d. across C_2 = 6 V

$V_1 = V_2 = 6\text{ V}$ $[\because q = CV]$

$\therefore q_1 = q_2 = 1\ \mu F \times 6\text{ V} = 6\ \mu C$

When S is open :

When dielectric slab (K = 3) are inserted,

$C_1 = 3 \times 1\ \mu F = 3\ \mu F$

$C_2 = 3 \times 1\ \mu F = 3\ \mu F$

P.d. across C_1,

$V_1' = 6\text{ V}$

$\therefore$ $q_1' = 3\ \mu F \times 6\text{ V} = 18\ \mu C$

P.d. across C_2,

$V_2' = \dfrac{q_2}{C_2} = \dfrac{6\ \mu C}{3\ \mu F} = 2\text{ V}$

$\therefore$ $V_2' = 2\text{ V}$

**Answer is not given due to the change in present syllabus.

12. **Two convex lenses of same focal length but of aperture A_1 and A_2 ($A_2 < A_1$), are used as the objective lenses in two astronomical telescopes having identical eyepieces. What is the ratio of their resolving power ? Which telescope will you prefer and why ? Give reason. [2]**

Answer : Resolving power of a telescope is proportional to its aperture, and is given by a relation,

$$\text{R.P.} = \frac{A}{1.22\,\lambda}$$

Where, A is aperture and λ is wavelength for a given light.

or $\dfrac{(\text{R.P.})_1}{(\text{R.P.})_2} = \dfrac{A_1}{A_2}$

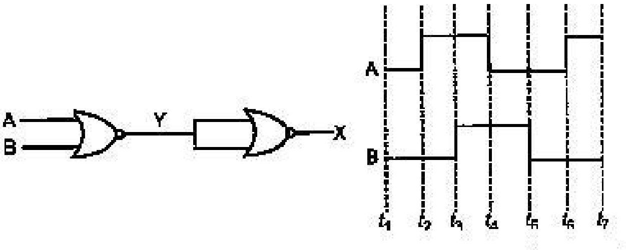
Since, $A_1 > A_2$ (Given),

Therefore, the telescope with objective of aperture A_1 should be preferred for viewing as this would :

(i) give a better resolution.

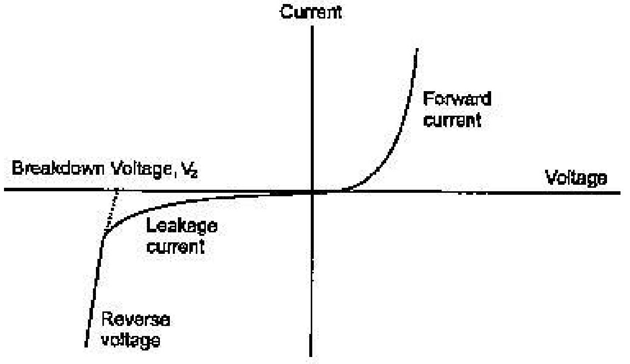
(ii) have a higher light gathering power of telescope.

13. **Draw the output waveform at X, using the given inputs A and B for the logic circuit shown below. Also, identify the logic operation performed by this circuit.** [2]**



14. **Name the semiconductor device that can be used to regulate an unregulated dc power supply. With the help of I-V characteristics of this device, explain its working principle. [2]**

Answer : Zener diode is a specially designed diode which is operated in reverse breakdown region continuously without any damage. When zener diode is operated in the reverse break down region, the voltage across it remains practically constant (V_z) for a large change in reverse current. Therefore, for any increase/ decrease of the input voltage, there is a increase/ decrease of the voltage drop across series resistance (R_s) without any change in the voltage across zener diode.



I-V characteristic curve of zener diode

15. **How are infrared waves produced ? Why are these referred to as 'heat wave' ? Write their one important use. [2]**

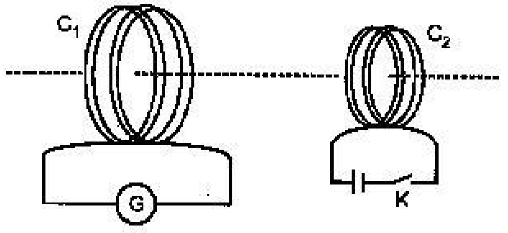
Answer : Infrared rays are produced by hot bodies or due to vibration of atoms and molecules of the bodies. Infrared waves are called heat waves as they cause heating effect. Infrared waves are used to maintain earth's warmth, in physical therapy, remote switches etc.

16. **Draw the transfer characteristic curve of a base biased transistor in CE configuration. Explain clearly how the active region of the V_o versus V_i curve in a transistor is used as an amplifier.**[2]**

17. **(a) Define modulation index.**

(b) Why is the amplitude of modulating signal kept less than the amplitude of carrier wave ? [2]**

18. **A current is induced in coil C_1 due to the motion of current carrying coil C_2. (a) Write any two ways by which a large deflection can be obtained in the galvanometer G. (b) Suggest an alternative device to demonstrate the induced current in place of a galvanometer. [2]**



Answer : (a) Any two ways to obtain large deflection in G :

(i) Moving C_2 faster towards C_1.

(ii) Insertion of soft iron core in C_1.

(b) Alternative device that can be used in place of galvanometer is LED.

19. **Define the terms (i) drift velocity, (ii) relaxation time.**

A conductor of length L is connected to a dc source of emf ε. If this conductor is replaced by another conductor of same material and same area of cross-section but of length 3 L, how will the drift velocity change ? [3]

Answer : (i) Drift velocity : The average velocity with which the free electrons drift towards positive terminal under the influence of an external electric field is called drift velocity.

(ii) Relaxation time : Average time interval between two successive collisions of an electron with the positive ions / atoms of the conductor.

Drift velocity is given by,

$$v_d = \frac{e\tau}{m}\frac{E}{L}$$

or $$v_d \propto \frac{1}{L}$$

The drift velocity is inversely proportional to L.

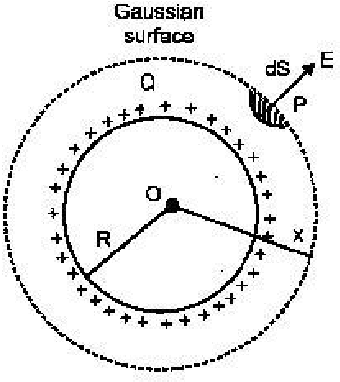
If length L of conductor is made 3 times, drift velocity will become one-third of its initial value.

$$v'_d = \frac{v_d}{3}$$

20. **Using Gauss's law obtain the expression for the electric field due to a uniformly charged thin spherical shell of radius R at a point outside the shell. Draw a graph showing the variation of electric field with r, for $r > R$ and $r < R$. [3]**

Answer : Electric field at point P at a distance 'r' outside the spherical shell.

According to Gauss' law,



$$\phi = \oint \vec{E}\cdot\vec{dS}$$

$$= \oint E \cdot dS$$

$$= E\oint dS$$

$$\phi = E \times 4\pi r^2 \quad ...(i)$$

**Answer is not given due to the change in present syllabus.

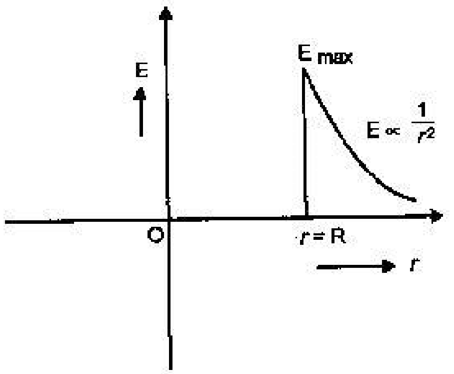
According to gauss' law, the electric flux through a surface is $\frac{1}{\varepsilon_0}$ times the net charge enclosed by it.

$$\therefore \qquad \phi = \frac{Q}{\varepsilon_0} \qquad ...(ii)$$

From equations (i) and (ii),

$$E \times 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$



Variation of E with r (distance)

For $r < R$, there is no strength of electric field inside a charged spherical shell.

For $r > R$, electric field outside a spherical shell is same as if the whole charge Q is concentrated at the centre.

21. An electron and a photon each have a wavelength 1.00 nm. Find

(a) their momenta,

(b) the energy of the photon, and

(c) the kinetic energy of electron. **[3]**

Answer : $\lambda_e = \lambda_p = 1.00 \text{ nm} = 10^{-9}$m

(a) For electron or photon, momentum

$$p = p_e = p_p = \frac{h}{\lambda}$$

$$\Rightarrow \quad p = \frac{6.63 \times 10^{-34}}{10^{-9}}$$

$$= 6.63 \times 10^{-25} \text{ kg m/s}$$

(b) Energy of photon,

$$E = \frac{hc}{\lambda}$$

$$= (6.63 \times 10^{-34}) \times \frac{3 \times 10^8}{10^{-9}} \approx 19.89 \times 10^{-17} \text{ J}$$

(c) Kinetic energy of electron,

$$= \frac{p^2}{2m}$$

$$= \frac{1}{2} \times \frac{(6.63 \times 10^{-25})^2}{9.1 \times 10^{-31}} \text{ J} \approx 2.42 \times 10^{-19} \text{ J}$$

22. Draw a schematic diagram showing the (i) ground wave (ii) sky wave and (iii) space wave propagation modes for em waves.

Write the frequency range for each of the following : **[3]**

(i) Standard AM broadcast

(ii) Television

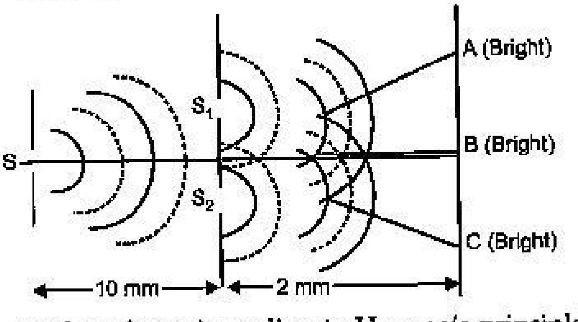
(iii) Satellite communication.**

23. Describe Young's double slit experiment to produce interference pattern due to a monochromatic source of light. Deduce the expression for the fringe width. **[3]**

OR

Use Huygen's principle to verify the laws of refraction.

Answer : S is a narrow slit (of width about 1 mm) illuminated by a monochromatic source of light. At a suitable distance (= 10 mm) from S, two slits S_1 and S_2 are placed parallel to S. When a screen is placed at a large distance (about 2 m) from the slit S_1 and S_2, alternate dark and bright bands appear on the screen. These are the interference bands or fringes. The band disappear when either slit is covered.



Explanation : According to Huygen's principle, the monochromatic source of light illuminating the slit S sends out spherical wavefront.

The two waves of same amplitude and same frequency superimpose on each other. Dark fringes appear on the screen when the crest of one wall falls on the trough of other and they neutralize the effect of each other. Bright fringes appear on the screen when the crest of one

****Answer is not given due to the change in present syllabus.**

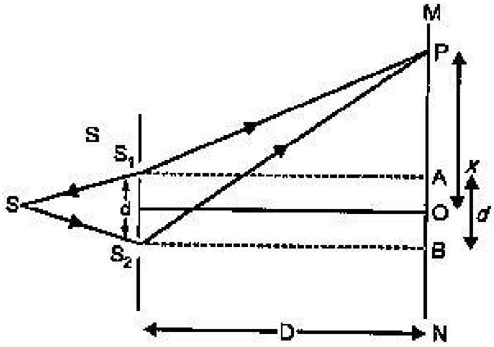
wave coincides with the crest of other and they reinforce each other.

Expression for the fringe width :

Let d = distance between slits S_1 and S_2,

D = distance of screen from two slits, and

x = distance between the central maxima 'O' and observation point P.



Light waves spread out from S and fall on both S_1 and S_2. The spherical waves emanating from S_1 and S_2 will produce interference fringes on the screen MN.

$$S_1P = \sqrt{(S_1A)^2 + (AP)^2}$$

$$\Rightarrow \quad \sqrt{D^2 + \left(x - \frac{d}{2}\right)^2} = \sqrt{D^2\left[1 + \frac{\left(x - \frac{d}{2}\right)^2}{D^2}\right]}$$

$$\Rightarrow \quad S_1P = D\left[1 + \frac{\left(x - \frac{d}{2}\right)^2}{D^2}\right]^{\frac{1}{2}}$$

By binomial theorem and neglecting higher terms, we have

$$S_1P = D\left[1 + \frac{\left(x - \frac{d}{2}\right)^2}{2D^2}\right] = D + \frac{\left(x - \frac{d}{2}\right)^2}{2D}$$

Similarly $S_2P = D + \frac{\left(x + \frac{d}{2}\right)^2}{2D}$

Hence, path difference = $S_2P - S_1P$

$$= D + \frac{\left(x + \frac{d}{2}\right)^2}{2D} - D - \frac{\left(x - \frac{d}{2}\right)^2}{2D}$$

$$= \frac{1}{2D}\left[x^2 + \frac{d^2}{4} + xd - x^2 - \frac{d^2}{4} + xd\right]$$

$$= \frac{1}{2D}.2xd = \frac{xd}{D}$$

For bright fringe,
Path difference = $n\lambda$, where $n = 0, 1, 2, \ldots\ldots\ldots$

$$\Rightarrow \quad \frac{xd}{D} = n\lambda$$

$$\therefore \quad x_n = \frac{n\lambda D}{d}$$

For dark fringe,
Path difference = $(2n-1)\frac{\lambda}{2}$, where $n = 1, 2, 3, \ldots\ldots$

$$\Rightarrow \quad \frac{xd}{D} = (2n-1)\frac{\lambda}{2}$$

$$\therefore \quad x_n = \left(n - \frac{1}{2}\right)\frac{\lambda D}{d}$$

So, fringe width

$$x_{n+1} - x_n = \frac{(n+1)\lambda D}{d} - \frac{n\lambda D}{d}$$

[Considering bright fringes]

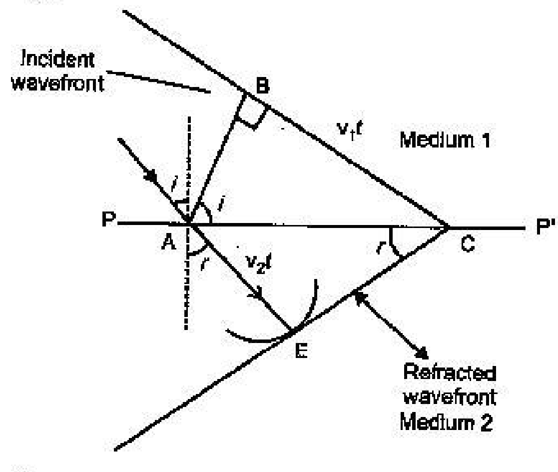
$$= \frac{\lambda D}{d}$$

Fringe width is same for both dark and bright fringe.

OR

Wavefront : The continuous locus of all the particles of a medium, which are vibrating in the same phase is called wavefront.

Laws of refraction : Let PP' represent the surface separating medium 1 and medium 2 as shown in fig.



From ΔABC, $\quad \sin i = \frac{BC}{AC} = \frac{v_1t}{AC}$

From ΔAEC, $\quad \sin r = \frac{AE}{AC} = \frac{v_2t}{AC}$

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{v_1 t}{AC} \times \frac{AC}{v_2 t} = \frac{v_1}{v_2} = \mu$$

$$\therefore \quad \frac{\sin i}{\sin r} = \mu$$

which is Snell's law of refraction of light (first law).

Second law : Incident wavefront, refracted wavefront, normals all lie in the same plane.

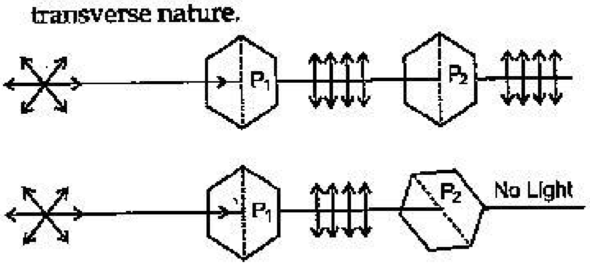
24. (a) Describe briefly, with the help of suitable diagram, how the transverse nature of light can be demonstrated by the phenomenon of polarization.

(b) When unpolarized light passes from air to a transparent medium, under what condition does the reflected light get polarized ? [3]

Answer :

(a) When a polaroid P_1 is rotated in the path of an unpolarized light, there is no change in transmitted intensity.

The light transmitted through polaroid P_1 is made to pass through polaroid P_2. On rotating polaroid P_2 in path of light transmitted from P_1 we notice a change in intensity of transmitted light. This shows the light transmitted from P_1 is polarized. Since light can be polarized, it has transverse nature.



(b) Whenever unpolarized light is incident from air to a transparent medium at an angle of incidence equal to polarizing angle, the reflected light gets fully polarized.

According to Brewster's law,

$$n = \tan i_p \qquad ...(i)$$

where i_p in the polarizing angle and n is refractive index of the transparent material.

By Snell's law, we have

$$n = \frac{\sin i_p}{\sin r}$$

or $$\tan i_p = \frac{\sin i_p}{\sin r} \qquad \text{[From (i)]}$$

$$\therefore \quad \cos i_p = \sin r$$

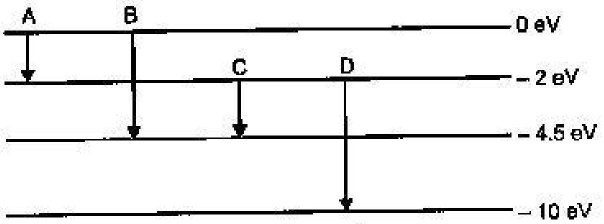
$$\cos i_p = \cos (90^\circ - r)$$

$$\therefore \quad i_p + r = 90^\circ$$

Thus, when the sum of polarizing angle and reflected angle is 90°, the reflected light is fully polarized.

25. The energy levels of a hypothetical atom are shown below. Which of the shown transitions will result in the emission of a photon of wavelength 275 nm ?

Which of these transitions correspond to emission of radiation of (i) maximum and (ii) minimum wavelength ? [3]



Answer : If a photon of wavelength λ = 275 nm is to be emitted, then energy of photon is given by

$$E = \frac{hc}{\lambda}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{275 \times 10^{-9} \times 1.6 \times 10^{-19}} \text{ eV} = 4.5 \text{ eV}$$

Hence transition B would result in the emission of a photon of wavelength 275 nm.

(i) Transition A corresponds to maximum wavelength.

(ii) Transition D corresponds to minimum wavelength.

26. State the law of radioactive decay.

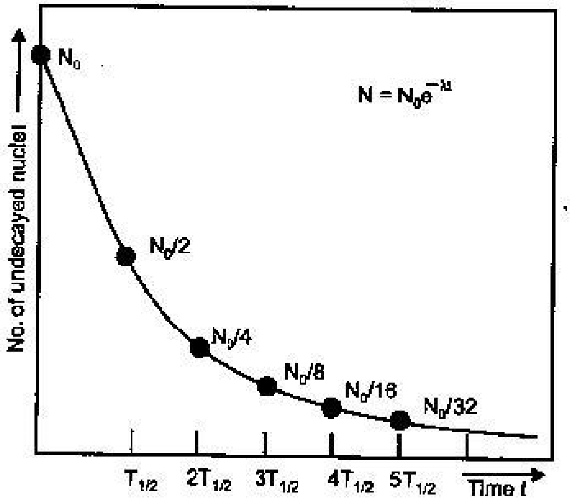
Plot a graph showing the number (N) of undecayed nuclei as a function of time (t) for a given radioactive sample having half life $T_{½}$.

Depict in the plot the number of undecayed nuclei at (i) $t = 3\,T_{½}$ and (ii) $t = 5\,T_{½}$. [3]

Answer : The number of nuclei undergoing decay per unit time, at any instant t, is proportional to the total number of nuclei in the sample at that instant.

$$-\frac{dN}{dt} \propto N$$

$$\Rightarrow \quad \frac{dN}{dt} = -\lambda N$$

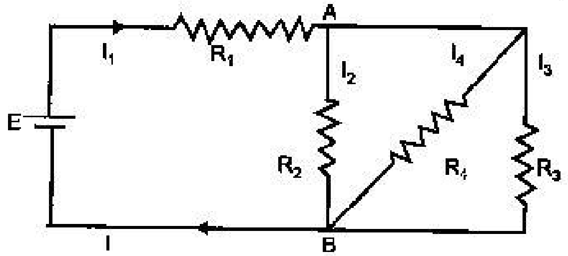


From graph, number of undecayed nuclei at

(i) $3\,T_{1/2}$ is $N_0/8$.

(ii) $5\,T_{1/2}$ is $N_0/32$.

27. In the circuit shown, $R_1 = 4\,\Omega$, $R_2 = R_3 = 15\,\Omega$, $R_4 = 30\,\Omega$ and $E = 10$ V. Calculate the equivalent resistance of the circuit and the current in each resistor. [3]



Answer : R_2, R_3, R_4 are in parallel combination.

$$\therefore \quad \frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{15} + \frac{1}{15} + \frac{1}{30}$$

$$= \frac{2+2+1}{30} = \frac{5}{30}$$

$$\Rightarrow \quad R_{234} = 6\,\Omega$$

Now R_{234} is in series with R_1, so,

$$R_{eq} = 4\,\Omega + 6\,\Omega = 10\,\Omega$$

$$\therefore \quad I = \frac{E}{R_{eq}} = \frac{10}{10}\,A = 1\,A$$

$\therefore$ Current through $R_1 = 1$ A

P.D. across R_1, $V = IR_1 = 1 \times 4 = 4$ V

So, P.D. across $R_{234} = 6$ V

$$\because \quad I_2R_2 = I_3R_3 = I_4R_4 = 6\,V$$

[Voltage in parallel combination is equal]

$$I_2 = \frac{6}{15}\,A = 0.4\,A$$

$$I_3 = \frac{6}{15}\,A = 0.4\,A$$

$$I_4 = \frac{6}{30}\,A = 0.2\,A$$

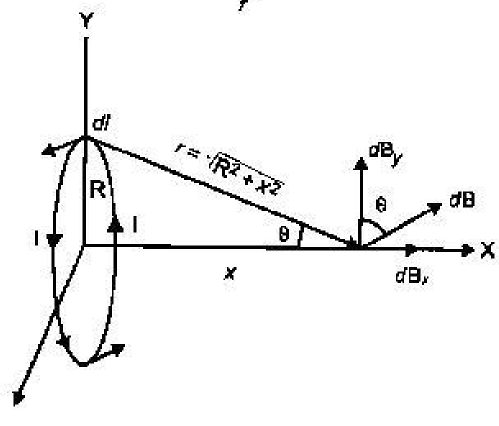
28. State Biot-Savart's law, giving the mathematical expression for it.
Use this law to derive the expression for the magnetic field due to a circular coil carrying current at a point along its axis.
How does a circular loop carrying current behave as a magnet ? [5]

OR

With the help of a labelled diagram, state the underlying principle of a cyclotron. Explain clearly how it works to accelerate the charged particles.
Show that cyclotron frequency is independent of energy of the particle. Is there an upper limit on the energy acquired by the particle ? Give reason.

Answer : Biot-Savart's law states that the magnitude of magnetic field $d\vec{B}$ due to current element is directly proportional to the current I, the element length $|dl|$ and inversely proportional to the square of the distance r of the field point. Its direction is perpendicular to the plane containing $\vec{dl}$ and $\vec{r}$.

$$d\vec{B} \propto \frac{I\,\vec{dl} \times \vec{r}}{r^3}$$



According to Biot-Savart's law

$$dB = \frac{\mu_0}{4\pi}\frac{I\vec{dl}\times\vec{r}}{r^3}$$

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

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}\sin 90^\circ \qquad \left[\because \vec{dl}\perp\hat{r}\right]$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}$$

dB has two components dB_x and dB_y. dB_y cancel out and only dB_x component remains.

$$\therefore \quad dB_x = dB\sin\theta$$

$$= \frac{\mu_0 Idl}{4\pi r^2}\times\frac{R}{(x^2+R^2)^{1/2}}$$

or
$$dB_x = \frac{\mu_0 Idl}{4\pi}\times\frac{R}{(x^2+R^2)^{3/2}}$$

$$[\because r^2 = x^2 + R^2]$$

Total magnetic field at P,

$$B = \int dB_x$$

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

$$\int dl = 2\pi R$$

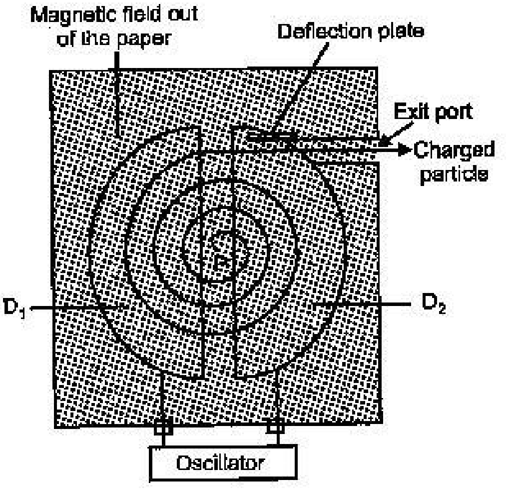
$$\therefore \quad B = \frac{\mu_0 IR^2}{2(x^2+R^2)^{3/2}}$$

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

Explanation : A magnetic needle placed at the centre or axis of a circular coil shows deflection. This implies that a circular coil behaves as a magnet.

OR

Principle : Cyclotron works on the principle that a charged particle moving normal to a magnetic field experiences Lorentz magnetic force due to which the particle moves in a circular path.



Working : High frequency oscillator maintains moderate alternating potential difference between the dees. This potential difference establishes an electric field that reverse its direction periodically. Suppose a positive ion of moderate mass produced at the centre of the dees finds D_2 at negative potential. It gets accelerated towards it. A uniform magnetic field, normal to the plane of the dees, makes it move in a circular track. Particle traces a semicircular track and returns back to the region between the dees. The moment it arrives in the region electric field reverses its direction and accelerate the charge towards D_1. This way charge keeps on getting accelerated until it is removed out of the dees.

Centripetal force, needed by the charged particle to move in circular track, is provided by the magnetic field.

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

$$\Rightarrow \quad v = \frac{qBr}{m}$$

Period of revolution, $T = \frac{2\pi r}{v}$

$$= \frac{2\pi rm}{qBr}$$

$$\Rightarrow \quad T = \frac{2\pi m}{qB}$$

$$\Rightarrow \quad \nu = \frac{1}{T} = \frac{qB}{2\pi m}$$

Thus, frequency of revolution is independent of the energy of the particle.

Yes, there is an upper limit on the energy acquired by the charged particle. The charged particle gains maximum speed when it moves in a path of radius equal to the radius of the dees.

i.e., $$v_{max} = \frac{qBR}{m}$$

where, R = radius of the dees.

So, maximum kinetic energy

$$K.E. = \frac{1}{2}mv^2_{max} = \frac{1}{2}m\left(\frac{qBR}{m}\right)^2 = \frac{q^2B^2R^2}{2m}$$

29. (a) Draw a ray diagram to show refraction of a ray of monochromatic light passing through a glass prism.

Deduce the expression for the refractive index of glass in terms of angle of prism and angle of minimum deviation.

(b) Explain briefly how the phenomenon of total internal reflection is used in fibre optics. [5]

OR

(a) Obtain Lens Maker's formula using the expression

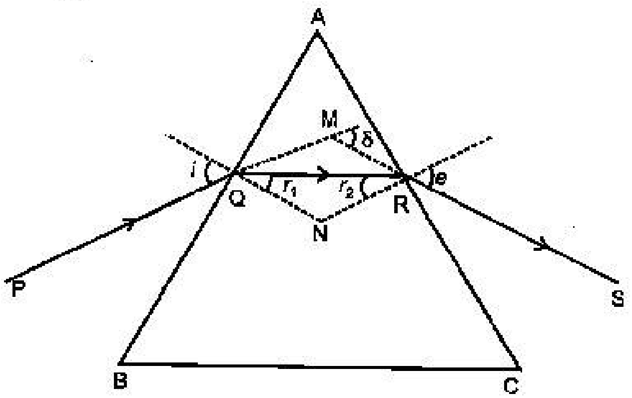
$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R}$$

Here the ray of light propagated from a rarer medium of refractive index (n_1) to a denser medium of refractive index (n_2) is incident on the convex side of spherical refracting surface of radius of curvature R.

(b) Draw a ray diagram to show the image formation by a concave mirror when the object is kept between its focus and the pole. Using this diagram, derive the magnification formula for the image formed.

Answer :

(a)



From ΔMQR, $(i - r_1) + (e - r_2) = \delta$

So, $$(i + e) - (r_1 + r_2) = \delta$$

From ΔRQN, $r_1 + r_2 + \angle QNR = 180°$

Also, $$A + \angle QNR = 180°$$

Thus, $$A = r_1 + r_2$$

So, $$i + e - A = \delta$$

At minimum deviation,

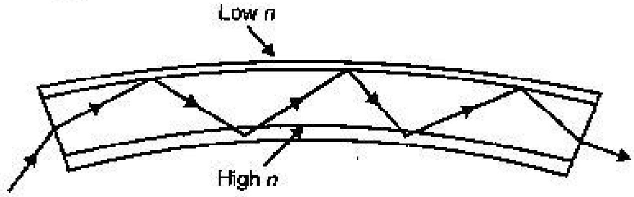
$$i = e, r_1 = r_2 = r \text{ and } \delta = \delta_m$$

$\Rightarrow$ $$i = \frac{A + \delta_m}{2} \text{ and } r = \frac{A}{2}$$

Also $$\mu = \frac{\sin i}{\sin r}$$

Hence $$\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

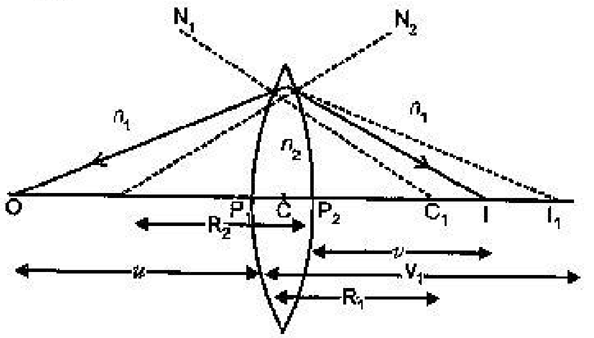
(b)



Each optical fibre consists of a core and cladding, refractive index of the material of the core is higher than that of cladding. When a signal, in the form of light, is directed into the optical fibre, at an angle greater than the critical angle, it undergoes repeated total internal reflections along the length of the fibre and comes out of it at the other end with almost negligible loss of intensity.

OR

(a)



For refraction at the first surface

$$\frac{n_2}{v_1} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \quad ...(i)$$

For the second surface, I_1 acts as a virtual object (located in the denser medium). So, for refraction at this surface, we have

$$\frac{n_1}{v} - \frac{n_2}{v_1} = \frac{n_1 - n_2}{R_2} \quad ...(ii)$$

Adding (i) and (ii),

$$\frac{n_1}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} + \frac{n_1 - n_2}{R_2}$$

$$\Rightarrow \quad \frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \quad \frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

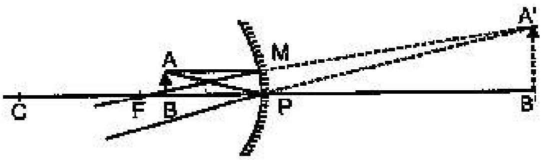
The point where image of an object, located at infinity, is formed is called the focus F of the lens and the distance f gives its focal length.

So for $u = \infty$,

$v = +f$

$$\Rightarrow \quad \frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

(b)



ΔABP is similar to ΔA'B'P

So, $\frac{A'B'}{AB} = \frac{B'P}{BP}$

Now, A'B' = I

AB = O

B'P = v

BP = $-u$

$\therefore$ Magnification,

$$m = \frac{I}{O} = -\frac{v}{u}$$

30. (a) With the help of a labelled diagram, describe briefly the underlying principle and working of a step up transformer.

(b) Write any two sources of energy loss in a transformer.

(c) A step up transformer converts a low input voltage into a high output voltage. Does it violate law of conservation of energy ? Explain. **[5]**

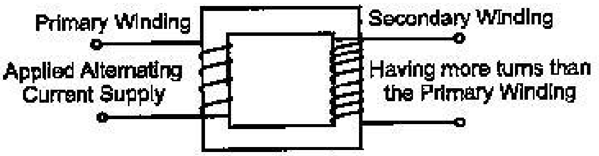
OR

Derive an expression for the impedance of a series LCR circuit connected to an AC supply of variable frequency.

Plot a graph showing variation of current with the frequency of the applied voltage.

Explain briefly how the phenomenon of resonance in the circuit can be used in the tuning mechanism of a radio or a TV set.

Answer : (a) Step-up transformer :



Principle : It works on the principle of mutual induction. When alternating current is passed through a coil, an induced emf is set up in the neighbouring coil.

Working : When an alternating voltage is applied to the primary, the resulting current produces an alternating magnetic flux which links the secondary and induces an emf in it. We consider an ideal transformer in which the primary has negligible resistance and all the flux in the core links with both primary and secondary windings. Let ϕ be the flux in each turn in the core at any time t due to current in the primary when a voltage V_p is applied to it.

Then the induced emf or voltage E_s in the secondary with N_s turns is

$$E_s = N_s \frac{d\phi}{dt}$$

The alternating flux also induces an emf, called back emf in the primary given by

$$E_p = -N_p \frac{d\phi}{dt}$$

But $E_p = V_p$ (since resistance of primary is small) and $E_s = V_s$ (since secondary current is small)

So, $\quad V_S = -N_p \frac{d\phi}{dt}$

And $\quad V_S = -N_p \frac{d\phi}{dt}$

Thus, $\quad \frac{V_s}{V_p} = \frac{N_s}{N_p}$

For a step up transformer,

$$\frac{V_s}{V_p} > 1$$

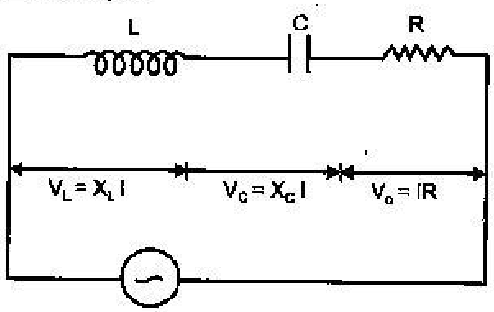
$\Rightarrow \quad V_s > V_p$

(b) Sources of energy loss in transformer are : Joule's loss in the resistance of windings, loss due to eddy currents.

(c) No. A step up transformer steps up the voltage while it steps down the current. So the input and output power remain same (provided there is no loss). Hence, there is no violation of the principle of energy conservation.

OR

Impedance (Z) in LCR circuit : The effective resistance offered by a series LCR circuit to the flow of current is called its impedance. It is denoted by Z.



Suppose an inductance L, capacitance C and resistance R are connected in series to a source of alternating emf given by,

$$V = V_0 \sin \omega t$$

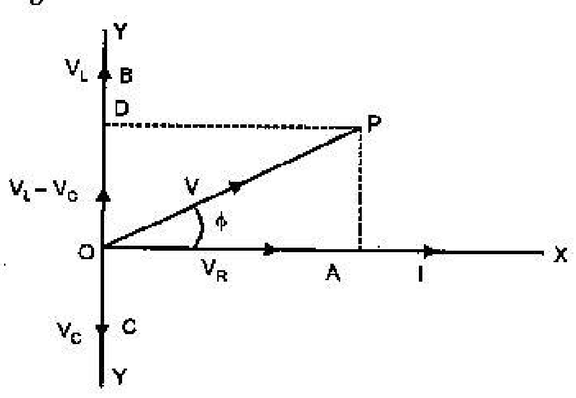
Let I be the instantaneous value of current in series circuit. Then voltages across the three components are :

(i) $V_L = X_L I$. It is ahead of current I in phase by 90°.

(ii) $V_C = X_C I$. It lags behind the current I in phase by 90°.

(iii) $V_R = RI$. It is in phase with current I.

These voltages are shown in the phasor diagram given below.



As V_L and V_C are in opposite direction, their resultant is $OD = V_L - V_C$, in the positive Y-direction.

By parallelogram law, the resultant voltage (V) is represented by $\overrightarrow{OP}$.

$$V = \sqrt{OA^2 + OD^2}$$

$$= \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$= \sqrt{R^2 I^2 + (X_L I - X_C I)^2}$$

$$= I\sqrt{R^2 + (X_L - X_C)^2}$$

$$\therefore \quad \frac{V}{I} = \sqrt{R^2 + (X_L - X_C)^2}$$

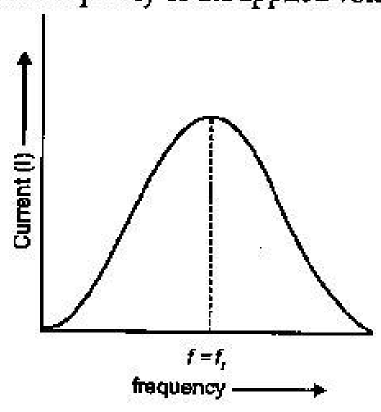
Here, V/I is the effective resistance of the series LCR circuit and is called impedance (Z).

$$\therefore \quad Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$\left[\because \begin{array}{l} X_L = \omega L \\ X_C = 1/\omega C \end{array}\right]$$

The given graph shows the variation of current with the frequency of the applied voltage.



The radio and TV receiver sets are the practical applications of series resonant circuits. Signals of several different frequencies are available in air. By turning the tuning knob of the radio set, we vary the frequency of the LC circuit till it matches the frequency of the desired signal.

Physics 2011 (Delhi) SET II

Time allowed : 3 hours | Maximum marks : 70

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

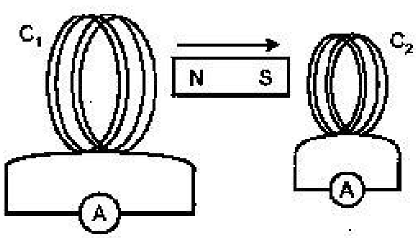
2. **The susceptibility of magnetic material is 1.9×10^{-5}. Name the type of magnetic materials it represents.** **[1]**

Answer : Paramagnetic substance because susceptibility of para-magnetic material is positive.

4. **A plane electromagnetic wave travels in vacuum along X-direction. What can you say about the direction of electric and magnetic field vectors ?** **[1]**

Answer : The electric and magnetic field vectors are in YZ-plane.

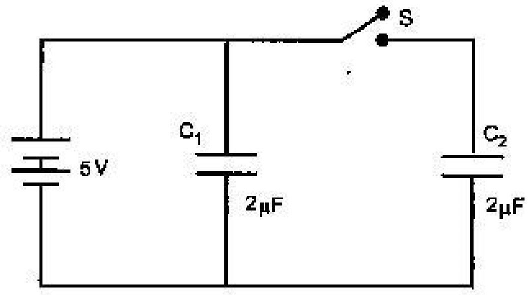
10. **A magnet is quickly moved in the direction indicated by an arrow between coils C_1 and C_2 as shown in figure. What will be the direction of induced current in each coil as seen from the magnet ? Justify your answer.** **[2]**



Answer : For coil C_1 : As the N-pole of the magnet is moving away from the coil C_1, the end of the coil will behave as S-pole so as to oppose the motion of the magnet. Therefore, looking from the end, the current in the coil C_1 will be in clockwise direction.

For coil C_2 : The end of the coil should behave as S-pole so as to repel the approaching magnet. Looking from the end, the direction of current in the coil of C_2 will be in clockwise direction.

11. **Figure shows two identical capacitors C_1 and C_2 each of 2 μF capacitance, connected to a battery of 5 V. Initially switch 'S' is closed. After sometime 'S' is left open and dielectric slabs of dielectric constant $k = 5$ are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted ?** **[2]**



Answer : When switch S is closed :

$$\text{p.d. across } C_1 = \text{p.d. across } C_2$$

i.e. $$V_1 = V_2 = 5 \text{ V}$$

Charge on each capacitor is same

i.e., $$Q = CV$$
$$= 2 \text{ μF} \times 5 \text{ V} = 10 \text{ μC}$$

When dielectric slab is inserted between plates of capacitors,

$$C_1 = C_2 = C' = KC = 5 \times 2 \text{ μF} = 10 \text{ μF}$$

When switch S is open :

For C_1, battery is still connected

$$\therefore \quad Q_1 = C'V_1 = 10 \text{ μF} \times 5 \text{ V} = 50 \text{ μC}$$

For C_2, charge remains the same

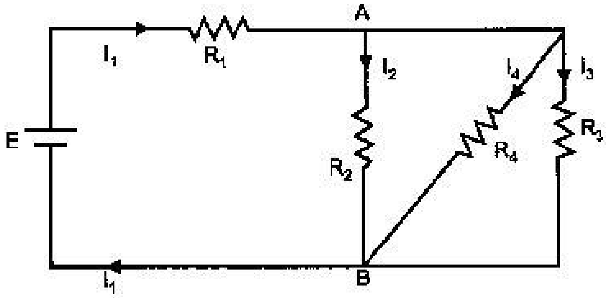
$$Q_2 = C'V_2$$
$$10 \text{ μC} = 10 \text{ μF} \times V_2$$
$$\therefore \quad V_2 = 1 \text{ volt}$$

16. **How is forward biasing different from reverse biasing in a *p-n* junction diode ?** **[2]**

Answer: Forward Biasing : The positive terminal of the external battery is connected to *p*-side and negative terminal of battery to *n*-side of *p-n* junction. The forward bias voltage oppose the potential barrier. Due to this, the potential barrier is reduced and hence the depletion becomes thin. The resistance of *p-n* region junction decreases.

Reverse biasing : The negative terminal of the external battery is connected to *p*-side and positive terminal of battery to *n*-side of *p-n* junction. The reverse bias voltage supports the potential barrier. Due to this, the potential barrier is increased. The resistance of *p-n* junction becomes high.

20. In the circuit shown, $R_1 = 4\Omega$, $R_2 = R_3 = 5\Omega$, $R_4 = 10\Omega$, and E = 6 V. Work out the equivalent resistance of the circuit and the current in each resistor. **[3]**



Answer : R_2, R_3, R_4 are in parallel.

$$\frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{5} + \frac{1}{5} + \frac{1}{10} = \frac{2+2+1}{10}$$

$$= \frac{5}{10} = \frac{1}{2}$$

$\therefore$ $R_{234} = 2\ \Omega$

R_{234} and R_1 are in series.

$\therefore$ $R_{1234} = 2 + 4 = 6\ \Omega$

$\therefore$ $I = \frac{V}{R} = \frac{6}{6}$

$I = 1$ A

23. An electron and a photon each have a wavelength of 1.50 nm. Find :
(i) their momenta
(ii) the energy of the photon
(iii) the kinetic energy of the electron **[3]**

Answer :

(i) For each electron or photon, momenta,

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{1.5 \times 10^{-9}}$$

$$= 4.42 \times 10^{-25} \text{ kg m/sec}$$

(ii) $$E = \frac{hc}{\lambda}$$

$$= \frac{(6.63 \times 10^{-34})(3 \times 10^{8})\text{eV}}{(1.5 \times 10^{-9})(1.6 \times 10^{-19})}$$

$$= 828.75 \text{ eV}$$

(iii) $$E_k = \frac{1}{2}\frac{p^2}{m}$$

$$= \frac{1(4.42 \times 10^{-25})^2}{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19}} \text{eV}$$

$$= 0.671 \text{ eV}$$

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Physics 2011 (Delhi) — SET III

Time allowed : 3 hours **Maximum marks : 70**

Note : Except for the following questions, all the remaining questions have been asked in previous Set.

2. A plane electromagnetic wave travels in vacuum along Y-direction. What can you say about the direction of electric and magnetic field vectors ? **[1]**

Answer : For an electromagnetic wave propagating along Y-direction, the electric and magnetic field vectors vary sinusoidally along X-direction and Z-direction respectively.

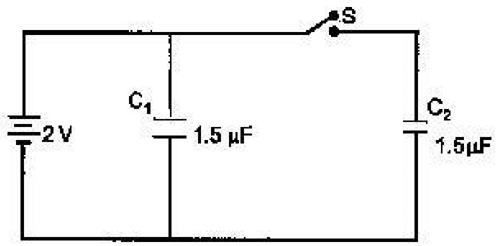
7. The susceptibility of a magnetic material is -4.2×10^{-6}. Name the type of magnetic materials it represents. **[1]**

Answer : Diamagnetic substance.

9. Explain how a depletion region is formed in a junction diode. **[2]**

Answer : With the formation of *p-n* junction, the holes from *p*-region diffuse into the *n*-region and electrons from *n*-region diffuse into the *p*-region and electron-hole pair combine and get annihilated. This in turn, produces potential barrier across the junction which opposes the further diffusion through the junction. Thus, a small region is formed which is depleted of free charge carriers and has only immobile ions. This region is called depletion region.

14. **Figure shows two identical capacitors C_1 and C_2 each of 1.5 μF capacitance, connected to a battery of 2 V. Initially switch 'S' is closed. After sometime 'S' is left open and dielectric slabs of dielectric constant K=2 are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted ?** **[2]**



Answer : When switch S is closed :

p.d. across C_1 = p.d. across C_2

i.e., $V_1 = V_2 = 2\text{ V}$

Charge on each capacitor

$$= C \times V$$

$$= 1.5\ \mu F \times 2\ V = 3\ \mu C$$

When dielectric slab is inserted between plates of capacitor,

$$C_1' = C_2' = C' = KC = 1.5\ \mu F \times 2 = 3\ \mu F$$

When switch S is open :

Battery is still connected to C_1

$\therefore$ $Q_1 = C'V_1 = 3\ \mu F \times 2 = 6\ \mu C$

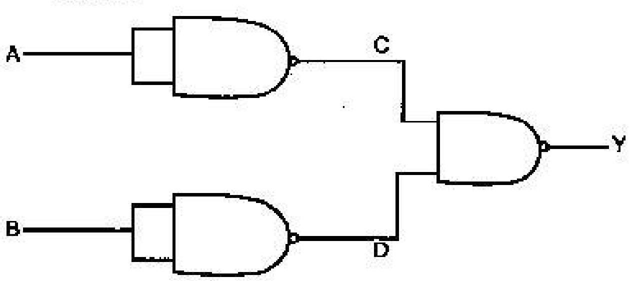
For C_2, charge remain constant

$$Q_2 = C'V_2$$

$$3\ \mu C = 3\ \mu F \times V_2$$

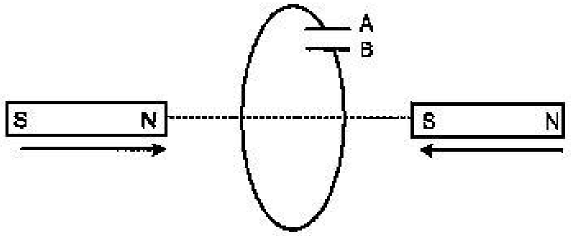
$$V_2 = 1 \text{ volt}$$

16. **Write the truth table for the logic circuit shown below and identify the logic operation by this circuit.****



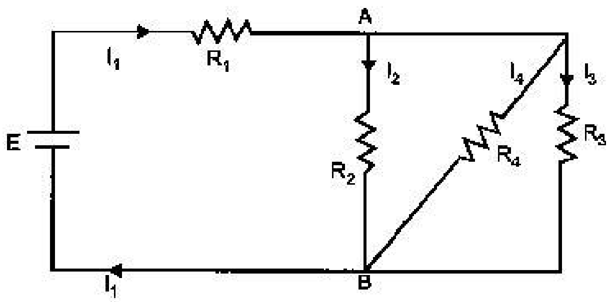
**Answer is not given due to the change in present syllabus.

17. **Predict the polarity of the capacitor when the two magnets are quickly moved in the directions marked by arrows.** **[2]**



Answer : In the situation shown, A will become positive with respect to B, as current induced is in clockwise direction.

23. **In the circuit shown, $R_1 = 2\ \Omega$, $R_2 = R_3 = 10\ \Omega$, $R_4 = 20\ \Omega$, and E = 6 V. Work out the equivalent resistance of the circuit and the current in each resistor.** **[3]**



Answer :

R_2, R_3 and R_4 are in parallel combination

$$\therefore \quad \frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{10} + \frac{1}{10} + \frac{1}{20}$$

$$= \frac{2+2+1}{20} = \frac{5}{20}$$

$$R_{234} = 4\ \Omega$$

R_{234} and R_1 are in series combination

$$R = R_{1234} = R_{234} + R_1$$

$$R = 4 + 2 = 6\ \Omega$$

$$I = \frac{V}{R} = \frac{6}{6}$$

$$\therefore \quad I = 1\text{ A}$$

25. An electron and a photon each have a wavelength of 2 nm. Find :

(i) their momenta

(ii) the energy of photon

(iii) the kinetic energy of the electron **[3]**

Answer.

(i) For each electron or photon, momenta,

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{2 \times 10^{-9}}$$

$$= 3.315 \times 10^{-25} \, kg \text{ m/sec}$$

(ii)

$$E = \frac{hc}{\lambda}$$

$$= \frac{(6.63 \times 10^{-34})(3 \times 10^{8}) \text{ eV}}{(2 \times 10^{-9})(1.6 \times 10^{-19})}$$

$$= 621.6 \text{ eV}$$

(iii)

$$E_k = \frac{1}{2}\frac{p^2}{m}$$

$$= \frac{1(3.315 \times 10^{-25})^2 \text{ eV}}{2(9 \times 10^{-31})(1.6 \times 10^{-19})}$$

$$= 0.3816 \text{ eV.}$$

●●