Solved Paper 2014
Physics
Class-XII

Time : 3 Hours *Max. Marks : 70*

General Instructions :

(i) *All questions are compulsory.*

(ii) *There are* ***29*** *questions in total. Questions* ***1*** *to* ***8*** *are very short answer type questions and carry one mark each.*

(iii) *Questions* ***9*** *to* ***16*** *carry* ***two*** *marks each, questions* ***17*** *to* ***25*** *carry three marks each and questions* ***27*** *to* ***29*** *carry five marks each.*

(iv) *There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all three questions of five marks each. You have to attempt only one of the choices in such questions.*

(v) *Question* ***26*** *is a value based question carrying four marks.*

(vi) *Use of calculators is* ***not*** *permitted. However, you may use log tables if necessary.*

(vii) *You may use the following values of physical constants wherever necessary :*

$$c = 3 \times 10^8 \text{ m/s}$$
$$h = 6.63 \times 10^{-34} \text{ Js}$$
$$e = 1.6 \times 10^{-19} \text{ C}$$
$$\mu_o = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$
$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$
$$m_e = 9.1 \times 10^{-31} \text{ kg}$$
$$\text{Mass of Neutron} = 1.675 \times 10^{-27} \text{ kg}$$
$$\text{Mass of Proton} = 1.673 \times 10^{-27} \text{ kg}$$

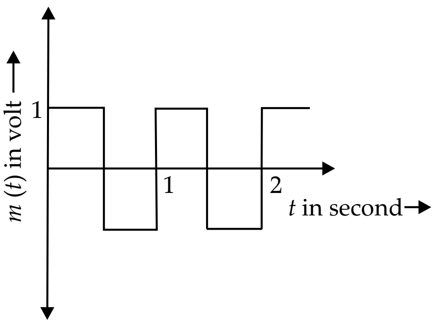
Delhi Set I **Code No. 2/1/1**

1. Define the term 'mobility' of charge carriers in a conductor. Write its S.I. unit. **1**

Ans. Mobility of charge carriers in a conductor is defined as the magnitude of their drift velocity per unit applied electric field.

Its S.I. unit is $m^2V^{-1}s^{-1}$

*** 2. The carrier wave is given by C(t) = 2 sin (8πt) volt. The modulating signal is a square wave as shown. Find modulation index.** **1**



3. For any charge configuration, equipotential surface through a point is normal to the electric field. Justify.

Ans. A surface where the potential is constant is referred to as an equipotential surface. That indicates that there is no work is involved in moving a charge along an equipotential surface from one point to another. In an equipotential surface, the potential difference between any two points is also zero.

That is, the Work done can be given as,

$$W = Fs \cos\theta = 0$$

Here, F is the electric force and s is the magnitude of displacement

Now we know that, for a non-zero displacement, the cos θ should be equal to zero

That is, $\cos\theta = 0$

Or $\theta = 90°$

This explains that the force acting on a point charge on an equipotential surface is vertical.

It is well known that the electric field lines indicate the direction of the electric force acting on a charge.

* *Out of Syllabus*

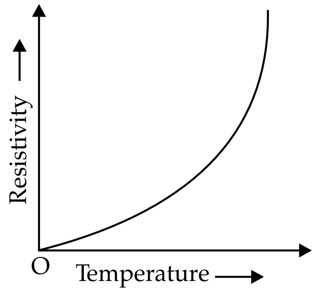
Therefore, we may say that the equipotential surface via a point is normal to the electric field for any charge arrangement.

4. Two spherical bobs, one metallic and the other of glass, of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach earlier and why? 1

Ans. The glass bob will touch the ground before the metallic bob. The metallic bob intercepts the earth's magnetic field as it falls. So, According to Lenz's law, the induced current is such that it opposes the free falling motion of the metallic bob and it experiences an upward force. However, the glass does not induce any such currents.

5. Show variation of resistivity of copper as a function of temperature in a graph.

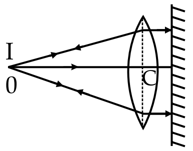
Ans. The variation of resistivity of copper with temperature is parabolic in nature. This is shown in the following graph:



6. A convex lens is placed in contact with a planer mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens?

Ans. Object distance, = 20 cm.

Image distance is also = 20 cm.



As the image I of the object coincides with O, the rays refracted first from the lens and then refracted by the plane mirror must be retracing their path. It is the condition only when rays refracted by the convex lens fall normally on the mirror i.e., the refracted rays form a beam parallel to principal axis of the lens.

Hence, the object O must be at the focus of the convex lens.

$$f = CO = 20 \text{ cm.}$$

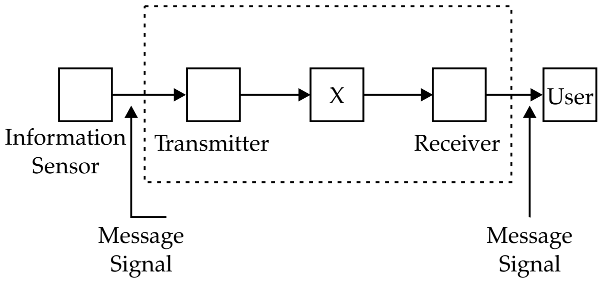
7. Write the expression, in a vector form, for the Lorentz magnetic force $\vec{F}$ due to a charge moving the velocity $\vec{v}$ in a magnetic field $\vec{B}$. What is the direction of the magnetic force? 2

Ans. The Lorentz force can be determined by the formula,

$$F = q(v \times B)$$

where q is the charge, v is the velocity and B is the magnetic field density. Lorentz force is Perpendicular to both magnetic field and velocity. The right-hand thumb rule is applicable in determining the Lorentz force.

*** 8. The figure given below shows the block diagram of a generalized communication system. Identify the element labelled 'X' and write its function. 2**



9. Out of the two magnetic materials, 'A' has relative permeability slightly greater than unity while 'B' has less than unity. Identify the nature of the materials 'A' and 'B'. Will their susceptibilities be positive or negative? 2

Ans. In paramagnetic and ferromagnetic materials, the relative permeability is more than unity; in diamagnetic materials, it is less than unity. Additionally, magnetic susceptibility is positive for paramagnetic and ferromagnetic materials while being negative for diamagnetic materials.

So A: paramagnetic B: Diamagnetic

Susceptibility for A: positive for B: negative

10. Give a uniform electric field $\vec{E} = 5 \times 10^3 \hat{i}$ N/C find the flux of this field through a square of 10 cm on a side whose plane is parallel to the YZ plane. What would be the flux through the same square if the plane makes a 30° angle with the X-axis? 2

Ans. (a) The plane of the square is parallel to the y-z plane. Hence, angle between the unit vector normal to the plane and electric field, $\theta = 0°$

Flux (Φ) through the plane is given by the relation,

$$\Phi = |\vec{E}| A \cos\theta$$

$$= 5 \times 10^3 \times 0.01 \times \cos 0°$$

$$= 50 \text{ N m}^2\text{/C}$$

* *Out of Syllabus*

(b) Plane makes an angle of 30° with the x-axis. Hence, angle between the unit vector normal to the plane and electric field, $\theta = 60°$

Flux, $\Phi = |\vec{E}| A \cos\theta$

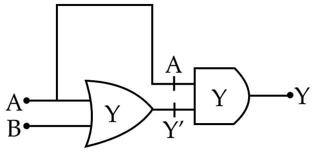
$= 5 \times 10^3 \times 0.01 \times \cos 60°$

$= 25 \text{ N m}^2/\text{C}$

11. For a single slit of width a, the first minimum of the interference pattern of a monochromatic light of wavelength l occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance a. Explain. 3

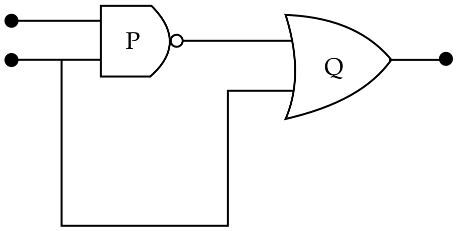
Sol. When a single slit is used, the interference pattern is due to the diffraction phenomenon. Since, corresponding wavelets from two halves of a single slit have a path difference of $\frac{\lambda}{2}$., the overlapping of their contributions in the first scenario results in a minimum. Because these wavefronts have a path difference of λ in the second example, the overlapping of the wavefronts from the two slits results in the first maximum.

*** 12. Write the truth table for the combination of the gates shown. Name the gates used. 3**



OR

* **Identify the logic gates marked 'P' and 'Q' in the given circuit. Write the truth table for the combination.**



13. State Kirchhoff's rules. Explain briefly how these rules are justified. 3

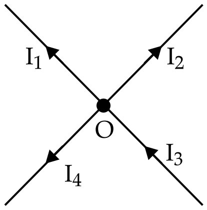
Ans. Junction rule: At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction.

Alternatively, $\xi i = 0$, where ξi is the total current.

Justification: Conservation of charge

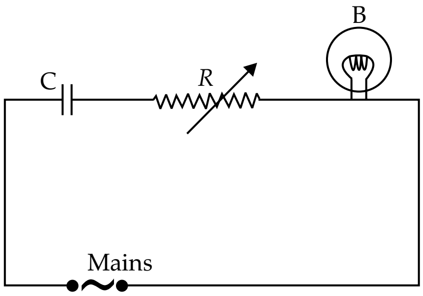
Loop rule: The algebraic sum of charges in the potential around a closed loop involving resistors and cells in the loop is zero.

Alternatively, $\Delta V = 0$, where ΔV is the change in potential.



Justification: Conservation of energy

14. A capacitor 'C', a variable resistor 'R' and a bulb 'B' are connected in series to the ac mains in circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistance R is increased keeping the same capacitance? 3



Ans. (i) The capacitance of the capacitor will rise as the dielectric slab is inserted between its of plates. As a result, the capacitor's potential drop will be smaller $\left(V = \frac{Q}{C}\right)$. As a result (since, both are connected in series), the potential drop across the bulb will rise. Its brightness will consequently rise.

(ii) The potential drop across the resistor will rise as resistance (R) is increased. The potential drop over the bulb will therefore be less (since, both are connected in series). So, it will become dimmer.

*** 15. State the underlying principle of a cyclotron. Write briefly how this machine is used to accelerate charged particles to high energies. 3**

16. An electric dipole of length 4 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $4\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if its has charge ± 8 nC.

Ans.

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

$$4\sqrt{3} = pE \sin\theta$$

$$pE\frac{\sqrt{3}}{2} = 4\sqrt{3}$$

* *Out of Syllabus*

So, $pE = 8$

Potential energy of the dipole $= -pE\cos\theta$

$$U = -pE\cos 60$$
$$U = -8 \times 0.5$$
$$U = -4J$$

*** 17. A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has**

(a) greater value of de-Broglie wavelength associated with it, and

(b) less momentum?

Give reasons to justify your Answer. 3

18. (i) Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. Estimate the number of photons emitted per second on an average by the source.

(ii) Draw a plot showing the variation of photoelectric current versus the intensity of incident radiation on a given photosensitive surface. 3

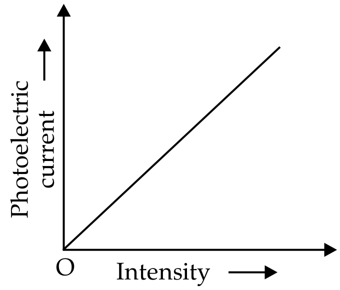
Ans. (i) An energy, $E = h\nu$

$$= 6.63 \times 10^{-34} \times 6.05 \times 10^{14}$$
$$= 3.98 \times 10^{-19}\ \text{J}$$

Now,number of photons emitted per second

$$n = \frac{p}{E} = 2.0 \times \frac{10^{-3}}{3.98} \times 10^{-19}\ \text{J}$$
$$= 5 \times 10^{15}\ \text{photons per second}$$

(ii)



19. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited? Calculate the wavelength of the first member of Lyman and first member of Balmer series. 3

Ans. For Hydrogen atom

The 1st excited energy $= E_2 - E_1 = 10.2$ eV

The 2nd excited energy $= E_3 - E_1 = 12.09$ eV

The 3rd excited energy $= E_4 - E_1 = 12.75$ eV

Hence, hydrogen atoms will be excited to 4th energy level or 3rd excited state.

For Balmer series

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$
$$\frac{1}{\lambda} = R\left(\frac{5}{36}\right)$$
$$\lambda = \frac{36}{5R}$$
$$\lambda = \frac{36}{(5 \times 1.09 \times 10^7)}$$
$$= 6.605 \times 10^{-7}\ \text{m}$$

For Lyman series

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$
$$\frac{1}{\lambda} = R\left(\frac{3}{4}\right)$$
$$\lambda = \frac{4}{3R}$$
$$= 1.285 \times 10^{-7}\ \text{m}$$

*** 20. When Sunita, a class XII student, came to know that her parents are planning to rent out the top floor of their house to a mobile company she protested. She tried hard to convince her parents that this move would be a health hazard.**

Ultimately her parents agreed: 3

(i) In what way can the setting up of transmission tower by a mobile company in a residential colony prove to be injurious to health?

(ii) By objecting to this move of her parents, What value of did Sunita display?

(iii) Estimate the range of e.m. waves which can be transmitted by an antenna of height 20 m. (Given radius of the earth = 6400 km) 3

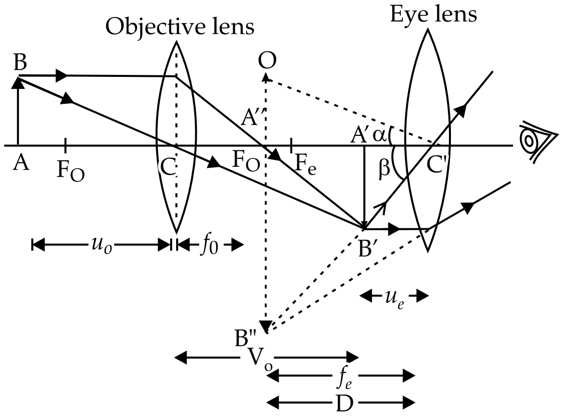
*** 21. A potentiometer wire of length 1 m has a resistance of 10 Ω. It is connected to a 6 V battery in series with a resistance of 5 Ω. Determine the emf of the primary cell which gives a balance point at 40 cm. 3**

22. (i) Draw a labelled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision.

(ii) The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece is 5. The microscope is focussed on a certain object. The distance between the objective and eye-piece is observed to be 14 cm. If least distance of distinct vision is 20 cm, calculate the focal length of the objective and the eye piece. 3

* *Out of Syllabus*

Ans. (i)



(ii) From
$$m = m_0 \times m_e$$
$$m_0 = \frac{m}{m_e} = \frac{20}{5} = 4$$

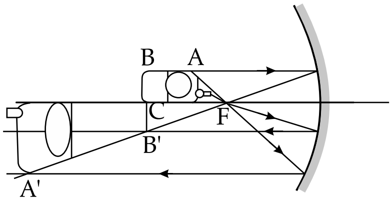
Now,
$$m_0 = \frac{v_0}{u_0} = \frac{L}{f_0} = 4$$
$$f_0 = \frac{L}{4} = \frac{14}{4} = 3.5 \text{ cm}$$

Also,
$$m_e = 1 + \frac{d}{f_e} = 5$$
$$\frac{d}{f_e} = 5 - 1 = 4$$
$$f_e = \frac{d}{4} = \frac{20}{4} = 5 \text{ cm}$$

23. (a) A mobile phone lies along the principal axis of a concave mirror. Show, with the help of a suitable diagram, the formation of its image. Explain why magnification is not uniform.

(b) Suppose the lower half of the concave mirror's reflecting surface is covered with an opaque material. What effect this will have on the image of the object? Explain. **4**

Ans. (a) The image of the mobile phone formed by the concave mirror will be as shown in fig. given below:



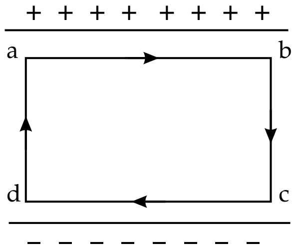
Since, the object distance for the different parts of the mobile phone along its length are different, the different parts will be magnified differently. Hence, the magnification is not uniform.

(b) As the laws of reflection are true for all points of the mirror, the height of the whole image will be produced. However, as the area of the reflecting surface has been reduced, the image intensity will be reduced. In other words, the image produced will be less bright.

* *Out of Syllabus*

24. * **(a) Obtain the expression for the energy stored per unit volume in a charged parallel plate capacitor.**

(b) The electric field inside a parallel plate capacitor is E. Find the amount of work done in moving a charge q over a closed rectangular loop *abcda*. **5**



OR

(a) Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d.

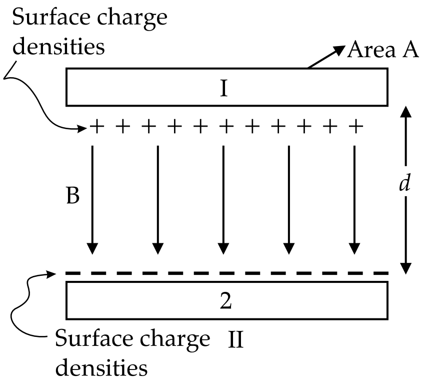
(b) Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charge q_1 and q_2 respectively. Find the ratio of their surface charge densities in terms of their radii.

Ans. (b)
$$W = \text{Force} \times \text{Displacement}$$
$$F = qE$$

As displacement = 0, so work done is also zero.

OR

(a)



$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$$

$\therefore$
$$V = Ed = \frac{Qd}{A\varepsilon_0}$$

Capacitance,
$$C = \frac{Q}{V} = \frac{\varepsilon_0 A}{d}$$

(b) When the two charged spherical conductors are connected by a conducting wire they acquire the same potential.

i.e.,
$$\frac{Kq_1}{R_1} = \frac{Kq_2}{R_2}$$

$\Rightarrow$
$$\frac{q_1}{q_2} = \frac{R_1}{R_2}$$

Hence, ratio of surface charge densities,

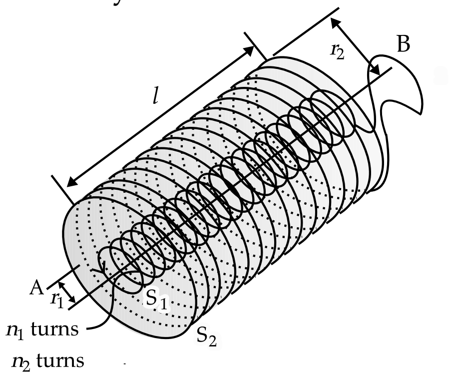
$$\frac{\sigma_1}{\sigma_2} = \frac{q_1 / 4\pi R_1^2}{q_2 / 4\pi R_2^2}$$

$$\frac{\sigma_1}{\sigma_2} = \frac{q_1 R_2^2}{q_2 R_1^2}$$

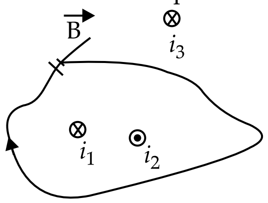
$$\frac{\sigma_1}{\sigma_2} = \frac{R_1}{R_2} \times \frac{R_2^2}{R_1^2} = \frac{R_2}{R_1}$$

25. (a) State Ampere's circuital law, expressing it in the integral form.

(b) Two long coaxial insulated solenoids, S_1 and S_2 of equal lengths are wound one over the other as shown in the figure. A steady current "I" flow through the inner solenoid S_1 to the other end B, which is connected to the outer solenoid S_2 through which the same current "I" flows in the opposite direction so as to come out at end A. If n_1 and n_2 are the number of turns per unit length,s find the magnitude and direction of the net magnetic field at a point (i) inside on the axis and (ii) outside the combined system. **5**



Ans. (a) Ampere's circuital law states that the circulation of the resultant magnetic field along a closed, plane curve is equal to μ_0 times the total current crossing the area bounded by the closed curve, provided the electric field inside the loop remains constant.



In the above illustration, the Ampere's circuital law can be written as follows:

$$\oint B \rightarrow .dl \rightarrow \;=\mu_0 i \text{ where } i = i_1 - i_2$$

(b) (i) The magnetic field due to a current carrying solenoid:

$$B = \mu_0 ni$$

where, n = number of turns per unit length,
i = current through the solenoid.

Now, the magnetic field due to solenoid S_1 will be in the upward direction and the magnetic field due to S_2 will be in the downward direction (by right-hand screw rule).

$$\begin{aligned} B \text{ net} &= B_1 - B_2 \\ &= \mu_0 n_1 I - \mu_0 n_2 I \\ &= \mu_0 I(n_1 - n_2) \end{aligned}$$

(ii) The magnetic field is zero outside a solenoid.

26. Answer the following: **5**

(a) Name the e.m. waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.

(b) If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.

(c) An e.m. wave exerts pressure on the surface on which it is incident. Justify.

Ans. (a) Microwaves are suitable for radar systems used in aircraft's navigation. The range of frequency for these waves is 10^9 Hz to 10^{12} Hz.

(b) In the absence of atmosphere, there would be no greenhouse effect on the surface of the Earth. As a result, the temperature of the Earth would decrease rapidly, making it difficult for human survival.

(c) The momentum transported by electromagnetic waves is given by

$$p = \frac{U}{c}$$

where U is the energy transported by electromagnetic waves in a given time and c is speed of electromagnetic waves in free space. As a result, when these waves strike a surface, pressure and hence force is exerted by them on the surface.

*** 27. (a) Deduce the expression, $N = N_0 e^{-\lambda t}$, for the law of radioactive decay.**

(b) (i) Write symbolically the process expressing the $\beta+$ decay of $^{22}_{11}$Na. Also write the basic nuclear process underlying this decay.

(ii) If the nucleus formed in the decay of the nucleus $^{22}_{11}$Na, and isotope or isobar? **5**

28. (a) (i) 'Two independent mono-chromatic sources of light cannot produce a sustained interference pattern'. Give reason

(ii) Light wave each of amplitude 'a' and frequency 'ω', emanating from two coherent light sources superpose at a point. If the displacements due to these wave is given by $y_1 = a \cos \omega t$ and $y_2 = a \cos(\omega t + \phi)$ where ϕ is the phase difference between the two, obtain the expression for the resultant intensity at the point.

(b) In Young's double slit experiment, using monochromatic light of wavelength λ, the intensity

* *Out of Syllabus*

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 $\frac{\lambda}{3}$. **5**

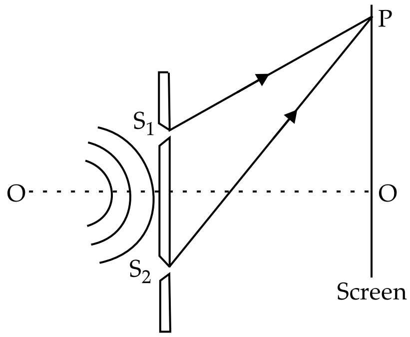
OR

*** (a) How does one demonstrate, using a suitable diagram, that unpolarised light when passed through a polaroid gets polarized?**

(b) A beam of unpolarised light is incident on a glass-air interface. Show, using a suitable ray diagram, that light reflected from the interface is totally polarised, when $\mu = \tan i_B$, where μ is the refractive index of glass with respect to air and i_B is the Brewster's angle.

Ans. (a) (i) The condition for the sustained interference is that both the sources must be coherent (i.e., they must have the same wavelength and the same frequency, and they must have the same phase or constant phase difference).

Two sources are monochromatic if they have the same frequency and wavelength. Since, they are independent, i.e., they have different phases with irregular difference, they are not coherent sources.



Let the displacement of the waves from the sources S_1 and S_2 at point P on the screen at any time t be given by:

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

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

Where, ϕ is the constant phase difference between the two waves.

By the superposition principle, the resultant displacement at point P is given by:

$$y = y_1 + y_2$$
$$y = a\cos\omega t + a\cos(\omega t + \phi)$$
$$y = 2a\left[\cos\left(\frac{\omega t + \omega t + \phi}{2}\right)\cos\left(\frac{\omega t - \omega t - \phi}{2}\right)\right]$$
$$y = 2a\cos\left(\omega t + \frac{\phi}{2}\right)\cos\left(\frac{\phi}{2}\right) \quad ...(i)$$

Let $2a\cos\left(\frac{\phi}{2}\right) = A$ ...(ii)

Then, equation (i) becomes

$$y = A\cos\left(\omega t + \frac{\phi}{2}\right)$$

Now, we have:

$$A^2 = 4a^2\cos^2\left(\frac{\phi}{2}\right) \quad ...(iii)$$

Then intensity of light is directly proportional to the square of the amplitude of the wave. The intensity of light at point on the screen is given by

$$I = 4a^2\cos^2\frac{\phi}{2}$$

(b) Intensity $I = 4I_0\cos^2\frac{\phi}{2}$

When path difference is λ, phase difference is 2π

$$I = 4I_0\cos^2\pi$$
$$= 4I_0 = k \quad \text{(given)}$$

When path difference, $\Delta = \frac{\lambda}{3}$, the phase difference

$$\phi_1 = \frac{2\pi}{\lambda}\Delta$$
$$= \frac{2\pi}{\lambda}\times\frac{\lambda}{3} = \frac{2\neq}{3}$$
$$I_1 = 4I_0.\cos^2\frac{2\pi}{3}$$

(since $k = 4I_0$)

$$= k\cos^2\frac{2\pi}{3}$$
$$= k\times\left(-\frac{1}{2}\right)^2$$
$$= \frac{1}{4}k$$

29. (a) Describe a simple experiment (or activity) to show that the polarity of emf induced in a coil is always such that it tends to produce a current which opposes the change of magnetic flux that produces it.

(b) The current flowing through an inductor of self inductance L is continuously increasing. Plot a graph showing the variation.

(i) Magnetic flux versus the current

(ii) Induced emf versus $\frac{dI}{dt}$

(iii) Magnetic potential energy stored versus the current. **5**

OR

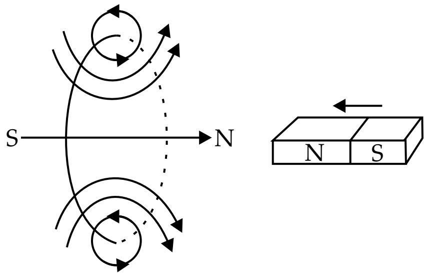
(a) Draw a schematic sketch of an ac generator describing its basic elements. State briefly its working principle. Show a plot of variation of

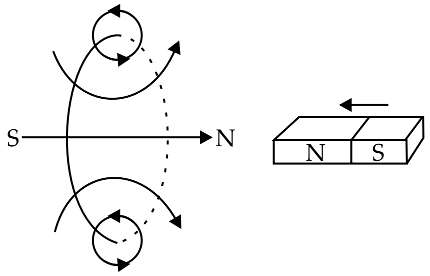
(i) Magnetic flux and

(ii) Alternating emf versus time generated by a loop of wire rotating in a magnetic field.

* *Out of Syllabus*

Ans. (a) Lenz's law: According to Lenz's law, the polarity of the induced emf is such that it opposes a change in magnetic flux responsible for its production.





When the north pole of a bar magnet is pushed towards the coil, the amount of magnetic flux linked with the coil increase. Current is reduced in the coil from a direction such that it opposes the increase in magnetic flux. This is possible only when the current induced in the coil is in anti-clockwise direction, with respect to an observer. The magnetic moment M associated with this induced emf has north polarity, towards the north pole of the approaching bar magnet.

Similarly, when the north pole of the bar magnet is moved away from the coil, the magnetic flux linked with the coil decreases. To counter this decrease in magnetic flux, current is induced in the coil in clockwise direction so that its south pole faces the receding north pole of the bar magnet. This would result in an attractive force which opposes the motion of the magnet and the corresponding decrease in magnetic flux

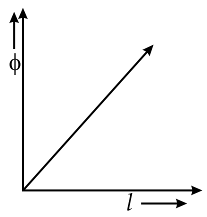
(b) (i) Since, $\phi = LI$

where, I = strength of current through the coil at any time

ϕ = Amount of magnetic flux linked

with all turns of the coil at that time and,

L = Constant of proportionally called coefficient of self induction.

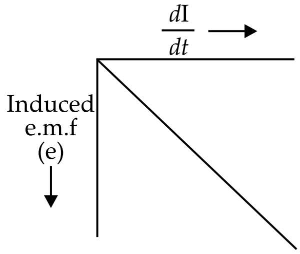


(ii) Induced emf,

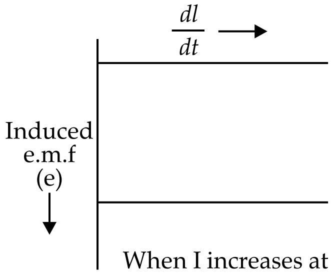
$$e = \frac{-d\phi}{dt} = -\frac{d(LI)}{dt}$$

i.e.,

$$e = -L\left(\frac{dI}{dt}\right)$$



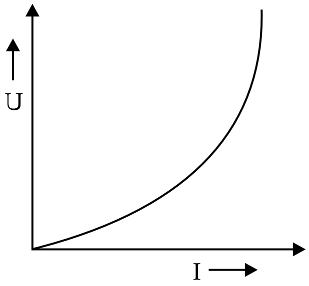
When $\frac{dI}{dt}$ increases at constant rate



When I increases at constant rate

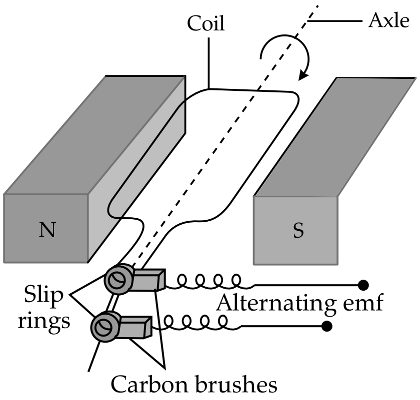
(iii) Since, magnetic potential energy is given by

$$U = \frac{1}{2}LI^2$$



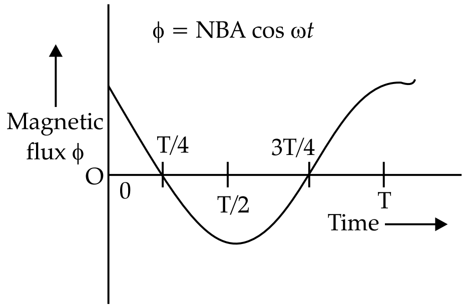
OR

(a)



It works on the process of electromagnetic induction, i.e., when a coil rotates continuously in a magnetic field, the effective area of the coil, linked (normally) with the magnetic field lines, changes continuously with time. This variation of magnetic flux with time results in the production of a (alternating) emf in the coil.

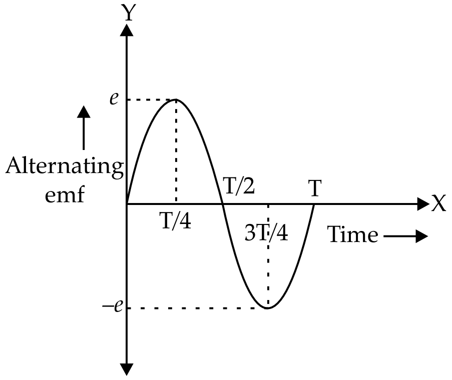
(i) Magnetic flux versus time



(ii) Alternating emf versus time

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

The graph between alternating emf versus time is shown below:



(b) A choke coil is an electrical appliance used for controlling current in an a.c. circuit. Therefore, if we use a resistance R for the same purpose, a lot of energy would be wasted in the form of heat etc.

30. (a) State briefly the processes involved in the formation of *p-n* junction explaining clearly how the depletion region is formed.

(b) Using the necessary circuit diagram, show how the V-I characteristics of a *p-n* junction are obtained in

(i) Forward biasing

(ii) Reverse biasing

How are these characteristics made use or in rectification? **5**

OR

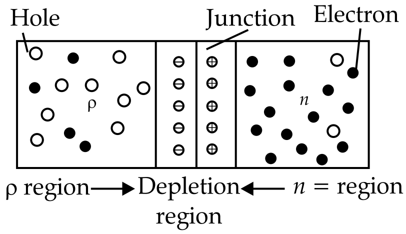
* **(a) Differentiate between three segments of a transistor on the basis of their size and level of doping.**

* **(b) How is a transistor biased to be in active state?**

* **(c) With the help of necessary circuit diagram, describe briefly how *n-p-n* transistor in CE configuration amplifies a small sinusoidal input voltage. Write the expression for the ac current gain.**

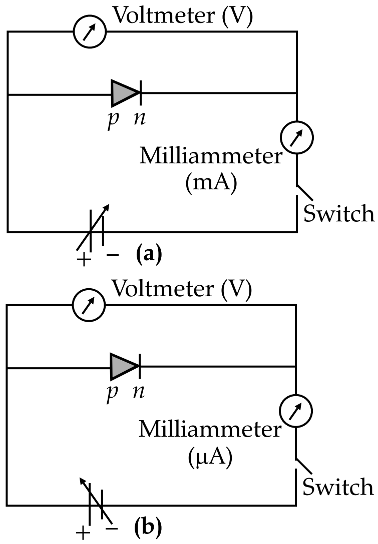
Ans. (a) As we know that *n*-type semi-conductor has more concentration of electrons than that of a hole and *p*-type semi-conductor has more concentration of holes than an electron. Due to the difference in concentration of charge carriers in the two regions of *p-n* junction, the holes diffuse from *p*-side to //-side and electrons diffuse from *n*-side to *p*-side.

When an electron diffuses from *n* to *p*, it leaves behind an ionized donor on *n*-side. The ionized donor (+*ve* charge) is immobile as it is bounded by the surrounding atoms. Therefore, a layer of positive charge is developed on the *n*-side of the junction. Similarly, a layer of negative charge is developed on the *p*-side.



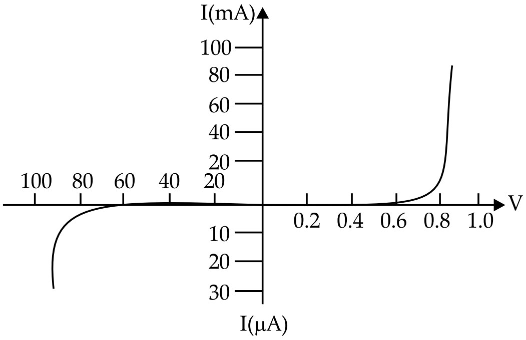
Hence, a space-charge region is formed on both side of the junction, which has immobile ions and is devoid of any charge carrier, called as depletion layer or depletion region.

(b)



Using the circuit arrangements shown in fig (a) and fig (b), we study the variation of current with applied voltage to obtain the V-I characteristics shown below.

* *Out of Syllabus*



(c)

From the V-I characteristics of a junction diode, it is clear that it allows the current to pass only when it is forward biased. So when an alternating voltage is applied across the diode, current flows only during that part of the cycle when it is forward biased.

Delhi Set II — Code No. 2/1/2

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

1. Define the term 'electrical conductivity' of a metallic wire. Write its S.I. unit.

Ans. The electrical conductivity of a metallic wire is defined as the ratio of the current density to the electric field it creates.

Electrical conductivity, $\sigma = \text{JE}$

$$\text{S.I. unit} = (\text{ohm m})^{-1}$$

OR

The reciprocal of resistivity of a material is called its electrical conductivity.

*** 2. The carrier wave is represented by C(*t*) = 5 sin (10π*t*) volt. A modulating signal is a square wave as shown. Determine modulation index.** **1**

10. An electric dipole of length 2 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $8\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has a charge of ±4 nC. **2**

Ans.

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

$$8\sqrt{3} = pE\sin\theta$$

$$pE\frac{\sqrt{3}}{2} = 8\sqrt{3}$$

So, $pE = 16$

Potential energy of the dipole

$$= -pE\cos\theta$$

$$U = -pE\cos 60$$

$$U = -16 \times 0.5$$

$$U = -8\text{J}$$

*** 15. A proton and an alpha particle are accelerated through the same potential? Which one of the two has (i) greater value of de-Broglie wavelength associated with it and (ii) less kinetic energy. Give reason to justify your answer.** **3**

16. Given a uniform electric field $\vec{E} = 2\times10^3\,\hat{i}$ N/C. Find the flux of this field through a square of side 20 cm, whose plane is parallel to the Y-Z plane. What would be the flux through the same square, if the plane makes an angle of 30° with the X-axis? **3**

Ans. (a) The plane of the square is parallel to the *y-z* plane. Hence, angle between the unit vector normal to the plane and electric field, $\theta = 0°$

Flux (Φ) through the plane is given by the relation,

$$\Phi = |\vec{E}|A\cos\theta$$

$$= 2 \times 10^3 \times 0.04 \times \cos 0°$$

$$= 80 \text{ N m}^2/\text{C}$$

(b) Plane makes an angle of 30° with the x-axis. Hence, angle between the unit vector normal to the plane and electric field, $\theta = 60°$

Flux, $$\Phi = |\vec{E}|A\cos\theta$$

$$= 2 \times 10^3 \times 0.04 \times \cos 60°$$

$$= 40 \text{ N m}^2/\text{C}$$

20. A 12.9 eV beam of electronic is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited? Calculate the wavelength of the first member of Paschen series and first member of Balmer series. **3**

Ans. Energy of the electron in the n^{th} state of an atom

Here, Z is the atomic number of the atom.

For hydrogen atom, $Z = 1$

Energy required to excite an atom from initial state (n_i) to final state (n_f),

$$E = -13.6\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)eV$$

$$\Rightarrow \quad \frac{-13.6}{n_f^2} + \frac{13.6}{n_i^2} = 12.9$$

* *Out of Syllabus*

This energy must be equal to or less than the energy of the incident electron beam.

$$\Rightarrow \quad 13.6 - 12.9 = \frac{13.6}{n_f^2} \qquad [\because n' = 1]$$

$$\Rightarrow \quad n_f = 4.4$$

State cannot be a fraction number.

$$\Rightarrow \quad n_f = 4$$

Hence, the hydrogen atom would be excited up to 4th energy level.

Rydberg's formula for the spectrum of the hydrogen atom is given by:

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Here, λ is the wavelength

Rydberg's canstant, $R = 1.097 \times 10^7$ m^{-1}

For the first member of the Paschen series

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{3^2} - \frac{1}{4^2}\right)$$

$$\lambda = 18752.4 \text{ Å}$$

For the first member of Balmer series

$$n_1 = 2, n_2 = 3$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\lambda = 6563.3 \text{ Å}$$

22. Answer the following: **3**

(a) Name the e.m. waves which are used for the treatment of certain forms of cancer. Write their frequency range.

(b) Thin ozone layer on top of stratosphere is crucial for human survival. Why?

(c) Why is the amount of the momentum transferred by the e.m. waves incident on the surface so small?

Ans. (a) Gamma rays are used for the treatment of certain forms of cancer. Their frequency range is 3×10^{19} Hz to 5×10^{20} Hz.

(b) The thin ozone layer on top of stratosphere absorb most of the harmful ultraviolet rays coming from the Sun towards the Earth. They include UVA, UVB and UVC radiations, which can destroy the life system on the Earth. Hence, this layer is crucial for human survival.

(c) The momentum transported by electromagnetic waves is given by

$$p = \frac{U}{c} = \frac{h\nu}{c}$$

where U is the energy transported by electromagnetic waves in a given time and c is speed of electromagnetic waves in free space.

Now, $h = 6.62 \times 10^{-34}$ J s, $c = 3 \times 10^8$ m s^{-1}

Therefore, even for γ-rays ($\nu \approx 10^{20}$ Hz),

$$p = \frac{6.62 \times 10^{-34} \times 10^{20}}{3 \times 10^8}$$

$$= 2.2 \times 10^{-22} \text{ kg m s}^{-1}$$

Thus, the amount of the momentum transferred by the e.m. waves incident on a surface is very small.

*** 24. A potentiometer wire of length 1.0 m has a resistance of 15 Ω. It is connected to a 5 V battery in series with a resistance of 5 Ω. Determine the emf of the primary cell which gives a balance point at 60 cm.** **5**

Delhi Set III — Code No. 2/1/2

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

1. Define the term 'drift velocity' of charge carriers in a conductor and write its relationship with the current flowing through it. **1**

Ans. The net speed achieved by an electron in a current carrying conductor is called as drift velocity. The average velocity acquired by the free electrons along the length of a metallic conductor under a potential difference applied across the conductor is called drift velocity of the electrons.

$$v_d = \frac{I}{neA}$$

Here:

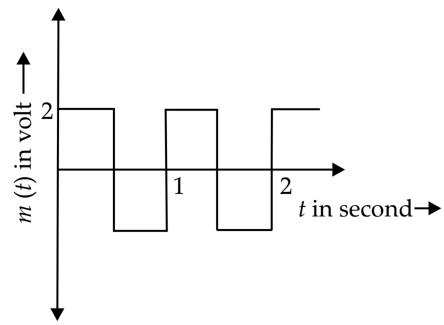
I is the current flowing through the conductor.

n is the number density of an electron.

A is the area of the conductor,

e is the charge of the electron.

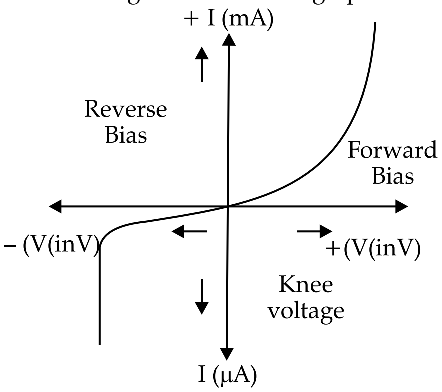
*** 2. The carrier wave of a signal is given by C(t) = 3 sin (8πt) volt. The modulating signal is a square wave as shown. Find its modulation index.** **1**



4. Plot a graph showing variation of current versus voltage for the material Ga. **1**

* *Out of Syllabus*

Ans. Current-Voltage characteristics graph for Ga:



9. An electric dipole of length 2 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences torque of $6\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has a charge of $\pm 2\, n$C. **1**

Ans.

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

$$6\sqrt{3} = pE \sin\theta$$

$$pE\frac{\sqrt{3}}{2} = 6\sqrt{3}$$

So, $pE = 12$

Potential energy of the dipole $= -pE\cos\theta$

$$U = -pE\cos 60°$$

$$U = -12 \times 0.5$$

$$U = -6\text{J}$$

*** 12. A deuteron and an alpha particle are accelerated with the same accelerating potential.** **3**

Which one of the two has

(i) greater value of de-Broglie wavelength, associated with it, and

(ii) less kinetic energy? Explain.

15. Given a uniform electric field $\vec{E} = 4\times10^3\,\hat{i}$ N/C. Find the flux of this field through a square of 5 cm on a side whose plane is parallel to the Y-Z plane. What would be the flux through the same square, if the plane makes an angle of 30° with the X-axis? **3**

Ans. (a) The plane of the square is parallel to the *y-z* plane. Hence, angle between the unit vector normal to the plane and electric field, $\theta = 0°$

Flux (Φ) through the plane is given by the relation,

$$\Phi = |\vec{E}|A\cos\theta$$

$$= 4 \times 10^3 \times 0.25 \times \cos 0°$$

$$= 10 \text{ N m}^2/\text{C}$$

(b) Plane makes an angle of 30° with the *x*-axis. Hence, angle between the unit vector normal to the plane and electric field, $\theta = 60°$

Flux, $\Phi = |\vec{E}|A\cos\theta$

$$= 4 \times 10^3 \times 0.25 \times \cos 60°$$

$$= 5 \text{ N m}^2/\text{C}$$

* *Out of Syllabus*

20. A 12.3 eV electron beam is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited? Calculate the wavelength of the second member of Lyman series and second member of Balmer series.

Ans. Let the hydrogen atoms be excited to n^{th} energy level.

$$E = -13.6\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \qquad [\because n_i = 1]$$

$$\Rightarrow \quad 12.3 = \left(\frac{1}{1^2} - \frac{1}{n^2}\right)$$

$$\Rightarrow \quad 12.3 = 13.6 - \frac{13.6}{n^2}$$

$$\Rightarrow \quad \frac{13.6}{n^2} = 13.6 - 12.3 = 1.3$$

$$\Rightarrow \quad n^2 = \frac{13.6}{1.3}$$

$$\Rightarrow \quad n \approx 3$$

The formula for calculating the wavelength of Lyman series is given below:

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$$

For second member of Lyman series, $n = 3$

$$\therefore \quad \frac{1}{\lambda} = R\left(1 - \frac{1}{3^2}\right)$$

$$\Rightarrow \quad \frac{1}{\lambda} = (1.09737\times10^7)\left(\frac{8}{9}\right)$$

$$\Rightarrow \quad \lambda = 1025.1 \text{ Å}$$

The formula for calculating the wavelength of Balmer series is given below:

$$\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{n^2}\right)$$

For second member of Balmer series:

$$n = 4$$

$$\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{4^2}\right)$$

$$\Rightarrow \quad \frac{1}{\lambda} = (1.09737\times10^7)\left(\frac{3}{16}\right)$$

$$\Rightarrow \quad \lambda = 4861 \text{ Å}$$

24. Answer the following:

(a) Name the em waves which are used for the treatment of certain form of cancer. Write their frequency range.

(b) Welders wear special glass goggles while working. Why? Explain.

(c) Why are infrared waves often called as heat waves? Give their one application.

Ans. (a) Gamma rays are used for the treatment of certain forms of cancer. The frequency range of Gamma rays is 3×10^{19} to 5×10^{20} Hz.

(b) Welders wear special glass goggles while working so that they can protect their eyes from harmful electromagnetic radiation.

(c) Infrared waves are often called as heat waves because they induce resonance in molecules and increase internal energy in a substance. Infrared waves are used in burglar alarms, security lights and remote controls for television and DVD players.

Outside Delhi Set I — Code No. 2/1/1

1. Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current. **1**

Ans. One Ampere current can be defined as the amount of current flowing through two infinitely low parallel thin wires kept in vacuum separated by one metre which produces an attractive force of 2×10^{-7} N/m.

2. To which part of the electromagnetic spectrum does a wave of frequency 5×10^{19} Hz belong?

Ans. A wave of frequency 5×10^{19} Hz will belong to Gamma/X Rays region.

3. What is the force between two small charges of 2×10^{-7} C and 3×10^{-7} C placed 30 cm apart in air?

Ans.

$$F = \frac{kq_1q_2}{r^2}$$

$$= \frac{9 \times 10^9 \times 2 \times 10^{-7} \times 3 \times 10^{-7}}{(30 \times 10^{-2})^2}$$

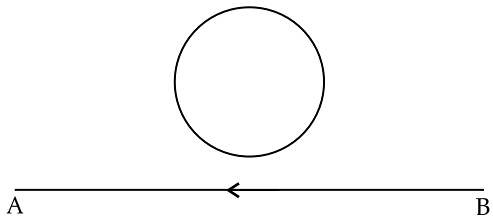
$$= 6 \times 10^{-3}\ \text{N}$$

4. Define intensity of radiation on the basis of photon picture of light. Write its S.I. unit. **1**

Ans. Intensity of radiation is defined as the energy transmitted to a surface per unit area per unit time by the photons striking on the surface. SI Unit:

$$\frac{W}{m^2} \text{ or } \frac{J}{m^2\,\text{sec}}$$

5. 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. **1**



Ans. The magnetic field due to the wire in the coil in going into the paper. So, according to Lenz's Law, if magnetic field going inside is decreasing as the current is decreasing, the direction current in the loop should be such that the magnetic field into the paper increases. Therefore, the current should be in clockwise direction.

6. Why is it found experimentally difficult to detect neutrinos in nuclear β-decay? **1**

Ans. The neutrinos are uncharged particles which have almost negligible mass and they interact weakly with matter. Therefore, it is difficult to detect them in β-decay.

7. Why is the use of A.C. voltage preferred over D.C. voltage ? Give two reasons **1**

Ans. Two reasons to use A.C. voltage over D.C. are:

(a) AC power can be easily step up or step down using a transformer.

(b) Electricity that is coming to our homes is AC because it comes from a faraway power generation plant so the loss of energy during transmission is very less in the case of AC power than DC power.

8. A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason. **1**

Ans. The biconvex lens will now behave as a diverging lens as the refractive index of water(1.33) is more than the refractive index of the material(1.25) of the lens.

9. Using Rutherford model of the atom, derive the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron? **2**

OR

Using Bohr's postulates of the atomic model, derive the expression for radius of n^{th} electron orbit. Hence, obtain the expression for Bohr's radius.

Ans. According to Rutherford,

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2}$$

$$mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}$$

$$\text{Total energy} = \text{P.E.} + \text{K.E.}$$

$$= -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r} + \frac{1}{8\pi\varepsilon_0}\frac{Ze^2}{r}$$

$$= -\frac{1}{8\pi\varepsilon_0}\frac{Ze^2}{r}$$

The negative sign shows that electron-nucleus form an abound system.

OR

According to Bohr's model, electrons revolve around the orbits such that their angular momentum is an integral multiple of $\frac{h}{2\pi}$

$$mvr = \frac{nh}{2\pi}$$

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2}$$

$$r = \frac{\varepsilon_0 n^2 h^2}{\pi Z e^2 m}$$

*** 10. A parallel plate capacitor of capacitance C is charged to a potential V. It is then connected to another uncharged capacitor having the same capacitance. Find out the ratio of the energy stored in the combined system to that stored initially in the single capacitor. 2**

11. Considering the case of a parallel plate capacitor being charged, show how one is required to generalize Ampere's circuital law to include the term due to displacement current. 2

Ans. An insulator occupies the space in between the capacitor. As a result, there is no actual charge transfer in this area. During the process of charging a capacitor, current moves through the circuit. This necessitates the presence of a magnetic field-generating displacement current in the capacitor.

12. A cell of emf 'E' and internal resistance '*r*' is connected across a variable resistor 'R'. Plot a graph showing variation of terminal voltage 'V' of the cell versus the current 'I'. Using the plot, show how the emf of the cell and its internal resistance can be determined.

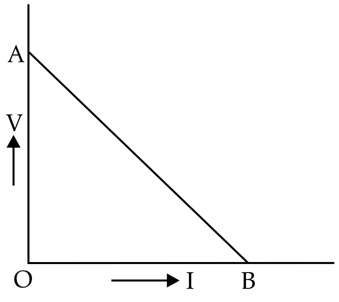
Ans. The relation between V and I is given by:

$$V = E - Ir$$

Thus the graph between I and V is as shown in figure below.

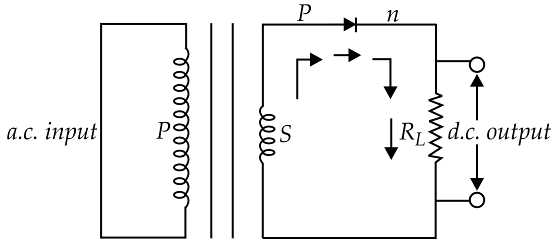
Emf is given by the intercept on the vertical axis, i.e., the V-axis.

Internal resistance is given by the slope of the line i.e., slope of V vs I graph.



13. Explain, with the help of a circuit diagram, the working of a *p-n* junction diode as a half-wave rectifier. 2

Ans. The circuit diagram for a *p-n* junction diode as a half wave rectifier is shown below:



During the positive half cycle of the input a.c., the *p-n* junction is forward biased i.e., the forward current flows from *p* to *n*. In the forward biasing, the diode provides a very low resistance and allows the current to flow. Thus, we get output across load.

During the negative half cycle of the input a.c., the *p-n* junction is reversed biased. In the reverse biasing, the diode provides a high resistance and hence a very small amount of current will flow through the diode which is of negligible amount. Thus, no output is obtained across the load. During the next half cycle, output is again obtained as the junction diode gets forward biased. Thus, a half wave rectifier gives discontinuous and pulsating d.c. output across the load resistance.

14. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}. 2

Ans. $v_d = \frac{I}{nAq}$, where

I is the current

n is charge density

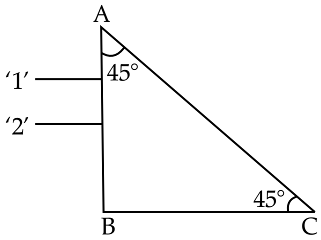
q is the charge of electron and

A is the cross sectional area

$$v_d = \frac{1.5}{9\times10^{28}\times1.0\times10^{-7}\times1.6\times10^{-19}}$$

$$v_d = 10.4 \times 10^{-4} \text{ m/sec}$$

15. Two monochromatic rays light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.35 and 1.45. Trace the path of these rays after entering through the prism. 2



* *Out of Syllabus*

Ans. Critical angle of ray '1':

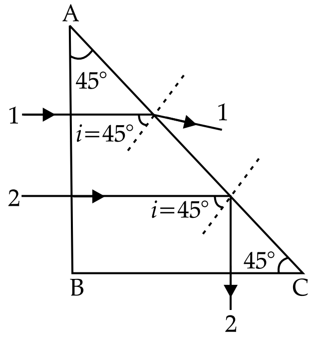
$$\sin(c_1) = \frac{1}{\mu_1} = \frac{1}{1.35}$$

$$c_1 = \text{arc}\sin\left(\frac{1}{1.35}\right) = 47.79°$$

Similarly, critical angle of ray '2':

$$\sin(c_2) = \frac{1}{\mu_2} = \frac{1}{1.45}$$

$$c_2 = \sin^{-1}\left(\frac{1}{1.45}\right) = 43.6°$$



Ray '1' and '2' will fall on the side AC at an angle of incidence (i) of 45°. Critical angle of ray '1' is greater than *i*, so it will get refracted from the prism. Critical angle of ray '2' is less than that of *i*, so it will undergo total internal reflection.

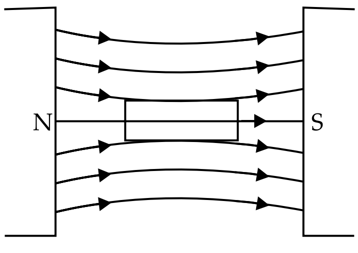
*** 16. Write the functions of the following in communication systems:** **2**

(i) Transducer

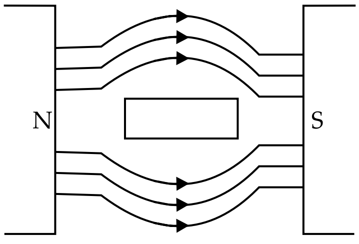
(ii) Repeater

17. Show diagrammatically the behaviour of magnetic field lines in the presence of (i) paramagnetic and (ii) diamagnetic substances. How does one explain this distinguishing feature? **2**

Ans. (i) The behaviour of magnetic field lines in the presence of a para magnetic substance is shown below:



(ii) The behavior of magnetic field lines in the presence of a diamagnetic substance is shown below:



Their differing relative permeabilities account for this distinguishing feature. When a diamagnetic substance has a relative permeability that is less than 1, the magnetic lines of force do not prefer to pass through the substance. On the other hand, when a paramagnetic substance has a relative permeability that is greater than 1, the magnetic lines of force prefer to pass through the substance.

*** 18. Draw a circuit diagram of *n-p-n* transistor amplifier in CE configuration. Under what condition does the transistor act as an amplifier?** **2**

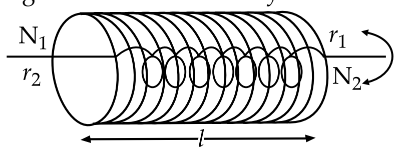
*** 19. (a) Using the phenomenon of polarization, show how transverse nature of light can be demonstrated.**

(b) 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 30° with that of P_1. Deterime the intensity of light transmitted through P_1, P_2 and P_3. **3**

20. Define the term 'mutual inductance' between the two coils.

Obtain the expression for mutual inductance of a pair of long coaxial solenoids each of length *l* and radii r_1 and r_2 ($r_2 \gg r_1$). Total number of turns in the two solenoids are (N_1 and N_2) respectively. **3**

Ans. Mutual inductance of two coils is equal to the e.m.f. induced in one coil when rate of change of current through the other coil is unity.



Mutual inductance of two co-axial solenoids : Consider two long co-axial solenoid each of length l with number of turns N_1 and N_2 wound one over the other. Number of turns per unit length in solenoid, $n = \frac{N_1}{l}$. If I_1 is the current flowing in primary solenoid, the magnetic field produced within this solenoid.

$$B_1 = \frac{\mu_0 N_1 I_1}{l}$$

The flux linked with each turn of inner solenoid coil is

$$\begin{aligned}\phi_2 &= N_2\phi \\ &= N_2 B_1 A_2 \\ &= N_2\left(\frac{\mu_0 N_1 I_1}{l}\right)A_2\end{aligned}$$

Mutual Inductance,

$$M_{21} = \left(\frac{\mu_0 N_1 N_2}{l}\right)A_2$$

If n_1 is number of turns per unit length of outer solenoid and r_2 is radius of inner solenoid, then

$$M = \mu_0 n_1 N_2 \pi r_2^2$$

* *Out of Syllabus*

*** 21. Answer the following:** **3**

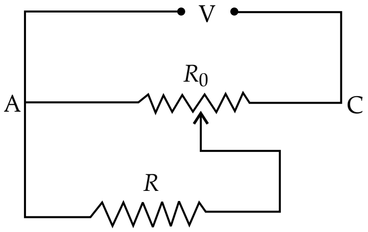
(a) Why are the connections between the resistors in a meter bridge made of thick copper strips?

(b) Why is it generally preferred to obtain the balance point in the middle of the meter bridge wire?

(c) Which material is used for the meter bridge wire and why?

OR

A resistance of R Ω draws current from a potentiometer as shown in the figure. The potentiometer has a total resistance R_0 Ω. 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.



22. A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept at 15 cm apart from each other. A point object lies 60 cm in front of the convex lens. Draw a ray diagram to show the formation of the image by the combination. Determine the nature and position of the image formed. **3**

Ans. $u = -60$ cm and $f = 20$ cm

From the lens formula, we have:

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

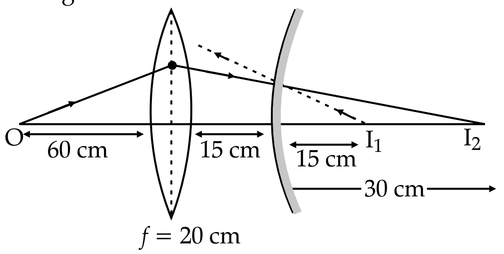
$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$$

$$= \frac{1}{20} + \frac{1}{-60}$$

$$= \frac{3-1}{60} = \frac{2}{60} = \frac{1}{30}$$

$$v = +30 \text{ cm}$$

The positive sign indicates that the image is formed at the right of the lens.



The image I_1 is formed behind the mirror and acts as a virtual oject for the mirror. The convex mirror forms the image I_2, whose distance from the mirror can be determined as:

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

Here, $u = 15$ cm

and, $f = \frac{R}{2} = 10$ cm

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

$$v = 30 \text{ cm}$$

Hence, the final virtual image is formed at a distance 30 cm from the convex mirror.

*** 23. A voltage $V = V_0 \sin \omega t$ is applied to a series LCR circuit. Derive the expression for the average power dissipated over a cycle. Under what condition is (i) no power dissipated even through the current flows through the circuit, (ii) maximum power dissipated in the circuit?** **3**

24. Write any two distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams. **3**

Ans. Conductors:

In case of conductors, the valence band is completely filled and the conduction band can have two cases-either it is partially filled with an extremely small energy gap between the valence and conduction bands or it is empty, with the two bands overlapping each other as shown below:

Case 1	Case 2
Conduction Band	Conduction Band
Valence Band	Valence Band

Even when a small current is applied, conductors can conduct electricity.

Insulators: In case of insulators, the energy gap between the conduction and valence bands is very large and the conduction band is practically empty.

Conduction Band

↑

Forbidden Energy Gap

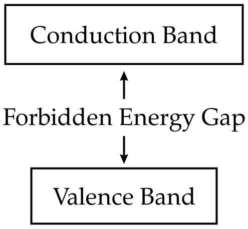
↓

Valence Band

When an electric field is applied to a semiconductor, the electrons in the valence band find it relatively easier to jump to the conduction band. So, the conductivity of semiconductors lies between the conductivity of conductors and insulators.

Semiconductors: In case of semiconductor, the energy band structure of semiconductors is similar to insulators, But in this case, the size of forbidden energy gap is quite smaller than that of the insulators.

* *Out of Syllabus*



When an electric field is applied to a semiconductor, the electrons in the valence band find it relatively easier to jump to the conduction band. So, the conductivity of semiconductors lies between the conductivity of conductors and insulators.

25. For the past some time, Arti had been observing some erratic body movement, unsteadiness and lack of coordination in the activities of her sister Radha, who also used to complain of severe headache occasionally. Aarti suggested to her parents to get a medical check-up of Radha. The doctor thoroughly examined Radha and diagnosed that she has a brain tumour. **3**

(a) What, according to you, are the values displayed by Aarti?

(b) How can radioisotopes help a doctor to diagnose brain tumour?

Ans. (a) Aarti has showed awareness and responsibility towards her sister.

(b) A little amount of radioisotope like radio iodine is inserted into the body along with organic dyes which are absorbed strongly by the tumor tissue than the normal tissues. By detecting the emitted radiation, the radiologist get information about the size and location of the tumor.

*** 26. Write two basic modes of communication. Explain the process of amplitude modulation. Draw a schematic sketch showing how amplitude modulated signal is obtained by superposing a modulating signal over a sinusoidal carrier wave.** **3**

*** 27. An electron microscope uses electrons accelerated by a voltage of 50 kV. Determine the de-Broglie wavelength associated with the electrons. Taking other factors, such as numerical aperture etc., to be same how does the resolving power of an electron microscope compare with that of an optical microscope which used yellow light?**

*** 28. Draw a labelled diagram of Van de Graff generator. State its working principle to show how by introducing a small charged sphere into larger sphere, large amount of charge can be transferred to the outer sphere. State the use of this machine and also point out its limitations.** **5**

OR

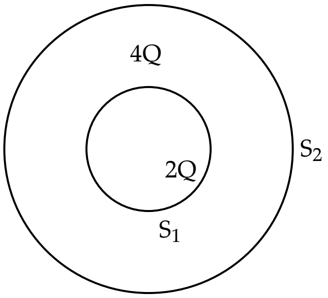
*** (a) Deduce the expression for the torque acting on a dipole of dipole moment $\vec{p}$ in the presence of a uniform electric field $\vec{E}$.**

(b) Consider two hollow concentric spheres, S_1 and S_2, enclosing charges 2Q and 4Q respectively as shown in the figure.

(i) Find out the ratio of the electric flux through them.

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

Deduce the necessary expression.



Ans. **OR**

(a) Consider an electric dipole consisting of charges $-q$ and $+q$ and of length $2a$ placed in a uniform electric field $\vec{E}$ making an angle θ with electric field.

Force on charge $-q$ at $A = -q\vec{E}$(opposite to $\vec{E}$)

Force on charge $+q$ at $B = +q\vec{E}$(along $\vec{E}$)

Electric dipole is under the action of two equal and unlike parallel force, which give rise to a torque on the dipole.

$$\tau = \text{Force} \times \text{Perpendicular distance between the two forces}$$

$$\tau = qE(AN) = qE(2a\sin\theta)$$

$$\tau = pE\sin\theta \qquad [\because 2qa = P]$$

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

(b) (i) Charge enclosed by sphere $S_1 = 2Q$

By Gauss' law, electric flux through sphere S_1 is

$$\phi_1 = \frac{2Q}{\varepsilon_0}$$

Charge enclosed by sphere S_2 is

$$Q' = 2Q + 4Q = 6Q$$

Electric flux through sphere S_2 is

$$\therefore \qquad \phi_2 = \frac{6Q}{\varepsilon_0}$$

The ratio of the electric flux is

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

* *Out of Syllabus*

(ii) For sphere S_1, the electric flux is

$$\phi' = \frac{2Q}{\varepsilon_r}$$

$$\therefore \quad \frac{\phi'}{\phi_1} = \frac{\varepsilon_0}{\varepsilon_r}$$

$$\Rightarrow \quad \phi' = \phi_1 \times \frac{\varepsilon_0}{\varepsilon_r}$$

$$\because \quad \varepsilon_r > \varepsilon_0$$

$$\therefore \quad \phi' < \phi_1$$

*** 29. (a) In Young's double slit experiment, describe briefly how bright and dark fringes are obtained on the screen kept in front of a double slit. hence obtain the expression for the fringe width.**

(b) The ratio of the intensities at minima to the maxima in the Young's double slit experiment is 9 : 25. Find the ratio of the widths of the two slits. **5**

OR

(a) Describe briefly how a diffraction pattern is obtained on a screen due to a single narrow slit illuminated by a monochromatic source of light. Hence obtain the conditions for the angular width of secondary maxima and secondary minima.

(b) Two wavelength s of sodium light of 590 nm and 596 nm are used in turn to study the diffraction taking place at a single slit of aperture 2×10^{-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 obtained in the two cases.

*** 30. (a) Deduce an expression for the frequency of revolution of a charged particle in a magnetic field and show that it is independent of velocity or energy of the particle.**

(b) Draw a schematic sketch of a cyclotron. Explain, giving the essential details of its construction, how it is used accelerate the charged particles. **5**

OR

(a) Draw a labelled diagram of a moving coil galvanometer. Describe briefly its principle and working.

(b) Answer the following:

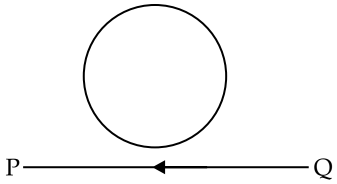
(i) Why is it necessary to introduce a cylindrical soft iron core inside the coil of a galvanometer.

(ii) Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity. Explain, giving reason.

Outside Delhi Set II — Code No. 2/1/2

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

1. 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. **1**



Ans. The magnetic field due to the wire in the coil in going into the paper. So, according to Lenz's Law, if magnetic field going inside is increasing as the current is increasing, the direction current in the loop should be such that the magnetic field into the paper decreases. Therefore, the current should be in anti-clockwise direction.

4. Why do the electrostatic field lines not form closed loops?

Ans. Since the electrostatic field is conservative in nature, electrostatic field lines do not form closed loops.

5. A biconvex lens made of a transparent material of refractive index 1.5 is immersed in water of refractive index 1.5 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason. **1**

Ans. The biconvex lens will now behave as a converging lens as the refractive index of water(1.33) is less than the refractive index of the material(1.5) of the lens.

7. To which part of the electromagnetic spectrum does a wave of frequency 3×10^{13} Hz belong?

Ans. It belongs to the infrared region.

9. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 2.5×10^{-7} m^2 carrying a current of 1.8 A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}. **2**

Ans. Given: Current (I) = 1.8 A

Charge density (n) = 9×10^{28} m^{-3}

Cross-section area (A) = 2.5×10^{-7} m^2

Charge of electron (q) = 1.6×10^{-19} C

$$v_d = \frac{I}{nAq}.$$

$$= \frac{1.8}{9 \times 10^{28} \times 2.5 \times 10^{-7} \times 1.6 \times 10^{-19}}$$

$$= 0.0005 \text{ m/s}$$

$$= 0.5 \text{ mm s}^{-1}$$

*** 13. Write the function of the following in communication systems:** **3**

(i) Transmitter

(ii) Modulator

*** 21. (a) Show with the help of a diagram, how unpolarised sunlight gets polarised due to scattering.**

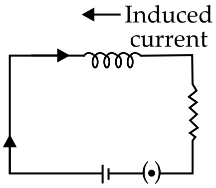
* *Out of Syllabus*

(b) 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 45° with that of P_1. Determine the intensity of light transmitted through P_1, P_2 and P_3.

22. Define the term self-inductance of a solenoid. Obtain the expression for the magnetic energy stored in an inductor of self-inductance I to build up a current I through it. 3

Ans. The ratio of magnetic flux through the solenoid to the current passing through it is called self-inductance of a solenoid. It is given by

$$L = \frac{\phi}{I}$$



Energy stored in an inductor: When a current grows through an inductor, a back e.m.f. is set up which opposes the growth of current. So work needs to be done against back e.m.f. (e) in building up the current. This work done is stored as magnetic potential energy.

Let I be the current through the inductor L at any instant t. The current rises at the rate $\frac{dI}{dt}$. So the induced e.m.f. is

$$e = \frac{-LdI}{dt}$$

The work done against induced e.m.f. in dt is

$$dW = Pdt$$

$$= -e\,Idt \qquad [P = VI]$$

$$= \frac{LdI}{dt}Idt$$

$$= LIdI$$

For total work from 0 to I_0 current

$$W = \int dW$$

$$= \int_0^{I_e} LIdI$$

$$= L\left[\frac{I^2}{2}\right]_0^{Io}$$

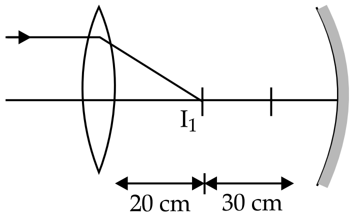
$$= \frac{1}{2}LI_0^2$$

Hence, this work done is stored as the magnetic potential energy U in the inductor

$$U = \frac{1}{2}LI^2$$

24. A convex lens of focal length 20 cm is placed coaxially with a concave mirror of focal length 10 cm at a distance of 50 apart from each other. A beam of light coming parallel to the principal axis is incident on the convex lens. Find the position of the final image formed by this combination. Draw the ray diagram showing the formation of the image. 5

Ans. The beem incident on lens L is parallel to principal axis. Hence, the lens forms an image I_1 at its focus, i.e., at a distanec $OI_1 = 20$ cm from the lens.



The image I_1 is formed in front of mirror and hence, acts as a real source for the mirror. The concave mirror forms the image I_2, whose distance from the mirror can be calculated as,

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

Here: $u = -30$ cm, and $f = -10$ cm

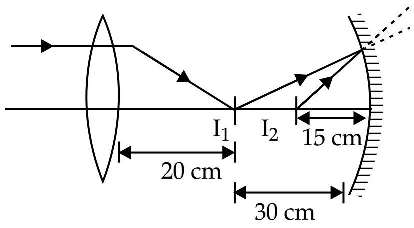
$$\Rightarrow \qquad \frac{1}{v} = \frac{1}{f}-\frac{1}{u}$$

$$\Rightarrow \qquad \frac{1}{v} = -\frac{1}{10}+\frac{1}{30}$$

$$\Rightarrow \qquad \frac{1}{v} = \frac{1-3}{30} = -\frac{2}{30}$$

$$\Rightarrow \qquad v = -15 \text{ cm}$$

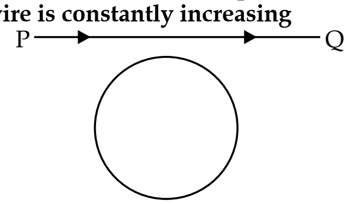
Hence, the final image is formed at a distance of 15 cm from the concave mirror, as shown in the following figure.



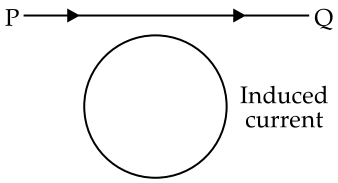
Outside Delhi Set III — Code No. 2/1/2

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

1. A conducting loop is held below a current carrying wire PQ as shown. Predict the direction of the induced current in the loop when the current in the wire is constantly increasing **1**



Ans. Anticlock wise direction



2. The graph shows variation of stopping potential V_0 versus frequency of incident radiation ν for two photosensitive metals A and B. Which of the two metals has higher threshold frequency and why? 1

Ans. Metal A has higher threshold frequency because from the graph it is clear that the minimum frequency required to start photo emission is more in A than that of B.

5. Why do the electric field lines never cross each other? **1**

Ans. At any point, if electric field lines cross each other than two tangents can be drawn, it means at that point there are two directions of electric field, which is impossible.

6. To which part of the electromagnetic spectrum does a wave of frequency 5×10^{11} Hz belong? **2**

Ans. A wave of frequency 5×10^{11} Hz will belong to the microwaves of electromagnetic spectrum.

10. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 2.5×10^{-7} m^2 carrying a current of 2.7 A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}. **2**

Ans. We know that drift velocity, $v_d = \dfrac{I}{nAq}$

Where I is the current, n is charge density, q is charge of electron and A is cross-sectional area.

$$v_d = \frac{27}{9\times10^{28}\times2.5\times10^{-7}\times1.6\times10^{-19}}$$

$$v_d = 7.5 \times 10^{-4} \text{ m/s}$$

or $$v_d = 0.75 \text{ mm s}^{-1}$$

This is the required average drift velocity.

*** 18. Write the functions of the following in communication systems:** **3**

(i) Receiver

(ii) Demodulator

19. A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept at 15 cm from each other. A point object placed 40 cm in front of the convex lens. Find the position of the image formed by this combination. Draw a ray diagram to show the formation.

Ans. Given, A = – 40 cm and, f = 20 cm

From the lens formula, we have:

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

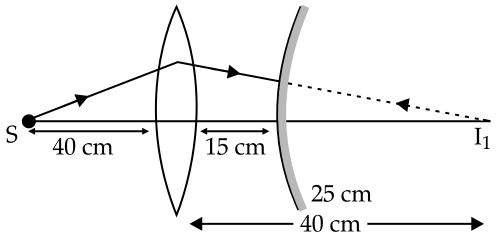
$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f} + \frac{1}{u}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{20} + \frac{1}{(-40)}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{2-1}{40} = \frac{1}{40}$$

$$\Rightarrow \quad v = 40 \text{ cm}$$

The positive sign describes that the image is formed to the right of the lens.



The image I_1 is formed behind the mirror and thus acts as a virtual source for the mirror. The convex mirror forms the image I_2, whose distance from the mirror is given by:

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

Here: $$u = 25 \text{ cm}$$

$$f = \frac{R}{2} = 10 \text{ cm}$$

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

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

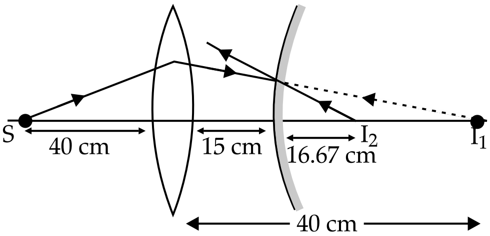
* *Out of Syllabus*

$$\Rightarrow \qquad \frac{1}{v} = \frac{1}{10} - \frac{1}{25}$$

$$\Rightarrow \qquad \frac{1}{v} = \frac{5-2}{50} = \frac{3}{50}$$

$$\Rightarrow \qquad v = +\,16.67 \text{ cm}$$

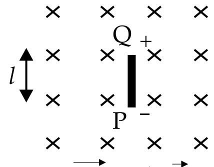
Hence, the final image is formed at a distance of 16.67 cm behind the convex mirror.



25. (a) A rod 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.

(b) How does one understand this motional emf by involving the Lorentz force acting on the free charge carriers of the conductor? Explain. 5

Ans. (a) Consider a rod PQ of length l moving in a magnetic field $\vec{B}$ with a constant velocity $\vec{v}$. The length of the rod is perpendicular to the magnetic field and also the velocity is perpendicular to both the rod and field. The free electrons of the rod also move at this velocity\overrightarrow{\mathrm{v}} because of which it experiences a magnetic force.



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

This force is towards Q to P.

Thus, the free electrons will move towards P and positive charge will appears at Q. An electrostatic field E is developed within the wire from Q to P. This field exerts a force.

$$\vec{F_e} = q\vec{E}$$

on each free electron. The charge keeps on gathering until

$$\vec{F_b} = \vec{F_e}$$

$$\Rightarrow \qquad |q\vec{v} \times \vec{B}| = |q\vec{E}|$$

$$vB = E$$

After this, resultant force on the free electrons of the wire PQ becomes zero. The potential difference between the ends Q and P is given by,

$$V = El = vBl$$

Thus, the potential difference is maintained by the magnetic force on the moving free electron and hence, produces an emf. $e = Bvl$

(b) Lorentz force acting on a charge q which is moving with a speed v in a (normal) uniform magnetic field B, is Bqv.

All the charges will experience the same force. Work done to move the charge from P to Q.

$$W = Bqv \times l$$

$$e = \frac{W}{q} = \frac{Bqvl}{q} = Blv$$

*** 26. (a) Show, giving via suitable diagram, how unpolarized light can be polarised by reflection.**

(b) 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° with that of P_1. Determine the intensity of light transmitted through P_1, P_2 and P_3. 5

* *Out of Syllabus*