Physics 2018

Time allowed : 3 hours | Maximum marks : 70

SECTION–A

1. **A proton and an electron travelling along parallel paths enter a region of uniform magnetic field, acting perpendicular to their paths. Which of them will move in a circular path with higher frequency? [1]**

Answer : Frequency of revolution of a particle,

$$f = \frac{Bq}{2\pi m}$$

or $$f \propto \frac{1}{m}$$

Since mass of electron is less than that of proton, therefore, its frequency of revolution will be higher than that of proton.

2. **Name the electromagnetic radiations used for (a) water purification, and (b) eye surgery. [1]**

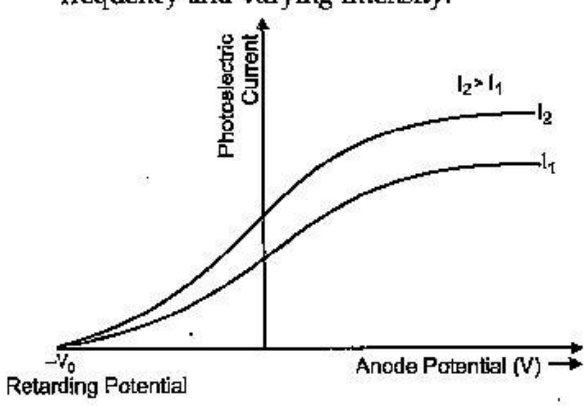
Answer :

(a) Water purification : Ultraviolet radiation.

(b) Eye surgery : Ultraviolet radiation/laser.

3. **Draw graphs showing variation of photoelectric current with applied voltage for two incident radiations of equal frequency and different intensities. Mark the graph for the radiation of higher intensity. [1]**

Answer : Graph for photoelectric current (I) versus applied potential for radiations of same frequency and varying intensity.



4. **Four nuclei of an element undergo fusion to form a heavier nucleus, with release of energy. Which of the two— the parent or the daughter nucleus—would have higher binding energy per nucleon? [1]**

Answer : When lighter nuclei combine to form a heavier nucleus, binding energy per nucleon increases and energy is released. Thus, the daughter nucleus would have higher binding energy per nucleon.

5. **Which mode of propagation is used by short wave broadcast services** [1]**

SECTION–B

6. **Two electric bulbs P and Q have their resistances in the ratio of 1 : 2. They are connected in series across a battery. Find the ratio of the power dissipation in these bulbs. [2]**

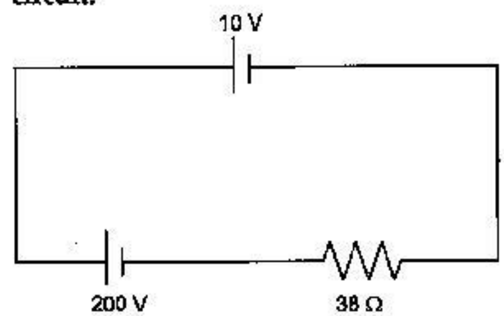
Answer : Let resistances of bulbs P and Q be R and 2R respectively.

As they are connected in series, so current through each bulb is same. Let the current be I.

$$\therefore \quad \frac{P_1}{P_2} = \frac{I^2R_1}{I^2R_2} = \frac{R_1}{R_2} = \frac{1}{2}$$

i.e. $$P_1 : P_2 = 1 : 2$$

7. **A 10 V cell of negligible internal resistance is connected in parallel across a battery of emf 200 V and internal resistance 38 Ω as shown in the figure. Find the value of current in the circuit. [2]**



OR

In a potentiometer arrangement for determining the emf of a cell, the balance point of the cell in open circuit is 350 cm. When a resistance of 9 Ω is used in the external circuit of the cell, the balance point shifts to 300 cm. Determine the internal resistance of the cell.

Answer: Given : $E_1 = 10$ V; $E_2 = 200$ V, $r = 38\ \Omega$, I = ?

Net emf, $E = E_2 - E_1$ (∵ two cells being in opposition)

$$= 200\text{ V} - 10\text{ V} = 190\text{ V}$$

$$\therefore \quad \text{Current, } I = \frac{\text{Net emf}}{\text{Resistance}} = \frac{190\text{ V}}{38\Omega} = 5\text{ A.}$$

OR

Balance point in open circuit, $l_1 = 350$ cm.

R = 9 Ω,

**Answers is not given due to change in the present Syllabus.

New balance point $l_2 = 300$ cm.
Internal resistance of a cell is given by,

$$r = R\left(\frac{l_1 - l_2}{l_2}\right) = 9\left(\frac{350-300}{300}\right) = 1.5\ \Omega.$$

8. (a) Why are infra-red waves often called heat waves ? Explain.

(b) What do you understand by the statement, "Electromagnetic waves transport momentum" ? **[1]**

Answer :

(a) Infra-red waves are called heat waves because they raise the temperature of the object on which they fall and hence increase their thermal motion. They also affect the photographic plate and are readily absorbed by most of the materials.

(b) Electromagnetic waves transport momentum. This means that when an electromagnetic wave travels through space with energy U and speed c, then it transports linear momentum $p = \frac{U}{c}$. If a surface absorbs the waves completely, then momentum 'p' is delivered to the surface. If the surface reflects the wave, then momentum delivered by both incident and reflected wave adds on to give '$2p$' momentum.

9. If light of wavelength 412.5 nm is incident on each of the metals given below, which ones will show photoelectric emission and why? **[2]**

Metal	Work Function (eV)
Na	1.92
K	2.15
Ca	3.20
Mo	4.17

Answer : Wavelength of incident light,

$$\lambda = 412.5 \text{ nm}$$
$$= 412.5 \times 10^{-9} \text{m}$$

∴ Energy of incident light

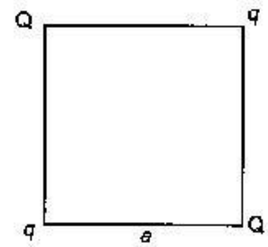
$$E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{412.5\times10^{-9}}$$
$$= 4.82 \times 10^{-19} \text{J}$$
$$= \frac{4.82\times10^{-19}}{1.6\times10^{-19}} \text{eV}$$
$$= 3.01 \text{ eV}$$

Since, the energy of incident radiation is greater than the work function of sodium and potassium, but less than that of calcium and molybdenum, therefore, photoelectric emission will take place in sodium and potassium.

10. A carrier wave of peak voltage 15 V is used to transmit a message signal. Find the peak voltage of the modulating signal in order to have a modulation index of 60%.** **[2]**

SECTION–C

11. Four point charges Q, q, Q and q are placed at the corners of a square of side 'a' as shown in the figure.



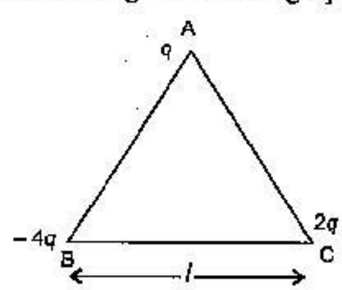
Find the

(a) resultant electric force on a charge Q, and

(b) potential energy of this system. **[3]**

OR

(a) Three point charges q, $-4q$ and $2q$ are placed at the vertices of an equilateral triangle ABC of side 'l' as shown in the figure. Obtain the expression for the magnitude of the resultant electric force acting on the charge q.



(b) Find out the amount of the work done to separate the charges at infinite distance.

Answer : (a) Force on charge Q at B due to charge q at A

$$F_1 = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{a^2} \text{ along } \overline{BY}$$

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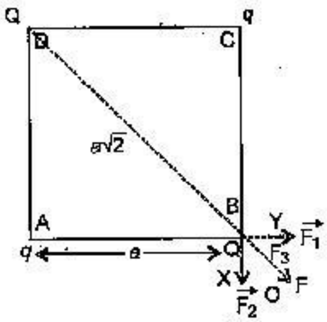


Force on charge Q at B due to charge q at c.

$$F_2 = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{a^2} \text{ along } \overline{BX}$$

Resultant force, $F = \sqrt{F_1^2 + F_2^2}$ along $\overrightarrow{BO}$

$$= \sqrt{2\left(\frac{1}{4\pi\varepsilon_0}\frac{qQ}{a^2}\right)^2}$$

$$= \frac{qQ\sqrt{2}}{4\pi\varepsilon_0 a^2}$$

Force due to charge Q = F_3

$$= \frac{1}{4\pi\varepsilon_0}\frac{QQ}{(\sqrt{2}a)^2} \text{ along } \overrightarrow{BO}$$

Total resultant force = F + F_3 along $\overrightarrow{BO}$

$$= \frac{1}{4\pi\varepsilon_0}\frac{\sqrt{2}\,Qq}{a^2} + \frac{1}{4\pi\varepsilon_0}\frac{QQ}{2a^2}$$

$$= \left[\frac{1}{4\pi\varepsilon_0}\frac{Q}{a^2}\left(\sqrt{2}q + \frac{Q}{2}\right)\right] \text{ along } \overrightarrow{BO}$$

(b) Total potential energy of the system,

$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{Qq}{a} + \frac{Qq}{a} + \frac{Qq}{a} + \frac{Qq}{a} + \frac{QQ}{\sqrt{2}a} + \frac{qq}{\sqrt{2}a}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{4Qq}{a} + \frac{Q^2}{\sqrt{2}a} + \frac{q^2}{\sqrt{2}a}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[4Qq + \frac{Q^2 + q^2}{\sqrt{2}}\right]$$

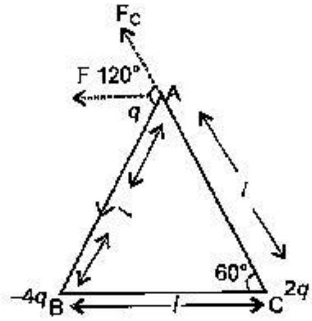
OR

(a) Electric force at A due to charge $2q$

$$F_C = \frac{1}{4\pi\varepsilon_0}\frac{q \times 2q}{l^2} \text{ along } \overrightarrow{CA}$$

Electric force at A due to charge $(-4q)$,

$$F_B = \frac{1}{4\pi\varepsilon_0}\frac{q \times (-4q)}{l^2} \text{ along } \overrightarrow{AB}$$



Resultant force,

$$F = \sqrt{F_B^2 + F_C^2 + 2F_BF_C \cos 120^\circ}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q^2}{l^2}\sqrt{(-4)^2 + (2)^2 + 2(-4)(2)\left(-\frac{1}{2}\right)}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2\sqrt{7}q^2}{l^2}$$

(b) Work done to separate the charges to infinity :

Initial potential energy,

$$U_i = \frac{1}{4\pi\varepsilon_0}\left[\frac{(-4q)q}{l} + \frac{(-4q)(2q)}{l} + \frac{(q)(2q)}{l}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q^2}{l}[-4-8+2]$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{-10q^2}{l}\right)$$

Final potential energy, $U_f = 0$

Thus, work done

$$= U_f - U_i = 0 - \left(\frac{-10q^2}{4\pi\varepsilon_0 l}\right) = \frac{10q^2}{4\pi\varepsilon_0 l} = \frac{5q^2}{2\pi\varepsilon_0 l}$$

12. (a) Define the term 'conductivity' of a metallic wire. Write its SI unit.

(b) Using the concept of free electrons in a conductor, derive the expression for the conductivity of a wire in terms of number density and relaxation time. Hence obtain the relation between current density and the applied electric field E. [3]

Answer :

(a) Conductivity of a metallic wire is defined as its ability to allow electric charges or heat to pass through it.

Numerically, conductivity of a material is reciprocal of its resistivity.

SI unit : $ohm^{-1}\ m^{-1}$ or mho m^{-1} or Siemen m^{-1}.

(b) Consider a potential difference V be applied across a conductor of length l and cross-section A.

Electric field inside the conductor, $E = \frac{V}{l}$.

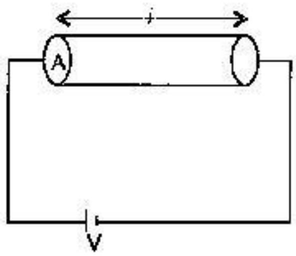
Due to the external field the free electrons inside the conductor drift with velocity v_d.

Let, number of electrons per unit volume = n,

charge on an electron = e

$\therefore$ Total electrons in length, $l = nAl$

And, total charge, $q = neAl$



Time taken by electrons to enter and leave the conductor,

$$t = \frac{l}{v_d}$$

$$\text{Current, } I = \frac{q}{t} = \frac{neAl}{l/v_d}$$

$$= neAv_d$$

$$\text{Current density, } J = \frac{I}{A} = nev_d \quad ....(i)$$

We know, $$v_d = \frac{eE\tau}{m} = \frac{eV\tau}{ml}$$

$$\therefore \quad I = neAv_d = \frac{neAVe\tau}{ml}$$

$$\Rightarrow \quad \frac{V}{I} = \frac{ml}{ne^2\tau A}$$

$$\Rightarrow \quad R = \frac{ml}{ne^2\tau A}$$

$$[\because \frac{V}{I} = R;\ \text{Ohm's law}]$$

Resistivity, $$\rho = \frac{RA}{l} = \frac{mlA}{ne^2\tau A \times e}$$

or $$\rho = m/ne^2\tau$$

Since conductivity, $$\sigma = \frac{1}{\rho}$$

$$\therefore \quad \sigma = \frac{ne^2\tau}{m} \quad ....(ii)$$

Relation between current density and field :

For an electron, charge $q = -e$

And,

$$\text{current density, } J = \frac{I}{A} = -nev_d \quad [\text{from (i)}]$$

$$J = (-ne)\left(\frac{eE\tau}{m}\right)$$

$$= \left(\frac{ne^2\tau}{m}\right)E$$

$$\Rightarrow \quad J = \sigma E \quad [\text{from (ii)}]$$

which is the required relation.

13. A bar magnet of magnetic moment 6 J/T is aligned at 60° with a uniform external magnetic field of 0.44 T. Calculate (a) the work done in turning the magnet to align its magnetic moment (i) normal to the magnetic field, (ii) opposite to the magnetic field, and (b) the torque on the magnet in the final orientation in case (ii). [3]

Answer : Given, magnetic momentum, $m = 6\ JT^{-1}$

External magnetic field, B = 0.44 T

$\theta_1 = 60° \Rightarrow \cos\theta_1 = \cos 60° = \frac{1}{2}$.

(a) Work done in turning the magnet normal to the field,

$$W = -mB(\cos\theta_2 - \cos\theta_1)$$

(i) Here, $\theta_2 = 90°$

$$\therefore \quad W = +mB\cos\theta_1$$

$$= 6 \times 0.44 \times \frac{1}{2} = 1.32\ J$$

(ii) Here $\theta_2 = 180°$

$$\therefore \quad W = -mB(\cos\theta_2 - \cos\theta_1)$$

$$W = -6 \times 0.44\left(-1 - \frac{1}{2}\right)$$

$$= 3.96\ J$$

(b) Torque on magnet when moment is aligned opposite to the field,

$$\text{Torque} = |\vec{m} \times \vec{B}|$$

$$\tau = mB\sin\theta$$

$$= 6 \times 0.44 \times \sin 180°$$

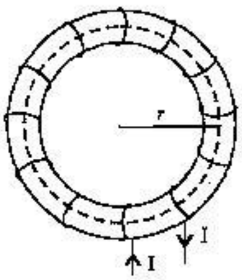
$$= 0 \quad (\because \sin 180° = 0)$$

14. (a) An iron ring of relative permeability μ_r has windings of insulated copper wire of n turns per metre. When the current in the windings is I, find the expression for the magnetic field in the ring.

(b) **The susceptibility of a magnetic material is 0.9853. Identify the type of magnetic material. Draw the modification of the field pattern on keeping a piece of this material in a uniform magnetic field.** **[3]**

Answer : (a) Consider a ring of radius r having n turns per metre. Then total number of turns in the ring $= 2\pi rn = N$

Current enclosed $= NI = 2\pi rnI$.



By Ampere's circuital law, $\oint \vec{B}.\vec{dl} = \mu_0 \mu r I$

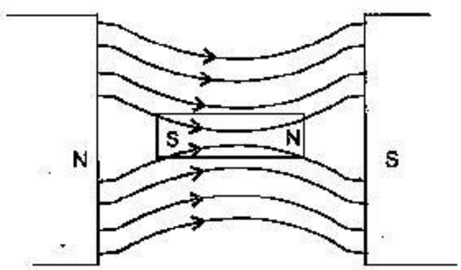
$$B \times 2\pi r = \mu_0 \mu r 2\pi r n I$$

or $$B = \mu_0 \mu r n I$$

(b) Given, susceptibility, $\chi = 0.9853$.

The material is paramagnetic in nature.

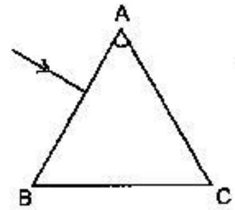
If a piece of this material is kept in uniform magnetic field, then field pattern gets modified as follows :



The lines of force tend to pass through the material rather than the surrounding air.

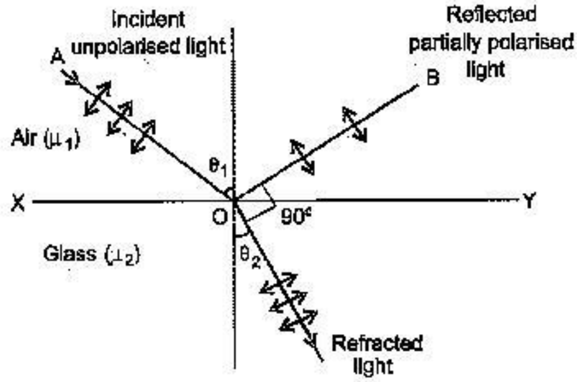
15. **(a) Show using a proper diagram how unpolarised light can be linearly polarised by reflection from a transparent glass surface.**

(b) The figure shows a ray of light falling normally on the face AB of an equilateral glass prism having refractive index $\frac{3}{2}$, placed in water of refractive index $\frac{4}{3}$. Will this ray suffer total internal reflection on striking the face AC ? Justify your answer. **[3]**



Answer :

(a) Polarisation of light by reflection from a transparent glass surface :



(b) Given, $^a\mu_g = \frac{3}{2}$ and $^a\mu_g = \frac{4}{3}$

$$^w\mu_g = \frac{^a\mu_g}{^a\mu_w} = \frac{3/2}{4/3} = \frac{9}{8} = 1.125$$

We know at critical angle C,

$$^w\mu_g = \frac{1}{\sin C}$$

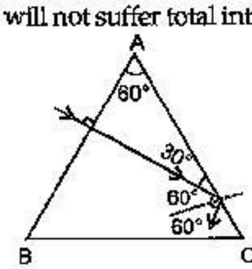
or $$\sin C = \frac{1}{^w\mu_g} = \frac{1}{1.125} = 0.88$$

i.e. $$C = 62.73°$$

But from the figure, light will incident on face AC making an angle 60° with the normal *i.e.*, $i = 60°$

So, $i < C$

∴ Light will not suffer total internal reflection.



16. **(a) If one of two identical slits producing interference in Young's experiment is covered with glass, so that the light intensity passing through it is reduced**

to 50%, find the ratio of the maximum and minimum intensity of the fringe in the interference pattern.

(b) What kind of fringes do you expect to observe if white light is used instead of monochromatic light? [3]

Answer : (a) The resultant intensity in Young's experiment is given by

$$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

When slit is not covered, then I_0 is the intensity from each slit.

Maximum intensity (I_{max}) occurs when $\phi = 0°$.

Minimum intensity (I_{min}) occurs when $\phi = 180°$.

If one slit is covered with glass to reduce its intensity by 50%, then

$$I_{max} = I_0 + \frac{I_0}{2} + 2\sqrt{I_0 \times \frac{I_0}{2}}\cos 0°$$

$$= 1.5\,I_0 + 2 \times 0.707\,I_0 = 2.914\,I_0$$

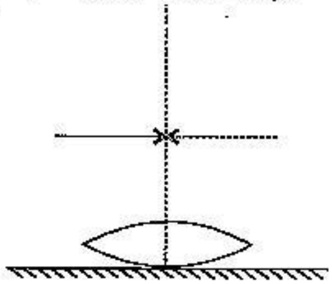
$$I_{min} = I_0 + \frac{I_0}{2} + 2\sqrt{I_0 \times \frac{I_0}{2}}\cos 180°$$

$$= 1.5\,I_0 - 2 \times 0.707\,I_0 = 0.086\,I_0$$

$$\text{Ratio} = \frac{I_{max}}{I_{min}} = \frac{2.914 I_0}{0.086 I_0} = 33.884 \approx 34$$

(b) If instead of monochromatic light, white light is used, then the central fringe will be white and the fringes on either side will be coloured. Blue colour will be nearer to central fringe and red will be farther away. The path difference at the centre on perpendicular bisector of slits will be zero for all colours and each colour produces a bright fringe thus resulting in white fringe. Further, the shortest visible wave, blue, produces a bright fringe first.

17. A symmetric biconvex lens of radius of curvature R and made of glass of refractive index 1.5, is placed on a layer of liquid placed on top of a plane mirror as shown in the figure. An optical needle with its tip on the principal axis of the lens is moved along the axis until its real, inverted image coincides with the needle itself. The distance of the needle from the lens is measured to be x. On removing the liquid layer and repeating the experiment, the distance is found to be y. Obtain the expression for the refractive index of the liquid in terms of x and y. [3]



Answer :

Given, refractive index of lens, $\mu_g = 1.5$

The distance of the needle from the lens in the first case = The focal length of the combination of convex lens and plano-concave lens formed by the liquid, $f = x$

And, the distance measured in the second case = Focal length of the convex lens, $f_1 = y$

If the focal length of plano-concave lens formed by the liquid be f_2, then

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\Rightarrow \quad \frac{1}{f_2} = \frac{1}{f} - \frac{1}{f_1} = \frac{1}{x} - \frac{1}{y}$$

$$= \frac{y-x}{xy}$$

$$\text{or} \quad f_2 = \frac{xy}{y-x}$$

Now, refractive index of lens, $\mu = 1.5$, radius of curvature of one surface = R and radius of curvature of other surface = $-$R

$$\therefore \quad \frac{1}{f_1} = (\mu_g - 1)\left(\frac{1}{R} - \frac{1}{-R}\right)$$

$$\frac{1}{y} = (1.5 - 1)\left(\frac{2}{R}\right) \Rightarrow R = y$$

And, if refractive index of liquid is μ_l,

Radius of curvature on the side of plane mirror = ∞

Radius of curvature on the side of lens = $-$R

$$\because \quad \frac{y-x}{xy} = (\mu_l - 1)\left(\frac{1}{-R} - \frac{1}{\infty}\right)$$

$$= (\mu_l - 1)\left(-\frac{1}{y}\right)$$

$$\Rightarrow \quad (\mu_l - 1) = -\left(\frac{y-x}{x}\right)$$

$$\text{or} \quad \mu_l = \frac{x-y}{x} + 1$$

$$= \frac{2x-y}{x}$$

18. (a) **State Bohr's postulate to define stable orbits in hydrogen atom. How does de Broglie's hypothesis explain the stability of these orbits ?**

(b) **A hydrogen atom initially in the ground state absorbs a photon which excites it to the $n = 4$ level. Estimate the frequency of the photon.** **[3]**

Answer : (a) Bohr's postulate for stable orbits in hydrogen atom : An electron can revolve only in those circular orbits in which its angular momentum is an integral multiple of $h/2\pi$, where h is planck's constant.

If n is the principal quantum number of orbit, then an electron can revolve only in certain orbits or definite radii. These are called stable orbits.

de Broglie explanation of stability of orbits: According to de Broglie, orbiting electron around the nucleus is associated with a stationary wave. Electron wave is a circular standing wave. Since destructive interference will occur if a standing wave does not close upon itself, only those de Broglie waves exist for which the circumference of circular orbit contains a whole number of wavelengths *i.e.,* for orbit circumference of n^{th} orbit as $2\pi r_n$,

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

$$2\pi r_n = n\left(\frac{h}{mv}\right)$$

or $$mvr_n = n\left(\frac{h}{2\pi}\right)$$

which is quantum condition proposed by Bohr.

(b) In ground state, $n = 1$

In excited state, $n = 4$

$$\frac{1}{\lambda} = R\left[\frac{1}{(1)^2} - \frac{1}{(4)^2}\right], \text{ where R is Rydberg constant}$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{15}{16} = 10284375$$

$$\doteq 1.028 \times 10^7 \, m^{-1}$$

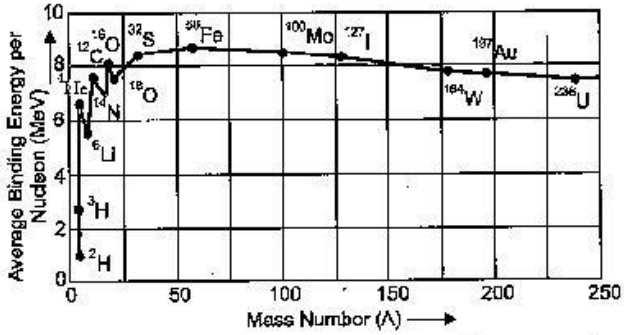
$$\text{Frequency, } \nu = \frac{c}{\lambda} = 3 \times 10^8 \times 1.028 \times 10^7$$

$$= 3.09 \times 10^{15} \text{ Hz}$$

19. (a) **Explain the processes of nuclear fission and nuclear fusion by using the plot of binding energy per nucleon (BE/A) versus the mass number A.**

(b) **A radioactive isotope has a half-life of 10 years. How long will it take for the activity to reduce to 3.125% ?** **[3]**

Answer : (a) Plot of binding energy per nucleon mass number :



1. When we move from the heavy nuclei region to the middle region of the plot, we find that there will be a gain in the overall binding energy and hence results in release of energy. This indicates that energy can be released when a heavy nucleus (A ≈ 240) breaks into two roughly equal fragments. This process is called nuclear fission.
2. Similarly, when we move from lighter nuclei to heavier nuclei, we again find that there will be gain in the overall binding energy and hence release of energy takes place. This indicates that energy can be released when two or more lighter nuclei fuse together to form a heavy nucleus. This process is called nuclear fusion.

(b) We know that, $\frac{R}{R_0} = \left(\frac{1}{2}\right)^n$

Given, $\frac{R}{R_0} = 3.125\% = \frac{3.125}{100}$

$\therefore$ $\frac{3.125}{100} = \left(\frac{1}{2}\right)^n$

or $\frac{1}{32} = \left(\frac{1}{2}\right)^n$

$\Rightarrow$ $\left(\frac{1}{2}\right)^5 = \left(\frac{1}{2}\right)^n$

$\Rightarrow$ $n = 5$

Given, T = 10 years

As $n = \frac{t}{T}$

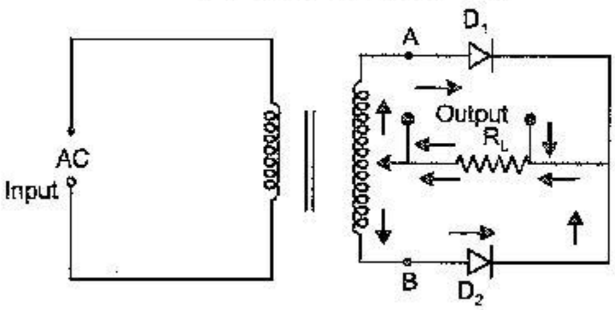
$\therefore$ $\frac{t}{T} = 5$ [$\because$ T = 10 year]

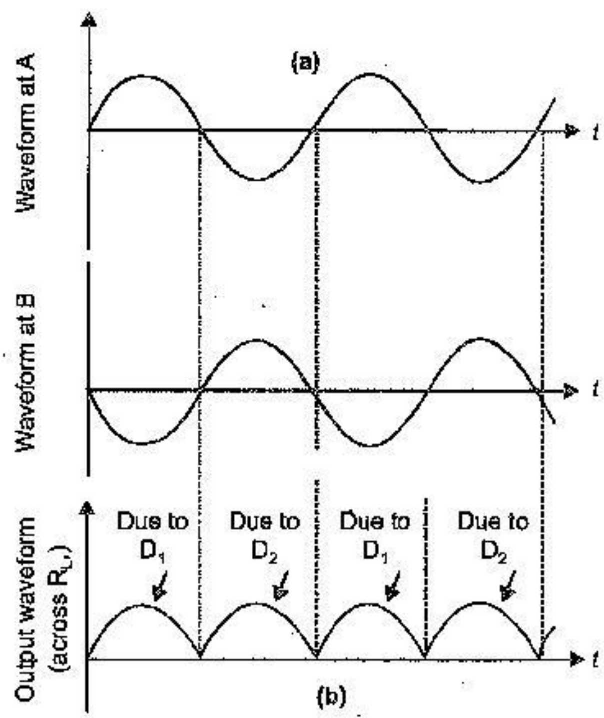
or $t = 5 \times 10 = 50$ years

20. (a) **A student wants to use two *p-n* junction diodes to convert alternating current into direct current. Draw the labelled circuit diagram she would use and explain how it works.**

(b) **Give the truth table and circuit symbol for NAND gate.**** **[3]**

Answer : (a) Full wave rectifier :





Explanation : In positive half cycle of AC, end A becomes positive and D_1 becomes forward biased and D_2 is reverse biased, so D_1 conducts and D_2 doesn't. So conventional current flows through D_1, R_L and upper half of secondary winding. Similarly, during negative half cycle of AC, diode D_2 becomes forward biased and D_1 is reverse biased, current flows through D_2, R_L and lower half of secondary winding. Thus, current flows in same direction in both half cycles of input AC voltage.

21. Draw the typical input and output characteristics of an *n-p-n* transistor in CE configuration. Show how these characteristics can be used to determine (a) the input resistance (r_i), and (b) current amplification factor (β).** **[3]**

22. **(a) Give three reasons why modulation of a message signal is necessary for long distance transmission.****

(b) Show graphically an audio signal, a carrier wave and an amplitude modulated wave.** **[3]**

SECTION–D

23. **The teachers of Geeta's school took the students on a study trip to a power generating station, located nearly 200 km away from the city. The teacher explained that electrical energy is transmitted over such a long distance to their city, in the form of alternating current (ac) raised to a high voltage. At the receiving end in the city, the voltage is reduced to operate the devices. As a result, the power loss is reduced. Geeta listened to the teacher and asked questions about how the ac is converted to a higher or lower voltage. [4]**

(a) Name the device used to change the alternating voltage to a higher or lower value. State one cause for power dissipation in this device.

(b) Explain with an example, how power loss is reduced if the energy is transmitted over long distances as an alternating current rather than a direct current.

(c) Write two values each shown by the teachers and Geeta.**

Answer : (a) The device used to change alternating voltage to a higher or lower value is a transformer.

Causes of power dissipation in this device are :

1. Core losses due to eddy currents and hysteresis loop due to alternating flux.
2. Copper losses due to resistance of winding in primary and secondary coils.

**Answers is not given due to change in the present Syllabus.

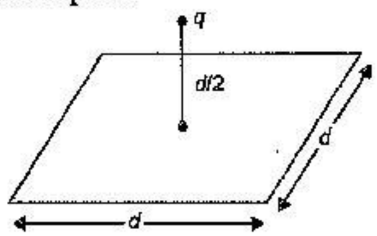
3. Loss of power due to leakage of magnetic flux in coil.

(b) The loss of power in the transmission lines is I^2R, where I is the strength of current and R is the resistance of the wires. To reduce the power loss a.c. is transmitted over long distances at extremely high voltages. This reduces I in the same ratio. Therefore, I^2R becomes negligibly low.

For the same reason, at the generating stations, the voltage is stepped up to transmit it over long distances to minimize power loss. Therefore a.c. is used because stepping up is not possible for direct current.

SECTION–E

24. **(a) Define electric flux. Is it a scalar or a vector quantity ? A point charge q is at a distance of $d/2$ directly above the centre of a square of side d, as shown in the figure. Use Gauss' law to obtain the expression for the electric flux through the square.**



(b) If the point charge is now moved to a distance 'd' from the centre of the square and the side of the square is doubled, explain how the electric flux will be affected. **[5]**

OR

(a) Use Gauss' law to derive the expression for the electric field (E) due to a straight uniformly charged infinite line of charge density λ C/m.

(b) Draw a graph to show the variation of E with perpendicular distance r from the line of charge.

(c) Find the work done in bringing a charge q from perpendicular distance r_1 to r_2 ($r_2 > r_1$).

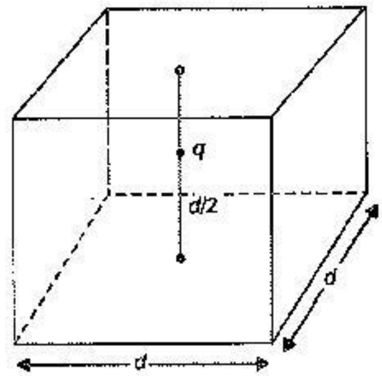
Answer : (a) Electric flux : Electric flux through an area is defined as the product of electric field strength E and area dS perpendicular to the field. It represents the field lines crossing the area. It is a scalar quantity. Imagine a cube of edge d, enclosing the charge. The square surface is one of the six faces of this cube. According to Gauss' theorem in electrostatics,

Total electric flux through the cube = $\frac{q}{\varepsilon_0}$

This is the total flux through all six surface

∴ Electric flux through the square surface

$$= \frac{q}{6\varepsilon_0}$$



(b) On moving the charge to distance d from the centre of square and making side of square $2d$, does not change the flux at all because flux is independent of side of square or distance of charge in this case.

OR

(a) Electric field ($\vec{E}$) due to a straight uniformly charged infinite line of charge density λ : Consider a cylindrical Gaussian surface of radius r and length l coaxial with line charge. The cylindrical Gaussian surface may be divided into three parts : (i) curved surface S_1 (ii) flat surface S_2 and (iii) flat surface S_3.

By symmetry, the electric field has the same magnitude E at each point of curved surface S_1 and is directed radially outward. We consider small elements of surfaces S_1, S_2 and S_3. The surface element vector $d\vec{S}$ is directed along the direction of electric field (*i.e.*, angle between $\vec{E}$ and $d\vec{S_1}$ is 0°); the elements $d\vec{S_2}$ and $d\vec{S_3}$ are directed perpendicular to field vector $\vec{E}$ (*i.e.*, angle between $d\vec{S_2}$ and $\vec{E}$, and $d\vec{S_3}$ and $\vec{E}$ is 90°).

Electric flux through the cylindrical surface,

$$\oint_S \vec{E}.d\vec{S} = \oint_{S_1} \vec{E}.d\vec{S_1} + \oint_{S_2} \vec{E}.d\vec{S_2} + \oint_{S_3} \vec{E}.d\vec{S_3}$$

$$= \oint_{S_1} E\,dS_1 \cos 0° + \oint_{S_2} E\,dS_2 \cos 90° + \oint_{S_3} E\,dS_3 \cos 90°$$

$$= E\int dS_1 - 0 + 0$$

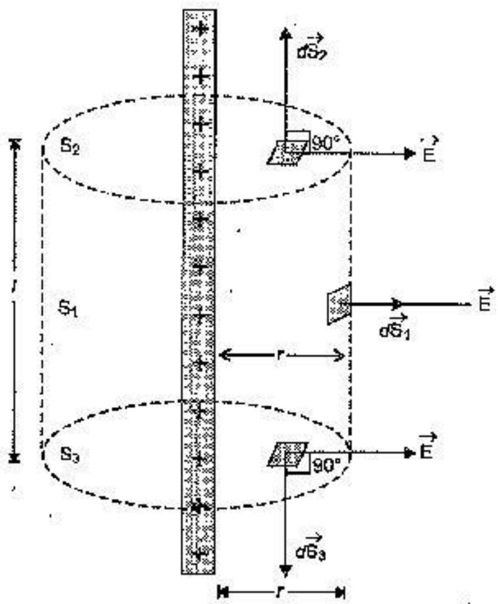
$$= E \times \text{area of curved surface} = E \times 2\pi r l$$

Total Charge enclosed, $q = \lambda l$
and flux,
By Gauss' theorem,

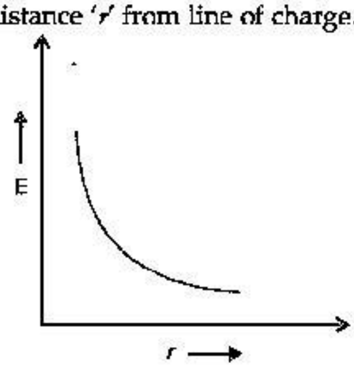
$$\phi_E = \frac{\lambda l}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$$

$$E.\ 2\pi r l = \frac{\lambda l}{\varepsilon_0}$$

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



(b) Graph showing variation of E with perpendicular distance from line of charge : The electric field is inversely proportional to distance 'r' from line of charge.



(c) Work done in bringing a charge q through a small displacement 'dr'.

$$dW = \vec{F}.\vec{dr}$$

$$dW = q\vec{E}.\vec{dr}$$

$$= qEdr\cos 0^\circ$$

$$dW = q \times \frac{\lambda}{2\pi\varepsilon_0 r} dr$$

Work done in moving the given charge from r_1 to r_2 $(r_2 > r_1)$

$$W = \int_{r_1}^{r_2} dW = \int_{r_1}^{r_2} \frac{\lambda q\, dr}{2\pi\varepsilon_0 r}$$

$$W = \frac{\lambda q}{2\pi\varepsilon_0}[\log_e r_2 - \log_e r_1]$$

$$W = \frac{\lambda q}{2\pi\varepsilon_0}.\log^e\left(\frac{r_2}{r_1}\right)$$

25. **(a) State the principle of an ac generator and explain its working with the help of a labelled diagram. Obtain the expression for the emf induced in a coil having N turns each of cross-sectional area A, rotating with a constant angular speed 'ω' in a magnetic field $\vec{B}$, directed perpendicular to the axis of rotation.**

(b) An aeroplane is flying horizontally from west to east with a velocity of 900 km/hour. Calculate the potential difference developed between the ends of its wings having a span of 20 m. The horizontal component of the Earth's magnetic field is 5×10^{-4} T and the angle of dip is 30°. **[5]**

OR

A device X is connected across an ac source of voltage $V = V_0 \sin \omega t$. The current through X is given as $I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$

(a) Identify the device X and write the expression for its reactance.

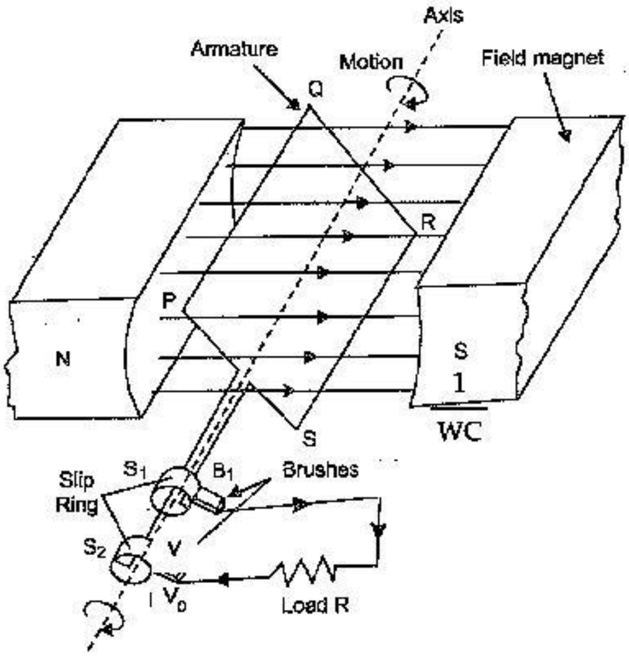
(b) Draw graphs showing variation of voltage and current with time over one cycle of ac, for X.

(c) How does the reactance of the device X vary with frequency of the ac? Show this variation graphically.

(d) Draw the phasor diagram for the device X.

Answer : (a) Principle of ac generator : The ac generator is based on the principle of electromagnetic induction. When closed coil is rotated in a uniform field with its axis perpendicular to field, then magnetic flux changes and emf is induced.

Working : When the armature coil rotates, the magnetic flux linked with it changes and produces induced current. If initially, coil PQRS is in vertical position and rotated clockwise, then PQ moves down and SR moves up. By Fleming's right hand rule, induced current flows from Q to P and S to R which is the first half rotation of coil. Brush B_1 is positive terminal and B_2 is negative. In second half rotation, PQ moves up and SR moves down. So induced current reverses and the alternating current is produced in this manner by the generator.



Expression for emf indı $\frac{3\pi}{2}$l : If number of turns in coil = N, cross-section = A, angular speed of rotation = ω, magnetic field = $\vec{B}$, then to find emf induced,

Flux through the coil when its normal makes angle θ with the field,

$$\phi = BA \cos \theta$$

When coil rotates with angular velocity ω and turns through θ in time 't' then $\theta = \omega t$

$$\Rightarrow \quad \phi = BA \cos \omega t$$

When coil rotates, ϕ changes to set an induced emf.

$$\varepsilon = \frac{-d\phi}{dt} = -\frac{d}{dt}(BA \cos \omega t)$$

$$= BA\,\omega \sin \omega t$$

For N turns, total induced emf,

$$\varepsilon = NBA\,\omega \sin \omega t$$

(b) Given : Velocity (v)

$$= 900 \text{ km/h} = 900 \times \frac{5}{18} \text{ m/s}$$

$$= 250 \text{ ms}^{-1}$$

Wing span (l) = 20 m

Horizontal component of earth's field (B_H) $= 5 \times 10^{-4}$ T

Angle of dip (δ) = 30°

Pontential difference

$$B_V = B_H \tan \delta$$

$$= 5 \times 10^{-4} \times \tan 30^\circ$$

$$= 5 \times 10^{-4} \times \frac{1}{1.732}$$

emf induced $= B_V\, lv$

$$= \frac{5\times10^{-4}}{1.732} \times 20 \times 250$$

$$= 1.44\text{V}$$

OR

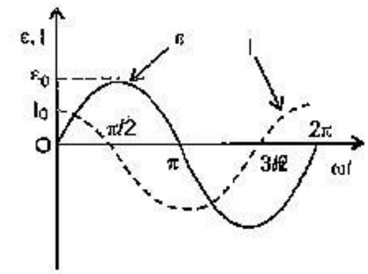
$$V = V_0 \sin \omega t\,;\; I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right).$$

(a) Since current leads the voltage by $\frac{\pi}{2}$ radians, X is a capacitor.

Capacitive reactance, $X_C = \quad = \frac{1}{2\pi f\,C}$

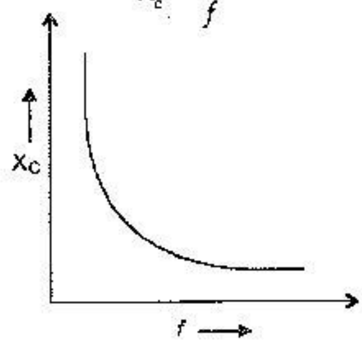
where, ω = angular velocity, C = capacitance.

(b)

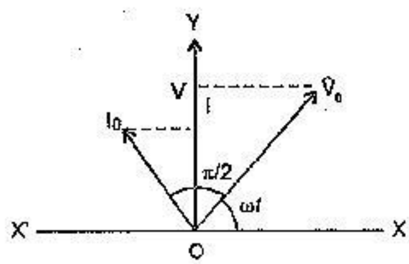


(c) Capacitive reactance varies inversely with frequency as $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

$$X_c \propto \frac{1}{f}$$



(d)



26. (a) Draw a ray diagram to show image formation when the concave mirror produces a real, inverted and magnified image of the object.

(b) Obtain the mirror formula and write the expression for the linear magnification.

(c) Explain two advantages of a reflecting

telescope over a refracting telescope. [5]

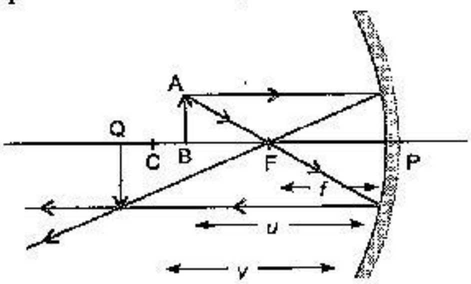
OR

(a) Define a wavefront. Using Huygens' principle, verify the laws of reflection at a plane surface.

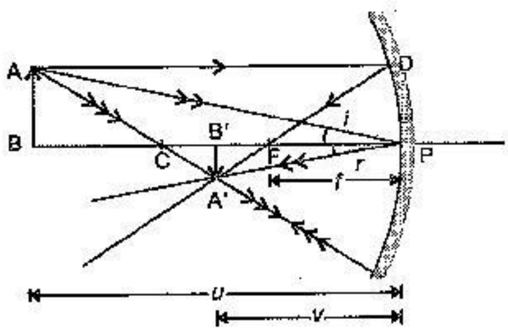
(b) In a single slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band ? Explain.

(c) When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the obstacle. Explain why ?

Answer : (a) Concave mirror produces real, inverted and magnified image for object placed between F and C :



(b) Derivation for mirror formula and magnification: Consider an object AB be placed in front of a concave mirror beyond centre of curvature C.



If F is the focus, focal length = f; object distance = u; image distance = v

As Δs ABC and A'B'C are similar,

$$\frac{AB}{A'B'} = \frac{CB}{CB'} \quad \text{... (i)}$$

Again, as Δs ABP and A'B'P are similar

$$\frac{AB}{A'B'} = \frac{PB}{B'P} \quad \text{... (ii)}$$

$$\Rightarrow \quad \frac{CB}{CB'} = \frac{PB}{PB'} \quad \text{... (iii)}$$

$$\therefore \text{ From (iii), } \frac{PB-PC}{PC-PB'} = \frac{PB}{PB'}$$

$$\Rightarrow \quad \frac{-u+R}{-R+v} = \frac{-u}{v}$$

$[\because PB = -u, PC = -R, PB' = -v]$

$$\Rightarrow \quad uR + vR = 2uv$$

$$\Rightarrow \quad \frac{1}{v} + \frac{1}{u} = \frac{2}{R}$$

$$\Rightarrow \quad \boxed{\frac{1}{v} + \frac{1}{u} = \frac{1}{f}} \quad (\because R = 2f)$$

$$\text{Linear magnification, } m = \frac{\text{Image height } (h_i)}{\text{Object height } (h_0)}$$

$$\text{From equation (ii), } \frac{A'B'}{AB} = \frac{PB'}{PB}$$

Using new Cartesian sign conventions, $A'B' = -h_2$, $AB = +h_1$, $PB' = -v$, $PB = -u$

$$\therefore \quad \frac{h_2}{h_1} = \frac{-v}{u} = \frac{v}{u}$$

$$\text{or} \quad m = \frac{h_2}{h_1} = \frac{-v}{u}$$

(c) Advantages of reflecting telescope over a refracting telescope are :

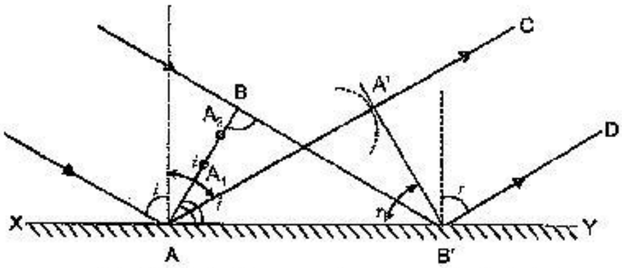
1. Reflecting telescope is free from chromatic and spherical aberrations unlike refracting telescope. Thus image formed is sharp and bright.
2. It has a larger light gathering power so that a bright image of even far off object is obtained.
3. Resolving power of reflecting telescope is large.

OR

(a) Wavefront is defined as the continuous locus of all the particles of a medium which are vibrating in the same phase.

Verification of laws of reflection using Huygen's principle : Let XY be a reflecting surface at which a wavefront is being incident obliquely. Let v be the speed of the wavefront and at time $t = 0$, the wavefront touches the surface XY at A. After time t, point B of wavefront reaches the point B' of the surface.

According to Huygen's principle each point of wavefront acts as a source of secondary waves. When the point A of wavefront strikes the reflecting surface, then due to presence of reflecting surface, it cannot advance further; but the secondary wavelet originating from point A begins to spread in all directions in the first medium with speed v. As the wavefront AB advances further, its points A_1, A_2, A_3 .... etc. strike the reflecting surface successively and send spherical secondary wavelets in the first medium.



First of all the secondary wavelet starts from point A and traverses distance AA' (= vt) in first medium in time t. In the same time t, the point B of wavefront, after travelling a distance BB', reaches point B' (of the surface), from where the secondary wavelet now starts. Now taking A as centre we draw a spherical arc of radius AA'(= vt) and draw tangent A'B' on this arc from point B'. As the incident wavefront AB advances, the secondary wavelets starting from points between A and B', one after the other and will touch A'B' simultaneously. According to Huygen's principle wavefront A'B' represents the new position of AB, *i.e.*, A'B' is the reflected wavefront corresponding to incident wavefront AB.

Now in right-angled triangles ABB' and AA'B'

$$\angle ABB' = \angle AA'B' = 90°$$

$$BB' = AA' = vt$$

and AB' is common

i.e., both triangles are congruent.

$\therefore$ $\angle BAB' = \angle AB'A'$

i.e, incident wavefront AB and reflected wavefront A'B' make equal angles with the reflecting surface XY. As the rays are always normal to the wavefront, therefore the incident and the reflected rays make equal angles with the normal drawn on the surface XY, *i.e.*,

angle of incidence i = angle of reflection r

This is the second law of reflection.

Since AB, A'B' and XY are all in the plane of paper, therefore the perpendiculars dropped on them will also be in the same plane. Therefore, we conclude that the incident ray, reflected ray and the normal at the point of incidence, all lie in the same plane. This is the first law of reflection. Thus, Huygen's principle explains both the laws of reflection.

(b) Width of central diffraction band = $2D.\frac{\lambda}{a}$

where a is the width of the slit.

So, on doubling the width of the slit, the size of the central diffraction band reduces to half value. But, the light amplitude becomes double, which increases the intensity four fold.

(c) If a tiny circular obstacle is kept in the path of light, a bright spot is seen at the centre of the obstacle. This is because the waves which get diffracted from the edge of the circular obstacle interfere constuctively at the centre of the shadow producing a bright spot.

Note : All the sets of outside Delhi and Delhi are same.

Physics 2017 (Outside Delhi) SET I

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

SECTION – A

1. Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Which wire gets heated up more ? Justify your answer. [1]

Answer :

We know that, $R = \rho\frac{l}{A}$

$$\frac{R_{Cu}}{R_{Ni}} = \frac{\rho_{Cu}}{\rho_{Ni}}$$

$\because$ $\rho_{Cu} < \rho_{Ni}$

$\therefore$ $R_{Cu} < R_{Ni}$

$\because$ $H = I^2Rt$

$H \propto R$

$\therefore$ Nichrome wire will get heated up more.

2. Do electromagnetic waves carry energy and momentum ? [1]

Answer : Yes, the electromagnetic waves carry energy and momentum because,

$$\text{Energy, } E = h\upsilon$$

$$\text{Momentum, } p = \frac{h}{\lambda}$$

3. How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced by red light ? Give reason. [1]

Answer : We have, $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin(A/2)}$

$\therefore \qquad \mu \propto \delta_m$

And $\qquad \mu_{red} < \mu_{violet}$

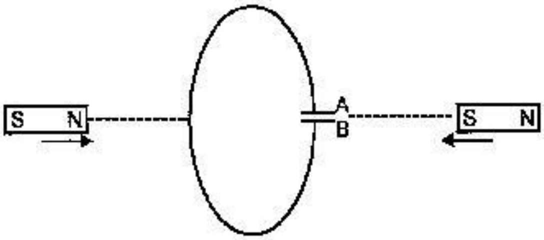
angle of minimum deviation

$\therefore$ Angle of minimum deviation (Sm) ill decrease.

4. **Name the phenomenon which shows the quantum nature of electromagnetic radiation.** **[1]**

Answer : Photoelectric effect.

5. **Predict the polarity of the capacitor in the situation described below :** **[1]**



Answer : A will be positive and B will be negative.

SECTION – B

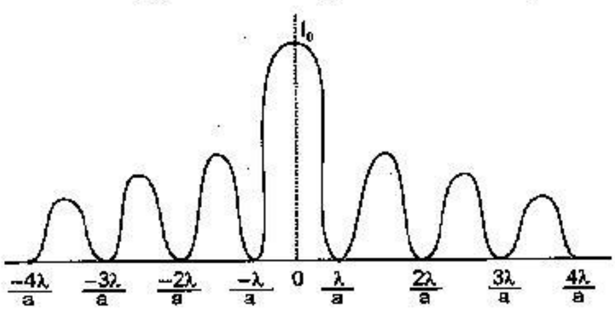
6. **Draw the intensity pattern for single slit diffraction and double slit interference. Hence, state two differences between interference and diffraction patterns.** **[2]**

OR

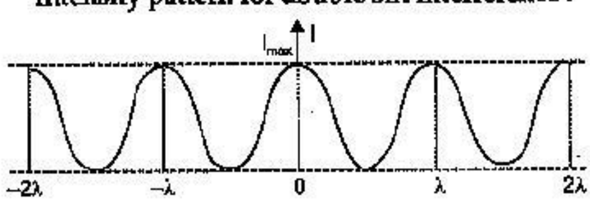
Unpolarised light is passed through a polaroid P_1. When this polarised beam passes through another polaroid P_2 and if the pass axis of P_2 makes angle θ with the pass axis of P_1, then write the expression for the polarised beam passing through P_2. Draw a plot showing the variation of intensity when θ varies from 0 to 2π.

Answer :

Intensity pattern for single slit diffraction :



Intensity pattern for double slit interference :



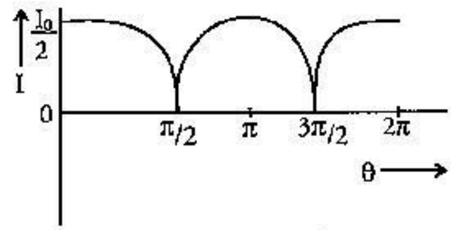
Difference between interference and diffraction patterns :

(a) Interference fringes are of the same width while diffraction fringes are not of the same width.

(b) In interference pattern all bright bands are of same intensity while in diffraction pattern all bright bands are not of same intensity.

OR

$$I = \frac{I_0}{2}\cos^2\theta$$



7. **Identify the electromagnetic waves whose wavelengths vary as**

(a) 10^{-12} m $< \lambda < 10^{-8}$ m

(b) 10^{-3} m $< \lambda < 10^{-1}$ m

Write one use for each. **[2]**

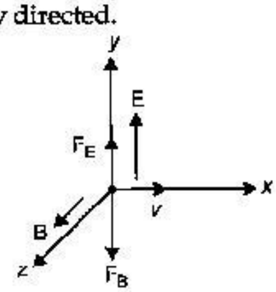
Answer : (a) X-rays → To detect fractures in the human body.

(b) Microwaves → For aircraft navigation in RADAR systems.

8. **Find the condition under which the charged particles moving with different speeds in the presence of electric and magnetic field vectors can be used to select charged particles of a particular speed.** **[2]**

Answer : (a) The velocity $\vec{v}$, of the charged particles, and the $\vec{E}$ and $\vec{B}$ vectors, should be mutually perpendicular.

Also the forces on q, due to $\vec{E}$ and $\vec{B}$, must be oppositely directed.



(b) If magnetic force = electrostatic force

$$F_m = F_e$$

$$qvB = qE$$

$$v = \frac{E}{B}$$

9. **A 12.5 eV electron beam is used to excite a gaseous hydrogen atom at room temperature. Determine the wavelengths and the corresponding series of the lines emitted.** **[2]**

Answer : Given : $\Delta E = 12.5$ eV

Let the electron jump from $n = 1$ to $n = n$ level.

$$\Delta E = E_n - E_1$$

$$\therefore \quad 12.5 = -\frac{13.6}{n^2} - \left(\frac{-13.6}{1^2}\right)$$

$$12.5 = 13.6\left(1 - \frac{1}{n^2}\right)$$

$$1 - \frac{12.5}{13.6} = \frac{1}{n^2}$$

$$\frac{1.1}{13.6} = \frac{1}{n^2}$$

$$\frac{13.6}{1.1} = n^2$$

$$12.36 = n^2$$

$$n = 3.5$$

$$\therefore \quad n = 3^{rd}$$

For $n = 3$ to $n = 1$,

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

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

$$\frac{1}{\lambda} = 1.097 \times 10^7\left(1 - \frac{1}{9}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{8}{9}$$

$$\lambda = 102.55 \text{ nm}$$

For $n = 2$ to $n = 1$,

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

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

$$\lambda = 121.54 \text{ nm}$$

For $n = 3$ to $n = 2$,

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

$$\frac{1}{\lambda} = 1.097 \times 10^7\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{5}{36}$$

$$\lambda = 656.33 \text{ nm}$$

Hence, $\lambda = 102.5$ nm and 121.5 nm → Lyman series

and $\lambda = 656.33$ nm → Balmer series

10. **Write two properties of a material suitable for making (a) a permanent magnet, and (b) an electromagnet.** **[2]**

Answer : Properties of a material suitable for making permanent magnet :

1. High retentivity.
2. High coercivity.

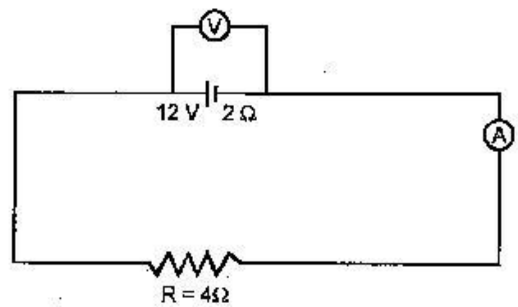
Properties of a material suitable for making electromagnet :

1. High permeability.
2. Low retentivity.

SECTION – C

11. **(a) The potential difference applied across a given resistor is altered so that the heat produced per second increases by a factor of 9. By what factor does the applied potential difference change ?**

(b) In the figure shown, an ammeter A and a resistor of 4 Ω are connected to the terminals of the source. The emf of the source is 12 V having the internal resistance of 2 Ω. Calculate the voltmeter and ammeter readings. **[3]**



Answer : (a) Heat produced,

$$H = \frac{V^2}{R}t$$

$$\Rightarrow \quad H \propto V^2$$

$$\frac{H'}{H} = \frac{V'^2}{V^2}$$

$$\frac{9H}{H} = \frac{V'^2}{V^2} \qquad [\because H' = 9H]$$

$$V'^2 = 9V$$

$$V' = 3V$$

So, potential difference is increased by a factor of 3.

(b) Current, $I = \dfrac{E}{R + r}$

$$I = \frac{12}{4+2} = \frac{12}{6} = 2\text{ A}$$

Ammeter reading = 2 A

Potential difference,

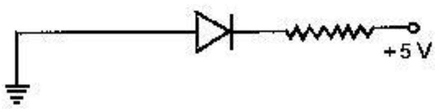
$$V = E - Ir$$
$$V = 12 - 2 \times 2$$
$$= 12 - 4$$
$$V = 8\text{ V}$$

Voltmeter reading = 8 V.

12. (a) How is amplitude modulation achieved ?**

(b) The frequencies of two side bands in an AM wave are 640 kHz and 660 kHz respectively. Find the frequencies of carrier and modulating signal. What is the bandwidth required for amplitude modulation ? [3]**

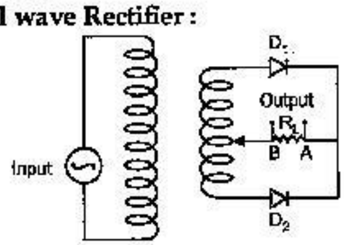
13. (a) In the following diagram, is the junction diode forward biased or reverse biased ?

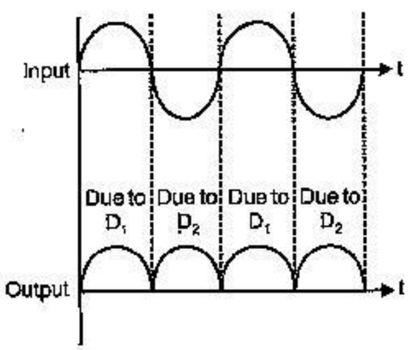


(b) Draw the circuit diagram of a full wave rectifier and state how it works. [3]

Answer : (a) Reverse biased.

(b) Full wave Rectifier :





Diode D_1 conducts only when the junction is forward biased. Hence during first half cycle of input A.C., D_1 will conduct while D_2 will not and current in R_L will flow from A to B. Diode D_2 is reverse biased. During second half cycle of input A.C., diode D_2 will conduct while D_1 will not conduct and current will again flow from A to B in R_L. Hence complete cycle will become unidirectional.

14. Using photon picture of light, show how Einstein's photoelectric equation can be established. Write two features of photoelectric effect which cannot be explained by wave theory. [3]

Answer : Einstein's photoelectric equation : Einstein explained the various laws of photo-electric emission on the basis of Planck's quantum theory. According to Planck's quantum theory, light radiations consist of tiny packets of energy called quanta. One quantum of light radiation is called a photon which travels with the speed of light.

The energy of a photon is given by,

$$E = h\nu$$

where h is Planck's constant and υ is the frequency of light radiation.

Einstein assumed that one photoelectron is ejected from a metal surface if one photon of suitable light radiation falls on it.

Consider a photon of light of frequency υ, incident on a photosensitive metal surface. The energy of the photon ($= h\nu$) is spent in two ways :

(a) A part of the energy of the photon is used in liberating the electron from the metal surface which is equal to the work function ϕ_0 of the metal.

(b) The rest of the energy of the photon is used in imparting the kinetic energy to the emitted photo electron.

If v_{max} is the maximum velocity of the emitted photoelectron and m is its mass, then

Max. K.E. of the photoelectron,

$$K_{max} = \frac{1}{2} m v^2_{max}$$

$$\therefore \quad h\upsilon = \phi_0 + \frac{1}{2} m v^2_{max}$$

This equation is called Einstein's photoelectric equation.

Features of photoelectric effect which can not be explained by wave theory :

1. The wave theory could not explain the instantaneous process of photoelectric effect.
2. Maximum kinetic energy of the emitted photoelectrous is independent of intensity of incident light.

15. (a) Monochromatic light of wavelength 589 nm is incident from air on a water surface. If μ for water is 1.33, find the wavelength, frequency and speed of the refracted light.

(b) A double convex lens is made of a glass of refractive index 1.55, with both faces of the same radius of curvature. Find the radius of

curvature required, if the focal length is 20 cm. **[3]**

Answer :

(a) Given : $\mu = 1.33$

$\lambda_a = 589$ nm

We know that, $\mu = \frac{c}{v}$

$$v = \frac{c}{\mu} = \frac{3\times10^8}{1.33}$$

Speed, $v = 2.26 \times 10^8$ m/s

Frequency remains same.

$$\therefore \quad \nu = \frac{c}{\lambda_a} = \frac{3\times10^8}{589\times10^{-9}}$$

Frequency, $\nu = 5.09 \times 10^{14}$ Hz

$$\text{Wavelength, } \lambda_w = \frac{\lambda a}{\mu} = \frac{589\ nm}{1.33} = 442.8 \text{ nm}$$

(b) Given : $\mu = 1.55, f = 20$ cm

We know that, $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$$\frac{1}{20} = (1.55 - 1)\left(\frac{1}{R} + \frac{1}{R}\right)$$

$$\frac{1}{20} = 0.55 \times \frac{2}{R}$$

$R = 20 \times 0.55 \times 2$

$R = 22$ cm

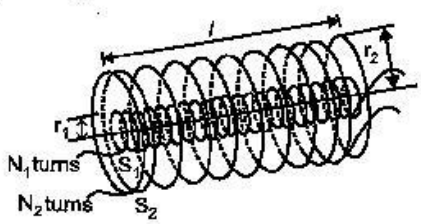
16. Define mutual inductance between a pair of coils. Derive an expression for the mutual inductance of two long coaxial solenoids of same length wound one over the other. **[3]**

OR

Define self-inductance of a coil. Obtain the expression for the energy stored in an inductor L connected across a source of emf.

Answer : Mutual inductance is numerically equal to the induced e.m.f in the secondary coil when the current in the primary coil changes by unity.

Suppose two long co-axial solenoids each of length l. We denote the area of the inner solenoid S_1 by A_1 and the number of turns per unit length by n_1. The corresponding quantities for the outer solenoid S_2 are A_2 and n_2 respectively. Let N_1 and N_2 be the total number of turns of coils S_1 and S_2 respectively.



When a current I_2 is set up through S_2, it in turn sets up a magnetic flux through S_1. Let us denote it by ϕ_1.

The magnetic field due to current I_1 in S_1 is given by

$$B_1 = \mu_0 n_1 I_1$$

Flux linked with each coil of second solenoid,

$$\phi_2 = B_1 A_1$$

$\therefore$ Total flux linked with N_2 turns,

$$\phi_2 = B_1 A_1 N_2$$

$$\phi_2 = \mu_0 n_1 I_1 A_1 N_2 \quad ...(i)$$

Also $\quad \phi_2 = M_{21} I_1 \quad ...(ii)$

Comparing,

$$M_{21} = \mu_0 n_1 N_2 A_1$$

$$M_{21} = \mu_0 n_1 n_2 l A_1 \quad [\because N_2 = n_2 l]$$

Similarly $\quad M_{12} = \mu_0 n_1 n_2 l A_1$

OR

Self inductance : Self inductance of a coil is equal to the magnitude of induced emf produced in the coil when rate of change of current through the coil is unity.

now, $\quad \phi = LI$

$\therefore$ Induced emf (e) $\quad e = -\frac{d\phi}{dt}$

$$e = -L\frac{dI}{dt}$$

Energy stored in an inductor : For the current I at an instant in a circuit, the rate of work done is

$$\frac{dW}{dt} = |e|\, I$$

$$\frac{dW}{dt} = LI\frac{dI}{dt}$$

$$dW = L\, I\, dI$$

Total work done in increasing the current from 0 to I is given by

$$W = \int_0^I LI\, dI$$

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

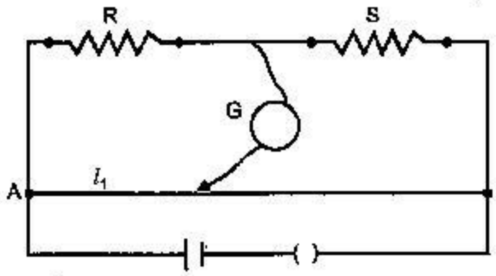
$$W = \frac{1}{2}LI^2$$

This work done is stored as magnetic potential energy.

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

17. (a) Write the principle of working of a metre bridge.

(b) In a metre bridge, the balance point is found at a distance l_1 with resistances R and S as shown in the figure.



An unknown resistance X is now connected in parallel to the resistance S and the balance point is found at a distance l_2. Obtain a formula for X in terms of l_1, l_2 and S. [3]

Answer : (a) Meter bridge works on the principle of balanced Wheatstone bridge *i.e.*, when the bridge is balanced,

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

where R_1, R_2, R_3 and R_4 are resistances connected in four arms of Wheatstone's bridge.

(b) In first case,

$$\frac{R}{S} = \frac{l_1}{100-l_1} \quad ...(i)$$

In second case,

$$\frac{R}{XS/(X+S)} = \frac{l_2}{100-l_2} \quad ...(ii)$$

Dividing (ii) by (i),

$$\frac{X+S}{X} = \frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right)$$

$$1+\frac{S}{X} = \frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right)$$

$$X = \frac{S}{\frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right)-1}$$

$$X = \frac{l_1(100-l_2)}{100(l_2-l_1)}S$$

18. Draw a block diagram of a generalized communication system. Write the functions of each of the following :** [3]

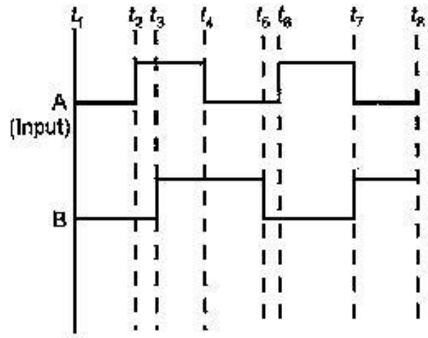
(a) Transmitter

(b) Channel

(c) Receiver

19. (a) Write the functions of the three segments of a transistor.**

(b) The figure shows the input waveforms A and B for 'AND' gate. Draw the output waveform and write the truth table for this logic gate.** [3]



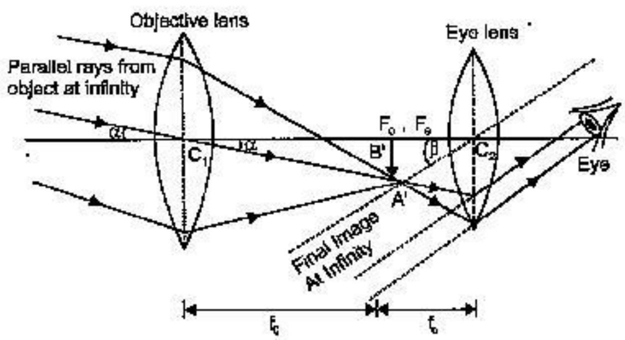
20. (a) Draw a ray diagram depicting the formation of the image by an astronomical telescope in normal adjustment.

(b) You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope ? Give reason. [3]

Lenses	Power (D)	Aperture (cm)
L_1	3	8
L_2	6	1
L_3	10	1

Answer :

(a)



(b) An astronomical telescope should have an objective of large aperture and longer focal length while an eyepiece of small aperture and small focal length.

Therefore, we will use L_1 as an objective and L_3 as an eyepiece.

21. (a) State Biot–Savart law and express this law in the vector form.

(b) Two identical circular coils, P and Q each of radius R, carrying currents 1 A and $\sqrt{3}$

**Answers is not given due to change in the present Syllabus.

A respectively, are placed concentrically and perpendicular to each other lying in the XY and YZ planes. Find the magnitude and direction of the net magnetic field at the centre of the coils. [3]

Answer : (a) Biot-Savart Law :

It states that the magnetic field strength (dB) produced due to a current element I and length dl at a point having position vector $\vec{r}$ relative to current element is

(i) directly proportional to the current I *i.e.,* $dB \propto I$.

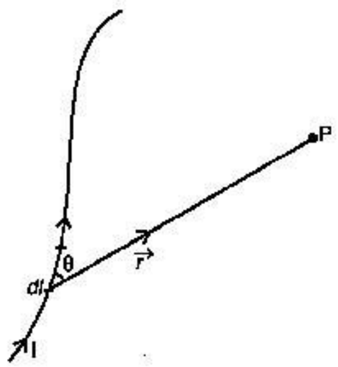
(ii) directly proportional to the length dl of the element *i.e.,* $dB \propto dl$.

(iii) directly proportional to sin θ, where θ is the angle between dl and r, *i.e.,* $dB \propto \sin\theta$.

(iv) inversely proportional to the square of the distance r from the current element *i.e.,* $dB \propto \frac{1}{r^2}$.

$$\therefore \quad dB \propto \frac{Idl\sin\theta}{r^2}$$

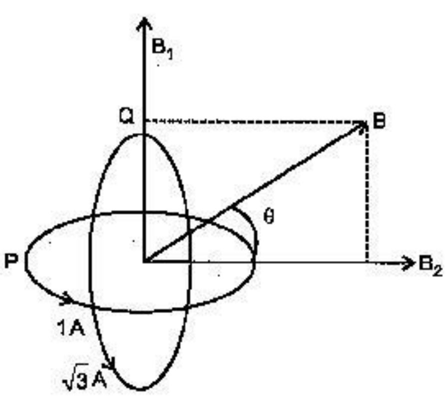
$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$



In vector form,

$$d\vec{B} = \frac{\mu_0}{4\pi}\cdot\frac{I\,\vec{dl}\times\vec{r}}{r^3}$$

(b)



We know that,

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

$$B_1 = \frac{\mu_0}{2R}.1 \text{ (along 3 - direction)}$$

$$B_2 = \frac{\mu_0}{2R}.\sqrt{3} \text{ (along x - direction)}$$

$$B = \sqrt{B_1^2 + B_2^2}$$

$$= \sqrt{\left(\frac{\mu_0}{2R}\right)^2 + \left(\frac{\mu_0}{2R}.\sqrt{3}\right)^2}$$

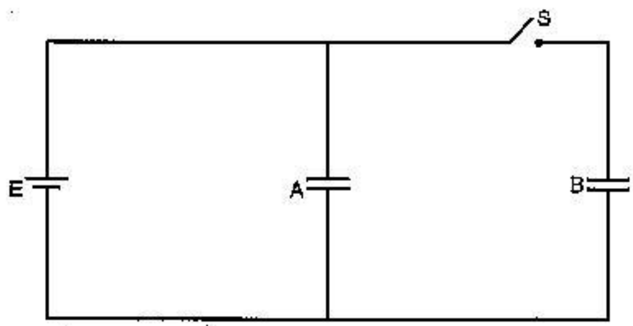
$$B = \frac{\mu_0}{2R}\sqrt{1+3} = \frac{\mu_0}{2R}.\sqrt{4}$$

$$B = \frac{\mu_0}{R}$$

$$\tan\theta = \frac{B_1}{B_2} = \frac{1}{\sqrt{3}}$$

$\Rightarrow \quad \theta = 30°$ in XZ - plane

22. Two identical parallel plate capacitors A and B are connected to battery of V volts with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric constant K. Find the ratio of the total electrostatic energy stored in both capacitors before and after the introduction of the dielectric. [3]



Answer :

$$\text{Energy stored} = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q_2}{C}$$

Net capacitance with switch S closed = C + C = 2C

$$\therefore \text{ Energy stored} = \frac{1}{2}\times 2C\times V^2 = CV^2$$

After the switch S is opened, capacitance of each capacitor = KC

$$\therefore \text{ Energy stored in capacitor A} = \frac{1}{2}KCV^2$$

For capacitor B,

Energy stored

$$= \frac{1}{2}\frac{Q^2}{KC} = \frac{1}{2}\frac{C^2V^2}{KC} = \frac{1}{2}\frac{CV^2}{K}$$

∴ Total energy stored

$$= \frac{1}{2}KCV^2 + \frac{1}{2}\frac{CV^2}{K}$$

$$= \frac{1}{2}CV^2\left(K+\frac{1}{K}\right)$$

$$= \frac{1}{2}CV^2\left(\frac{K^2+1}{K}\right) \quad \text{(ii)}$$

on dividing (i) and (ii)

$$\therefore \text{ Required ratio} = \frac{2CV^2K}{CV^2(K^2+1)} = \frac{2K}{(K^2+1)}$$

SECTION – D

23. Asha's mother read an article in the newspaper about a disaster that took place at Chernobyl. She could not understand much from the article and asked a few questions from Asha regarding the article. Asha tried to answer her mother's questions based on what she learnt in Class XII Physics. **[4]**

(a) What was the installation at Chernobyl where the disaster took place ? What, according to you, was the cause of this disaster ?

(b) Explain the process of release of energy in the installation at chernobyl.

(c) What, according to you, were the values displayed by Asha and her mother ?**

Answer : (a) Nuclear power plant was installed at Chernobyl where the disaster took place.

The causes of this disaster are deficiencies in the reactor design and in operating regulations.

(b) Nuclear fission.

SECTION – E

24. (a) Derive an expression for the electric field E due to a dipole of length '$2a$' at a point distant r from the centre of the dipole on the axial line.

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

(c) If this dipole were kept in a uniform external electric field E_0, diagrammatically represent the position of the dipole in stable and unstable equilibrium and write the expressions for the torque acting on the dipole in both the cases. **[5]**

OR

(a) Use Gauss's theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet with surface charge density σ.

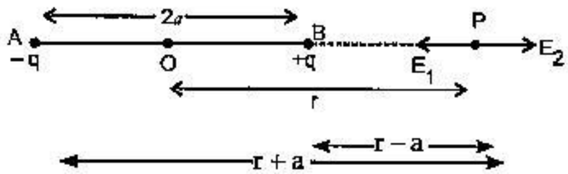
(b) An infinitely large thin plane sheet has a uniform surface charge density + σ. Obtain the expression for the amount of work done in bringing a point charge q from infinity to a point, distant r, in front of the charged plane sheet.

Answer : (a) Consider an electric dipole AB. The charges $-q$ and $+q$ of dipole are situated at A and B respectively, as shown in the figure. The separation between the charges is $2a$. Electric dipole moment is given by

$$p = q.2a \quad ...(i)$$

Consider a point P on the axis of dipole at a distance r from mid point O of electric dipole. The distance of point P from charge $+q$ at B is, $BP = r - a$

and distance of point P from charge $-q$ at A is, $AP = r + a$ Let E_1 and E_2 be the electric field strengths at point P due to charges $+q$ and $-q$ respectively.



The resultant electric field due to electric dipole is given by

$$E = E_2 - E_1$$

$$= \frac{1}{4\pi\epsilon_0}.\frac{q}{(r-a)^2} - \frac{1}{4\pi\epsilon_0}.\frac{q}{(r+a)^2}$$

$$E = \frac{1}{4\pi\epsilon_0}.q\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]$$

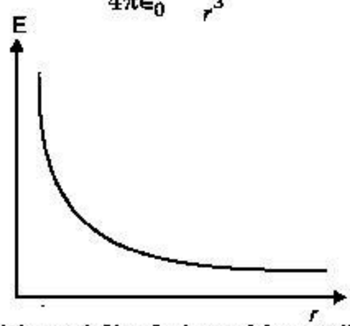
$$E = \frac{1}{4\pi\epsilon_0}.q\left[\frac{(r+a)^2-(r-a)^2}{(r-a)^2(r+a)^2}\right]$$

$$E = \frac{1}{4\pi\epsilon_0}.q\left[\frac{4ra}{\left(r^2-a^2\right)^2}\right]$$

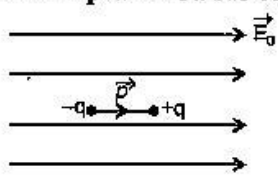
$$E = \frac{1}{4\pi\epsilon_0}.\frac{2pr}{(r^2-a^2)^2} \quad \text{[From (i)]}$$

(b) If $r >> a$,

$$E = \frac{1}{4\pi\epsilon_0}.\frac{2p}{r^3}$$



(c) **Position of dipole in stable equilibrium :**

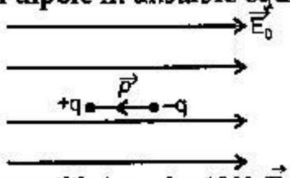


In stable equilibrium, $\theta = 0°$ ($\vec{P}$ is parallel to $\vec{E}_0$)

$$\vec{\tau} = \vec{p} \times \vec{E} = pE \sin\theta = pE \sin 0°$$

$$\vec{\tau} = 0$$

Position of dipole in unstable equilibrium :



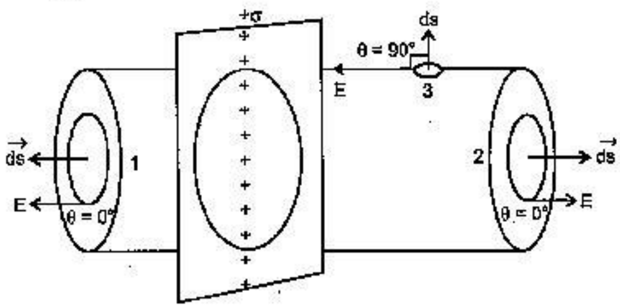
In unstable equilibrium, $\theta = 180°$ ($\vec{P}$ is autiparallel to $\vec{E}_0$)

$$\vec{\tau} = pE \sin 180°$$

$$\vec{\tau} = 0$$

OR

(a)



Let electric charge be uniformly distributed over the surface of a thin non-conducting infinite sheet. Let the surface charge density be σ.

According to Gauss theorem :

$$\int_1 \vec{E}\cdot\vec{ds} + \int_2 \vec{E}\cdot\vec{ds} + \int_3 \vec{E}\cdot\vec{ds} = \frac{q}{\epsilon_0}$$

$$\int_1 E\,ds \cos 0° + \int_2 E\,ds \cos 0° + \int_3 E\,ds \cos 90° = \frac{q}{\epsilon_0}$$

$$\int_1 E\,ds + \int_2 E\,ds = \frac{q}{\epsilon_0}$$

$$2\int E\,ds = \frac{q}{\epsilon_0}$$

$$2E.S = \frac{\sigma S}{\epsilon_0}$$

$$E = \frac{\sigma}{2\epsilon_0}$$

(b) The electric field due to a uniformly charged infinitely large thin sheet with surface charge density σ is,

$$E = \frac{\sigma}{2\epsilon_0} \quad ...(i)$$

The amount of work done in bringing a point charge q from infinity to a point, at a distance r is given by

$$W = \int_{\infty}^{r} F.dr$$

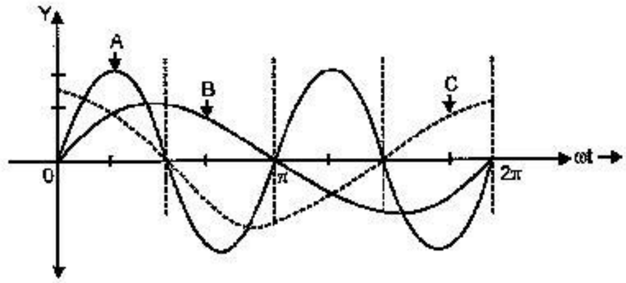
Where F is the force experienced by charge q.

Now, $$W = q\int_{\infty}^{r} -E.\,dr \quad [\because F = -Eq]$$

$$W = -q\frac{\sigma}{2\epsilon_0}\int_{\infty}^{r} dr \quad \text{[From (i)]}$$

$$W = q\frac{\sigma}{2\epsilon_0}[\infty - r] = \infty$$

25. A device 'X' is connected to an ac source $V = V_0 \sin \omega t$. The variation of voltage, current and power in one cycle is shown in the following graph : [5]



(a) Identify the device 'X'.

(b) Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit ? Justify your answer.

(c) How does its impedance vary with frequency of the ac source ? Show graphically.

(d) Obtain an expression for the current in the circuit and its phase relation with ac voltage.

OR

(a) Draw a labelled diagram of an ac generator. Obtain the expression for the emf induced in the rotating coil of N turns each of cross-sectional area A, in the presence of magnetic field $\vec{B}$.

(b) A horizontal conducting rod 10 m long extending from east to west is falling with a speed 5.0 ms^{-1} at right angles to the horizontal component of the Earth's magnetic field, 0.3×10^{-4} Wb m^{-2}. Find the instantaneous value of the emf induced in the rod.

Answer : (a) The device X is a capacitor.

(b) The curves A,B and C represents power consumption, voltage and current respectively.

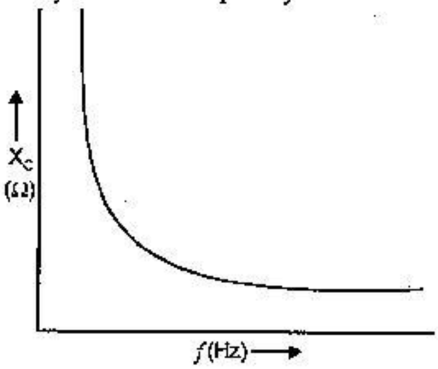
Since, it is given $V = V_0 \sin \omega t$; this sinusoidal variation is represented by the curve B. In case of capacitor, current (I) leads the voltage by 90° which is being represented by curve C. Now, we know power is given by

$$P = V \times I$$

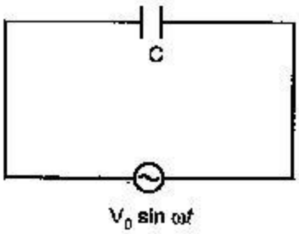
So, the power would be positive for those cycles where both V and I are either positive or negative. Power would be negative when one of the two voltage or current, is negative. This illustration is followed by the curve A.

(c) Capacitive reactance, $X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

This shows that capacitive reactance vary inversely with the frequency.



(d)



In the given figure,

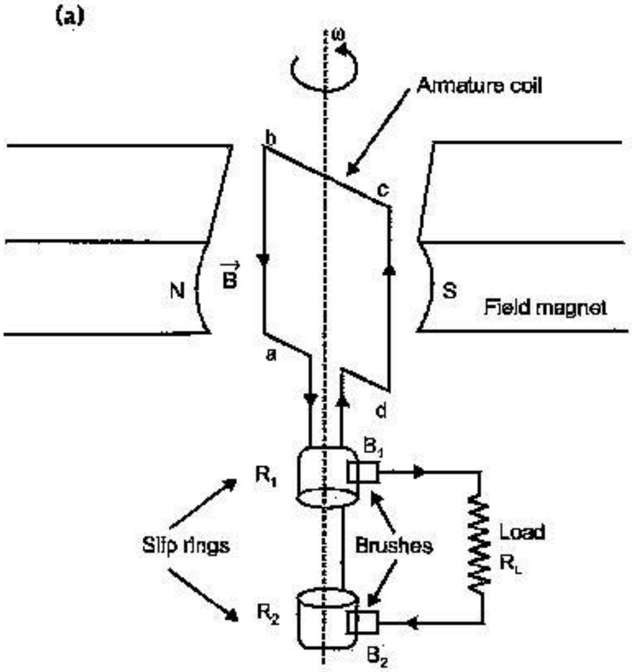
$$V = V_0 \sin \omega t$$
$$Q = CV = CV_0 \sin \omega t$$
$$I = \frac{dq}{dt} = \omega CV_0 \cos \omega t$$
$$= I_0 \sin (\omega t + \pi/2)$$

Where $I_0 = \omega CV_0$

Current leads the voltage by a phase angle of 90°.

OR

(a)



If N is the number of turns in coil, A is the area of coil and B the magnetic induction, then flux ϕ is given by

$$\phi = B.A$$
$$\phi = BA \cos \omega t$$

The e.m.f induced in the coil is given by

$$e = -N\frac{d\phi}{dt}$$
$$e = -N\frac{d}{dt}(BA \cos \omega t)$$
$$e = +NBA\omega \sin \omega t$$
$$e = e_0 \sin \omega t$$

Where, $e_0 = NAB\omega$

(b) $e = B_H l v$

$$= 0.3 \times 10^{-4} \times 10 \times 5$$
$$e = 1.5 \times 10^{-3}\ V = 1.5\ mV$$

26. (a) Define wavefront. Use Huygens' principle to verify the laws of refraction.

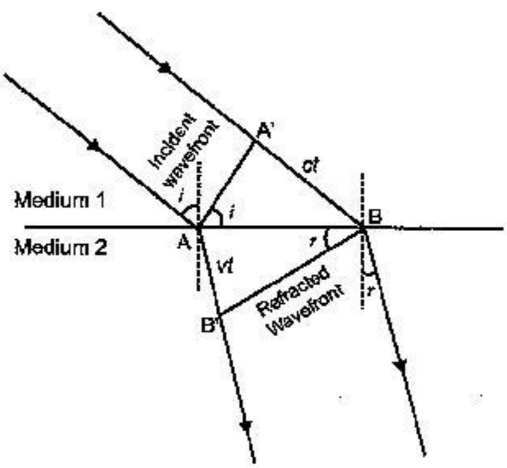
(b) How is linearly polarised light obtained by the process of scattering of light ? Find the Brewster angle for air-glass interface, when the refractive index of glass = 1.5. [5]

OR

(a) Draw a ray diagram to show the image formation by a combination of two thin convex lenses in contact. Obtain the expression for the power of this combination in terms of the focal lengths of the lenses.

(b) A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is $\frac{3}{4}$th of the angle of prism. Calculate the speed of light in the prism.

Answer : (a) Wavefront : A wavefront is a continuous locus of all the particles of a medium which are vibrating in the same phase.



In $\Delta AA'B$,

$$\sin i = \frac{A'B}{AB} \quad ...(i)$$

In $\Delta ABB'$,

$$\sin r = \frac{AB'}{AB} \quad ...(ii)$$

Dividing equation (i) by (ii),

$$\frac{\sin i}{\sin r} = \frac{A'B/AB}{AB'/AB}$$

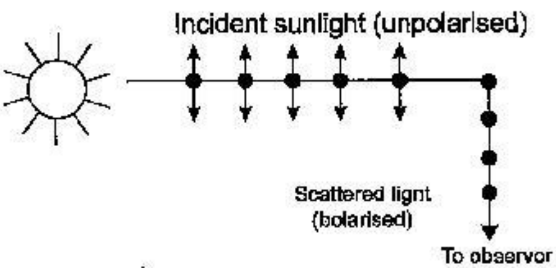
$$\frac{\sin i}{\sin r} = \frac{A'B}{AB'}$$

$$= \frac{ct}{vt}$$

$$\frac{\sin i}{\sin r} = \frac{c}{v} = \mu$$

This is the snell's law of refraction.

(b) When a beam of white light is passed through a medium containing particles whose size is of the order of wavelength of light, then the beam gets scattered. When the scattered light is viewed through an analyser in a direction at the right angle to the direction of indcidence, it is found to be plane polarised. This is called polarisation by scattering.



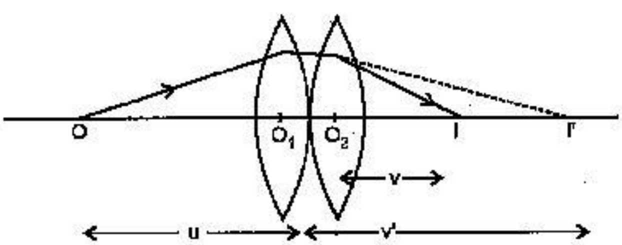
We know that, $\tan i_p = \mu$

$\Rightarrow \quad \tan i_p = 1.5$

$\Rightarrow \quad i_p = \tan^{-1}(1.5) = 56.31°$

OR

(a)



For first lens, object is at O, and image is at I'.

$$\frac{1}{f_1} = \frac{1}{v'} - \frac{1}{u} \quad ...(i)$$

For second lens, object is at I and image is at I.

$$\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v'} \quad ...(ii)$$

Adding (i) and (ii),

$$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{v} - \frac{1}{u} \quad ...(iii)$$

If f is the combined focal length then

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

From equation (iii),

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$P = \frac{1}{f_1} + \frac{1}{f_2} \quad \left[\because \frac{1}{f} = P\right]$$

$$P = \frac{f_1 + f_2}{f_1 f_2}$$

(b) Given : $A = 60°$

$$i = \frac{3}{4}A$$

$$i = \frac{3}{4} \times 60°$$

$$i = 45°$$

For angle of minimum deviation,

$$r = A/2 = \frac{60°}{2}$$

$$r = 30°$$

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

$$\frac{c}{v} = \frac{\sin 45°}{\sin 30°} \quad \left[\because \mu = \frac{c}{v}\right]$$

$$\frac{3 \times 10^8}{v} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}}$$

$$\frac{3 \times 10^8}{v} = \sqrt{2}$$

$$v = \frac{3 \times 10^8}{1.414} \text{ m/s}$$

$\therefore$ Speed of light in the prism

$$vs = 2.12 \times 10^8 \text{ m/s}$$

●●