CBSE Board Exam
2018
Class – XII
Subject – Physics

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

General Instructions:

(a) All questions are compulsory.

(b) There are 26 questions in all. Question number 1 to 5 carry one mark each, question number 6 to 10 carry two marks each, question number 11 to 22 carry three marks each, question number 23 carry four marks and question number 24 to 26 carry 5 marks each.

(c) There is no overall choice. However, internal choices have been provided in some questions.

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

$c = 3 \times 10^8 \text{m/s}$

$h = 6.63 \times 10^{-34} \text{Js}$

$e = 1.6 \times 10^{-19} \text{C}$

$\mu_0 = 4\pi \times 10^{-7} \text{ T mA}^{-1}$

$\varepsilon_0 = 8.854 \times 10^{-12} \text{ C}^2\text{N}^{-1}\text{m}^{-2}$

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2\text{C}^{-2}$

$m_e = 9.1 \times 10^{-31} \text{ kg}$

Mass of neutron= 1.675×10^{-27} kg

Mass of proton = 1.673×10^{-27} kg

Avogadro's number = 6.023×10^{23} per gram mole

Boltzmann constant = 1.38×10^{-23} JK

Section A

Question 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?

Solution 1:

Charges will trace a circular path as soon as they will enter a region of uniform magnetic field (acting perpendicular to their paths)

Using equations of force balance, we have,

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

$$\Rightarrow r = \frac{mv}{qB} \quad ...(i)$$

$$\text{As, } v = r\omega \Rightarrow \omega = \frac{v}{r}$$

Putting value of r from equation …(i), we have

$$\omega = \frac{v}{mv/qB}$$

$$\Rightarrow \omega = \frac{qB}{m}$$

$$\Rightarrow 2\pi f = \frac{qB}{m}$$

$$\Rightarrow f = \frac{qB}{2\pi m} \Rightarrow f \propto \frac{1}{m} \text{ or frequency} \propto \frac{1}{\text{mass}}$$

As electron has less mass, so, it will move with high frequency.

Question 2:

Name the electromagnetic radiations used for (a) water purification, and (b) eye surgery.

Solution 2:

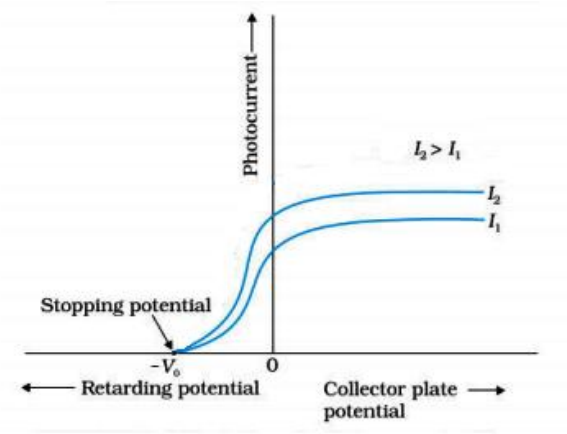
(a) Ultraviolet rays

(b) Infrared rays

Question 3:

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

Solution 3:



Question 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?

Solution 4:

The binding energy per nucleon of the fused heavier nuclei is more than the binding energy per nucleon of the lighter nuclei. So, binding energy is more per nucleon in daughter nuclei.

Section B

Question 5:

Which mode of propagation is used by short wave broadcast services?

Solution 5:

In the frequency range from a few MHz up to 30 to 40 MHz, long distance communication can be achieved by ionospheric reflection of radio waves back towards the earth. This mode of propagation is called sky wave propagation and is used by short wave broadcast services.

Question 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 of these bulbs.

Solution 6:

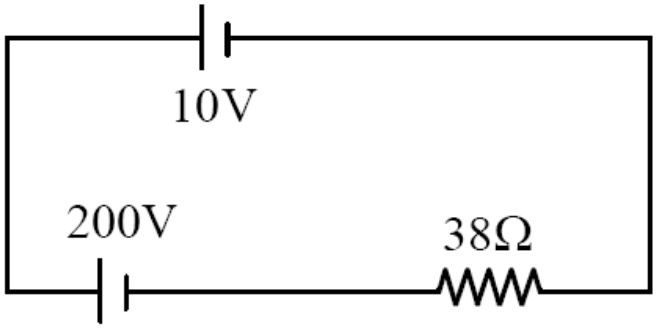
For series combination, power dissipated by a bulb is directly proportional to its resistance.

$P \propto R$

$P_1/P_2 = R_1/R_2 = 1/2.$

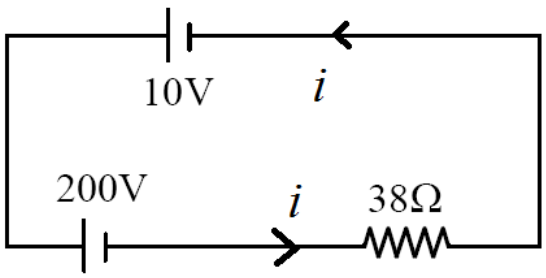
Question 7:

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.



Solution 7:

Let *i* be the current in the circuit and its direction is in anticlockwise direction.



$10 - 200 + 38\,i = 0$

$\Rightarrow 38\,i = 190 \Rightarrow i = 5\,A$

OR

Question 7:

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.

Solution 7:

Internal resistance of a cell is given by,

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

Here, R = 9 Ω, l_1 =350, l_2= 300

Now,

$$r = R\left(\frac{350}{300} - 1\right) = 9\left(\frac{7}{6} - 1\right) = 1.5\,\Omega.$$

Question 8:

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

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

Solution 8:

(*a*) Infrared waves often called heat waves because water molecules present in most materials readily absorb infrared waves (many other molecules, for example, CO_2, NH_3, also absorb infrared waves). After absorption, their thermal motion increases, that is, they heat up and heat their surroundings.

(*b*) It means when these waves strike a surface, a pressure is exerted on the surface.

Question 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?

Metal	Wok function (eV)
Na	1.92
K	2.15
Ca	3.20
Mo	4.17

Solution 9:

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

Given, $\lambda = 412.9 \times 10^{-9}$ m

$\therefore E = \frac{6.67 \times 10^{-34} \times 3 \times 10^{8}}{412.5 \times 10^{-9}} = 0.048 \times 10^{-7}\,\text{J}$

$1\,\text{Joule} = \frac{1}{1.6 \times 10^{-19}}\,\text{eV}$

$\Rightarrow \text{E} = \frac{0.048 \times 10^{-17}}{1.6 \times 10^{-19}}\,\text{eV} = 3\,\text{eV}.$

Energy of photon of falling light is 3 eV. So, the metals having work-function less than energy of photon of falling light will show photoelectric effect. In this question, Na and K will show photo electric effect.

Question 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 of 60 %.

Solution 10:

Given,

Modulation index, μ = 60 % = 0.60

Amplitude of carrier wave = A_c = 15 V

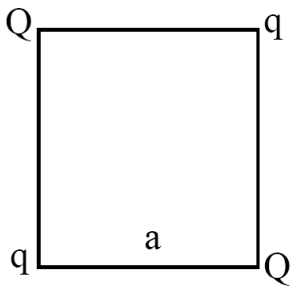
Amplitude of modulating wave = A_m =?

$$\mu = \frac{A_m}{A_c} \Rightarrow 0.60 = \frac{A_m}{15} \Rightarrow A_m = 9 \text{ V}.$$

Section C

Question 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.



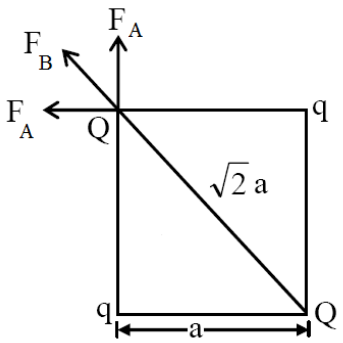
Find the

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

(b) Potential energy of this system.

Solution 11:

(*a*) Force on Q due to other charges is shown in the figure given below



Here,

F_A is force acting on Q due to q

F_B is force acting on Q due to Q

Using Coulomb's law

$$F_A = k\frac{Qq}{a^2} \text{ and } F_B = k\frac{Q^2}{2a^2} \quad \left[\text{ here, } k = \frac{1}{4\pi \in_o}\right]$$

Net force is equal to *resultant of two perpendicular forces F_A (acting in different direction) + force F_B*

$$\Rightarrow F_{net} = \sqrt{2}F_A + F_B$$

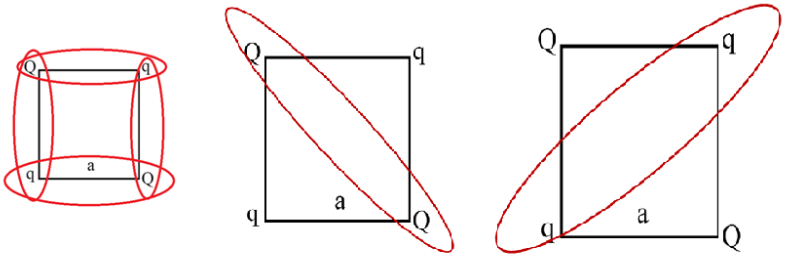
$$\Rightarrow F_{net} = k\left[\sqrt{2}\frac{Qq}{a^2} + \frac{Q^2}{2a^2}\right]$$

(*b*)

Potential energy of a system of two charges (q_1 and q_2) separated by a distance'*d*' is given by

$$V = k\frac{q_1 q_2}{a}$$

There are 6 pairs, as shown in the figures given below

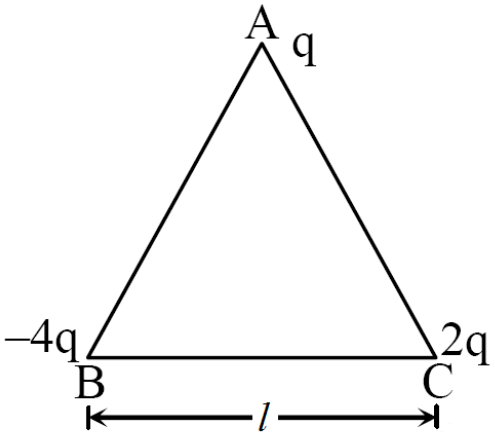


Potential energy of the system $= \frac{4kQq}{a} + \frac{kQ^2}{\sqrt{2}a} + \frac{kq^2}{\sqrt{2}a}$

OR

Question 11:

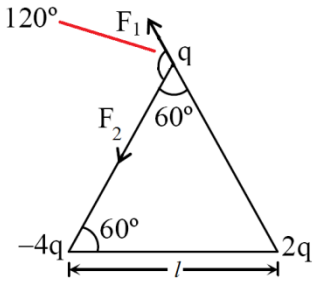
(*a*) Three point charges *q*, –4*q* and 2*q* are placed at the vertices of an equilateral triangle ABC of side '*l*' a shown in the figure. Obtain the expression for the magnitude of the resultant electric force acting on the charge *q*.



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

Solution 11:

The forces on the charge *q* due to other charges are shown in the figure given below:



The resultant electric force acting on the charge q is the resultant of forces F_1 and F_2

Using Coulombs' law,

$$|F_1| = k\frac{2qq}{l^2} = k\frac{2q^2}{l^2}$$

$$|F_2| = k\frac{4qq}{l^2} = k\frac{4q^2}{l^2}$$

Now, resultant force = $\sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos 120^o}$

$\Rightarrow$ resultant force = $\sqrt{F_1^2 + F_2 - 2F_1F_2}$ $\quad \left[\because \cos 120^o = -\frac{1}{2}\right]$

(*b*)

The amount of the work done to separate the charges at infinite distance is difference in initial and final potential energy i.e.,

Work done = (final potential energy) – (initial potential energy)

Final potential energy (when charges are at infinite distance) = 0

$\Rightarrow$ Initial potential energy = $-k\frac{4q^2}{l} - k\frac{8q^2}{l} + k\frac{2q^2}{l}$

$\Rightarrow$ Initial potential energy = $-k\frac{10q^2}{l}$

$\therefore$ Work done = (final potential energy) – (initial potential energy) = $0 - \left(-k\frac{10q^2}{l}\right)$

$\therefore$ Work done = $k\frac{10q^2}{l}$.

Question 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.

Solution 12:

(*a*) The reciprocal of the resistivity of a material is called its conductivity and is denoted by σ.

SI unit of conductivity: siemens per meter.

(*b*)

Drift velocity of electrons in a conductor is given as

$$V_d = \frac{eE\tau}{m} ....(a)$$

Where, E= electric field set up across a conductor, *m* = mass of electron, τ = average relaxation time

Electron drift to a small distance in a time $\Delta t = V_d \Delta t$

Amount of charge passing through the area A in time $\Delta t, q = I\Delta t$

$$I\Delta t = neAv_d \Delta t$$
$$\text{or } I = neAv_d ...(b)$$

Where

$n =$ Number of free electrons per unit volume or number density

Now from equation (a) and (b), we get

$$I = \frac{ne^2 \tau AE}{m} ...(c)$$

Since resistivity of a conductor is given as

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

Now, we know that conductivity of a conductor is mathematically defined as the reciprocal of resistivity of the conductor. Thus,

$$\rho = \frac{1}{\sigma} ...(d)$$

Where, $\sigma =$ conductivity of the conductor, so, from equation (3) and (4), we get

$$\sigma = \frac{ne^2\tau}{m} ...(e)$$

Now, from equation (c) and (e), we have

$$\frac{I}{A} = \sigma E ...(f)$$

and current density is given as

$$J = \frac{I}{A}$$

Thus, $J = \sigma E$

Question 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).

Solution 13:

(a)

$(i)\, W = \vec{M}\vec{B}(\cos\theta_1 - \cos\theta_2)$

$\Rightarrow W = 6\times 0.44\times(\cos 60^o - \cos 90^o)$

$\Rightarrow W = 6\times 0.44\times(0.5-0) = 1.32.$

(ii)

$W = \vec{M}\vec{B}(\cos\theta_2 - \cos\theta_1)$

$\Rightarrow W = 6\times 0.44\times(\cos 60^o - \cos 180^o)$

$\Rightarrow W = 6\times 0.44\times[0.5-(-1)] = 3.96\ \text{J}$

(b)

$\tau = \vec{M}\times\vec{B} = 6\times 0.44\times\sin 180^o = 0.$

Question 14

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

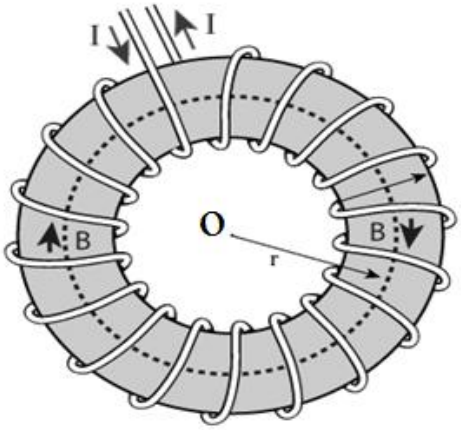
(*b*) The susceptibility of a magnetic material is 0·9853. Identify the type of magnetic material. Draw the modification of the field pattern on keeping a piece of this material in a uniform magnetic field.

Solution 14:

(*a*) Here, an iron ring of relative permeability μ_r having windings of insulated copper wire of *n* turns per meter. It means it is acting as toroid.

CBSE Class 12th Physics Board Exam 2018: Solved Paper

Consider a toroidal solenoid with centre O as shown in the figure given below



By Ampere circuital law, we have

$$\oint \vec{B}.\, d\vec{L} = \mu_o \mu_r NI$$

$$B\oint dL = \mu_o \mu_r NI$$

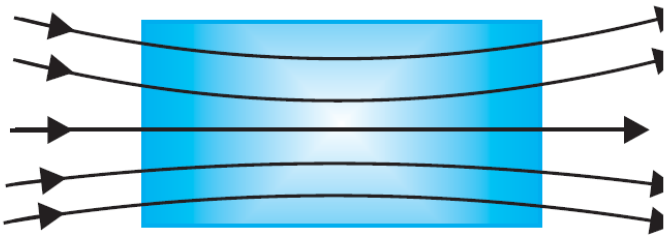
$$B(2\pi r) = \mu_o \mu_r NI$$

$$B = \frac{\mu_o \mu_r NI}{2\pi r}$$

$$B = \mu_o \mu_r nI$$

Where, $n = \frac{N}{2\pi r}$ and n is the number of turns per unit length.

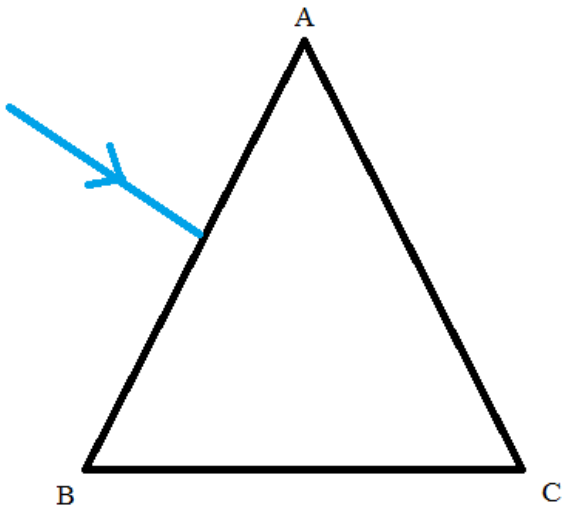
(*b*) Susceptibility of a paramagnetic substance is positive but small. Hence, the given magnetic material is paramagnetic in nature.
The required field pattern on keeping a piece of this material in a uniform magnetic field is shown below:



Question 15

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

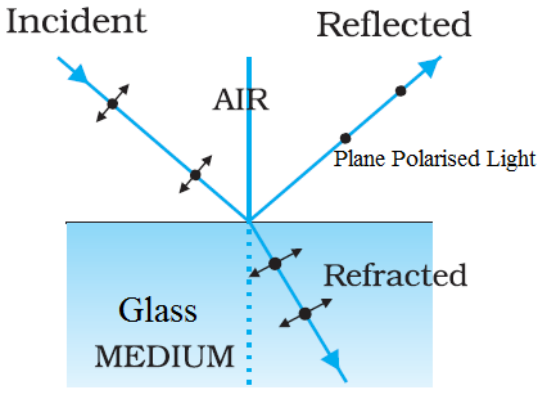
(*b*) The figure shows a ray of light falling normally on the face AB of an equilateral glass prism having refractive index 3/2, placed in water of refractive index 4/3. Will this ray suffer total internal reflection on striking the face AC? Justify your answer.



Solution 15:

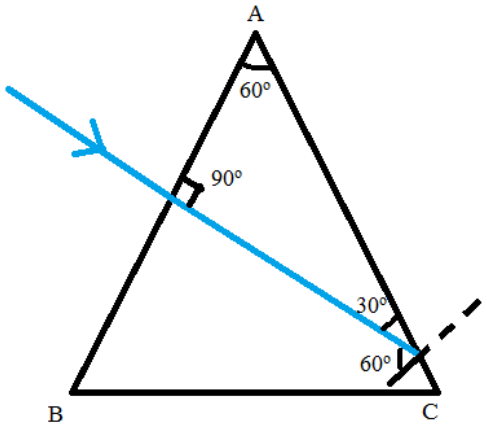
(*a*)

When unpolarised light is incident on the boundary between two transparent media, the reflected light is polarised with its electric vector perpendicular to the plane of incidence when the refracted and reflected rays make a right angle with each other.



In other words, when reflected wave is perpendicular to the refracted wave, the reflected wave is a totally polarised wave. The angle of incidence in this case is called Brewster's angle

(*b*)



Light way is going from prism to water,

Refractive index of prism = n_g = 3/2

Refractive index of water = n_l = 4/3

Suppose the ray suffers total internal reflection, for limiting ray,

Angle of incidence = i , angle of emergence = 90^o

Applying Snell's law,

$(n_g) \sin i = n_l (\sin 90^o)$

$\Rightarrow \sin i = (n_l)/(n_g) \Rightarrow \sin i = 8/9 = 0.88$.

In the given question, angle of incidence (inside prism) is 60^o. Now, $\sin 60^o = \sqrt{3}/2 = 0.816$.

Clearly angle of incidence is smaller. Therefore, total internal reflection in this case will not take place.

Question 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?

Solution 16:

(*a*)

Intensity ratio is given by

$$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right)^2 \quad ...(i)$$

Suppose intensity in first case in given by I, therefore intensity in second case is $I/2$

i.e., $I_1 = I$ and $I_2 = I/2$, putting in …(*i*), we have

$$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I}+\sqrt{I/2}}{\sqrt{I}-\sqrt{I/2}}\right)^2 = \left[\frac{\sqrt{I}\left(\sqrt{2}+1\right)}{\sqrt{I}\left(\sqrt{2}-1\right)}\right]^2 = \left[\frac{\left(\sqrt{2}+1\right)}{\left(\sqrt{2}-1\right)}\right]^2$$

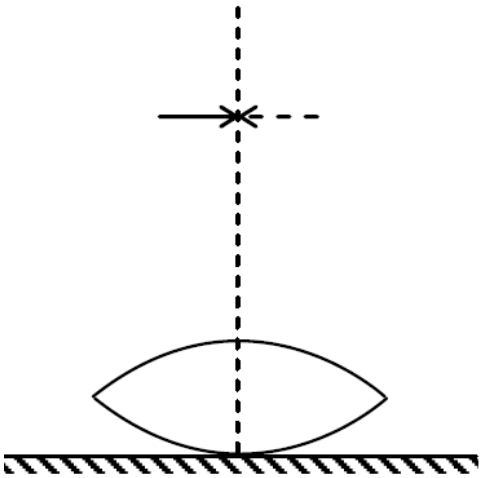
(*b*)

The interference patterns due to different component colours of white light overlap (incoherently). The central bright fringes for different colours are at the same position. Therefore, the central fringe is white. For a point P for which which $S_2P - S_1P = \lambda_b/2$, where λ_b (≈ 4000 Å) represents the wavelength for the blue colour, the blue component will be absent and the fringe will appear red in colour

Slightly farther away where $S_2Q - S_1Q = \lambda_b = \lambda_r/2$ where λ_r (≈ 8000 Å) is the wavelength for the red colour, the fringe will be predominantly blue. Thus, the fringe closest on either side of the central white fringe is red and the farthest will appear blue. After a few fringes, no clear fringe pattern is seen.

Question 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.



Solution 17:

In first case there are two lens in combination double convex and plane concave lens.

The image overlapped at object when it placed on focus

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

The distance x given so $f_1 = x$

$$\frac{1}{x}=\frac{1}{f_1}+\frac{1}{f_2} \qquad ...(1)$$

When liquid removed distance given y

So,

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

Here,

$$\frac{1}{y}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$
$$\frac{1}{y}=(1.5-1)\left(\frac{1}{R}+\frac{1}{R}\right)$$
$$\frac{1}{y}=\frac{1}{2}\times\frac{2}{R}$$
$$y = R$$

For f_2

$$\frac{1}{f_2}=(\mu-1)\left(\frac{1}{-R}-\frac{1}{\infty}\right)$$
$$\frac{1}{f_2}=(\mu-1)\left(\frac{-1}{R}\right)$$
$$\frac{1}{f_2}=\frac{(\mu-1)}{-R}$$
$$\frac{1}{f_2}=\frac{1-\mu}{R}$$
$$\frac{1}{f_2}=\frac{1-\mu}{y}(y=R)$$

From equation …(*i*)

$$\frac{1}{x}=\frac{1}{f_1}+\frac{1}{f_2}$$
$$\frac{1}{x}=\frac{1}{y}+\frac{1-\mu}{y}$$
$$\frac{1}{x}=\frac{1+1-\mu}{y}$$
$$\frac{1}{x}=\frac{2-\mu}{y}$$
$$\frac{y}{x}=2-\mu$$
$$\mu=2-\frac{y}{x}.$$

Question 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*) An hydrogen atom initially in the ground state absorbs a photon which excites it to the n = 4 level. Estimate the frequency of the photon.

Solution 18:

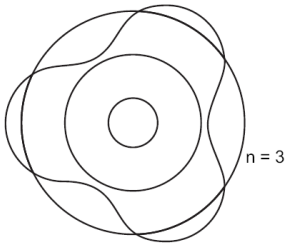
(*a*) According to Bohr postulate, electrons revolve around the nucleus only in those discrete orbits which are non radiating and for which the angular momentum of the revolving electron is an integral multiple of h/2π. These discrete orbits are known as stationary or stable orbits.

From de Broglie's hypothesis, $\lambda = \frac{h}{mv_n} ...(i)$

Where λ is wavelength of electron in moving with velocity v_n in n^{th} orbit.
From de Broglie's condition of stationary orbits, the stationary orbits are those which contain complete de-Broglie wavelength $2\pi r_n = n\lambda ...(ii)$

Substituting value of λ from …(*ii*) in …(*i*), we get $2\pi r_n = n\frac{h}{mv_n} \Rightarrow mv_n r_n = n\frac{h}{2\pi}.$

Which is the Bohr's postulate of quantization of energy levels.



Only a certain number of wavelengths would fit in the electron orbits.

(*b*)

Here,

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

Given, $n_1 = 1$ and $n_2 = 4$

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

$$\Rightarrow \frac{1}{\lambda} = R\left(\frac{15}{16}\right)$$

Now, $c = v\lambda$ [c is velocity of light]

$$\Rightarrow v = \frac{c}{\lambda}$$

$$\Rightarrow v = 3\times10^{8}\times R\left(\frac{15}{16}\right)$$

$$\Rightarrow v = 3\times10^{8}\times1.09\times10^{7}\times\left(\frac{15}{16}\right)$$

$$\Rightarrow v = 3\times10^{15}\ \text{Hz}$$

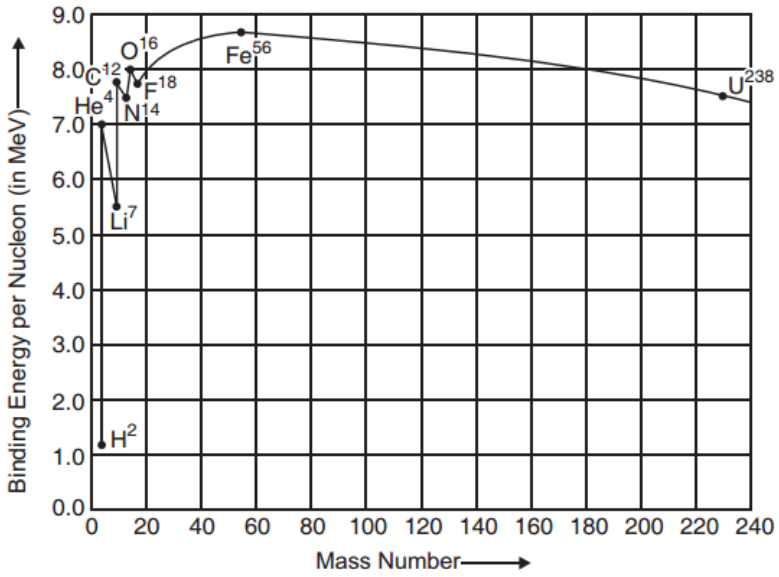
Question 19

(*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 3.12 %?

Solution 19:

(*a*)



In nuclear fission, a heavy nucleus breaks into two lighter nuclei. When a heavy nucleus (Mass number ≥ 235 say) breaks into two lighter nuclei (nuclear fission), the binding energy per nucleon increases i.e., nucleons get more tightly bound. This implies that energy would be released in nuclear fission.

In nuclear fusion process, two nuclei fused to form a heavy nucleus. When two very light nuclei $(\text{Mass number} \leq 10)$ join to form a heavy nucleus, the binding energy per nucleon of fused heavier nucleus will be more than the binding energy per nucleon of lighter nuclei, so again energy would be released in nuclear fusion.

(*b*)

According to the question,

$$N = N_o 3.12\%$$

$$\Rightarrow \frac{N}{N_o} = 3.12\% \Rightarrow \frac{N}{N_o} = \frac{1}{32}$$

Again, $\frac{N}{N_o} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{32}\right) = \left(\frac{1}{5}\right)^5$

Number of years it will take for the activity to reduce to 3.12 % = 5 × half life = 5 × 10 years = 50 years.

Question 20

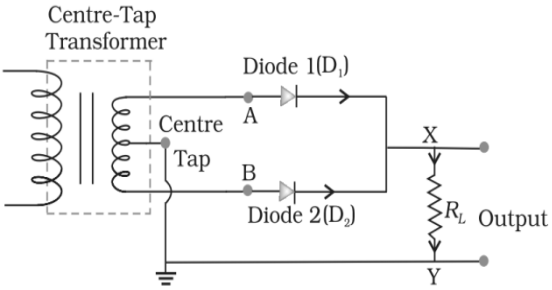
(*a*) A student wants to use two p-n junction diodes to convert alternating current into direct current. Draw the labeled circuit diagram she would use and explain how it works.

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

Solution 20:

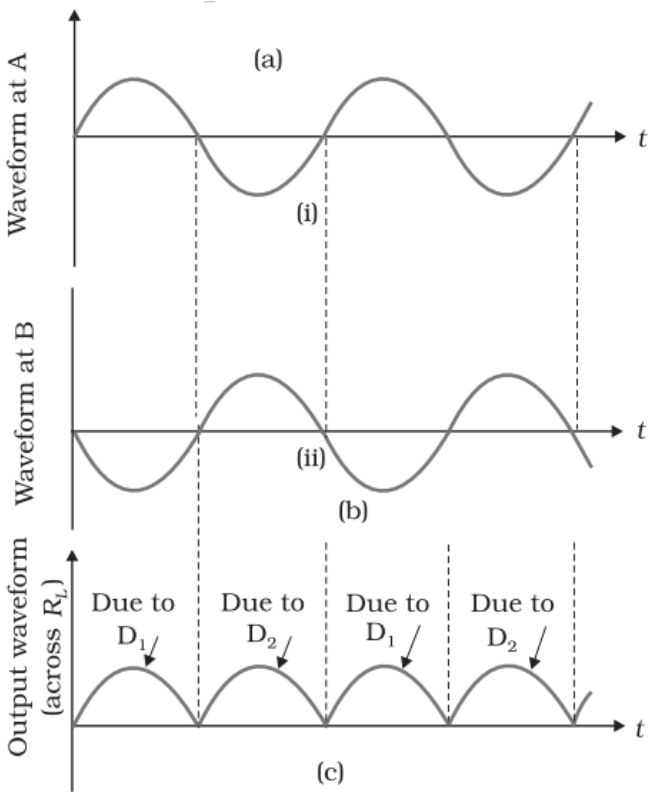
(*a*)

Circuit diagram of full wave rectifier:



The circuit consists of two diodes as shown in the figure given above. It gives output rectified voltage corresponding to both the positive as well as negative half of the AC cycle. Hence, it is known as full-wave rectifier.
Here the *p*-side of the two diodes are connected to the ends of the secondary of the transformer. The *n*-side of the diodes are connected together and the output is taken between this common point of diodes and the midpoint of the secondary of the transformer.
So for a full-wave rectifier the secondary of the transformer is provided with a centre tapping and so it is called centre-tap transformer.

The voltage rectified by each diode is only half the total secondary voltage. Each diode rectifies only for half the cycle, but the two do so for alternate cycles. Thus, the output between their common terminals and the centretap of the transformer becomes a full-wave rectifier output.



Suppose the input voltage to A with respect to the centre tap at any instant is positive, at that instant, voltage at B being out of phase will be negative. So, diode D_1 gets forward biased and conducts (while D_2 being reversed biased is not conducting). Hence, during this positive half cycle we get an output current (and a output voltage across the load resistor R_L).

(*b*)

Symbol of logic gate:

Truth table:

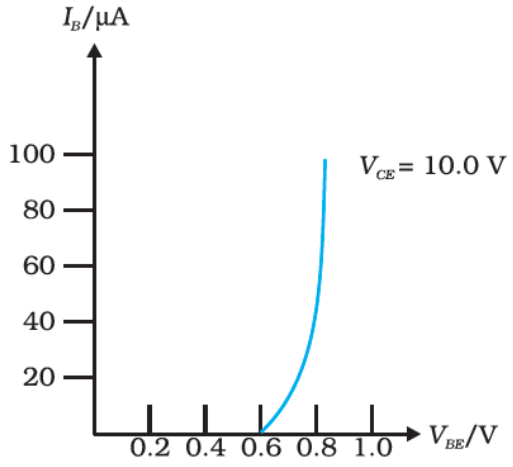
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

Question 21

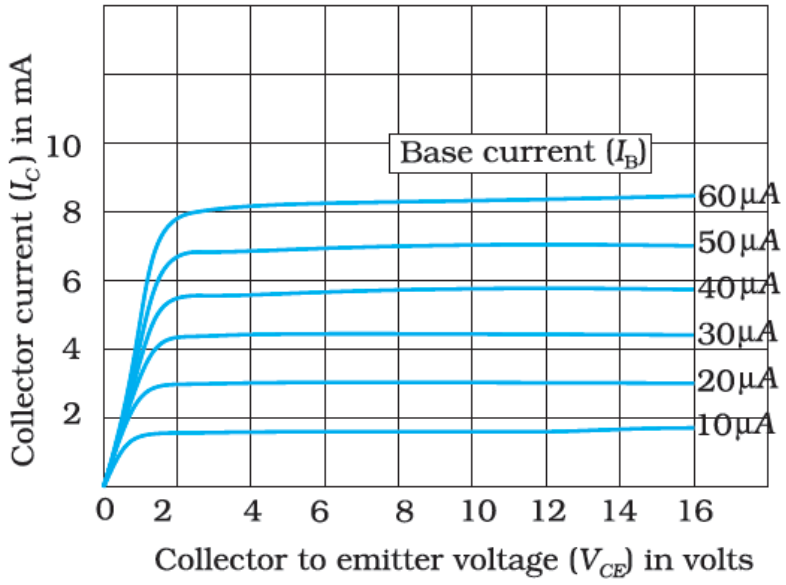
Draw the typical input and output characteristics of an n-p-n transistor in CE configuration. Show how these characteristics can be used to determine (*a*) the input resistance (r_1), and (*b*) current amplification factor (β).

Solution 21:

Input characteristics:



Output characteristics:



(a)

Input resistance (r_i): This is defined as the ratio of change in base emitter voltage (ΔV_{BE}) to the resulting change in base current (ΔI_B) at constant collector-emitter voltage (V_{CE}). This is dynamic (ac resistance) and as can be seen from the input characteristic, its value varies with the operating current in the transistor:

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B} \right)_{V_{CE}}$$

The value of r_i can be anything from a few hundreds to a few thousand ohms.

(b)

This is defined as the ratio of the change in collector current to the change in base current at a constant collector-emitter voltage (V_{CE}) when the transistor is in active state.

$$\beta_{ac} = \left(\frac{\Delta I_C}{\Delta I_B} \right)_{V_{CE}}$$

This is also known as small signal current gain and its value is very large.

If we simply find the ratio of I_C and I_B we get what is called dc β of the transistor. Hence,

$$\beta_{dc} = \frac{I_C}{I_B}$$

Since I_C increases with I_B almost linearly and $I_C = 0$ when $I_B = 0$, the values of both β_{dc} and β_{ac} are nearly equal. So, for most calculations β_{dc} can be used. Both β_{ac} and β_{dc} vary with VCE and I_B (or I_C) slightly.

Question 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.

Solution 22:

(*a*) Three reasons why modulation of a message signal is necessary for long distance transmission are:

(1) Size of the antenna or aerial:

For transmitting a signal, we need an antenna or an aerial. This antenna should have a size comparable to the wavelength of the signal (at least $\lambda/4$ in dimension) so that the antenna properly senses the time variation of the signal. For an electromagnetic wave of frequency 20 kHz, the wavelength λ is 15 km. obviously, such a long antenna is not possible to construct and operate.

(2) Effective power radiated by an antenna:

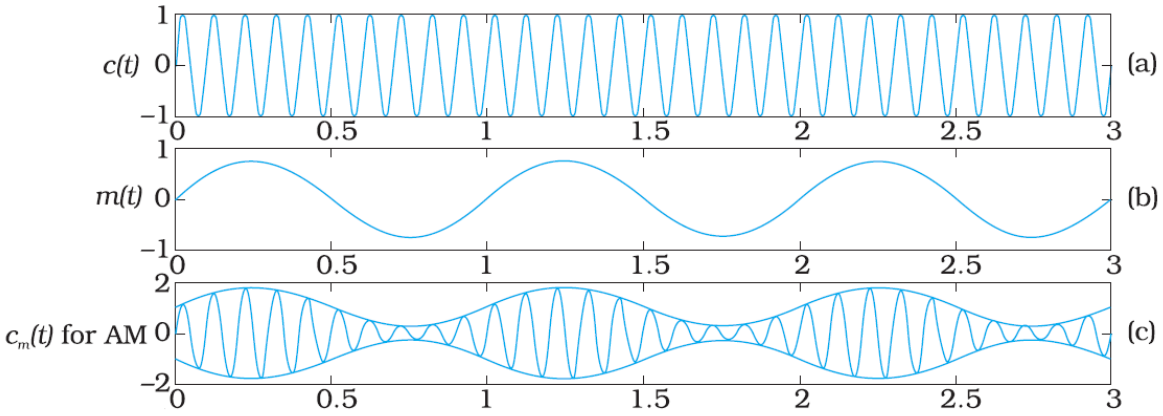
A theoretical study of radiation from a linear antenna (length l) shows that the power radiated is proportional to $(l/\lambda)^2$. This implies that for the same antenna length, the power radiated increases with decreasing λ, i.e., increasing frequency. Hence, the effective power radiated by a long wavelength baseband signal would be small. For a good transmission, we need high powers and hence this also points out to the need of using high frequency transmission.

(3) Mixing up of signals from different transmitters:

If we transmit the baseband signals directly, the signals from different transmitters will get mixed up and the information will be lost.

Due to the above mentioned reasons, we use the technology of modulation, for transmitting message signals effectively for long distances

(*b*)



Here, (a) an audio signal; (b) a carrier wave; (c) amplitude modulated wave.

Section D

Question 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 listed to the teacher and asked questions about how the ac is converted to a higher or lower voltage.

(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.

(a) Define electric flux. Is it a scalar or a vector quantity?

Solution 23:

(*a*) Device – Transformer.

Reason for loss: Heating and Flux leakage

(*b*)

In long distance transmission of energy through transmission lines, the power loss is mainly due to heat loss (due to resistance).

This resistive loss is proportional to square of current flowing through the lines i.e. $H \propto I^2$.To minimise heat loss, we need to minimise the current flowing in the wire.

In case of dc, if the current flowing in the wire decrease then, the power losses will decrease but simultaneous power received at the receiving station will also decrease.

In order to achieve the required amount of power at the receiving station, we transmit the ac signal by stepping up the voltage with lower value of current as ac gives the flexibility of stepping up or down the voltage.

In this way the power losses are reduced while maintaining the required amount of power at the receiving station.

(*c*)

Values observed are:

Two values shown by the teacher are:

(*i*) Responsible

(*ii*) Enthusiasm

Two values shown by Geeta are:

(*i*) Curious

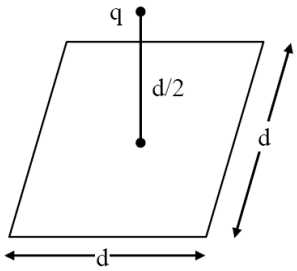
(*ii*) Good listener

Section E

Question 24

(*a*) Define electric flux. Is it a scalar or a vector quantity?

A point charges *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.

Solution 24:

(*a*) Electric flux is defined as the number of electric filed lines crossing the per unit area. It is scalar quantity.

When cube is of side *d* and point charge *q* is at the center of the cube then the total electric flux due to this charge will pass evenly through the six faces of the cube. So, the electric flux through one face will be equal to 1/6 of the total electric flux due to this charge.

i.e., Flux through 6 faces = $\frac{q}{\in_o}$

Flux through 1 face = $\frac{q}{6 \in_o}$

(*b*) If we moved point charge *d* from centre and square side changes to 2*d*, still the point charge can be imagined at the center of a cube of side 2*d*. Again the flux through one face of the cube will be 1/6 of the total electric flux due to the charge *q*.

Hence, the electric flux through the square will not change and it will remain the same i.e., $q/6\in_o$.

OR

Question 24

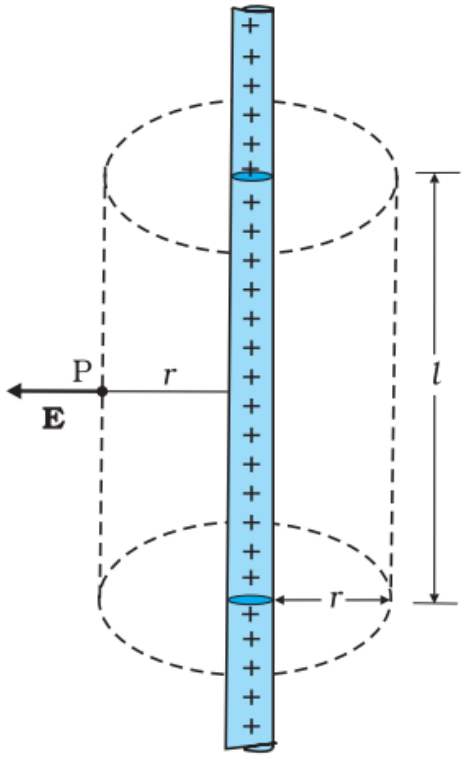
(a) Use Gauss' law to derive the expression for the electric field (**E)** due to a straight uniformly charged infinite line of charge density λ C/m.

(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 ($r_2 > r_1$).

Solution 24:

(*a*)



Consider a thin, infinitely long straight line charge of linear charge density λ (as shown in the figure given above).

Suppose P be the point at a distance *r* from the line. To find the electric field at point P, we draw a cylindrical gaussian surface of radius '*r*' and length *l*.

If E is the magnitude of electric field at point P, then electric flux through the Gaussian surface,

Φ = E × Area of the curved surface of a cylinder of radius *r* and length *l*

As electric lines of force are parallel to end faces (circular caps) of the cylinder, there is no component of the field along the normal to the end faces.

$$\phi = \frac{q}{\in_o}$$

Here, $q = \lambda l$

$$\therefore \phi = \frac{\lambda l}{\in_o} \quad ...(ii)$$

For equations ...(*i*) and...(*ii*), we get

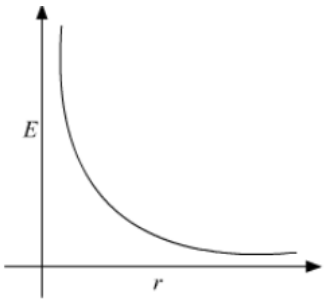
$$E \times 2\pi rl = \frac{\lambda l}{\epsilon_o}$$

$$\Rightarrow E = \frac{1}{2\pi \epsilon_o}\frac{\lambda}{r}$$

(*b*)

From above equation, we can observe, $E \propto \frac{1}{r}$

The graph showing the variation of *E* with perpendicular distance '*r*' from the line of charge.



(c)

Assume the charge has move by an infinitely small distance *dr*.

$$V = \int \vec{E}.d\vec{r}$$

$$\Rightarrow V = \int_{r_1}^{r_2} \frac{\lambda}{2\pi \epsilon_o r} dr = \frac{\lambda}{2\pi \epsilon_o}\int_{r_1}^{r_2} \frac{1}{r} = \frac{\lambda}{2\pi \epsilon_o}\left[\log \frac{r_2}{r_1}\right]$$

Work done, W = $qV = \frac{q\lambda}{2\pi \epsilon_o}\left[\log \frac{r_2}{r_1}\right]$.

Question 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 **B**, directed perpendicular to the axis of rotation.

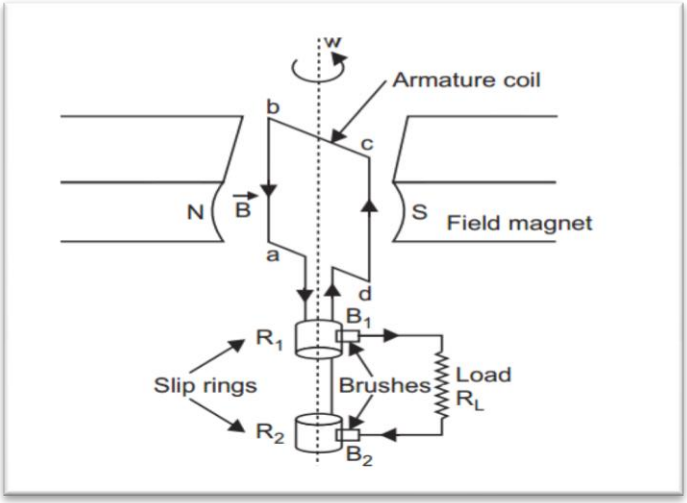
(*b*) An aeroplane is flying horizontally form west to east with a velocity of 900 km/hour. Calculate the potential difference developed between the ends of its wings having a span of 20

m. The horizontal component of the Earth's magnetic field is 5×10^{-4} T and the angle of dip is 30°.

Solution 25:

(*a*)

AC generator consists of the four main parts:



(*a*) Field Magnet: It produces the magnetic field. In the case of a low power dynamo, the magnetic field is generated by a permanent magnet, while in the case of large power dynamo. The magnetic field is produced by an electromagnet.
(*b*) Armature: It consists of a large number of turns of insulated wire in the soft iron drum or ring. It can revolve around an axle between the two poles of the field magnet. The drum or ring serves the two purposes: (*i*) It serves as a support to coils and (*ii*) It increases the magnetic field due to air core being replaced by an iron core.
(*c*) Slip Rings: The slip rings R_1 and R_2 are the two metal rings to which the ends of armature coil are connected. These rings are fixed to the shaft which rotates the armature coil so that the rings also rotate along with the armature.
(*d*) Brushes: These are two flexible metal plates or carbon rods (B_1 and B_2) which are fixed and constantly touch the revolving rings. The output current in external load R_L is taken through these brushes.
Principle: When the armature coil is rotated in the strong magnetic field, the magnetic flux linked with the coil changes and the current is induced in the coil, its direction being given by Fleming's right hand rule. The direction of current remains unchanged during the first half turn of armature. During the second half revolution, the direction of current is reversed. Thus, the direction of induced emf and current changes in the external circuit after each half revolution.
If *N* is the number of turns in coil, *f* the frequency of rotation, *A* area of coil and *B* the magnetic induction, then induced emf

$$e = -\frac{d\phi}{dt} = -\frac{d(N\vec{B}.\vec{A})}{dt} = -\frac{d(NBA\cos\omega t)}{dt} = -\frac{d}{dt}\{NBA(\cos\omega t) = (\omega NBA)\sin\omega t.$$

(*b*)

OR

Question 25

A device X is connected across an ac source of voltage V = V_0 sin ω*t*. The current through X is given as I = I_o sin (ω*t* + π/2)

(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.

Solution 25:

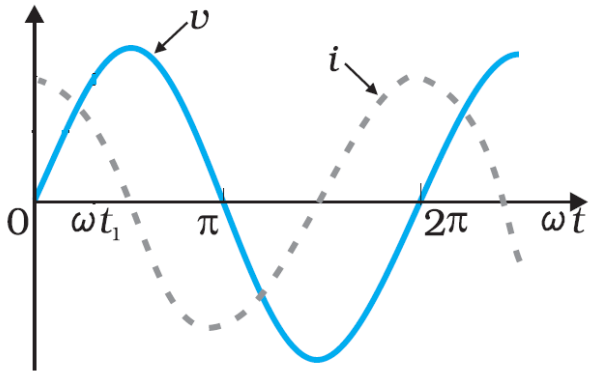
(a)

According to the question, the current is leading the voltage by 90 degree, so the device X is capacitor.

The expression for reactance is X_C = 1/ωC = 1/(2π*v*C)

(b)

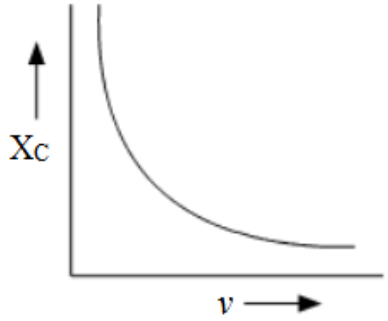
Graph showing variation of voltage and current with time over one cycle of ac



(c)

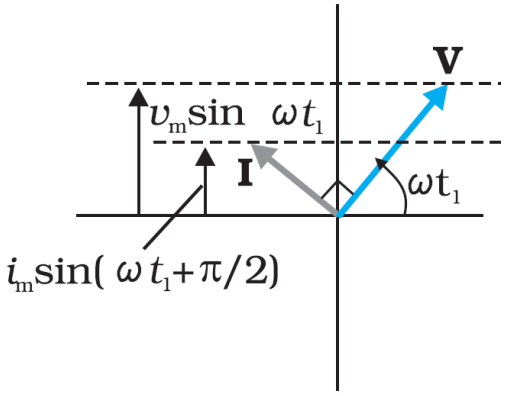
$X_C \propto 1/v$

The reactance varies inversely with frequency.



(d)

Phasor diagram for the device:



Question 26

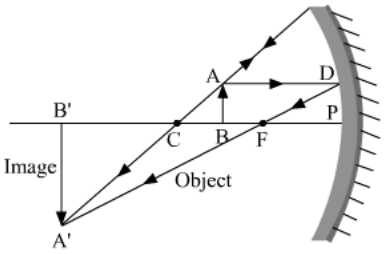
(a) Draw a ray diagram to show image formation when the concave mirror produces a real, inverted and magnified image of the object.

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

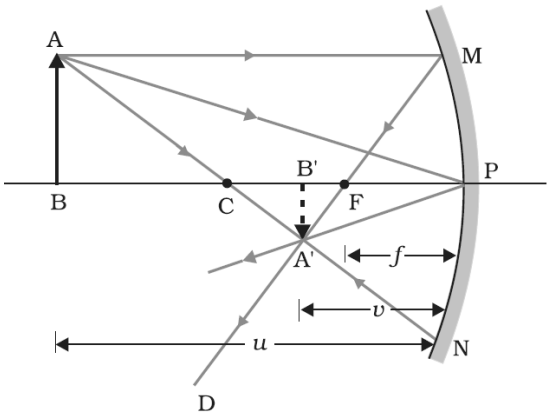
(c) Explain two advantages of a reflecting telescope over a refracting telescope. [5]

Solution 26:

(a)



(b)



The ray diagram above shows the image A′B′ (in this case, real) of an object AB formed by a concave mirror.

Now we derive the mirror equation or the relation between the object distance (u), image distance (v) and the focal length (f).
The two right-angled triangles A′B′F and MPF are similar. (For paraxial rays, MP can be considered to be a straight line perpendicular to CP.) Therefore,

$$\frac{B'A'}{PM} = \frac{B'F}{FP} \; or \; \frac{B'A'}{BA} = \frac{B'F}{FP} \; (\because PM = AB)$$

$\because \angle APB = \angle A'PB'$,

the right angled triangles A'B'P and ABP are also similar.

So,

$$\frac{B'A'}{BA} = \frac{B'P}{BP}$$

From above equations, we have

$$\frac{B'F}{FP} = \frac{B'P - FP}{FP} = \frac{B'P}{BP}$$

We note that light travels from the object to the mirror MPN. Hence this is taken as the positive direction. To reach the object AB, image A′B′ as well as the focus F from the pole P, we have to

travel opposite to the direction of incident light. Hence, all the three will have negative signs. Applying sign convention, we have,

B′ P = –*v*, FP = –*f*, BP = –*u*

Using these, we get

$$\frac{-v+f}{-f}=\frac{-v}{-u} \text{ or } \frac{v-f}{f}=\frac{v}{u} \text{ or } \frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

(c)

(i) Images are brighter (as compared to that in a refracting type telescope).

(ii) Chromatic aberration is absent in reflecting type telescope.

OR

Question 26

(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.

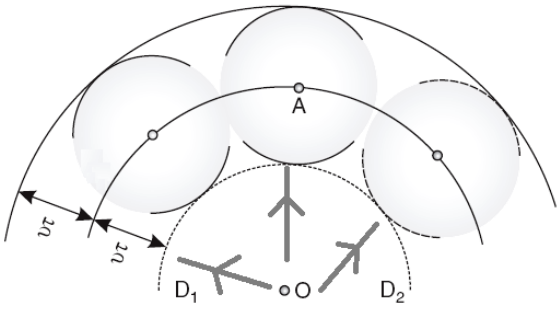
(c) When a tiny circular obstalce is placed in the path of light from a distant source, a bright spot is seen at the centre of the obstacle. Explain why.

Solution 26:

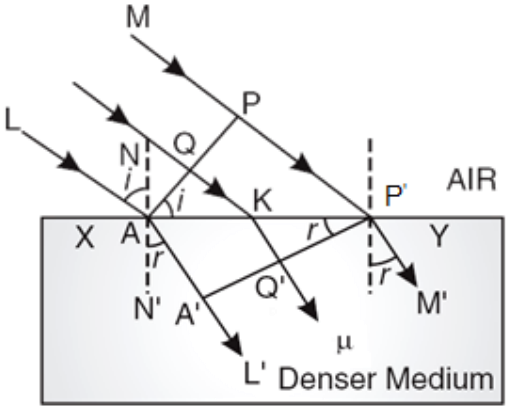
(a)

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

Huygens proposed a geometrical construction to explain the propagation of a wavefront in the medium and determined the position of the wavefront after any interval of time. This is known as 'Huygens principle' and stated as follows:
(i) Every particle of the medium situated on the wavefront acts as a new wave source from which fresh waves originate. These waves are called 'secondary wavelets'.
(ii) The secondary wavelets travel in the medium in all directions with the speed of light in the medium.
(iii) The envelope of the secondary wavelets in the forward direction at any instant gives the new wavefront at that instant**.**



The above model has one shortcoming: we also have a backwave which is shown as D_1D_2 in figure below. Huygens argued that the amplitude of the secondary wavelets is maximum in the forward direction and zero in the backward direction, by making this assumption, Huygens could explain the absence of the backwave.



Suppose there is a point Q on the incident wave front. When disturbance from point P on incident wave front reaches point P' on the refracted wave front, the disturbance from point Q reaches Q' on the refracting surface XY.

As P'A' represents the refracted wave front, the time taken by light to travel from a point on incident wave front to the corresponding point on refracted wave front should always be the same, Now, time taken by light to go from Q to Q' will be

$$t = \frac{QK}{c} + \frac{KQ}{v} \quad \text{.....(i)}$$

In right-angled ΔAQK, $\angle QAK = i$ and $QK = AK\sin i$ .....(ii)

In right-angled $\Delta P'Q'K$, $\angle Q'A'K = r \; and \; KP' = KP'\sin r$ .....(iii)

From equation .....(i), ...(ii) and .....(iii)

$$t = \frac{AK\sin i}{c} + \frac{KP'\sin r}{v}$$

$$or \quad t = \frac{AK\sin i}{c} + \frac{(AP' - AK)\sin r}{v} \quad (\because KP' = AP' - AK)$$

$$or \quad t = \frac{AP'}{c}\sin r + AK\left(\frac{\sin i}{c} - \frac{\sin r}{v}\right) \quad \text{.....(iv)}$$

The rays from different points on the incident wave front will take the same time to reach the corresponding points on the refracted wave front which means t given by equation..... (iv) is independent of AK.

It will be possible only when $\frac{\sin i}{c} - \frac{\sin r}{v} = 0 \Rightarrow \frac{\sin i}{sinr} = \frac{c}{r} \Rightarrow \mu = \frac{\sin i}{\sin r}$

This is the Snell's law for refraction of light.

(b)

Size of central diffraction pattern = $2D\lambda/d$

Where d is the width of the slit. If we increase size of width 2d than central maxima becomes half.

Thus, if the width of the single slit is doubled than the original width, then the size of the central diffraction pattern halves.

Now, as the size of the central diffraction pattern becomes half, the area of central diffraction pattern will become 1/4. Therefore, the intensity of central diffraction pattern will become 4 times.

(c)

Light when pass from border of a tiny circular obstacle then the waves get diffracted from the edges of circular obstacle and interfere constructively at the centre resulting in the formation of a brighter spot.

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