PHYSICS

Paper & Solution

SET-1

Time : 3 Hrs. **Max. Marks : 70**

General Instruction :

(i) All questions are compulsory. There are **26** questions in all.

(ii) This question paper has **five** sections : Section A, Section B, Section C, Section D, Section E.

(iii) Section A contain **five** questions of **one** mark each. Section B contains **five** questions of **two** marks each, Section C contains **twelve** questions of **three** marks each, Section D contains **one** value based question of **four** marks and Section E contains **three** questions of **five** marks each.

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

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

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

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

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

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

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

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

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

Mass of Neutrons = 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^{-1}

SECTION A

Q.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]**

Sol. As we know charge particle enters into perpendicular magnetic field it trace circular path.

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

$$r = \frac{mv}{qB}$$

$$v = r\omega$$

$$\omega = \frac{v}{r}$$

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

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

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

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

$f \propto \frac{1}{m}$ frequency $\propto \frac{1}{\text{mass}}$

Thus electron has less mass. So electron will move with high frequency.

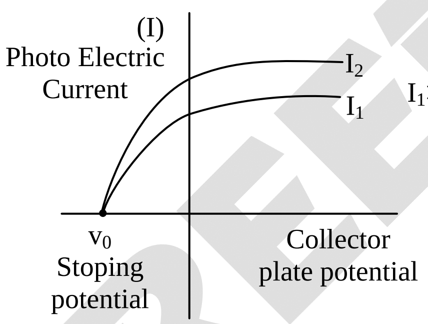
Q.2 Name the electromagnetic radiations used for (a) water purification, and (b) eye surgery. **[1]**

Sol. (a) For water purification ultra violet (uv) rays use

(b) For eye treatment infrared wave used

Q.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. **[1]**

Sol.



Q.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]**

Sol. **Nuclear fusion** : The process in which two light nuclei combined to form a single heavier nucleus is called nuclear fusion.

The mass of the heavier nucleus formed is less than the sum of masses of the combining nuclei.

So mass defect is more in daughter nuclei so binding energy is more per nucleon in daughter nuclei.

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

Sol. **Sky wave propagation** : When radio wave propagates from one place of earth to other after reflection by ionosphere, the range of frequencies from few MHz to 30 MHz gets reflected back by ionosphere. This range also reflected as short wave band. This mode of propagation is used by short wave broadcast service.

SECTION B

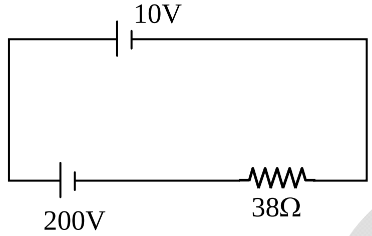
Q.6 Two electric bulbs P and Q have their resistances in the ratio of 1 : 2. They are connected in series across a battery. Find the ratio of the power dissipation of these bulbs. **[2]**

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

$$P \propto R$$

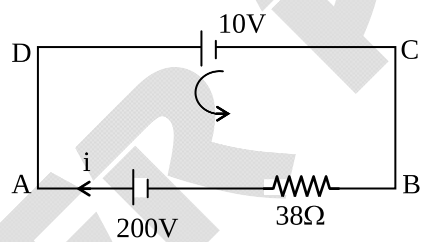
$$\frac{P_1}{P_2} = \frac{R_1}{R_2} = \frac{1}{2}$$

Q.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

Sol.



Applying Kirchoff's loop ABCDA

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

$$38\,i = 190$$

$$i = \frac{190}{38} = 5\text{ A}$$

OR

An internal resistance of the cell $r = R\left(\frac{\ell_1}{\ell_2} - 1\right)$

Here $R = 9\,\Omega$

$\ell_1 = 350$

$\ell_2 = 300$

$$r = 9\left(\frac{350}{300} - 1\right)$$

$$r = 9\left(\frac{7}{6} - 1\right)$$

$$= 9 \times \frac{1}{6} = \frac{3}{2} = 1.5\,\Omega$$

CAREER POINT

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

(b) What do you understand by the statement, "Electromagnetic waves transport momentum" ? **[2]**

Sol. (i) Infra-red waves have frequencies lower than those of visible light they have ability to vibrate not only the electrons but the entire atom on molecules of a body this vibration increases the internal energy and temperature of the body.

(ii) As electromagnetic wave contains both electric and magnetic fields, if there are charges they will be set and sustained in motion by electric and magnetic fields of the em wave. The charges thus acquire energy and momentum from the waves. This just illustrates the fact that an electromagnetic wave carries energy and momentum.

If total energy transferred to a surface in time t is u, it can be shown that the magnitude of total momentum delivered to surface

$$P = \frac{u}{C} \qquad P = \text{momentum}$$

Electromagnetic wave transfer momentum but $C = 3 \times 10^8$ is very large, the amount of momentum to transferred is extremly small.

Q.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

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

$$E = \frac{6.67 \times 10^{-34} \times 3 \times 10^8}{412.5 \times 10^{-9}}$$

$E = 0.048 \times 10^{-17}$ Joule

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

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

$E = 3$ eV

Thus metals having work-function less than energy of photon of falling light will show photoelectric effect.

So Na and K will show photo electric effect.

Q.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 %. **[2]**

Sol. Peak voltage = 15 V

Modulation index = 60 % = 0.60

Amplitude of modulating wave = A_m

Amplitude of carrier wave = A_c

$$\mu = \frac{A_m}{A_c}$$

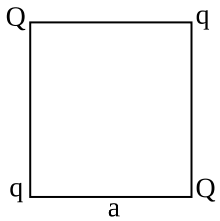
$$0.60 = \frac{A_m}{15}$$

$0.60 \times 15 = A_m$

$9\text{ V} = A_m$

SECTION C

Q.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.



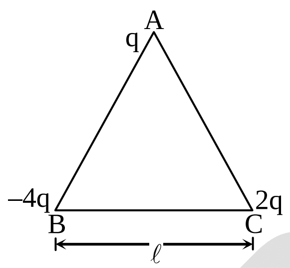
Find the

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

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

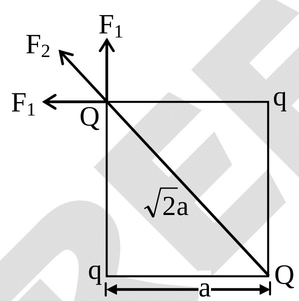
OR

(a) Three point charges q, –4q and 2q are placed at the vertices of an equilateral triangle ABC of side 'ℓ' 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.

Sol. (a)



$F_1 \rightarrow$ force act at Q by q

$F_2 \rightarrow$ force act at Q by Q

$F_1 = \frac{k.q.Q}{a^2}$, $F_2 = \frac{k.Q.Q}{(\sqrt{2}a)^2}$

$F_1 = \frac{k.q.Q}{a^2}$, $F_2 = \frac{k.Q^2}{2a^2}$

$F_{net} = \sqrt{2}\,F_1 + F_2$

$= \sqrt{2}\,\frac{k.Q.q}{a^2} + \frac{k.Q^2}{2a^2}$ [F of F_1 and F_1 will be $\sqrt{2}\,F_1$ because F_1 and F_1 perpendicular]

(b) Potential energy of system

$W_1 = \frac{k.Q.q}{a}$

CAREER POINT

$$W_2 = \frac{k.q^2}{\sqrt{2}a}$$

$$W_3 = \frac{k.Q.q}{a}$$

$$W_4 = \frac{k.q^2}{a}$$

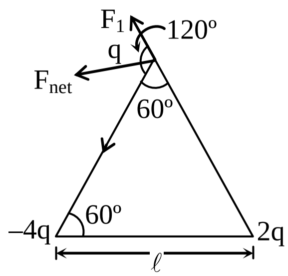
$$W_5 = \frac{k.q^2}{a}$$

$$W_6 = \frac{k.Q.q}{\sqrt{2}\,a}$$

$W = W_1 + W_2 + W_3 + W_4 + W_5 + W_6$

OR

(a)

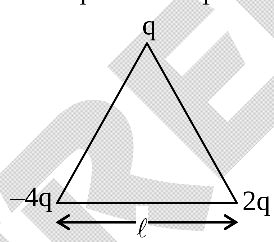


$$F_1 = \frac{k.2q.q}{\ell^2},\ F_2 = \frac{k.4q.q}{\ell^2}$$

$$F_{net} = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos 120^o}$$

$$F_{net} = \sqrt{F_1^2 + F_2^2 - F_1F_2} \qquad \cos 120^o = -\frac{1}{2}$$

(b) Work done required to separate the charges at infinity equal to electric potential energy of system. So



$$W_1 = \frac{k.q.2q}{\ell},\ W_2 = \frac{k.(-4q).q}{\ell},\ W_3 = \frac{k.(-4q).(2q)}{\ell}$$

$$W_1 = \frac{2k.q^2}{\ell},\ W_2 = \frac{-4k.q^2}{\ell},\ W_3 = \frac{-8k.q^2}{\ell}$$

$W = W_1 + W_2 + W_3$

$$W = \frac{2k.q^2}{\ell} - \frac{4k.q^2}{\ell} - \frac{8k.q^2}{\ell}$$

$$\boxed{W = \frac{-10k.q^2}{\ell}}$$

Q.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]**

Sol. (a) Conductivity: The reciprocal of the resistivity of a material is called its conductivity and is denoted by σ. Thus

$$\text{Conductivity} = \frac{1}{\text{Resistivity}}$$

$$\sigma = \frac{1}{\rho}$$

The SI unit of conductivity is ($\text{ohm}^{-1}\ \text{m}^{-1}$)

(b) When a potential difference V is applied across a conductor of length ℓ, the drift velocity in term of v is given by

$$v_d = \frac{eE}{m}\tau = \frac{eV}{m\ell}\tau$$

If area of cross-section A and n number of electron per unit volume the current through

$$I = nev_dA = neA.\left(\frac{eE}{m}\tau\right) \qquad \left(v_d = \frac{eE}{m}\tau\right)$$

$$I = \frac{ne^2E\tau}{m}$$

$$I = \frac{Ane^2V}{m\ell}\tau \qquad \left(\frac{V}{\ell} = E\right)$$

$$\frac{V}{R} = \frac{Ane^2V}{m\ell}\tau \qquad (V = IR)$$

$$R = \frac{m\ell}{Ane^2\tau}$$

$$\frac{\rho\ell}{A} = \frac{m\ell}{ne^2A\tau} \qquad \left\{R = \frac{\rho L}{A}\right\}$$

$$\rho = \frac{m}{ne^2\tau} \qquad \left(\sigma = \frac{1}{\rho}\right)$$

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

$$V = IR \qquad \text{Ohm's law}$$

$$V = I\left(\frac{\rho\ell}{A}\right)$$

$$V = \frac{I}{A}.\rho.\ell \qquad \left(j = \frac{I}{A}\right)$$

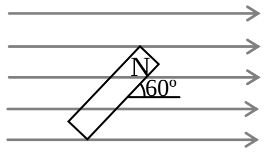
$$\frac{V}{\ell} = j\,.\,\rho$$

$$E = j.\rho$$

$$\sigma E = j \qquad \left(\frac{1}{\rho} = \sigma\right)$$

Q.13 A bar magnet of magnetic moment 6 J/T is aligned at 60º 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]**

Sol.



B = 0.44 Tesla (magnetic field)
μ = 6 J/T (Magnetic moment)

$\Delta W = \mu B[\cos\theta_1 - \cos\theta_2]$

(a) (i) Magnetic moment align normal to magnetic field

$\theta_1 = 60º$, $\theta_2 = 90º$

$\Delta W = 6 \times 0.44\ [\cos60º - \cos90º]$

$= 6 \times 0.44 \times \left[\frac{1}{2} - 0\right]$

$= 3 \times 0.44$

$\Delta W = 1.32$ J

(ii) Opposite to magnetic field $\theta_1 = 60º$, $\theta_2 = 180º$

$\Delta W = 6 \times 0.44\ [\cos60º - \cos90º]$

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

$\Delta W = 6 \times 0.44 \left[\frac{3}{2}\right]$

$= 3 \times 0.44 \times 3$

$\Delta W = 3.96$ J

(b) Torque acting on magnet placed in magnetic field

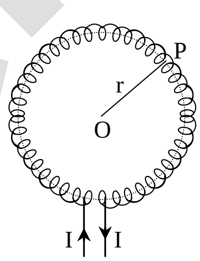
$\tau = \mu B \sin\theta$

$\tau = \mu B \sin 180º = 0$

Q.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]**

Sol. (a)



Applying Amper's Law

$\oint \vec{B}.d\vec{\ell} = \mu_0 \Sigma i$

$\oint B.d\ell \cos 0^o = \mu_0 \Sigma i$

$B\oint d\ell = \mu_0 \Sigma i$ [cos 0º = 1]

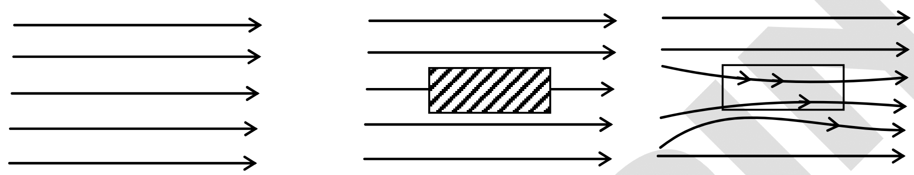
$B.2\pi r = \mu_0[n.2\pi r.i]$

$B = \mu_0 ni$ $\mu_r = \frac{\mu_m}{\mu_0}$

$B = \mu_r.\mu_0 ni$ μ_m (permeability of iron) = $\mu_r.\mu_0$

$\boxed{B = \mu_r.\mu_0 ni}$

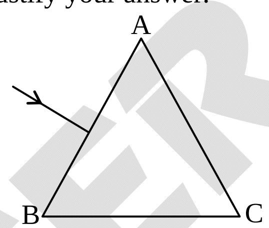
(b) x = 0.9853
the susceptibility of paramagnetic is less than 1 so it is paramagnetic material which is weakly attracted by magnetic field.



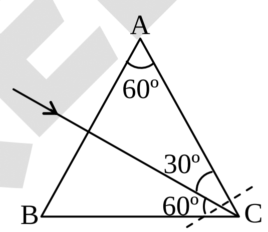
Magnetic field

Q.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]**



Sol. (a)



(b) $n_1 = \frac{3}{2}$, $n_2 = \frac{4}{3}$ (water)

Incident of light on Ac face is 60º

For total internal reflection

$$\frac{\sin i_c}{\sin 90^o} = \frac{4/3}{3/2}$$

$$\sin i_c = \frac{8}{9} = 0.88$$

$$\sin 60^o = \frac{\sqrt{3}}{2} = \frac{1.732}{2} = 0.816$$

So incident angle is smaller than i_c

Total internal reflection does not take place.

Q.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 king of fringes do you expect to observe if white light is used instead of monochromatic light ?

[3]

Sol. (a) Intensity ratio

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

Assume

$I_1 = I$

$I_2 = I/2$

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

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

$$= \left(\frac{\sqrt{2}.\sqrt{I}+\sqrt{I}}{\sqrt{2}.\sqrt{I}-\sqrt{I}}\right)^2$$

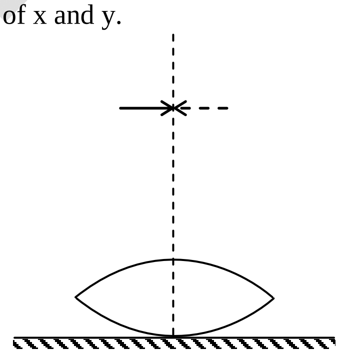
$$= \left(\frac{\sqrt{I}(\sqrt{2}+1)}{\sqrt{I}(\sqrt{2}-1)}\right)^2$$

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

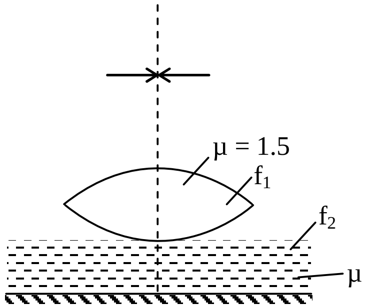
(b) The light should be monochromatic other wise different colours will produce different interference patterns and fringes of different colours will overlap.

White light has seven colours.

Q.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]**



Sol.



In first case there are two lens in combination double convex (μ = 1.5) and plane concave lens.
The image overlaped at object when it placed on focus

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

The distance x given so $f_1 = x$

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

When liquid removed distance given y
So

$$\frac{1}{f_1} = \frac{1}{y}$$

$$f_1 = y$$

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

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

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

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

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

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

$$\frac{1}{f_2} = \frac{(\mu - 1)}{-R}$$

$$\frac{1}{f_2} = \frac{1-\mu}{R}$$

$$\frac{1}{f_2} = \frac{1-\mu}{y} \qquad (y = R)$$

From equation (i)

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

$$\frac{1}{x} = \frac{1}{y} + \frac{1-\mu}{y}$$

$$\frac{1}{x} = \frac{1+1-\mu}{y}$$

$$\frac{1}{x} = \frac{2-\mu}{y}$$

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

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

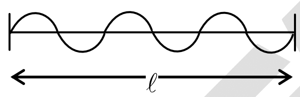
Q.18 (a) State Bohr's postulate to define stable orbits in hydrogen atom. How does de Broglie's hypothesis explain the stability of these orbits ?

(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. **[3]**

Sol. (a) For stable orbit the angular momentum of revolving e^- equal to $\frac{nh}{2\pi}$

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

According to de-Broglie's hypothesis



$$\boxed{n\lambda = \alpha\ell}$$

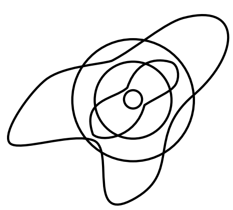
revolving e^- is stable orbit also associated with wave character. Hence a circular orbit can be taken to be stable orbit if it contains an integral number of de-Broglie wavelengths

$$2\pi r = n\lambda$$

$$2\pi r = n\left(\frac{h}{P}\right)$$

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

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



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

(b)

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

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

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

$$\nu = \frac{C}{\lambda}$$

$$\nu = C \times R\left(\frac{15}{16}\right)$$

$$\nu = 3 \times 10^8 \times 1.09 \times 10^7 \times \frac{15}{16}$$

$$\boxed{\nu = 3 \times 10^{15}\ \text{Hz}}$$

Q.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.

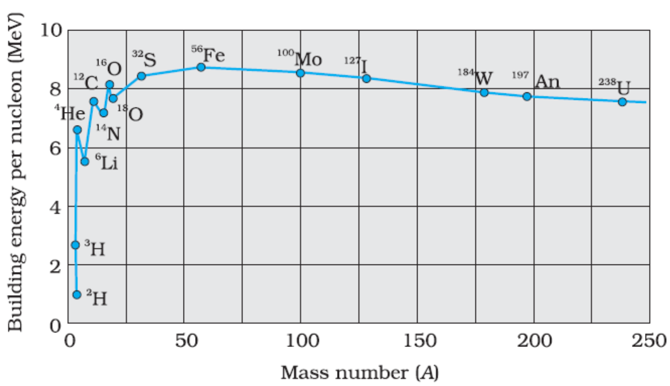
(b) A radioactive isotope has a half-life of 10 years. How long will it take for the activity to reduce to 3.12 % ? **[3]**

Sol. (a) Nuclear fission : In a nuclear fission, the sum of the masses of final products is less than the sum of the masses of the reactant components. The difference of masses called mass defect, is converted into energy.

If we devide this energy with nucleons then it is called binding energy per nucleons.

Nuclear fusion : The process in which two light nuclie combine to form a single heavier nucleus is called nuclear fusion.

The mass of heavier nucleus formed is less than the sum of the masses of the combining nuclei. The mass defect is released as energy. If we devide this energy by nucleons than it is called binding energy per nucleons.



(b) $N = N_0 e^{-\lambda t}$

$$N = \frac{3.125}{100} \times N_0$$

$$N = \frac{1}{32} \times N_0 = \frac{N_0}{32}$$

$$\frac{N_0}{32} = N_0 e^{-\lambda t}$$

$$N_0 \times 2^{-5} = N_0 e^{-\lambda t}$$

$$2^5 = e^{\lambda t}$$

$$5 \log 2 = \lambda t$$

$$t = \frac{5 \log 2}{\lambda}$$

$$\lambda = \frac{\log 2}{T_{1/2}}$$

$$\lambda = \frac{\log 2}{10}$$

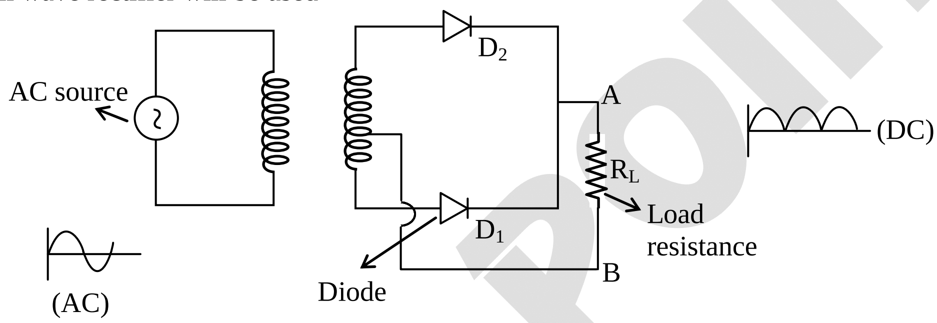
$$t = \frac{5 \log 2}{\log 2} \times 10$$

t = 50 years

Q.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.

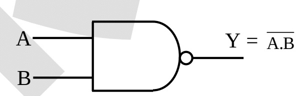
(b) Give the truth table and circuit symbol for NAND gate. **[3]**

Sol. (a) Device use to convert AC to DC is rectifier.
Here full wave rectifier will be used



When first half cycle diode D_2 behave forward and D_1 behave reverse biased current passes from A to B force second half cycle D_1 behave forward but D_2 behave reverse so current again pass from A to B. Due to both cycle current in output pass in same direction if can convert AC current into DC.

(b)

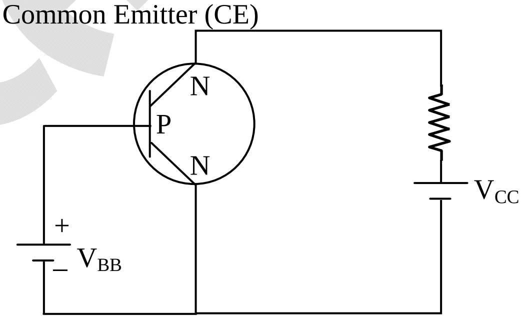


Truth table

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

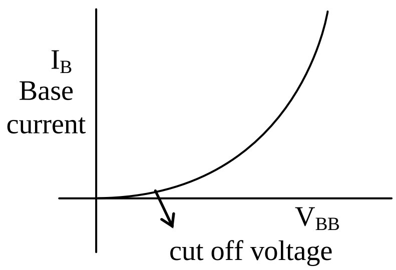
Q.21 Draw the typical input and output characteristics of an n-p-n transistor in CE configuration. Show how these characteristics can be used to determine (a) the input resistance (r_1), and (b) current amplification factor (β). **[3]**

Sol. (a) Common Emitter (CE)



Input characteristics : V_{CC} = constant

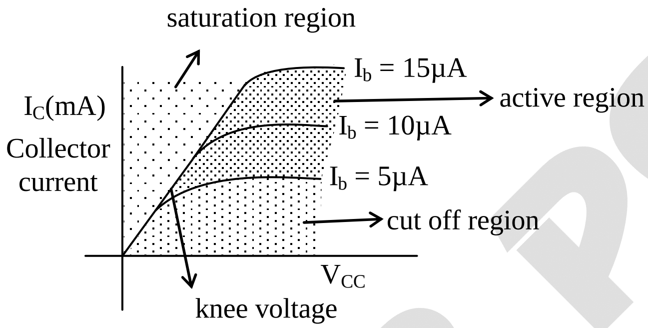
V_{BB} = increase from zero



(input resistance) $R_i = \frac{V_{BB}}{I_B}$

Output characteristics : V_{BB} = constant

V_{CC} = increase from zero



Current amplification (β) = $\frac{\Delta I_C}{\Delta I_B}$

Q.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]**

Sol. (a)

(i) Practical antenna length : To transmit a signal effectively, the height of antenna should be comparable to the wavelength of the signal at least $\frac{\lambda}{4}$ in length

$$\text{Wave length} = \frac{\text{wave velocity}}{\text{freqeuncy}}$$

$$= \frac{3\times10^8}{20\times10^3\ \text{Hz}}$$

λ = 15 μm

$\ell = \frac{\lambda}{4}$ = 3.75 km

3.75 km antenna practically not possible.

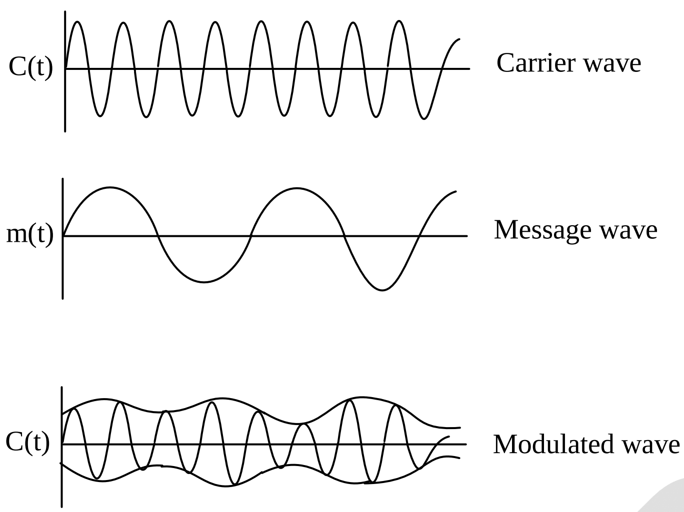
(ii) effective power radiated by antenna :

$$\text{Power radiated} \propto \left(\frac{\ell}{\lambda}\right)^2$$

Thus the power radiated by short wavelength would be large

(iii) Multiplexing frequency : In order to transmit different audio signals simultaneously through one antenna, each signal is translated to a low frequency range so that it is easily distinguishable from other signals at the receiving station.

(b)



SECTION D

Q.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. **[4]**

Sol. (a) The device which convert high voltage to low or low voltage to high voltage is transformer. Power can loss by heat and flux leakage.

(b) Electric power is transmitted from power station to homes through cables. These cables have resistance power is wasted in them as heat.

Suppose power P is delivered to a load R via cables of resistance R_t. If V is the voltage across load R and I current.

$$P = V\text{-}I$$

Power wasted $P_t = I^2R_t = \dfrac{P^2R_t}{V^2}$

$$P_t \propto \frac{1}{V^2}$$

So high voltage waste less power

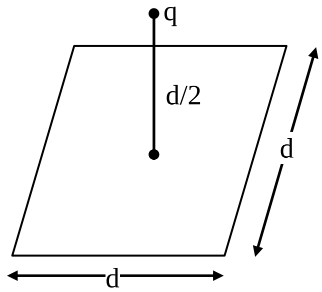
(c) They should be polite and thankful to each other.

CAREER POINT

SECTION E

Q.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 a, 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

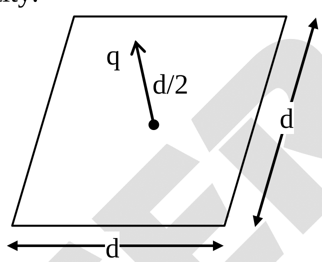
(a) Use Gauss' law to derive the expression for the electric field ($\vec{E}$) due to a straight uniformly charged infinite line of charge density λ C/m.

(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 ($r_2 > r_1$).

Sol. (a) Electric flux : The number of electric field lines passing through any area normally is known as electric flux (d).

It is scalar quantity.



Making square the cube and charge becomes at centre.

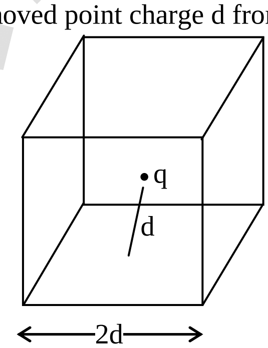
$$\phi = \frac{q_{in}}{\in_0}$$

$$\phi = \frac{q}{\in_0}$$

Flux from only one square of cube

$$\boxed{\phi = \frac{q}{6\in_0}}$$

(b) If we moved point charge d from centre



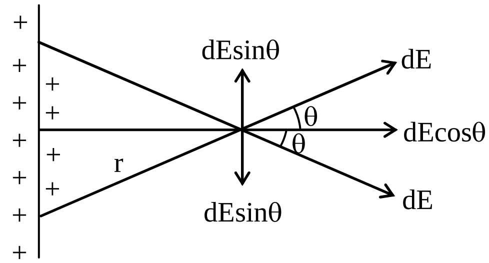
$$\phi = \frac{q}{\epsilon_0}$$

$$\phi = \frac{q}{6\epsilon_0}$$

Flux will remain same in both cases.

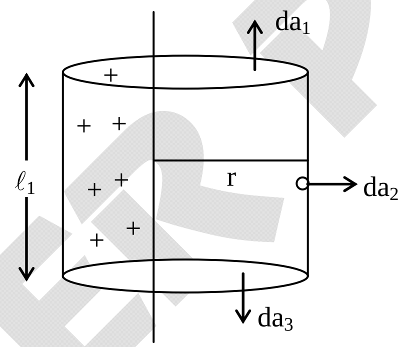
OR

(a)



$$\lambda = \frac{Q}{\ell} \quad \frac{\text{total charge}}{\text{total length}}$$

Vertical component cancel and horizontal add if we assume whole wire made up with pair of λ then resultant field will be horizontal.



$$\phi = \oint \vec{E}.d\vec{a}$$

$$\phi = \int \vec{E}.d\vec{a}_1 + \int \vec{E}.d\vec{a}_2 + \int \vec{E}.d\vec{a}_3$$

$$\phi = \int \vec{E}.d\vec{a}_1 \cos 90^o + \int \vec{E}.d\vec{a}_2 \cos 0^o + \int \vec{E}.d\vec{a}_3 \cos 90^o$$

$$\phi = \int E.da_2$$

$$\phi = E.2\pi r\ell_1$$

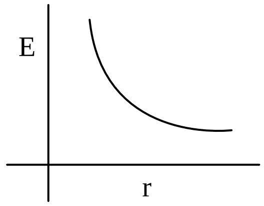
$$\phi = \frac{\Sigma q_{in}}{\epsilon_0} = \frac{\lambda \ell_1}{\epsilon_0}$$

equate them

$$\frac{\lambda \ell_1}{\epsilon_0} = E.2\pi r\ell_1$$

$$E = \frac{\lambda}{2\pi r \epsilon_0}$$

(b)



$$E = \frac{\lambda}{2\pi r \in_0}$$

$$E \propto \frac{1}{r}$$

(c) Work done to moving from r_1 to r_2

$$dV = \int E.dr$$

$$dV = \int_{r_1}^{r_2} \frac{\lambda}{2\pi \in_0 r} dr$$

$$dV = \frac{\lambda}{2\pi \in_0 r} \int_{r_1}^{r_2} \frac{1}{r} dr$$

$$= \frac{\lambda}{2\pi \in_0} \left[\log \frac{r_2}{r_1} \right]$$

$$W = qV$$

$$W = q\left(\frac{\lambda}{2\pi \in_0} \log\left(\frac{r_2}{r_1} \right) \right)$$

Q.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 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 30º. **[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.

Sol. (a) **AC Generator :** Consider a coil PQRS free to rotate in a uniform magnetic field B. The axis of rotation of the coil is perpendicular to the field B. The flux through the coil.

$$N\phi = N.B.A \cos\theta$$

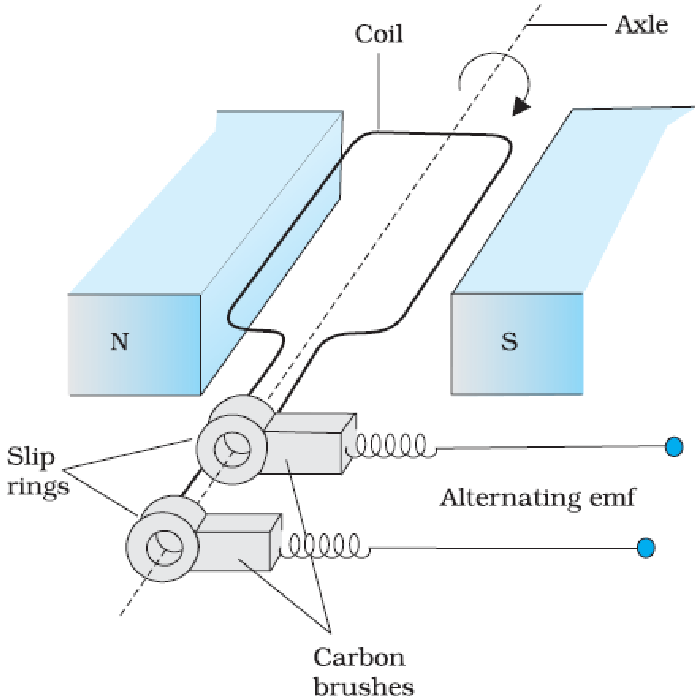
$$N\phi = N.B.A \cos(\omega t)$$

$$N\frac{d\phi}{dt} = N.B.A. \frac{d}{dt}\cos(\omega t) \qquad \text{differentiate}$$

$$N\frac{d\phi}{dt} = -NBA\omega \sin(\omega t) \qquad \left(\varepsilon = -N\frac{d\phi}{dt}\right)$$

$-\varepsilon = -NBA\omega \sin(\omega t)$ $\varepsilon_0 = NBA\omega$

$\varepsilon = \varepsilon_0 \sin(\omega t)$



The AC generator work on change in flux induce emf in coil on [EMI]

(b) $V = 900 \times \frac{1000}{3600} = 250$ m/s

$\ell = 20$ m

When aeroplane going in west to east its wings cross vertical component of earth magnetic field.

$B = 5 \times 10^{-4}$ Tesla

$\theta = 30^o$

$B \sin\theta = B_\perp$

$B_\perp = 5 \times 10^{-4} \times \sin 30^o = 2.5 \times 10^{-14}$

$\varepsilon = B\ell v$

$= 2.5 \times 10^{-4} \times 20 \times 250$

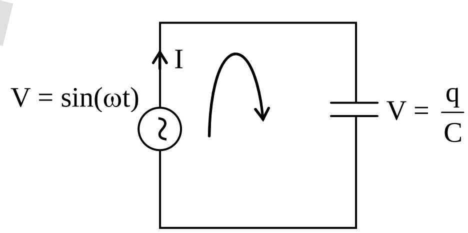
$= 50 \times 25 \times 10^{-3}$

$= 125 \times 10^{-2}$

$= 1.25$ volt

OR

(a)



Applying Kirchoff's law

$V_0 \sin(\omega t) - \frac{q}{C} = 0$

$V_0\sin(\omega t) = \dfrac{q}{C}$

$V_0C\sin(\omega t) = q$

$V_0C\dfrac{d}{dt}\sin(\omega t) = \dfrac{dq}{dt}$

$\omega V_0C\cos(\omega t) = i$

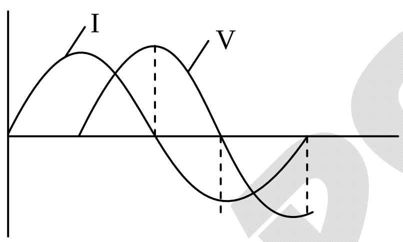
$\dfrac{V_0}{1/\omega C}\cos(\omega t) = i$

$\dfrac{V_0}{X_C}\cos(\omega t) = i$

$i_0\sin\left(\dfrac{\pi}{2}+\omega t\right) = i \qquad i_0 = \dfrac{V_0}{X_C \rightarrow \text{capacitive reactance } (\Omega)}$

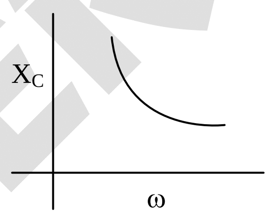
Here X is capacitor

(b)

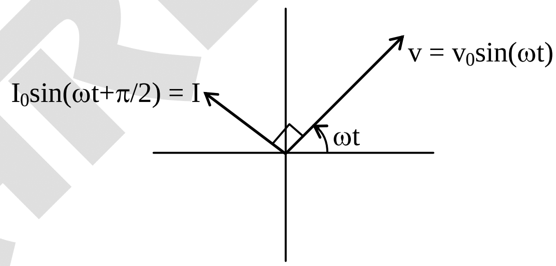


(c) $X_C = \dfrac{1}{\omega C}$

$X_C \propto \dfrac{1}{\omega}$



(d)



Q.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]**

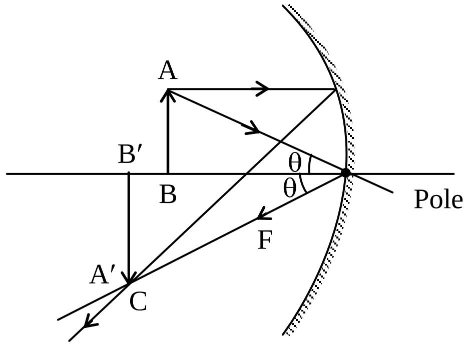
OR

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

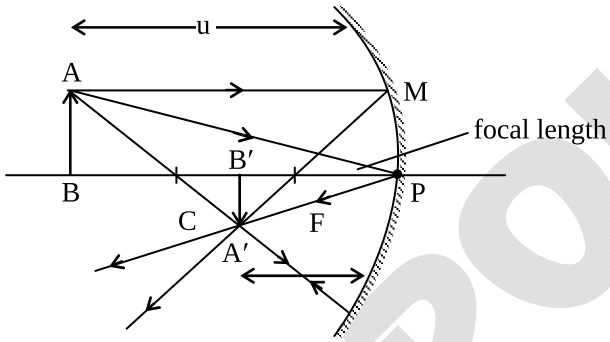
(b) In a single slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band ? Explain.

(c) When a tiny circular 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.

Sol. (a)



(b)



ΔA′B′F and MPF are similar (A-A)

So

$$\frac{A'B'}{MP} = \frac{B'F}{FP} \quad ....(i)$$

ΔABP and A′B′P are similar (A-A)

$$\frac{A'B'}{BP} = \frac{B'P}{BP} \quad .....(ii)$$

MP = AB (By geometry)

$$\frac{A'B'}{AB} = \frac{B'F}{FP} \quad ....(iii)$$

equate (ii) and (iii)

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

$$\frac{(-v)}{(-u)} = \frac{B'P - FP}{FP}$$

$$\frac{v}{u} = \frac{(-v) - (-f)}{-f}$$

$$\frac{-vf}{uvf} = \frac{-uv + uf}{uvf}$$

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

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

CAREER POINT

From equation (ii)

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

$$\frac{-h'}{h} = \frac{-v}{-u}$$

$$m = \frac{h'}{h} = \frac{-v}{u}$$

$$\boxed{m = \frac{v}{u}}$$ $h' \rightarrow$ height of image, $h \rightarrow$ height of object

$$\boxed{m = \frac{h'}{h}}$$

(c) (i) Reflecting telescope have height resolving power due to a large aperture of mirror.

(ii) Due to availability of paraboloidal mirror, the image is free from chromatic and spherical aberration.

OR

(a) Wavefront : A wavefront is defined as the continuous locus of all such particle of the medium which are vibrating in same phase at any instant. Wave (secondary wavelets) emit from wavefront perpendicularly.

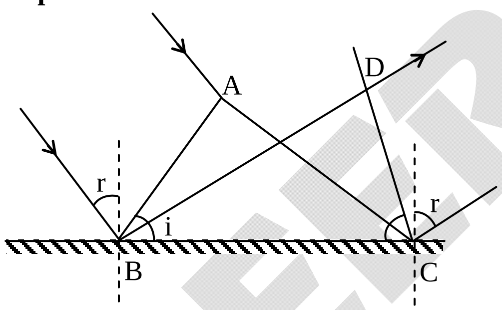
There are different type of wavefront

(i) Spherical wavefront

(ii) Plane wavefront

(iii) Cylindrical wavefront

Explanation of Reflection



Here in triangle ABC and BDC

BC = BC

$\angle BAC = \angle BDC = 90^\circ$

AC = BD

$\Delta ABC \cong \Delta BDC$

$i = r$ hence law of reflection $i = r$

(b) In diffraction

$d\sin\theta = \lambda$ d = slit size

$d\theta = \lambda$

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

Linear width of central maximum : If D is the distance of the screen from the single slit, then the linear width of central maximum will be

$$\beta_0 = D \times 2\theta = \frac{2D\lambda}{d}$$

If we increase size of width 2d than central maxima becomes half

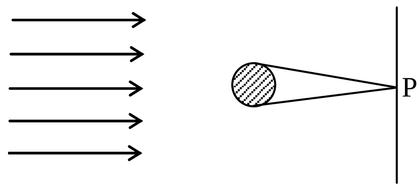
$$\beta_0 = \frac{2D\lambda}{2d}$$

$$2\beta = \beta_0$$

$$\beta = \frac{\beta_0}{2}$$

Intensity of central maximum becomes 4 times.

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



Light when pass from border of circular obstacle it diffracted toward centre of the obstacle.
In centre part all diffracted wavefront meet thats why centre becomes bright.

CAREER POINT