CBSE Class 12 Physics
Sample Paper 09 (2020-21)

Maximum Marks: 70
Time Allowed: 3 hours

General Instructions:

i. All questions are compulsory. There are 33 questions in all.
ii. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
iii. Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.
iv. There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

Section A

1. Write an expression for the flux $\Delta\phi$, of the electric field $\vec{E}$ through an area element $\overrightarrow{\Delta S}$.
2. What is Bohr's quantisation condition for the angular momentum of an electron in the second orbit?

OR

Name the series of hydrogen spectrum which does not lie in the visible region.

3. In Young's double slit experiment, the separation of the slits is doubled and the distance between the slits and the screen is halved. How will it affect the fringe width?
4. What is the ratio of slit widths when amplitudes of light waves from them have a ratio $\sqrt{2} : 1$.

OR

Why should we have narrow sources to produce good interference fringes?

5. What is the length of a telescope in a normal adjustment?
6. A source of light of frequency greater than threshold frequency is placed at a distance of 1 m from the cathode of a photocell. The stopping potential is found to be V. If the distance of the light source from the cathode is reduced, explain giving reasons, what change will you observe in the
   i. photoelectric current and
   ii. stopping potential?
7. Can a metal sphere of radius 1 cm hold a charge of 1 coulomb?

OR

Write the formula for capacity of a parallel plate air capacitor with a metal sheet of thickness t in between the plates.

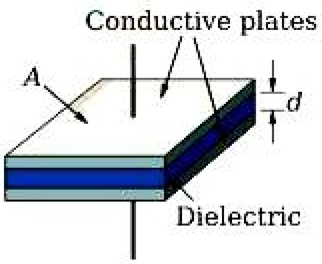
8. In the Figure, is the diode D forward or reverse biased?

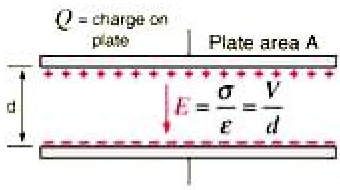
9. What is the probable cause of earth's magnetism?
10. How does the energy gap in an intrinsic semiconductor change, when doped with a trivalent impurity?
11. **Assertion (A):** X-rays travel at the speed of light.
    Reason (R): X-rays are electromagnetic rays.
    a. Both A and R are true and R is the correct explanation of A
    b. Both A and R are true but R is NOT the correct explanation of A
    c. A is true but R is false
    d. A is false and R is also false
12. **Assertion (A):** Cobalt-60 is useful in cancer therapy.
    Reason (R): Cobalt-60 is a source of y-radiations capable of killing cancerous cells.
    a. Both A and R are true and R is the correct explanation of A
    b. Both A and R are true but R is NOT the correct explanation of A
    c. A is true but R is false
    d. A is false and R is also false

13. **Assertion:** Out of galvanometer, ammeter and voltmeter, the resistance of ammeter is the lowest and resistance of voltmeter is highest.
Reason: An ammeter is connected in series and a voltmeter is connected in parallel, in a circuit.
 a. Both A and R are true and R is the correct explanation of A
 b. Both A and R are true but R is NOT the correct explanation of A
 c. A is true but R is false
 d. A is false and R is also false
14. **Assertion (A):** A piece of copper and a similar piece of stone are dropped simultaneously from a height near the earth's surface. Both will touch the ground at the same time.
Reason (R): There is no effect of the earth's magnetic field on the motion of falling bodies.
 a. Both A and R are true and R is the correct explanation of A
 b. Both A and R are true but R is NOT the correct explanation of A
 c. A is true but R is false
 d. A is false and R is also false

Section B

15. **Read the source given below and answer any four out of the following questions:**
Capacitance is the ratio of the change in the electric charge of a system to the corresponding change in its electric potential. Capacitors consist of two parallel conductive plates (usually a metal) which are prevented from touching each other (separated) by an insulating material called the "dielectric". When a voltage is applied to these plates an electrical current flows charging up one plate with a positive charge with respect to the supply voltage and the other plate with an equal and opposite negative charge. The generalized equation for the capacitance of a parallel plate capacitor is given as: $C = k\epsilon_0 \frac{A}{d}$ where ε_0 represents the absolute permittivity of the dielectric material being used, and the charge is given by q = CV





 i. When a conductor is placed in an electric field, the field inside the conductor is:-

a. positive
b. negative
c. constant
d. zero

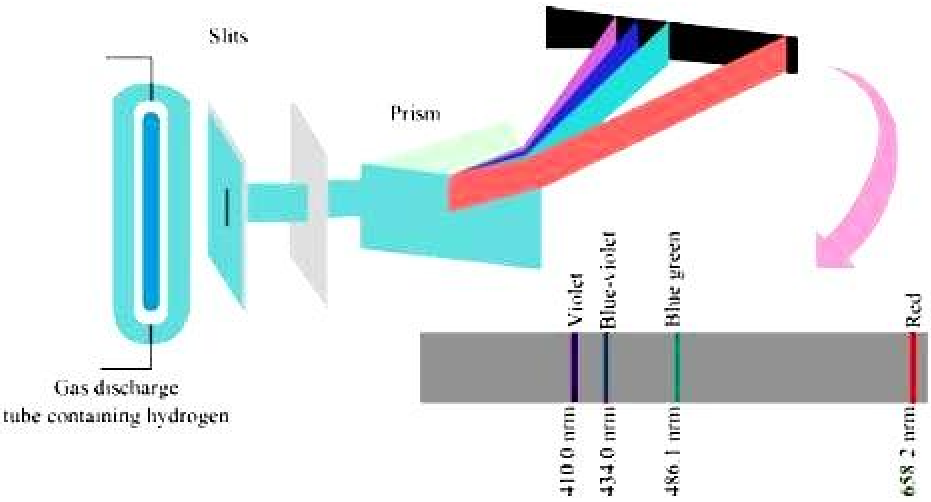
ii. The charge on a capacitor is doubled. Its capacity becomes k times where k:
a. k = 2
b. k = 1
c. k = 0.5
d. k = 0

iii. Why does the capacitor block dc signal at a steady-state?
a. Due to the high frequency of dc signal
b. Due to the zero frequency of dc signal
c. The capacitor does not pass any current at a steady-state
d. Due to zero frequency of dc signal

iv. What is the value of capacitance of a capacitor which has a voltage of 4V and has 16C of charge?
a. 2F
b. 4F
c. 6F
d. 8F

v. Capacitor blocks ________ after long time.
a. alternating current
b. direct current
c. both (a) and (b)
d. none of these

16. **Read the source given below and answer any four out of the following questions:**
Electrons in an atom or a molecule absorb energy and get excited, they jump from a lower energy level to a higher energy level, and they emit radiation when they come back to their original states. This phenomenon accounts for the emission spectrum through hydrogen too, better known as the hydrogen emission spectra.



i. If 13.6 eV energy is required to ionize the hydrogen atom, then energy required to remove an electron from n = 2 is:-
   a. 10.2 eV
   b. 0 eV
   c. 3.4 eV
   d. 6.8 eV
ii. In Bohr's model of an atom which of the following is an integral multiple of $\frac{h}{2\pi}$?
   a. Kinetic energy
   b. The radius of an atom
   c. Angular momentum
   d. None of these
iii. The ratio between Bohr radii is:-
   a. 1 : 2 : 3
   b. 2 : 4 : 6
   c. 1 : 4 : 9
   d. none of these
iv. On moving up in the energy states of an H-like atom, the energy difference between two consecutive energy states:-
   a. increase
   b. decrease
   c. unchanged
   d. none of these
v. The Bohr model of atoms:
   a. Assumes that the angular momentum of electrons is quantized

b. Uses Einstein's photoelectric equation

c. Predicts continuous emission spectra for atoms

d. None of these

Section C

17. The resistance of the platinum wire of a platinum resistance thermometer at the ice point is 5 Ω and at the steam point is 5.23 Ω. When the thermometer is inserted in a hot bath, the resistance of the platinum wire is 5.795 Ω. Calculate the temperature of the bath.

18. The image obtained with a convex lens is erect and its length is four times the length of the object. If the focal length of the lens is 20 cm, calculate the object and image distances.

OR

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

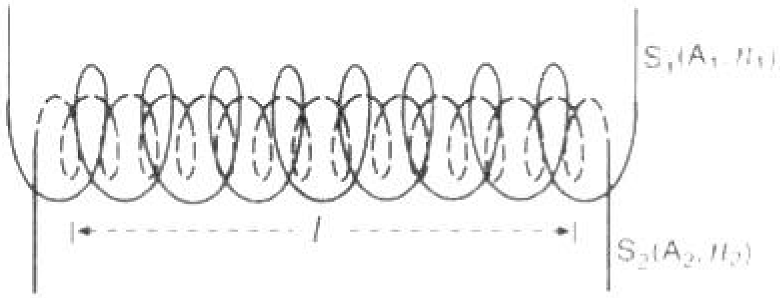
19. Plot a graph showing the variation of Coulomb force (F) versus $1/r^2$, where r is the distance between the two charges of each pair of charges (1μC, 2μC) and (1μC, -3μC). Interpret the graphs obtained.

OR

Suppose that the particle in an electron projected with velocity $v_x = 2.0 \times 10^6 ms^{-1}$. If E between the plates separated by 0.5 cm is $9.1 \times 10^2 N/C$, where will the electron strike the upper plate? $(|e| = 1.6 \times 10^{-19}\ C, m_e = 9.1 \times 10^{-31} kg)$.

20. State and explain Fleming's right hand rule.

21. In a figure shows two long coaxial solenoids, each of length l. The outer solenoid has an area of crosssection A_1 and number of turns per unit length n_1. The corresponding values for the inner solenoid are A_2 and n_2.



Write the expression for self-inductance L_1, L_2 of the two coils and their mutual inductance M. Hence, show that $M < \sqrt{L_1 L_2}$.

22. i. State two distinguishing features of nuclear force.
    ii. Draw a plot showing the variation of the potential energy of a pair of nucleons as a function of their separation. Mark the regions on the graph where the force is
        a. attractive, and
        b. repulsive.
23. An object of size 3.0 cm is placed 14 cm in front of a concave lens of focal length 21 cm. Describe the image produced by the lens. What happens if the object is moved further away from the lens?
24. 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^o.

OR

A hypothetical bar magnet (AB) is cut into two equal parts as shown in Figure.

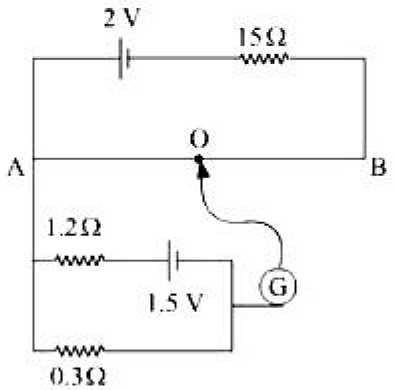
One part is now kept over the other, so that pole C_2 is above C_1. If M is the magnetic moment of the original magnet, what would be the magnetic moment of the combination so formed?

25. Draw the ray diagram of an astronomical telescope showing image formation in the normal adjustment position. Write the expression for its magnifying power.

Section D

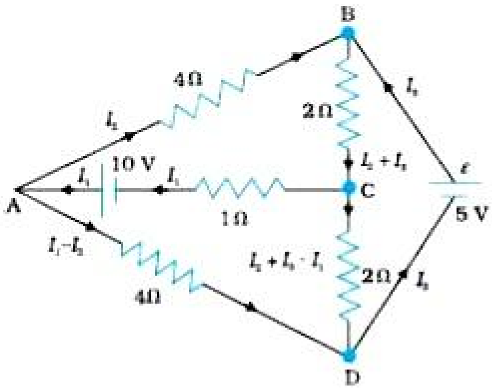
26. In Young's double slit experiment, the two slits 0.15 mm apart are illuminated by monochromatic light of wavelength 450 nm. The screen is 1.0 m away from the slits.
    i. Find the distance of the second
        a. bright fringe
        b. dark fringe from the central maximum.
    ii. How will the fringe pattern change if the screen is moved away from the slits?
27. i. State the principle of working of a potentiometer.

ii. In the following potentiometer, circuit AB is a uniform wire of length 1 m and resistance 10Ω. Calculate the potential gradient along the wire and balance length AO(l).



OR

Determine the current in each branch of the network shown in Fig.

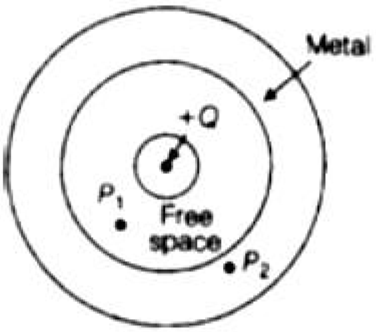


28. Two insulated charged copper spheres A and B have their centres separated by a distance of 50 cm. What is the mutual force of electrostatic repulsion if the charge on each is 6.5×10^{-7} C? Suppose the spheres A and B have identical sizes. A third sphere of the same size but uncharged is brought in contact with the first, then brought in contact with the second, and finally removed from both. What is the new force of repulsion between A and B?

OR

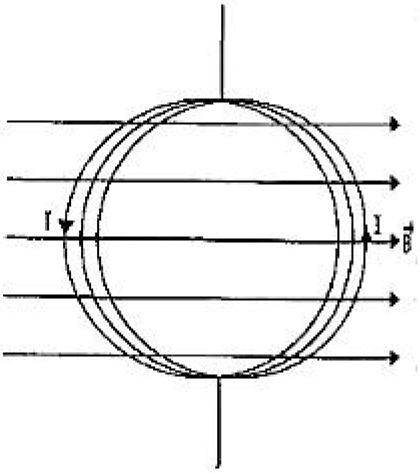
Define electric flux. Write its SI unit.

A small metal sphere carrying charge +Q is located at the centre of a spherical cavity inside a large uncharged metallic spherical shell as shown in the figure. Use Gauss' law to find the expressions for the electric field at points P_1 and P_2.



29. Write Einstein's photoelectric equation and mention which important features in photoelectric effect can be explained with the help of this equation.
The maximum kinetic energy of the photoelectrons gets doubled when the wavelength of light incident on the surface changes λ_1 from to λ_2. Derive the expressions for the threshold wavelength λ_0 and work function for the metal surface.

30. A circular coil of 25 turns and radius 6.0 cm carrying a current of 10 A, is suspended vertically in a uniform magnetic field of magnitude 1.2 T. The field lines run horizontally in the plane of the coil. Calculate the force and torque on coil due to the magnetic field.



Section E

31. i. State briefly the processes involved in the formation of p-n junction, explaining clearly how the depletion region is formed.
 ii. Using the necessary circuit diagrams, show how the V-I characteristics of a p-n junction are obtained in (a) forward biasing (b) reverse biasing? How are these characteristics made use of in rectification?

OR

 i. Write the important considerations which are to be taken into account while fabricating a p-n junction diode to be used as a Light Emitting Diode (LED). What should be the order of band gap of an LED, if it is required to emit light in the visible range? Draw a circuit diagram and explain its action.

ii. Draw the V-I characteristics of an LED. State two advantage of LED lamps over conventional incandescent lamps.

32. i. An alternating voltage $V = V_m \sin \omega t$ applied to a series L-C-R circuit derives a current given by
$I = I_m \sin(\omega t + \phi)$. Deduce an expression for the average power dissipated over a cycle.

ii. For circuit used for transporting electric power, a low power factor implies large power loss in transmission. Explain.

OR

A resistor of 400 Ω, an inductor of $\frac{5}{\pi}$ H and a capacitor of $\frac{50}{\pi} \mu F$ are connected in series across a source of alternating voltage of 140 sin $100\pi t\, V$. Find the voltage (rms) across the resistor, the inductor and the capacitor. Is the algebraic sum of these voltages more than the source voltage? If yes, resolve the paradox.
(Given, $\sqrt{2} = 1.414$).

33. i. Define a wavefront. How is it different from a ray?

ii. Depict the shape of a wavefront in each of the following cases.

a. Light diverging from point source.
b. Light emerging out of a convex lens when a point source is placed at its focus.
c. Using Huygen's construction of secondary wavelets, draw a diagram showing the passage of a plane wavefront from a denser into a rarer medium.

OR

What is interference of light? Write two essential conditions for sustained interference pattern to be produced on the screen. Draw a graph showing the variation of intensity versus the position on the screen in Young's experiment when (a) both the slits are opened and (b) one of the slit is closed. What is the effect on the interference pattern in Young's double-slit experiment when:

i. Screen is moved closer to the plane of slits?
ii. Separation between two slits is increased. Explain.

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Solution

Section A

1. If an elementary surface area ΔS is held inside the electric field E and E_n is the component of electric field normal to the surface area ΔS, then electric flux through the surface,
   $\Delta\phi = E_n\Delta S$
   In vector notation, $\Delta\phi = \overrightarrow{E} \cdot \overrightarrow{\Delta S}$
2. Quantisation of angular momentum is, $L = \frac{nh}{2\pi}$
   When n = 2, then $L = \frac{2h}{2\pi}$
   $\Rightarrow L = \frac{h}{\pi}$
   This is the required Bohr's quantisation condition for the angular momentum of an electron in the second orbit.

   OR

   Lyman series of hydrogen spectrum does not lie in the visible region.
3. In the interference pattern, the fringe width is given by
   $\beta = \frac{D\lambda}{d}$
   When D is halved and d is doubled, β becomes one-fourth. i.e. the fringe width reduces to one-fourth of its previous value.
4. $\frac{\omega_1}{\omega_2} = \frac{I_1}{I_2} = \frac{a^2}{b^2}$
   $\Rightarrow \frac{\omega_1}{\omega_2} = \left(\frac{\sqrt{2}}{1}\right)^2 = \frac{2}{1} \Rightarrow \omega_1 : \omega_2 = 2 : 1$

   OR

   It is because, a broad source is equivalent to a large number of narrow sources lying close to each other. Due to overlapping of interference patterns due to different pairs of narrow sources, (in the broad source) the interference pattern obtained is not a distinct one.
5. Length of a telescope is given by the sum of the focal length of the objective and the

eyepiece, i.e.

$L = f_o + f_e$

where, f_o is the focal length of the objective and, f_e is the focal length of the eyepiece.

6. i. On decreasing the distance of the source of light from the photocell, the intensity of light will increase. As the photocurrent is directly proportional to the intensity of light, the photocurrent will increase.
   ii. There will be no effect on the stopping potential.
7. Here, r = 1 cm = 0.01 m; q = 1 C

   Capacitance of the metal sphere,

   $C = 4\pi\varepsilon_0 r = \frac{1}{9\times10^9} \times 0.01\text{F}$

   Therefore, potential of the metal sphere, when a charge of 1 C is given to it,

   $V = \frac{q}{C} = \frac{1\times9\times10^9}{0\cdot01} = 9 \times 10^{11}\text{V}$

   Thus, for metal sphere to hold a charge of 1 C, it will have to be raised to a potential of 9×10^{11} V. But even before such a high potential is reached, the surrounding air becomes highly ionised and the charge leaks to the surroundings. Therefore, the given metal sphere will not be able to hold charge of 1C.

   OR

   $C = \frac{\varepsilon_0 A}{d-t}$

   where A is area of cross-section of plates, d is the distance between the plates and t is the thickness of metal plate.
8. Since n-section is connected to earth and p-section is at -10 V, the diode is reverse biased.
9. The exact cause of earth's magnetism is not yet known. It must be basically due to the magnetic effect of currents. The earth rotates about its axis of rotation. Since every substance is made of charged particle, the rotating earth is equivalent to circulating current and it gives rise to the earth's magnetism.
10. In a p-type semiconductor, energy band increases. Fermi levels shifts closer to the valence bond because holes are the majority carriers.
11. (a) Both A and R are true and R is the correct explanation of A

    Explanation: All electromagnetic waves have the same speed in a vacuum. X-ray is a high energy electromagnetic wave.
12. (a) Both A and R are true and R is the correct explanation of A

Explanation: Cobalt 60 is the radioactive isotope of cobalt. γ-radiation emitted by it is used in radiation therapy is cancer as it destroys cancerous cells. So, assertion and reason are true and reason explains assertion.

13. (c) A is true but R is false

    Explanation: A is true but R is false

14. (d) A is false and R is also false

    Explanation: A is false and R is also false

Section B

15. i. (d) zero
    ii. (b) k = 1
    iii. (d) Due to zero frequency of dc signal
    iv. (b) 4F
    v. (b) direct current
16. i. (c) 3.4 eV
    ii. (c) Angular momentum
    iii. (c) 1 : 4 : 9
    iv. (b) Decrease
    v. (a) Assumes that the angular momentum of electrons is quantized

Section C

17. The resistance of a platinum wire at ice point $R_0 = 5\ \Omega$,

    The resistance of a platinum wire at steam point $R_{100} = 5.23\ \Omega$ and

    When the thermometer is inserted in a hot bath the resistance of the platinum wire is $R_t = 5.795\ \Omega$

    Now, $t = \frac{R_t - R_0}{R_{100} - R_0} \times 100$, $R_t = R_0(1 + \alpha t)$

    $= \frac{5.795-5}{5.23-5} \times 100$

    $= \frac{0.795}{0.23} \times 100 = 345.65^\circ\text{C}$

18. Given: Here it is given that, $v = 4u$

    By using lens formula, we have

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

    $\frac{1}{f} = \frac{1}{(4u)} - \frac{1}{(u)}$

    $\Rightarrow \quad \frac{1}{20} = \frac{1-4}{4u} = \frac{-3}{4u} \Rightarrow u = \frac{-20\times3}{4} = -15\text{cm}$

    Hence, v = 4u = -15×4 = -60 cm

Object distance = 15 cm, Image distance from lens = 60 cm

OR

Resolving power of telescope is given by

$$R_p = \frac{A}{1.22\lambda}$$

where, A = aperture or diameter of the objective telescope

and λ = wavelength of the objective.

$$\Rightarrow \quad R \propto A$$

Therefore, the Ratio of resolving powers of two telescopes will be:

$$\frac{R_1}{R_2} = \frac{A_1}{A_2}$$

$\because A_1 > A_2$

$\therefore R_1 > R_2$

Hence, larger the aperture of objective, higher will be the resolving power of telescope. Also there will be more gathering of light to form the image more and more brighter. Thus here, telescope having convex lens of aperture A_1 is preferred.

19. As per Coulomb's law, the force acting between two stationary point charges will be given by

$$F = \left(\frac{q_1 q_2}{4\pi\varepsilon_0}\right)\left(\frac{1}{r^2}\right)$$

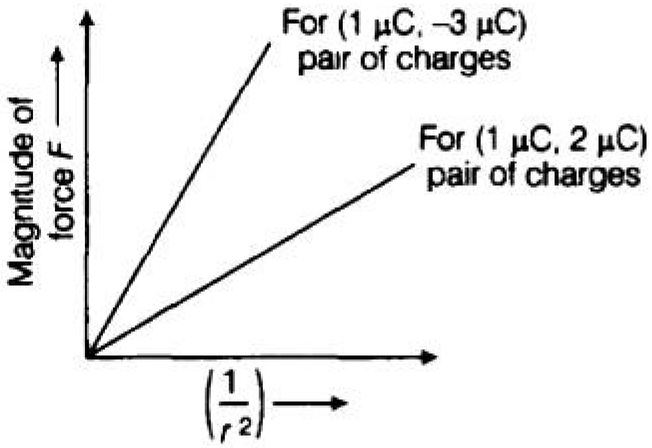
For fixed charges q_1 and q_2,

$$F \propto \left(\frac{1}{r^2}\right)$$

The slope of F versus $\frac{1}{r^2}$ graph depends on q_1 and q_2.

Magnitude of force is higher for the second pair as higher the product of charges more will be the force at fixed distance r according to Coulomb's law.

$\therefore$ Slope of F versus $\frac{1}{r^2}$ graph corresponding to second pair (1μC,- 3μC) is greater. Higher the magnitude of product of charges q_1 and q_2, higher the slope of the graph between F and $1/r^2$.



OR

Acceleration, $a=\frac{qE}{m}$

$=\frac{1.6\times10^{-19}\times9.1\times10^{2}}{9.1\times10^{-31}}=1.6\times10^{14}m/s^2$

Using formula $y=ut+\frac{1}{2}at^2$

We get, $0.005=0+\frac{1}{2}\times1.6\times10^{14}\times t^2$

Simplifying for value of t, we get

$t=8\times10^{-9}s$

The electron covers vertical distance is shown as

$y = v_x t$

$=2.0\times10^{6}\times8\times10^{-9}$

$=1.6\times10^{-2}m$

= 1.6 cm

20. It states that if the thumb, fore finger and the central finger of the right hand are kept perpendicular to each other, so that the fore finger points in the direction of the field and the thumb in the direction of motion of the conductor, then the induced current flows in the direction of the central finger.

    We know that when a conductor is moved inside the magnetic field in a direction perpendicular to the direction of magnetic field, induced e.m.f. is produced across its two ends. The direction of flow of current can be found by applying Lenz's rule. The direction of flow of the induced current can also be found by applying Fleming's right hand rule, when the direction of motion of conductor inside the magnetic field and the direction of magnetic field acting on it are known.

21. The self-inductances of the two solenoids are given by

$L_1 = \mu_0 n_1^2 A_1 l$ and $L_2 = \mu_0 n_2^2 A_2 l$

As the magnetic flux linked between the two solenoids is confined to the cross-sectional area A_2 only, the mutual inductance of the two solenoids is given by

$M = \mu_0 n_2^2 A_2 l$

Now, $\sqrt{L_1 L_2} = \sqrt{\mu_0 n_1^2 A_1 l \times \mu_0 n_2^2 A_2 l}$

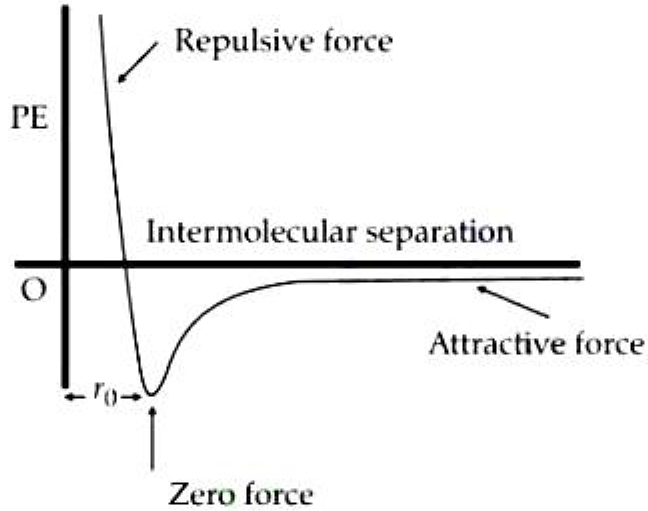
or $\sqrt{L_1 L_2} = \mu_0 n_1 n_2 A_1 A_2 l$

It follows that

$MA_1 = \sqrt{L_1 L_2}$ or $M < \sqrt{L_1 L_2}$ (provided $A_1 > 1$)

22. i. The distinguishing features of nuclear force are:
    a. These forces are attractive by nature.
    b. The nuclear force is a short-range force. It means that it exists only when particles are very very close to each other.
    c. These forces do not obey inverse square law.

ii.



23. O = 3.0 cm, u = -14cm, f = -21cm

Now, $\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = -\frac{1}{21} - \frac{1}{14} = -\frac{35}{14 \times 21}$ or v = -8.4 cm

The image is located 8.4 cm, from the lens on the same side as the object.

As, $m = \frac{I}{O} = \frac{v}{u}$

$I = \frac{v}{u} \times O = \frac{-8.4}{-14} \times 3 = 1.8$ cm

As size of image is +ve. So, image is erect and virtual of smaller size.

As the object is moved away from the lens, the virtual image moves towards the focus of the lens but never beyond. The image progressively diminishes in size.

24. Let the potential difference between the ends of the wings 'e' = B_V

Given Velocity, v = 900 km/hour = 250 m/s

Wing span length (l) = 20 m

Vertical component of Earth's magnetic field is given as

$B_V = B_H \tan\delta = 5 \times 10^{-4} \tan 30^o$

Potential difference, E = $B_V lv$

$= 5 \times 10^{-4} \tan 30^o \times 20 \times 250$

$= \frac{5 \times 20 \times 250 \times 10^{-4}}{\sqrt{3}}$

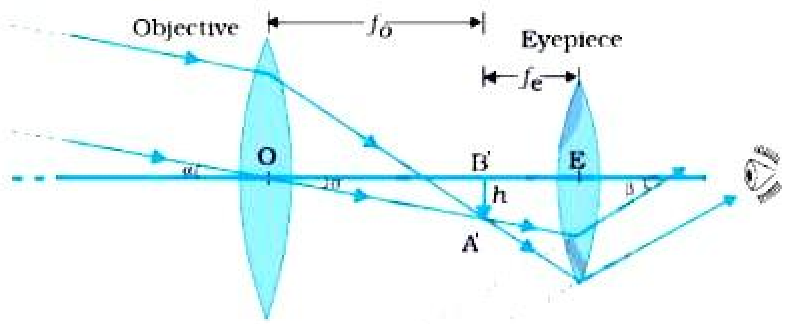
= 1.44 volt

So, 1.44 V potential difference is developed across the ends of the wings of aeroplane.

OR

Each part will behave as a magnet of magnetic moment $\frac{M}{2}$. But as the poles developed at the ends C_1 and C_2 will be of opposite nature, the net magnetic moment of the combination will be zero.

25. Ray diagram:



Magnification, m = $\frac{f_0}{f_e}$

or m = $\frac{\beta}{\alpha}$

Section D

26. d = 0.15mm $= 15 \times 10^{-4}$m

$\lambda = 450\text{nm} = 4.5 \times 10^{-7}\text{m}$

D = 1m

i. a. The distance of nth order bright fringe from central fringe is given by

$y_n = \frac{Dn\lambda}{d}$

For second bright fringe,

$y_2 = \frac{2D\lambda}{d} = \frac{2 \times 1 \times 4.5 \times 10^{-7}}{1.5 \times 10^{-4}}$

$y_2 = 6 \times 10^{-3}\text{m}$

The distance of the second bright fringe,

y_2 = 6mm

b. The distance of nth order dark fringe from central fringe is given by

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

For second dark fringe, n = 2

$y_n' = (2 \times 2 - 1)\frac{D\lambda}{2d} = \frac{3D\lambda}{2d}$

$y_n' = \frac{3}{2} \times \frac{1 \times 45 \times 10^{-7}}{1.5 \times 10^{-4}}$

The distance of the second dark fringe,

$y_n' = 45\text{mm}$

ii. With increase of D, fringe width increases as

$\beta = \frac{D\lambda}{d}$ or $\beta \propto D$

27. i. The potentiometer works on the principle that potential difference across any two points of a uniform current carrying conductor is directly proportional to the length between those two points.

ii. Here, AB = 1 m, R_{AB} = 10Ω

Potential gradient, k = ?, AO = l = ?

Current passing through AB,

$I = \frac{2}{15+R_{AB}} = \frac{2}{15+10} = \frac{2}{25}A$

$\therefore V_{AB} = I \times R_{AB} = \frac{2}{25} \times 10 = \frac{4}{5}\text{V}$

$\therefore \quad k = \frac{V_{AB}}{AB} = \frac{4}{5}Vm^{-1}$

Current in the external circuit,

$I' = \frac{1.5}{1.2+0.3} = \frac{1.5}{1.5} = 1\text{A}$

For no deflection in galvanometer,

Potential difference across AO = 1.5 - 1.2I'

$\Rightarrow \quad k(l) = 1.5 - 1.2 \times I' \Rightarrow \frac{4}{5}l = 0.3$

or $l = \frac{03 \times 5}{4} = 0.375m$

$\therefore$ l = 37.5 cm

OR

Each branch of the network is assigned an unknown current to be determined by the application of Kirchhoff's rules. To reduce the number of unknowns at the outset, the first rule of Kirchhoff is used at every junction to assign the unknown current in each branch. (current entering into the junction is equal to current leaving the junction) We then have three unknowns I_1, I_2 and I_3 which can be found by applying the second rule of Kirchhoff to three different closed loops. Kirchhoff's second rule for the closed-loop ADCA gives,

$10 - 4(I_1 - I_2) + 2(I_2 + I_3 - I_1) - I_1 = 0$ ...(i)

that is, $7I_1 - 6I_2 - 2I_3 = 10$

For the closed-loop ABCA, we get

$10 - 4I_2 - 2(I_2 + I_3) - I_1 = 0$

that is, $I_1 + 6I_2 + 2I_3 = 10$ ...(ii)

For the closed-loop BCDEB, we get

$5 - 2(I_2 + I_3) - 2(I_2 + I_3 - I_1) = 0$

that is, $2I_1 - 4I_2 - 4I_3 = -5$ ...(iii)

Equations (i, ii, iii) are three simultaneous equations in three unknowns. These can be solved by the usual method to give

$I_1 = 2.5A, I_2 = \frac{5}{8}$ A, $I_3 = 1\frac{7}{8}$ A

The currents in the various branches of the network are

AB : $\frac{5}{8}$ A, CA : $2\frac{1}{2}$ A, DEB : $1\frac{7}{8}$ A

AD : $1\frac{7}{8}$ A, CD : 0 A, BC : $2\frac{1}{2}$ A

It is easily verified that Kirchhoff's second rule applied to the remaining closed loops does not provide any additional independent equation, that is, the above values of currents satisfy the second rule for every closed loop of the network. For example, the total voltage drop over the closed-loop BADEB

$5V + \left(\frac{5}{8} \times 4\right)V - \left(\frac{15}{8} \times 4\right)V$ equal to zero, as required by Kirchhoff's second rule.

28. Distance between the spheres, A and B, r = 0.5 m

Initially, the charge on each sphere, $q = 6.5 \times 10^{-7}$ C

When an uncharged sphere is brought near the charged sphere, the charge is induced on the uncharged sphere. Thus in the given question,

When sphere A is touched with an uncharged sphere C, $\frac{q}{2}$ the amount of charge from A will transfer to sphere C. Hence, charge on each of the spheres, A and C, is $\frac{q}{2}$.

When sphere C with charge $\frac{q}{2}$ is brought in contact with sphere B with charged, total charges on the system will divide into two equal halves given as,

$$\frac{\frac{q}{2}+q}{2}=\frac{3q}{4}$$

Each sphere will share each half. Hence, charge on each of the spheres, C and B, is $\frac{3q}{4}$.

Force of repulsion between sphere A having charge $\frac{q}{2}$ and sphere B having charge

$$\frac{3q}{4}=\frac{\frac{q}{2}\times\frac{3q}{4}}{4\pi\epsilon_0 r^2}=\frac{3q^2}{8\times 4\pi\epsilon_0 r^2}$$

$$= 9\times 10^9\times\frac{3\times(6.5\times10^{-7})^2}{8\times(0.5)^2}$$

$$= 5.703\times 10^{-3}\ \text{N}$$

Therefore, the force of attraction between the two spheres is 5.703×10^{-3} N.

OR

Electric flux is defined as the number of electric field lines passing through an area normal to the surface.

Alternatively, it is defined as surface integral of the electric field is defined as the electric flux through a closed surface

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

SI unit: $\frac{N\cdot m^2}{C}$ or volt metre

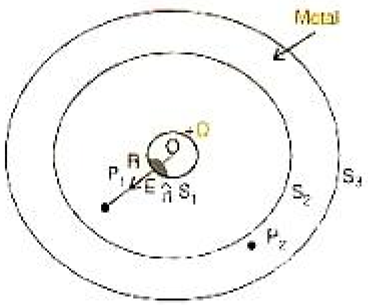
Let point P_1 is at a distance R from the centre O. S_1 is the Gaussian surface, then according to Gauss's theorem

$$\oint_s\vec{E}\cdot\vec{ds}=\frac{q}{\varepsilon_0}$$

or $E\oint_s ds=\frac{q}{\varepsilon_0}$

or $E=\frac{q}{\varepsilon_0\times\oint_s ds}$

$$=\frac{q}{4\pi\varepsilon_0 R^2}\quad\left[\text{As }\oint_s ds=4\pi R^2\right]$$



Inside the shell, the net charge is zero, so the field is also zero. Hence, the electric field at point P_2 will be zero.

29. Einstein's photoelectric equation

$K_{\max} = \frac{1}{2}mv^2 = h\nu - \phi_0 = h\nu - h\nu_0$........(i)

Important features are

a) The photoelectric effect will occur when the incident frequency is greater or equal to the threshold frequency for a given metal i.e $\nu \geq \nu_0$.

b) When the incident frequency is greater than the threshold frequency, the maximum kinetic energy is proportional to $\nu - \nu_0$.

c) The number of photon incident per unit time per unit area increases with the increase of intensity of incident light. This implies photo current is directly proportional to the intensity of radiation.

From Eq. (i),

$K_{\max} = \frac{hc}{\lambda_1} - \phi_0$

According to question,

$K_{\max} = \frac{hc}{\lambda_1} - \phi_0$........(i)

$2K_{\max} = \frac{hc}{\lambda_2} - \phi_0$ ....(ii)

From Eqs. (ii) and (iii),

$2\left(\frac{hc}{\lambda_1} - \phi_0\right) = \frac{hc}{\lambda_2} - \phi_0$

$\phi_0 = \frac{2hc}{\lambda_1} - \frac{hc}{\lambda_2} = hc\left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right)$

Also, $\phi_0 = \frac{hc}{\lambda_0}$

$\therefore \quad \frac{hc}{\lambda_0} = hc\left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right)$

or $\frac{1}{\lambda_0} = \frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}$

$\lambda_0 = \frac{\lambda_1\lambda_2}{2\lambda_2 - \lambda_1}$

30. Consider any element $\overrightarrow{dl}$ of the wire. The force on this element is $I(\overrightarrow{dl} \times \overrightarrow{B})$. For each element $\overrightarrow{dl}$, there is another length element $-\overrightarrow{dl}$ on the closed loop given by $-\overrightarrow{dl}$. Since $\overrightarrow{B}$ is uniform therefore, the forces cancel for each pair of such elements. So, the net force on the coil is zero.

The torque $\overrightarrow{\tau}$ on a plane loop of any shape carrying a current I in a magnetic field B is given by

$\overrightarrow{\tau} = IA\widehat{n} \times \overrightarrow{B}$

Where $\widehat{n}$ is a unit vector normal to the plane of the loop (direction of motion of a right handed screw rotating in the same of current). For a circular coil of radius r and N turns,

$A = N \times \pi r^2$

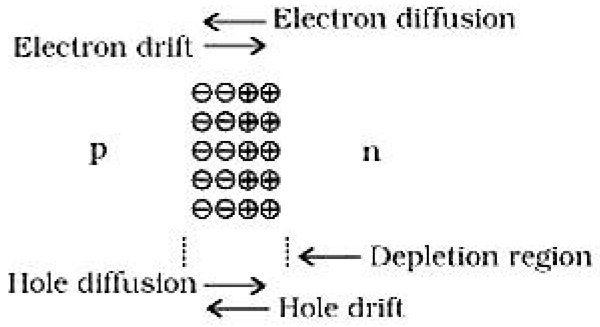
The angle between $\hat{n}$ and $\vec{B}$ is 90°.

Now, $\tau = BIA \sin \alpha$

$= 1.2 \times 10 \times 25 \times \pi (0.06)^2 \sin 90^\circ$ = 3.39 Nm

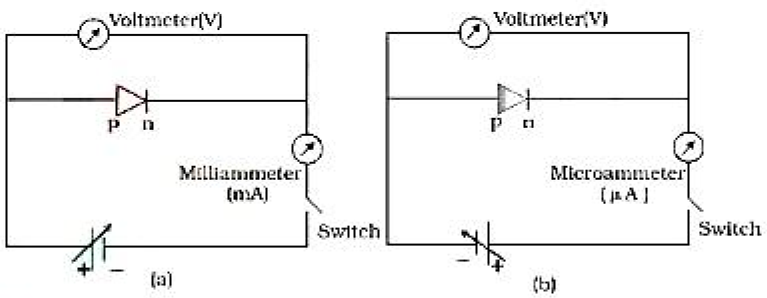
Section E

31. 1. Two important processes occur during the formation of a p-n junction: diffusion and drift.

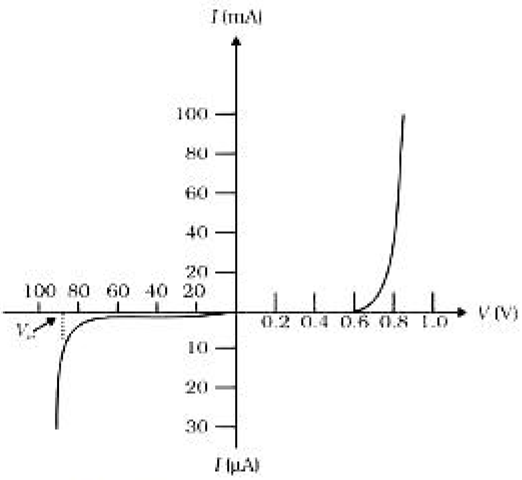


In the p-section, holes are the majority carriers; while in n-section, the majority carriers are electrons. Due to the high concentration of different types of charge carriers in the two sections, holes from p-region diffuse into n-region and electrons from n-region diffuse into p-region. In both cases, when an electron meets a hole, the two cancel the effect of each other and as a result, a thin layer at the junction becomes devoid of charge carriers. This is called **depletion layer** as shown in Fig.

2. The circuit arrangement for studying the V-I characteristics of a diode, (i.e., the variation of current as a function of applied voltage) are shown in Fig. (a) in forward bias, (b) in reverse bias.



The battery is connected to the diode through a potentiometer (or rheostat) so that the applied voltage to the diode can be changed. For different values of voltages, the value of the current is noted. A graph between V and I is obtained as in Fig. (c).



Note that in forward bias measurement, we use a milliammeter since the expected current is large while a micrometer is used in reverse bias to measure the current. We can see in Fig. (c) that in forward bias, the current first increases very slowly, almost negligible, till the voltage across the diode crosses a certain value. After the characteristic voltage, the diode current increases significantly (exponentially), even for a very small increase in the diode bias voltage. This voltage is called the threshold voltage or cut-in voltage (~0.2V for germanium diode and ~0.7 V for silicon diode). For the diode in reverse bias, the current is very small (~μA) and almost remains constant with change in bias. It is called reverse saturation current. However, for special cases, at very high reverse bias (break down voltage), the current suddenly increases.

From the V-I characteristic of a junction diode we see that it allows current to pass only when it is forward biased. So if an alternating voltage is applied across a diode the current flows only in that part of the cycle when the diode is forward biased. This property is used to rectify alternating voltages and the circuit used for this purpose is called a rectifier.

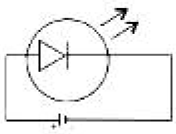
OR

Important considerations in the fabrication of LED are:

i) LED is heavily doped p-n junction.

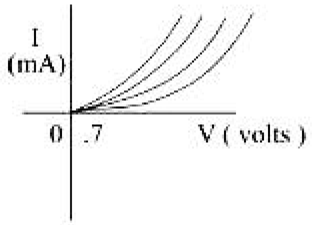
ii) Reverse breakdown voltage of LED's are very low, typically around 5 V.

The order of band gap of an LED to emit light in the visible range is about 1.8 eV to 3 eV.



When the diode is forward biased, electron are sent from n side to p side and holes are sent from p side to n side and at the junction boundary, the excess minority carrier recombines with the majority carriers releasing energy in the form of photons.

i. The V-I characteristics of an LED are shown below:



Two advantages of LED over conventional incandescent lamps are:

(i) In LED energy is produced in the form of light only, whereas in incandescent lamp energy is produced in the form of heat and light. Thus, there is no energy loss in LED.

(ii) To operate LED, very small voltage (≈ 1V) is required, whereas for the incandescent lamp higher voltages are required.

32. i. Let at any instant, the current and voltage in an L-C-R series AC circuit is given by

$V = V_m \sin \omega t$ and

$I = I_m \sin(\omega t + \phi)$

where V_m and I_m are the peak values of the ac voltage and ac current respectively.

The instantaneous power is given by

$P = VI = I_m \sin(\omega t + \phi) V_m \sin \omega t$

$\Rightarrow P = \frac{V_m I_m}{2}[2 \sin \omega t \sin(\omega t + \phi)]$

$\therefore P = VI = \frac{V_m I_m}{2}[\cos \phi - \cos(2\omega t + \phi)] \quad \ldots (i)$

$[\because 2 \sin A \sin B = \cos(A - B) - \cos(A + B)]$

Work done for a very small time interval dt is given by

$dW = Pdt$

$\Rightarrow dW = VIdt$

$\therefore$ Total work done over a complete cycle i.e. from 0 to T is given by,

$W = \int_0^T VIdt$

But $P_{av} = \frac{W}{T} = \frac{\int_0^T VIdt}{T}$

$\Rightarrow \quad P_{av} = \frac{1}{T} \int_0^T VIdt$

$= \frac{1}{T} \int_0^T \frac{V_m I_m}{2}[\cos \phi - \cos(2\omega t + \phi)]dt$

$= \frac{V_m I_m}{2T}\left[\int_0^T \cos\phi dt - \int_0^T \cos(2\omega t + \phi)dt\right]$

$= \frac{V_m I_m}{2T}[\cos \phi(t)]_0^T - 0 \; (By \text{ trigonometry})$

$= \frac{V_m I_m}{2T} \cos \phi \times T = \frac{V_m I_m}{2} \cos \phi$

$= \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} \cos \phi$

$\Rightarrow P_{av} = V_{rms} I_{rms} \cos \phi$

This is the required expression.

ii. Power factor, $\cos\phi = \frac{R}{Z}$

where, R = resistance and Z = impedance of the circuit.

Low power factor (cos ϕ) implies lower ohmic resistance which implies larger power loss in power system (transmission line), because in power system power, P $\propto \frac{1}{R}$.

OR

$C = \frac{50}{\pi} \mu F, L = \frac{5}{\pi} H, R = 400\Omega$

As applied voltage, $V = 140 \sin 100\pi t$

Comparing it with $V = V_0 \sin \omega t$,

$V_0 = 140\text{V}, \omega = 100\pi$

Inductive reactance, $X_L = \omega L$

$X_L = 100\pi \times 5/\pi = 500\Omega$

Capacitive reactance, $X_C = \frac{1}{\omega C}$

$X_c = \frac{1}{100\pi \times \frac{50}{\pi} \times 10^{-6}} = 200\Omega$

Impedance of the AC circuit,

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

$= \sqrt{1409^2 + (500 - 200)^2}$

$Z = \sqrt{1600 + 900} = 500\Omega$

Maximum current in the circuit,

$I_0 = \frac{V_0}{Z} = \frac{140}{500}$

$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = \frac{140}{500 \times \sqrt{2}} = 0.2\text{A}$

V_{rms} across resistor R, $V_{rms} = I_{rms} R$

$V_{rms} = 0.2 \times 400 = 80\text{V}$

V_{rms} across inductor, $V_L = I_{\text{rms}} X_L$

$V_L = 0.2 \times 500 = 100\text{V}$

V_{rms} across capacitor, $V_C = I_{\text{rms}} X_C$

$V_C = 0.2 \times 200 = 40\text{V}$

Now, V

Here, $V \neq V_R + V_L + V_C$

Because V_C, V_L and V_R are not in same phase,

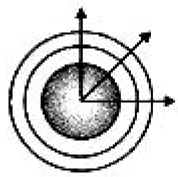
$\therefore V = \sqrt{V_R^2 + (V_L - V_C)^2}$

V = $\sqrt{80^2 + (100 - 40)^2} = 100\ V$

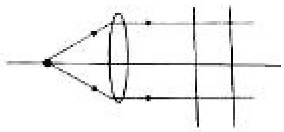
which is same as the applied rms voltage.

33. i. A wave front is defined as a surface of constant phase. The ray, at each point of a wave front, is normal to the wave front at that point. The ray indicates the direction of propagation of wave while the wave front is the surface of constant phase.

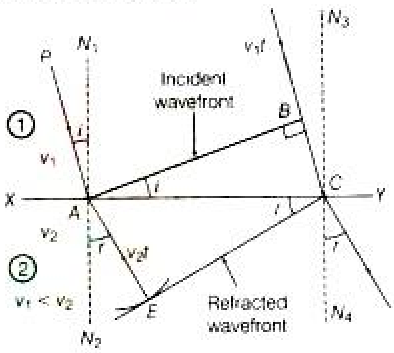
ii. (a) In case of light diverging from a point source, the shape of wave-front is a spherical as shown in the figure:



(b) In case of light emerging out of a convex lens when a point source is placed at its focus, the wave-front is a plane wave front as shown below:



(c) The following diagram shows the passage of a plane wavefront from a denser into a rarer medium.



then, $BC = v_1 t$ ...(i)

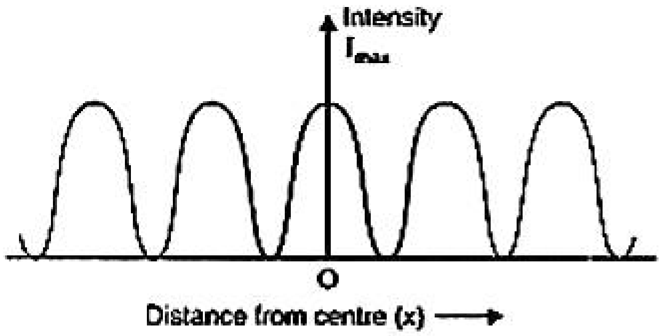
OR

Interference of light: Phenomenon of redistribution of light energy in a medium on account of superposition of light waves from two coherent sources is called interference of light.

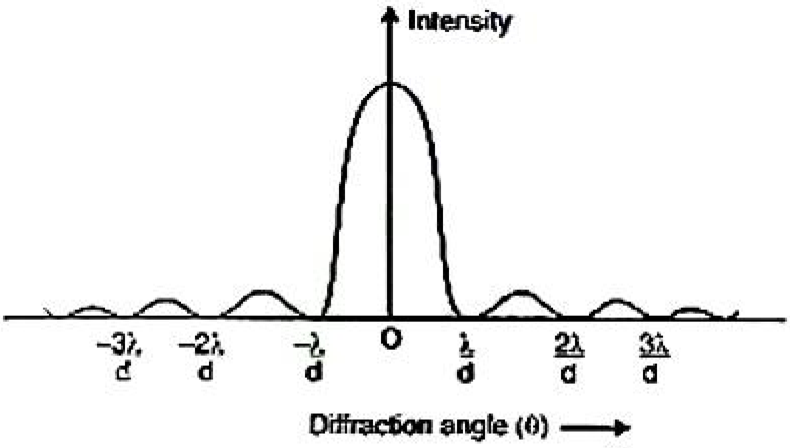
Conditions for sustained interference: The two essential conditions of sustained interference are as follows:

i. The two sources of light should emit light continuously.
ii. The light waves should be of same wavelength (Monochromatic).

(a) When both the slits are open, we get an interference pattern on the screen. Then the following intensity distribution curve is obtained.



(b) When one of the slits is closed, diffraction pattern is obtained on the screen. The following intensity curve is obtained.



Also we know that, Fringe width, $\beta = \frac{D\lambda}{d}$, therefore

i. The distance D decreases, the fringe width β also decreases if screen is moved closer to the plane of the slits.
ii. Fringe width β decreases if separation d between two slits is increased.