CBSE Class 12 Physics

Sample Paper 10 (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. Why must the electrostatic field at the surface of a charged conductor is perpendicular to every point on it?
2. Calculate the orbital period of the electron in the first excited state of hydrogen atom.

OR

Using Bohr model, calculate the electric current created by the electron when the H-atom is in the ground state.

3. What are coherent sources of light?
4. What is the phase difference corresponding to path difference λ of two waves reaching a point?

OR

Yellow light ($\lambda = 6000\overset{o}{A}$) illuminates a single slit of width $1 \times 10^{-4} m$. Calculate the distance between two dark lines on either side to the central maximum, when the diffraction pattern is viewed on a screen kept 1.5 m away from the slit.

5. Refractive indices of glass for blue, red and yellow colours are μ_b, μ_y and μ_r respectively. Write these symbols in decreasing order of values.
6. Show, on a graph the nature of variation of the (associated) de-Broglie wavelength (λ) with the accelerating potential (V), for an electron initially at rest.
7. The top of the atmosphere is at about 400 kV with respect to the surface of the earth, corresponding to an electric field that decreases with altitude. Near the surface of the earth, the field is about 100 Vm^{-1}. Why then do we not get an electric shock as we step out of our house into the open? (Assume the house to be a steel cage so there is no field inside!)

OR

A parallel plate capacitor with air between the plates has a capacitance of 8pF (1pF = 10^{-12}F). What will be the capacitance if the distance between the plates is reduced by half, and the space between them is filled with a substance of dielectric constant 6?

8. For an extrinsic semiconductor, indicate on the energy band diagram the donor and acceptor levels.
9. Which physical quantity has the unit Wb/m^2? Is it a scalar or a vector quantity?
10. What is a hole?
11. **Assertion (A):** If the current in a solenoid is reversed in direction while keeping the same magnitude, the magnetic field energy stored in the solenoid decreases.
    Reason (R): Magnetic field energy density is proportional to square of magnetic field.
    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:** The resultant magnetic field of the circular loop is due to x-component.

Reason: In the circular loop of wire, perpendicular components of the magnetic field at some distance from centre of loop turned over the whole loop, the result is zero.

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 vertical iron rod has a coil of Wire-wound over it at the bottom end. An alternating current flows in the coil. The rod goes through a conducting ring as shown in the adjoining figure. The ring can float at a certain height above the coil.

Reason (R): In the above situation, a current is induced in the ring which interacts with the horizontal component of the magnetic field to produce an average force in the upward direction.

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

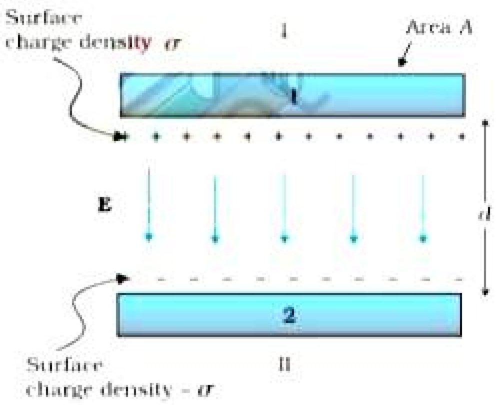
c. A is true but R is false

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:**

Once the opposite charges have been placed on either side of a parallel-plate capacitor, the charges can be used to do work by allowing them to move towards each other through a circuit. The total energy that can be extracted from a fully charged capacitor is given by the equation: $U = \frac{1}{2} CV^2$



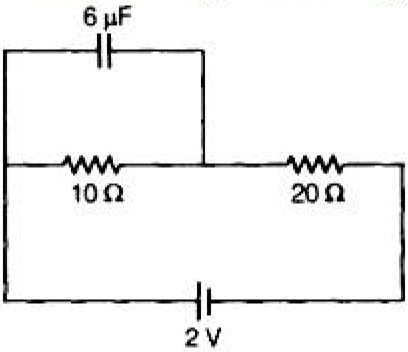
i. Amount of energy stored in a capacitor of $5\mu F$ when it is charged to a potential difference of 250 V:

a. 0.156 joule
b. 1 joule
c. 0.25 joule
d. 0.125 joule

ii. A condenser is charged to double its initial potential. The energy stored becomes x times, where x is

a. 2
b. 4
c. 1
d. 0.5

iii. Find the charge on the capacitor as shown in the circuit.



a. $3\mu C$
b. $6\mu C$
c. $8\mu C$
d. $4\mu C$

iv. The capacitance is a circuit component that opposes the change in the circuit _____ .

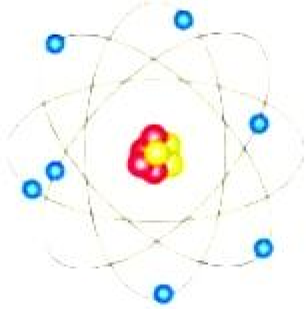
a. Current
b. Voltage
c. Impedance
d. None of these

v. In a region of constant potential:

a. the electric field is uniform
b. the electric field is zero
c. there can be no charge inside the region
d. both b and c

16. **Read the source given below and answer any four out of the following questions:**

The Bohr model of hydrogen was the first model of atomic structure to correctly explain the radiation spectra of atomic hydrogen. It was preceded by the Rutherford nuclear model of the atom. In Rutherford's model, an atom consists of a positively charged point-like nucleus that contains almost the entire mass of the atom and of negative electrons that are located far away from the nucleus. Bohr's model of the hydrogen atom is based on three postulates: (1) an electron moves around the nucleus in a circular orbit, (2) an electron's angular momentum in the orbit is quantized, and (3) the change in an electron's energy as it makes a quantum jump from one orbit to another is always accompanied by the emission or absorption of a photon.



i. The ionization potential of hydrogen is:
   a. -13.6 eV
   b. 13.6 eV
   c. 13.6 V
   d. none of these

ii. The series of hydrogen spectrum which lies in the visible region is:
   a. Lyman
   b. Balmer
   c. Paschen
   d. none of these

iii. The diameter of the first orbit of the hydrogen atom is of the order of:
   a. 0.5×10^{-10} m
   b. 1×10^{-10} m
   c. 4×10^{-10} m
   d. none of these

iv. Name the series of the hydrogen atom which lies in UV region:-
   a. Lyman series

b. Balmer series
c. Paschen series
d. none of these

v. What is the ratio of radii first excited state to the ground state in hydrogen atom?
a. 4:1
b. 1:4
c. 1:2
d. 2:1

Section C

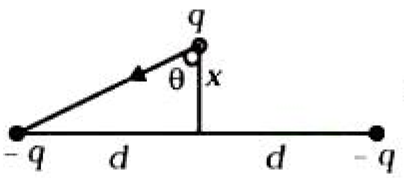
17. A cell of emf 4 V and internal resistance 1 Ω is connected to a d.c. source of 10 V through a resistor of 5 Ω. Calculate the terminal voltage across the cell during charging.

18. i. State the principle on which the working of an optical fibre is based.
ii. What are the necessary conditions for this phenomenon to occur?

OR

A ray of light is incident at a glass-water interface at an angle of i, it emerges finally parallel to the surface water, then what will be the value of μ_g?

19. Two charges –q each are fixed separated by distance 2d. A third charge q of mass m placed at the mid-point is displaced slightly by x (x<<d) perpendicular to the line joining the two fixed charged as shown in Fig.



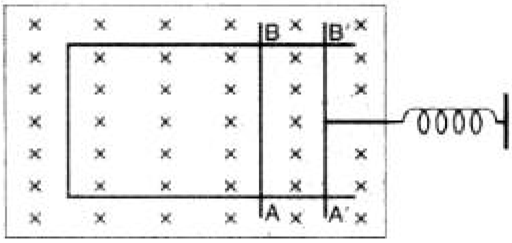
$$T = \left[\frac{8\pi^3\varepsilon_0 m d^3}{q^2}\right]^{1/2}$$

OR

Suppose we have a large number of identical particles, very small in size. Any of them at 10 cm separation repel with a force of 3×10^{-10} N.
i. If one of them is at 10 cm from a group of n others, how strongly do you expect it to be repelled?
ii. Suppose you measure the repulsion and find it 6×10^{-6} N. How many particles were there in the group?

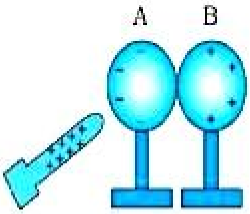
20. A rectangular wire frame, as shown in a figure, is placed in a uniform magnetic field

directed upward and normal to the plane of the paper.



The part AB is connected to a spring. The spring is stretched and released, when the wire AB has come to the position A'B' (t = 0). How would the induced e.m.f. vary with time? Neglect damping.

21. The given figure shows that when a charged rod is brought near two conducting spheres touching each other, then charges appear on the spheres as shown in the figure.



1. (i) Which phenomenon is responsible for the production of charges on the spheres?

   (ii) What happens to charges on spheres when the rod is removed?

   (iii) What happens to the charges on the spheres when spheres are slightly separated and the rod is at its place?

   (iv) What happens to charges on spheres if spheres are slightly separated and the rod is removed?

   (v) What changes occur to the charges on spheres when the rod is removed and spheres are separated quite apart?

22. What are the constituents of the nucleus? Give four properties of neutrons.
23. Double-convex lenses are to be manufactured from a glass of refractive index 1.55, with both faces of the same radius of curvature. What is the radius of curvature required if the focal length is to be 20cm?
24. A magnetised needle in a uniform magnetic field experiences a torque but no net force. An iron nail near a bar magnet, however, experiences a force of attraction in addition to a torque. Why?

OR

You are given two identical looking bars A and B. One of these is a bar magnet and the other an ordinary piece of iron. Give an experiment to identify, which one of the two is a bar magnet. You are not to use any additional materials for the experiment.

25. A convex lens of refractive index 1.5 has a focal length of 18 cm in air. Calculate the change in its focal length when it is immersed in water of refractive index 4/3.

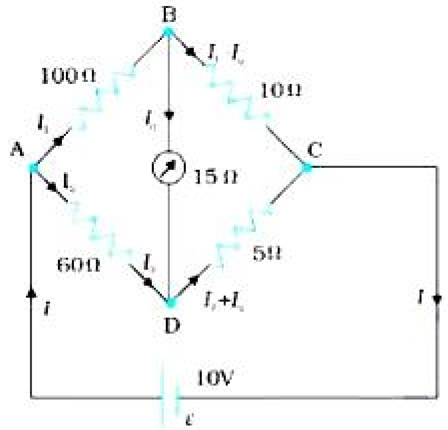
Section D

26. State two conditions to obtain sustained interference of light.

In Young's double slit experiment, using light of wavelength 400 nm, interference fringes of width 'X' are obtained. The wavelength of light is increased to 600 nm and the separation between the slits is halved. If one wants the observed fringe width on the screen to be the same in the two cases, find the ratio of the distance between the screen and the plane of the interfering sources in the two arrangements.

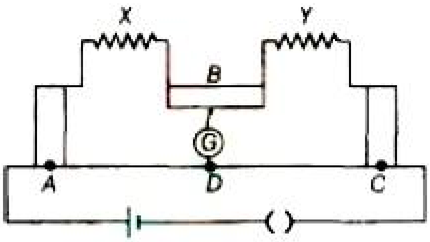
27. The four arms of a Wheatstone bridge (Fig.) have the following resistances:

AB = 100Ω, BC = 10Ω, CD = 5Ω, and DA = 60Ω.



A galvanometer of 15Ω resistance is connected across BD. Calculate the current through the galvanometer when a potential difference of 10 V is maintained across AC.

OR



The figure shows experimental set up of a meter bridge. When the two unknown resistances X and Y are inserted, the null point D is obtained 40 cm from the end A. When a resistance of 10Ω is connected in series with X, the null point shifts by 10cm.

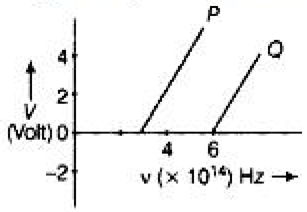
Find the position of the null point when the 100 resistance is instead connected in series with resistance Y. Determine the values of the resistances X and Y.

28. An oil drop of 12 excess electrons is held stationary under a constant electric field of $2.55 \times 10^4\ N/C$ in Millikan's oil drop experiment. The density of the oil is 1.26 $g\ cm^{-3}$. Estimate the radius of the drop (g = 9.81 ms^{-2}, e = $1.6 \times 10^{-19} C$).

OR

Four charges +q, +q, -q and -q are placed respectively at the four comers A, B, C and D respectively of a square of side a. Calculate the force on a charge Q placed at the centre of the square.

29. In the study of a photoelectric effect, the graph between the stopping potential *V* and frequency ν of the incident radiation on two different metals *P* and *Q* is shown below.



i. Which one of the two metals has higher threshold frequency?
ii. Determine the work function of the metal which has greater value.

30. A long straight wire of a circular cross-section of radius a carries steady current I. The current is uniformly distributed across the cross-section. Apply Ampere's circuital law to calculate the magnetic field B(r) at a point in the region for (i) r < a and (ii) r > a. Draw a graph showing the dependence of B(r) on r.

Section E

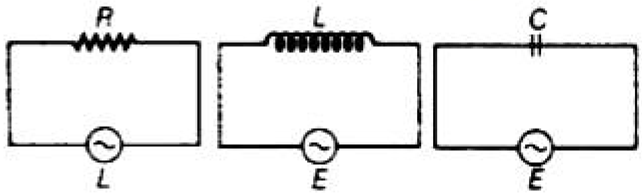
31. a. Distinguish between metals, insulators and semiconductors on the basis of their energy bands.
    b. Why are photodiodes used preferably in reverse bias condition? A photodiode is fabricated from a semiconductor with band gap of 2.8 eV. Can it detect a wavelength of 6000 nm? Justify.

OR

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?

32. i. What do you understand by the sharpness of resonance in a series L-C-R circuit? Derive an expression for Q-factor of the circuit.

ii. Three electrical circuits having AC sources of variable frequency are shown in the figures. Initially, the current flowing in each of these is same. If the frequency of the applied AC source is increased, how will the current flowing in these circuits be affected? Give the reason for your answer.



OR

A series L-C-R circuit is connected to an AC source. Using the phasor diagram, derive the expression for the impedance of the circuit. Plot a graph to show the variation of current with frequency of the source, explaining the nature of its variation.

33. a. What are coherent sources of light? Two slits in Young's double slit experiment are illuminated by two different sodium lamps emitting light of the same wavelength. Why is no interference pattern observed?

b. Obtain the condition for getting dark and bright fringes in Young's experiment. Hence write the expression for the fringe width.

c. If S is the size of the source and its distance from the plane of the two slits, what should be the criteria for the interference fringes to be seen?

OR

i. What is the effect on the interference fringes to a Young's double slit experiment when

a. the separation between the two slits is decreased?

b. the width of the source slit is increased?

c. the monochromatic source is replaced by a source of white light? Justify your answer in each case.

ii. The intensity at the central maxima in Young's double slit experimental set up is I_0. Show that the intensity at a point is $\frac{I_0}{4}$, where the path difference is $\frac{\lambda}{3}$.

CBSE Class 12 Physics

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Solution

Section A

1. As the electric field inside a conductor is always zero, the electric lines of forces exert lateral pressure on each other which leads to repulsion between like charges. Thus, in order to stabilize spacing, the electric field lines are normal to the surface.
   Other reason can also be defined as if the electric field lines are not perpendicular to the surface there will be a tangential component of electric field along the surface which forces charge to move along the circumference due to which potential will not remain same on the surface.
2. We know that the orbital period, T = $\frac{2\pi r}{v}$
   $r_1 = 0.53 \times 10^{-10}$ m
   $T_1 = \frac{2\pi \times 0.53 \times 10^{-10}}{2.19 \times 10^6} = 1.52 \times 10^{-16} s$
   $r_2 = 4r_1$ and $v_2 = \frac{1}{2} v_1$
   $T_2 = 8T_1 = 8 \times 1.52 \times 10^{-16}$

   OR

   Let v is velocity for an electron of H-atom in orbit, a_0 = Bohr radius or radius of orbit
   So, Number of revolutions per sec, T = $\frac{(2\pi a_o)}{v}$
   Now, current, i = -eT = $-\frac{2\pi a_0}{v} e$
   Negative sign shows direction of current is opposite to that of electron.
3. Two sources obtained from a single source of light are called coherent sources.
4. Phase difference = $\frac{2\pi}{\lambda} \times$ path difference.

   OR

   Given wavelength of the light used, $\lambda = 6000\overset{o}{A} = 6 \times 10^{-7}$ m ; distance of separation between the slits, $d = 1 \times 10^{-4} m$ and source to screen distance, D = 1.5 m. The separation between two dark lines on either side of the central maxima = fringe width of central maxima $= \frac{2D\lambda}{d}$

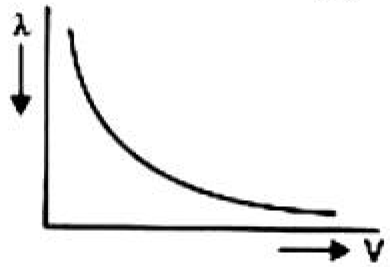
$= \frac{2\times1.5\times6\times10^{-7}}{1\times10^{-4}} = 18 \times 10^{-3}\text{m} = 18\text{mm}$

5. Now, μ_b = 1.51690, μ_y = 1.51124, μ_r = 1.50917

   Thus,

   $\mu_b < \mu_y < \mu_r$

6. We know that $\lambda = \frac{1.227}{\sqrt{V}}$. The variation of λ with V is shown in figure:



7. The surface of earth and our body both are good conductor of electricity .We do not get an electric shock as we step out of our house because the original equipotential surfaces of open air changes, keeping our body and the ground at the same potential.

OR

We know that, $C_0 = \frac{\varepsilon_0 A}{d}$ or $\frac{\varepsilon_0 A}{d} = 8 \times 10^{-12}$

If the distance is reduced to half i.e. d/2 and space between the plates is filled by a substance of k = 6.

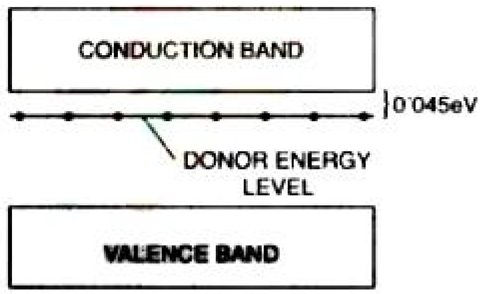
Then, $C = \frac{k\varepsilon_0 \cdot A}{d/2}$

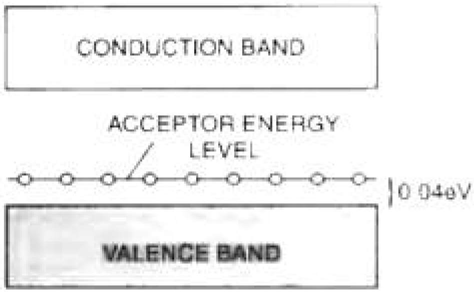
$= \frac{2k(\varepsilon_0 A)}{d}$

$= 2 \times 6 \times 8 \times 10^{-12}$

$= 96 \times 10^{-12} F$ = 96 pF

8. In an energy band diagram of extrinsic semiconductor. the donor and acceptor levels are shown below:





9. The unit of Magnetic Flux Density is Wb/m^2. It is a vector quantity.
10. A vacancy created in the covalent bond of a semiconductor is called hole.
11. (d) A is false and R is also false

    Explanation: A is false and R is also false
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. (a) Both A and R are true and R is the correct explanation of A

    Explanation: The magnetic field at distance from centre of loop, can be resolved into a component along x-axis and perpendicular to it. When perpendicular components are summed over the whole loop, the result is zero. That is, by symmetry any element on one side of the loop sets up a perpendicular component that cancels the component set up by an element dimetrically opposite to it.
14. (c) A is true but R is false

    Explanation: A is true but R is false

Section B

15. i. (a) 0.156 joule
    ii. (b) 4
    iii. (d) $4\mu C$
    iv. (b) Voltage
    v. (d) there can be no charge inside the region
16. i. (c) 13.6V
    ii. (b) Balmer series
    iii. (b) 1×10^{-10} m
    iv. (a) Lyman series
    v. (a) 4:1

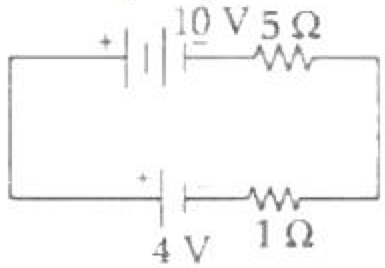
Section C

17. emf = 4 V internal resistance = 1 ohm

voltage =10 volt

Calculation of Terminal Voltage

10 - 4 = I(1 + 5)



I = 1 A

∴ Terminal voltage across cell

= (4 + 1 × 1)V

= 5 V

18. i. Optical fiber works on the principle of total internal reflection of light. According to the principle, the phenomenon of reflection of light that takes place, when a ray of light travelling in a denser medium gets incident at the interface of the two media at an angle greater than the critical angle for that pair of media.

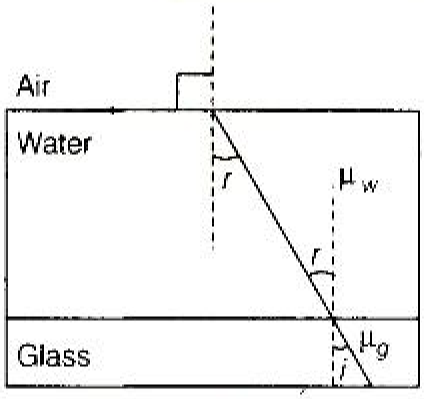
ii. The conditions for total internal reflection of light are

a) Light should travel from denser medium to the rarer medium.

b) The angle of incidence should be greater than the critical angle for the given pair of media.

OR

For glass-water interface, consider the figure below.



Applying Snell's law,

$\frac{\sin i}{\sin r}=\frac{\mu_w}{\mu_g}\Rightarrow\mu_g=\left(\frac{\mu_w\sin r}{\sin i}\right)$.........(i)

For water-air interface,

$\frac{\sin r}{\sin 90^\circ}=\frac{1}{\mu_w}\Rightarrow\sin r=\frac{1}{\mu_w}$.............(ii)

From Eqs. (i) and (ii), we get,

$\mu_g=\frac{\mu_w\times\frac{1}{\mu_w}}{\sin i}\Rightarrow\mu_g=\frac{1}{\sin i}$

19. In fig. two charges are -q are held at a distance of 2d. Horizontal component of the forces cancel each other and the vertical component gives the net amount of force. So , Net force F on q towards the centre O

$F=2\frac{q^2}{4\pi\varepsilon_o r^2}\cos\theta=-\frac{2q^2}{4\pi\varepsilon_0 r^2}\cdot\frac{x}{r}$

$F=-\frac{2q^2}{4\pi\varepsilon_o}\frac{x}{(d^2+x^2)^{3/2}}$

$\approx-\frac{2q^2}{4\pi\varepsilon_o d^3}x=-k$; for $x<<d$

Thus, the force on the third charge q is proportional to the displacement and is towards the centre of the two other charges.

Therefore, the motion of the third charge is harmonic with frequency

$\omega=\sqrt{\frac{\bar{K}}{m}}$

$\Rightarrow T=\frac{2\pi}{\omega}=2\pi\sqrt{\frac{m}{K}}\Rightarrow T=2\pi\sqrt{\frac{m.4\pi\varepsilon_0 d^3}{2q^2}}=\left[\frac{8\pi^3\varepsilon_0 md^3}{q^2}\right]^{1/2}$

OR

i. The group of n small charged particles must behave as a single point charge, so that it can have a separation of 10 cm from the one particle in question. Obviously, force on this particle due to the group of n particles is n times the force due to a single particle. Hence, force due to group of n particles,

   $F = n \times 3 \times 10^{-10}$ N

ii. Here, $F = 6 \times 10^{-6}$ N

   $\therefore n=\frac{F}{3\times10^{-10}}=\frac{6\times10^{-6}}{3\times10^{-10}}=2\times10^4$

20. When the stretched spring is released, the area of the loop inside the magnetic field and hence magnetic flux linked with the loop will decrease. Due to change in the magnetic flux, induced e.m.f. will be produced. As the wire comes back to the position AB, the induced e.m.f. will become zero. Hence, when the spring is released, the induced e.m.f.

produced will decrease with the time.

21. (i) Electromagnetic Induction

(ii) Charge on spheres disappear and these get neutralized.

(iii) Charges on spheres remains at the same position on the spheres.

(iv) Charges shift to the opposite sides of the spheres.

(v) Charges spread uniformly on the spheres.

22. **Constituents of the nucleus.** Protons and neutrons.

Properties of neutrons

i. Neutron is an elementary particle having mass equal to 1.6748×10^{-27} kg.
ii. It is an uncharged particle and hence the electric and magnetic fields have no effect on it.
iii. Being neutral, it possesses very high penetrating power and very low ionising power.
iv. Neutron is a stable particle within the nucleus. However, outside the nucleus, the neutron is an unstable particle.

23. Given: $\mu = 1.55$, f = 20 cm

The radius of curvature of one face of the lens = R_1

Radius of curvature of the other face of the lens = R_2

Radius of curvature of the double-convex lens = R

$\therefore R_1 = R$ and $R_2 = -R$

The value of R can be calculated using lens-maker formula as:

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$
$$\frac{1}{20} = (1.55 - 1)\left[\frac{1}{R} + \frac{1}{R}\right]$$
$$\frac{1}{20} = 0.55 \times \frac{2}{R}$$
$$\therefore R = 0.55 \times 2 \times 20 = 22\text{cm}$$

24. The force and torque act on the nail due to the induced magnetic moment acquired by it. The iron needle will also not experience any force, if magnetic field is uniform. The magnetic field due to a bar magnet is not uniform. Therefore, an iron nail experiences both a force and torque, when placed near a bar magnet.

It may be pointed that the nail experiences a net attractive force. It is because the attractive force on the nearer end (unlike induced pole) of the nail is greater than the repulsive force on its farther end (like induced pole).

OR

If on bringing different ends of the two bars close to each other, they produce repulsion in some case, then both the iron bars are magnetised. Otherwise, one bar is magnetised and the other is simply iron bar. To find out which one is magnetised, call one bar as A and the other as B. Place bar B on table. Bring one end of bar A close to the one end of bar B. The bar A will experience attraction. Now, move the bar A to the middle of bar B. If A experiences no force, then A is iron bar and B is magnetised. On the other hand, if bar A experiences force, then A is magnetised and B is iron bar.

25. Given: ${}^{a}\mu_g = 1.5$, ${}^{a}\mu_w = \frac{4}{3}$, $f_a = 18$

For the lens in air,

$\frac{1}{f_a} = ({}_a\mu_g - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

or $\frac{1}{18} = (1.5 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

or $\frac{1}{R_1} - \frac{1}{R_2} = \frac{1}{4}$

When the lens is immersed in water,

$\frac{1}{f_w} = \left(\frac{{}^{a}\mu_g}{{}^{a}\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$= \left(\frac{1.5}{\frac{4}{3}} - 1\right) \times \frac{1}{4}$

$= \frac{1}{8} \times \frac{1}{4} = \frac{1}{32}$

Thus, f_w = 32 cm

Section D

26. **Conditions for sustained interference:**

i. The two sources of light should emit light continuously.

ii. The two waves must be in same phase or bear a constant phase difference.

Fringe width in first case,

$\beta = \frac{D\lambda}{d} = \frac{D\times 400}{d}$

Fringe width in second case is same.

$\therefore \beta = \frac{D'\times 600}{\frac{d}{2}} = \frac{D'\times 1200}{d}$

$\therefore \frac{D\times 400}{d} = \frac{D'\times 1200}{d}$

or $\frac{D}{D'} = \frac{3}{1} \Rightarrow$ D : D' = 3 : 1

27. Applying kirchoff law:

Considering the loop BADB, we have

$100I_1 + 15I_g - 60I_2 = 0$

or $20I_1 + 3I_g - 12I_2 = 0$ [(a)]

Considering the loop BCDB, we have

$10(I_1 - I_g) - 15I_g - 5(I_2 + I_g) = 0$

$10I_1 - 30I_g - 5I_2 = 0$

$2I_1 - 6I_g - I_2 = 0$ [(b)]

Considering the loop ADCEA,

$60I_2 + 5(I_2 + I_g) = 10$

$65I_2 + 5I_g = 10$

$13I_2 + I_g = 2$ [(c)]

Multiplying Eq. (b) by 10

$20I_1 - 60I_g - 10I_2 = 0$ [(d)]

From Eqs. (d) and (a) we have

$63I_g - 2I_2 = 0$

$I_2 = 31.5I_g$ [(e)]

Substituting the value of I_2 into Eq. [(c)], we get

$13(31.5I_g) + I_g = 2$

$410.5\,I_g = 2$

$I_g = 4.87$ mA.

OR

Applying the condition of balanced Wheatstone bridge,

$\frac{X}{Y} = \frac{l}{100-l}$

where l is the balancing length from end A.

Initially, l = 40 cm

$\Rightarrow \quad \frac{X}{Y} = \frac{40}{100-40} = \frac{40}{60} = \frac{2}{3} \Rightarrow X = \frac{2}{3}Y$ ...(i)

When 10Ω resistance connected in series with X, null points shift to 40 + 10 = 50 cm.

$\therefore \frac{X+10}{Y} = \frac{50}{100-50}$

$\Longrightarrow \frac{50}{50} = 1$

$\therefore X + 10 = Y$

$\Rightarrow$ Y - X = 10 ...(ii)

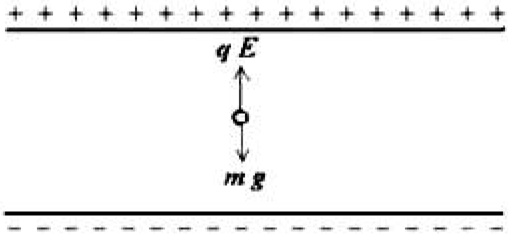
From Eqs. (i) and (ii), we get

$$Y/3 = 10\Omega \Rightarrow Y = 30\Omega \Rightarrow X = 20\Omega$$

Now, 10Ω resistance connected in series with Y and let the null point is obtained at length of ' l ' cm from one end.

$$\frac{X}{Y+10} = \frac{l}{100-l}$$
$$\frac{20}{30+10} = \frac{1}{100-l} \quad (\because X = 20\Omega Y = 30\Omega)$$
$$\frac{1}{2} = \frac{l}{100-l} \Rightarrow 100 - l = 2l \Rightarrow 3l = 100$$
$$l = \frac{100}{3}\text{cm} = 33.33\text{cm}$$

So, null point is obtained at the length 33.33 cm from one end.

28. 

In Millikan"s oil drop experiment, a negatively charged oil drop is suspended in a uniform electric field such that its weight is balanced by the electric force due to the field. The net force on the charge is zero.

Thus, mg = qE

Or, m = $\frac{qE}{g}$

Since q is due to the excess electrons,

q = 12e = 12 × 1.6 × 10^{-19} = 19.2 × 10^{-19}C

Therefore,

$$m = \frac{qE}{g} = \frac{19.2\times10^{-19}\times2.55\times10^{4}}{9.81} = 4.99 \times 10^{-15}\text{kg}$$

The density of the oil is given

ρ = 1.26g cm^{-3} = 1.26 × 10^3 kg m^{-3}

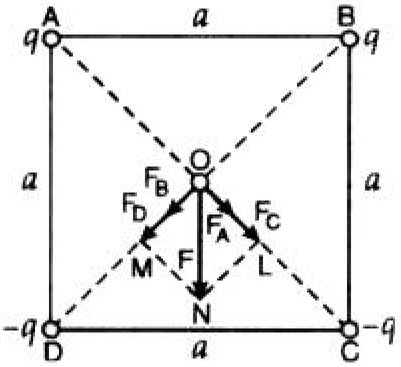
Thus, the volume of the oil drop is

$$V = \frac{m}{\rho} = \frac{4.99\times10^{-15}}{1.26\times10^{3}} = 3.96 \times 10^{-18}\text{m}^3$$

Assuming the drop to be spherical, we have

$$V = \frac{4}{3}\pi r^3 = 3.96 \times 10^{-18}\text{m}^3$$
$$\Rightarrow r^3 = \frac{3\times3.96\times10^{-18}}{4\times3.14} = 0.982 \times 10^{-18} \Rightarrow r = 0.98 \times 10^{-6}\text{m}$$

OR



Here, AB = BC = CD = DA = a

Obviously, AO = BO = CO = DO = a cos 45° = $\frac{a}{\sqrt{2}}$

Let F_A , F_B, F_C and F_D be the forces exerted by the charges at the points A, B, C and D on the charge Q at point O. It follows that

$F_A = F_B = F_C = F_D = \frac{1}{4\pi\varepsilon_0}.\frac{q\times Q}{(\frac{a}{\sqrt{2}})^2} = \frac{1}{4\pi\varepsilon_0}.\frac{2qQ}{a^2}$

The resultant of the forces F_A and F_C,

$F_1 = F_A + F_C = \frac{1}{4\pi\varepsilon_0}.\frac{2qQ}{a^2} + \frac{1}{4\pi\varepsilon_0}.\frac{2qQ}{a^2}$

$F_1 = \frac{1}{4\pi\varepsilon_0}.\frac{4qQ}{a^2}$ (along OL)

Similarly, the resultant of the forces F_B and F_D,

$F_2 = F_B + F_D = \frac{1}{4\pi\varepsilon_0}.\frac{4qQ}{a^2}$ (along OM)

Therefore, resultant force on the charge Q,

$F = \sqrt{F_1{}^2 + F_2{}^2} = \frac{1}{4\pi\varepsilon_0}.\frac{4\sqrt{2}qQ}{a^2}$ (along ON)

Since forces F_1 and F_2 are equal in magnitude, the resultant force F will act along the bisector of $\angle COD$ i.e. parallel to side AD or BC.

29. i. Einstein's photoelectric equation is given by,

$h\nu = \phi + eV$

$V = \frac{h\nu}{e} - \frac{\phi}{e}$ ....(i)

Eq. (1) represents a straight line given by line P and Q, $\frac{\phi}{e}$ represents negative intercept on the Y-axis. Since Q has greater negative intercept, it will have greater ϕ (work function) and hence higher threshold frequency.

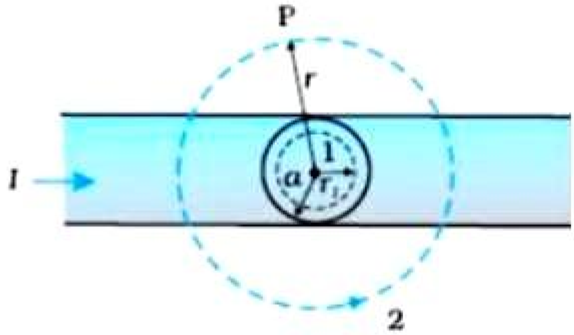
ii. To know work function of Q, we put V = 0 in (i),

$0 = \frac{h\nu}{e} - \frac{\phi}{e} \Rightarrow \phi = h\nu$

$\therefore \quad \phi = 6.6 \times 10^{-34} \times 6 \times 10^{14}$ J

$= \frac{6.6 \times 6 \times 10^{-20}}{1.6 \times 10^{-19}} \mathrm{eV} = 25\mathrm{eV}$

30. i. Consider the case r < a. The Amperian loop is a circle labelled 1 (fig.)



For this loop, taking the radius of the circle to be r

Let this loop contains charge I_e. This current enclosed I_e is not I, but is less than this value.

Since the current distribution is uniform, the current enclosed is

$I_e = I\left(\frac{\pi r^2}{\pi a^2}\right) = I\left(\frac{r^2}{a^2}\right)$

Using Ampere's law,

$B.2\pi r = \mu_0 I\left(\frac{r^2}{a^2}\right)$

$B = \frac{\mu_0 I}{2\pi}\left(\frac{r}{a^2}\right)$

So, $B \propto r \quad for\ r < a$

ii. Consider the case r > a. The Amperian loop, labelled 2, is a circle concentric with the cross-section. For this loop,

$L = 2\pi r$

I_e = Current enclosed by the loop = I

The result is the familiar expression for a long straight wire

$B.2\pi r = \mu_0 I$

$B = \frac{\mu_0 I}{2\pi r}$

$B \propto \frac{1}{r}$ when $r > a$

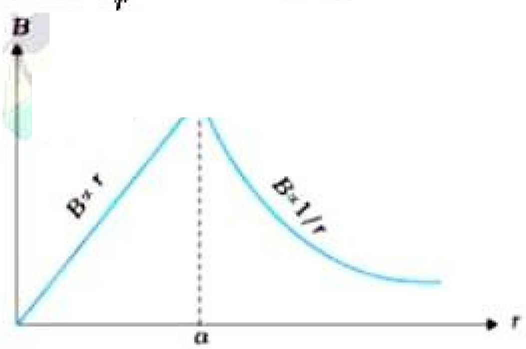
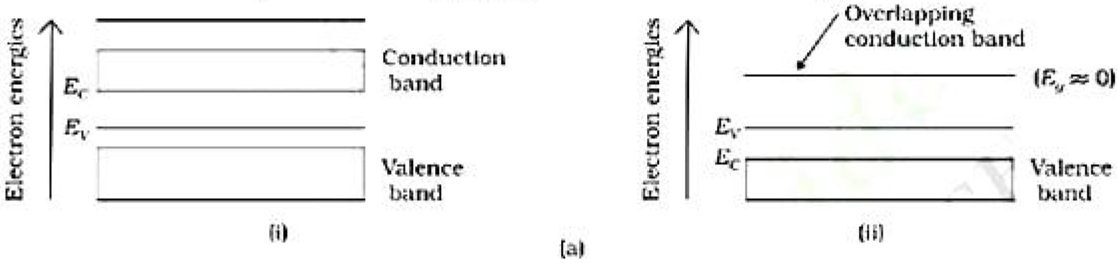


Fig. shows a plot of the magnitude of B with distance r from the centre of the wire. The direction of the field is tangential tothe respective circular loop (1 or 2) and given by the right-hand rule.

Section E

31. a. **Metals:** The energy band structure in solids have two possibilities:

(i) The valence band may be completely filled and the conduction band partially filled with an extremely small energy gap between them [Fig. a(i)].



(a)

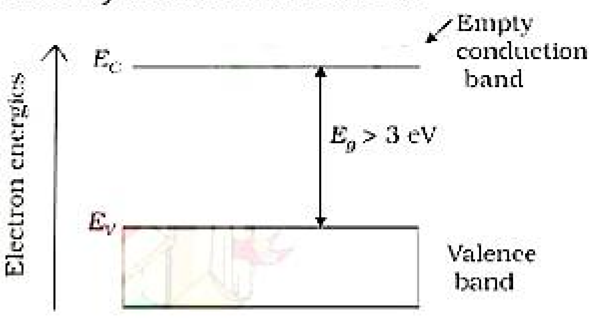
(ii) The valence band is completely filled and the conduction band is empty but the two overlap each other [Fig. a(ii)].

In both situations, it can be assumed that there is a single energy band, which is partially filled. Therefore, on applying even a small electric field, the metals conduct electricity.

Insulators: In this case, as shown in Fig. (b), a large bandgap E_g exists (E_g > 3 eV).

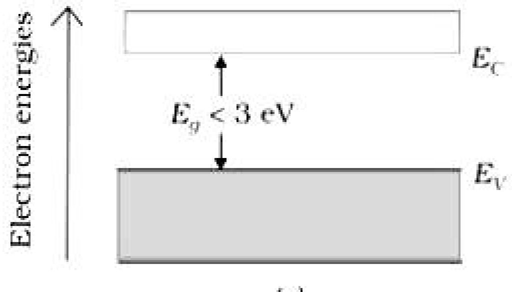
There are no electrons in the conduction band, and therefore no electrical conduction is possible. Note that the energy gap is so large that electrons cannot be excited from the valence band to the conduction

band by thermal excitation.



(b)

Semiconductors: This situation is shown in Fig. (c). Here a finite but small band gap (E_g < 3 eV) exists. Because of the small band gap, at room temperature some electrons from valence band can acquire enough energy to cross the energy gap and enter the conduction band. These electrons (though small in numbers) can move in the conduction band. Hence, the resistance of semiconductors is not as high as that of the insulators.



(c)

b. The fractional change due to the photo effects on the minority carrier dominated reverse bias current is more easily measurable than the fractional change in the forward bias current. Hence, photodiodes are preferably used in the reverse bias condition for measuring light intensity.

Now,

$\lambda = 6000nm = 6 \times 10^{-6}m$

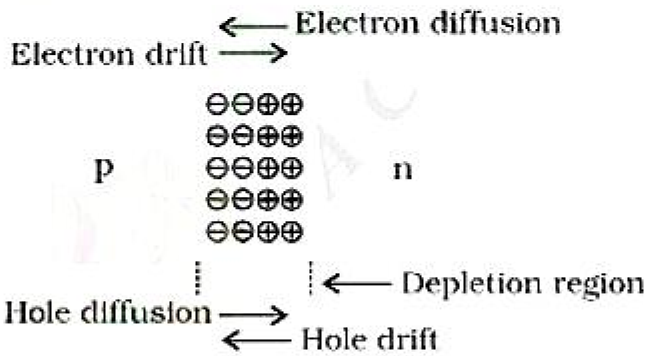
Since, $E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{6 \times 10^{-6}} = 3.3 \times 10^{-20}J$

or, $E = \frac{3.3 \times 10^{-20}}{1.6 \times 10^{-19}} = 0.206eV$

As the energy of the photon is less than E_g = 2.8eV of the semiconductor, so a wavelength of 6000 nm cannot be detected.

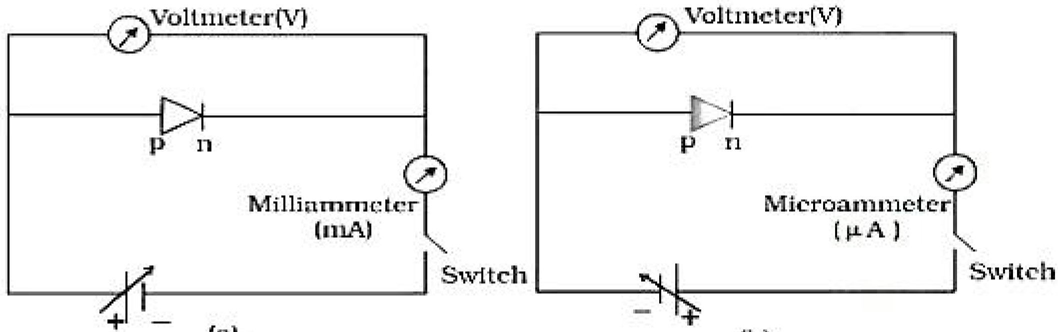
OR

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



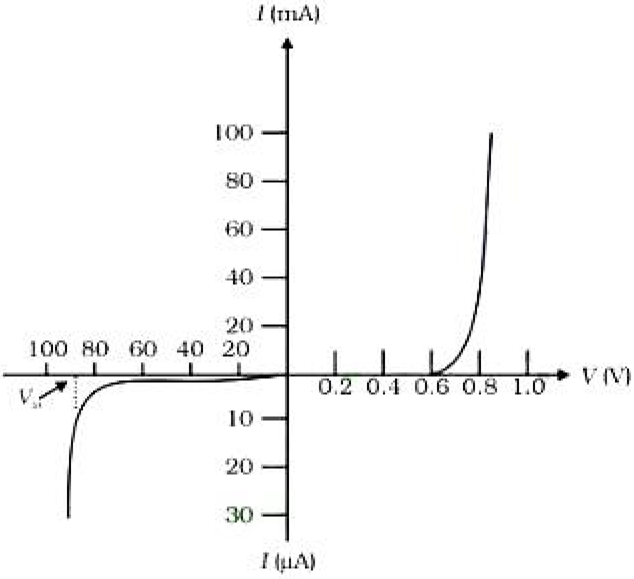
In the p-section, holes are the majority carriers; while in n-section, the majority carriers are electrons. Due to the high concentration of different types of charge carriers in the two sections, holes from p-region diffuse into n-region and electrons from n-region diffuse into p-region. In both cases, 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.



(a) (b)

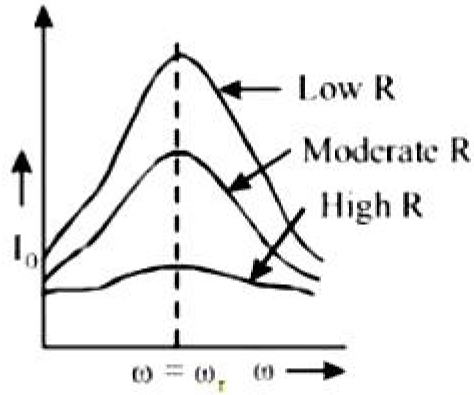
The battery is connected to the diode through a potentiometer (or rheostat) so that the applied voltage to the diode can be changed. For different values of voltages, the value of the current is noted. A graph between V and I is obtained as in Fig. (c).



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.

32. i. The sharpness of resonance in series L-C-R circuit refers how quick fall of alternating current in circuit takes place when the frequency of alternating voltage shifts away from the resonant frequency. It is measured by the quality factor (Q-factor) of circuit.



The Q -factor of the series resonant circuit is defined as the ratio of the voltage developed across the capacitance or inductance at resonance to the impressed voltage which is the voltage applied.

i.e., quality factor (Q) = $\frac{\text{voltage across L or } C}{\text{applied voltage}}$

Q = $\frac{(\omega_r L)I}{RI}$

[$\because$ applied voltage = voltage across R]

or Q = $\frac{\omega_r L}{R}$ or Q = $\frac{(1/\omega_r C)I}{RI} = \frac{1}{RC\omega_r}$

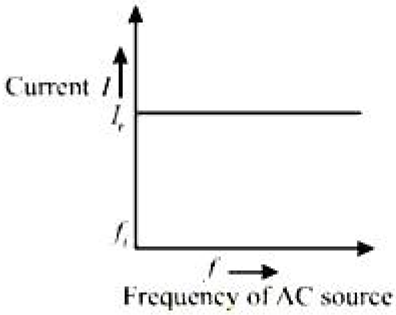
$\therefore$ Q = $\frac{L}{RC\cdot\frac{1}{\sqrt{LC}}}$ [using $\omega_r = \frac{1}{\sqrt{LC}}$]

Thus, Q = $\frac{1}{R}\sqrt{\frac{L}{C}}$

This is required expression.

ii. Let initially I_r current is flowing in all the three circuits. If the frequency of applied AC source is increased then, the change in current will occur in the following manner:

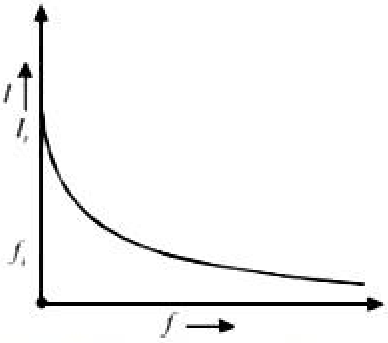
Circuit containing resistance R only:



where, f_i = initial frequency of AC source.

There is no effect on current with the increase in frequency.

AC circuit containing inductance only:



With the increase of frequency of AC source, inductive reactance increase as

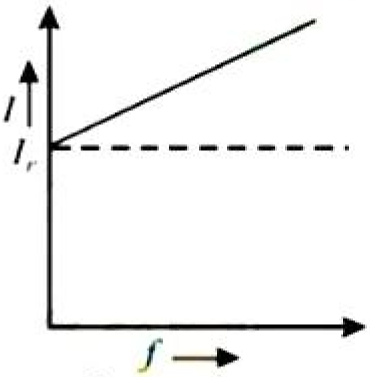
I = $\frac{V_{\mathrm{rms}}}{X_L} = \frac{V_{\mathrm{rms}}}{2\pi f L}$

For given circuit,

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

Current decreases with the increase of frequency.

AC circuits containing capacitor only:



$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

Current, I = $\frac{V_{\mathrm{rms}}}{X_C} = \frac{V_{\mathrm{rms}}}{\left(\frac{1}{2\pi f C}\right)}$

I = $2\pi f C V_{\mathrm{rms}}$

For given circuit, I $\propto$ f

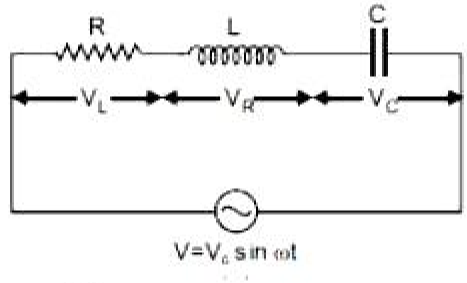
Current increases with the increase of frequency.

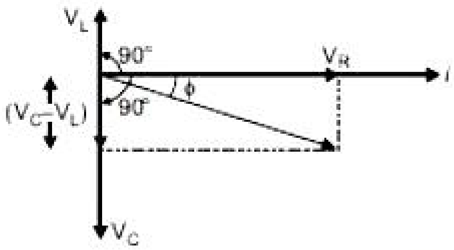
OR

Suppose a resistance R, inductance L and capacitance C in series. An alternating source of voltage V = $V_0 \sin \omega t$ is applied across it. Since all the components are connected in series, the current flowing through all is same.

Voltage across resistance R is V_R, voltage across inductance L is V_L and voltage across capacitance C is V_C.

V_R and $(V_C - V_L)$ are mutually perpendicular and the phase difference between them is 90^o.





From the figure above, we have

$$V^2 = V_R^2 + (V_C - V_L)^2 \Rightarrow V = \sqrt{V_R^2 + (V_C - V_L)^2} \text{ ..... (i)}$$

and $V_R = Ri$, $V_C = X_C i$ and $V_L = V_L i$ ..... (ii)

where $X_C = \frac{1}{\omega C}$ = capacitance reactance and $X_L = \omega L$ = inductive reactance

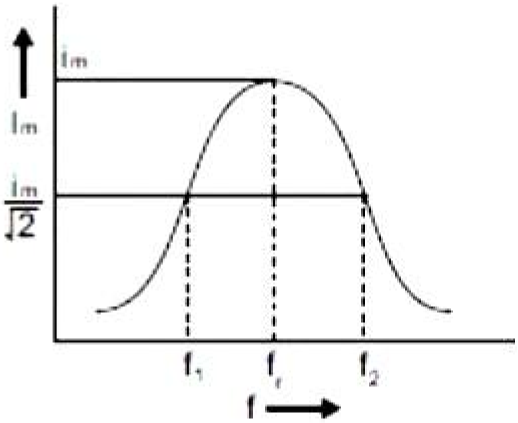
$$\therefore \quad V = \sqrt{(Ri)^2 + (X_C i - X_L i)^2}$$

$\therefore$ Impendance of circuit, $Z = \frac{V}{i} = \sqrt{R^2 + (X_C - X_L)^2}$

i.e. $Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}$

The phase difference between current and voltage is given by,

$$\tan \phi = \frac{X_C - X_L}{R}$$



From the graph, we can see that with increase in frequency, current first increases and then decreases. At resonant frequency, current amplitude is maximum.

33. a. Sources emitting waves of same frequency or wavelength having either a zero or a constant phase difference are said to be coherent sources of light.

Two independent sources of light do not fulfill the requirement of constant phase difference. As the case of two different sodium lamps is given here. Hence, such sources cannot be used for producing interference pattern.

b. For bright fringes (maxima),

Path difference, $\frac{xd}{D} = n\lambda$

$\therefore x = n\frac{\lambda D}{d}$

Where n = 0, 1, 2, 3, . . .

For dark fringes (minima),

Path difference, $\frac{xd}{D} = (2n-1)\frac{\lambda}{2}$

$\therefore x = (2n-1)\frac{\lambda}{2}\frac{D}{d}$

Where n = 0, 1, 2, 3,. . .

The separation between the centre of two consecutive bright fringes is the width of a dark fringes.

$\therefore$ Fringe width, $\beta = x_n - x_{n-1}$

$\beta = n\frac{\lambda D}{d} - (n-1)\frac{\lambda D}{d}$

$\therefore \beta = \frac{\lambda D}{d}$

c. S should be a monochromatic source producing two coherent light waves of comparable or equal amplitudes and d should be preferably small (i,e. the two slits should be close to each other.

OR

i. a. From the fringe width expression, we have
$\beta = \frac{\lambda D}{d}$, therefore with the decrease in separation between two slits, 'd' the fringe width increases.

b. For interference fringes to be seen, $\frac{s}{S} < \frac{\lambda}{d}$, condition should be satisfied otherwise, the interference patterns produced by different parts of the source slit will overlap.
As, the source slit width increases, the fringe pattern gets less and less sharp. When the source slit is so wide, the above condition does not satisfy and the interference pattern disappears. However, as long as the fringes are visible, the fringe width remains constant.

c. When monochromatic light is replaced by white light, then coloured fringe pattern is obtained on the screen.
The interference pattern due to different colour component of white light overlap. The central bright fringes for different colours are at the same position. Therefore, central fringes are white. And on the either side of the central fringe white coloured bands will appear.

ii. Intensity at a point is given by
$I = 4I' \cos^2 \phi/2$
where I' = intensity produced by each one of the individual sources.
At central maxima, $\phi = 0$,
The intensity at the central maxima,
$I_0 = 4I'$
$I' = \frac{I_0}{4}$ ..... (i)
As, path difference $= \frac{\lambda}{3}$
Phase difference, $\phi' = \frac{2\pi}{\lambda} \times$ path difference
$= \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3}$
Now, intensity at this point
$I'' = 4I' \cos^2 \frac{1}{2}\left(\frac{2\pi}{3}\right)$
$= 4I' \cos^2 \frac{\pi}{3}$
$= 4I' \times \frac{1}{4} = I'$
$= \frac{I_0}{4}$ [from Eq. (i)]
Hence proved.