CBSE Class 12 Physics
Sample Paper 06 (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. Two point charges of $3\mu C$ each are 100 cm apart. At what point on the line joining the charges will the electric intensity be zero?
2. If the radius of the ground level hydrogen atom is 5.3 nm, what is the radius of the first excited state?

OR

An electron and alpha particle have the same de-Broglie wavelength associated with them. How are their kinetic energies related to each other?

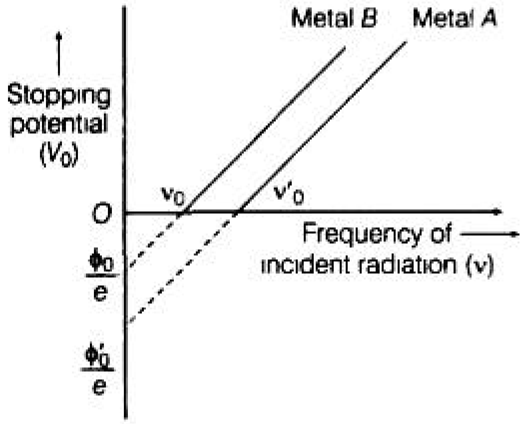
3. Why cannot we obtain interference using two independent sources of light?
4. State Huygens principle.

OR

What type of wavefront will emerge from a

i. point source
ii. distant light source?

5. Define critical angle for total internal reflection.
6. The graph shows the variation of stopping potential with frequency of incident radiation for two photosensitive metals A and B. Which one of the two has higher value of work function? Justify your answer.

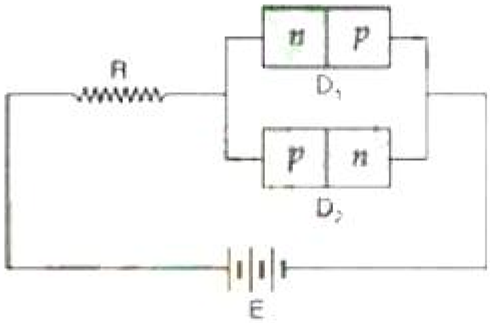


7. Why it is not possible to make a spherical conductor of capacity one farad? Explain.

OR

What do you mean by dielectric polarisation?

8. In Figure shows two p-n junctions diodes along-with a resistance R and a d.c. battery E.



Indicate the path and direction of flow of appreciable current in the circuit.

9. What is the basic difference between magnetic lines of force and electric lines of force?
10. How does the potential barrier change, when a p-n junction is reverse biased?
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:** 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):** An emf E is induced in a closed loop where magnetic flux is varied. The induced E is not a conservative field.

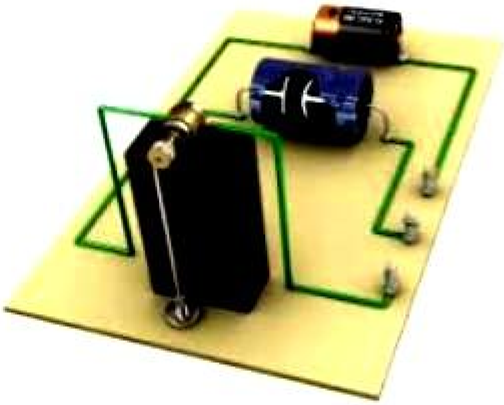
Reason (R): The line integral of $\vec{E} \cdot \vec{dl}$ around the closed loop is non-zero.

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

Section B

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

Capacitance is the electrical property of a capacitor and is the measure of a capacitor's ability to store an electrical charge onto its two plates. A capacitor is an arrangement for storing a large amount of electric charge and hence electric field in a small space.



i. The capacitance of 1 μF equals

a. 10^{-12} F

b. 10^{-8} F

c. 10^{-6} F

d. 10^{-4} F

ii. The capacitance between two plates increases with:-

a. Shorter plate area and higher applied voltage

b. Shorter plate area and shorter distance between them

c. Larger plate area, long-distance between plates

d. Larger plate area and shorter distance between plates

iii. Capacitor stores which type of energy:

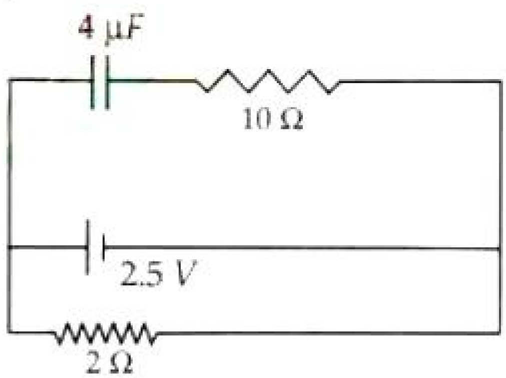
a. kinetic energy

b. vibrational energy

c. potential energy

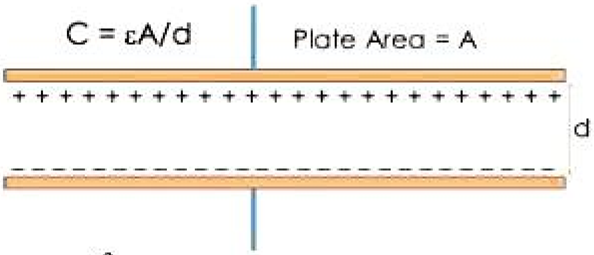
d. none of these

iv. A capacitor of 4 μF is connected as shown in the circuit Figure. The internal resistance of the battery is 0.5 Ω. The amount of charge on the capacitor plates will be :



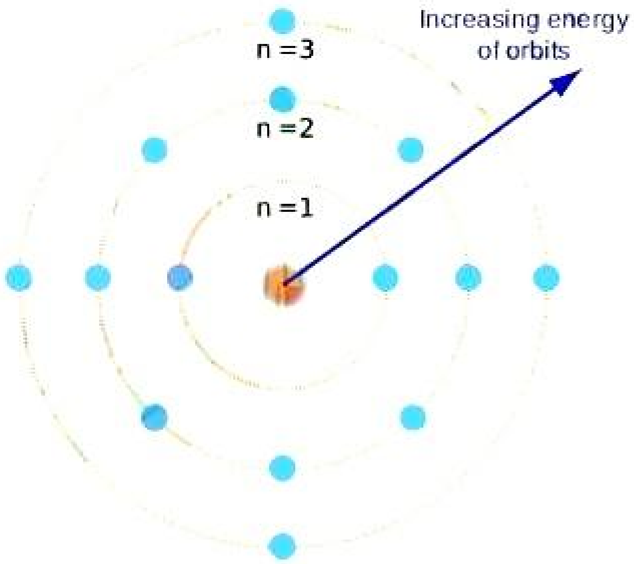
a. $16\mu C$
b. 0
c. $4\mu C$
d. $8\mu C$

v. The force of attraction between the plates of parallel plate capacitor having area A and charge Q is given by:



a. $\frac{Q^2}{2A\epsilon_0}$
b. $\frac{Q^2}{4A\epsilon_0}$
c. $\frac{Q^2}{A\epsilon_o}$
d. $\frac{Q}{A\epsilon_0}$

16. **Read the source given below and answer any four out of the following questions:**
The Bohr model of the atom was proposed by Neil Bohr in 1915. It came into existence with the modification of Rutherford's model of an atom. Rutherford's model introduced the nuclear model of an atom, in which he explained that a nucleus (positively charged) is surrounded by negatively charged electrons.



i. Which of the following statements does not form a part of Bohr's model of a hydrogen atom?

a. The energy of the electrons in the orbit is quantized
b. The electron in the orbit nearest the nucleus has the lowest energy
c. Electrons revolve in different orbits around the nucleus
d. The position and velocity of the electrons in the orbit cannot be determined simultaneously

ii. What is in the center of the Rutherford model?
a. Single proton
b. Multiple electrons
c. A nucleus
d. Neutrons

iii. When an electron jumps from its orbit to another orbit, energy is:
a. emitted only
b. absorbed only
c. both (a) and (b)
d. none of these

iv. How were the limitations of the Rutherford model which could not explain the observed features of atomic spectra explained in Bohr's model of a hydrogen atom?
a. It must emit a continuous spectrum
b. It loses its energy
c. Gaining its energy
d. A discrete spectrum

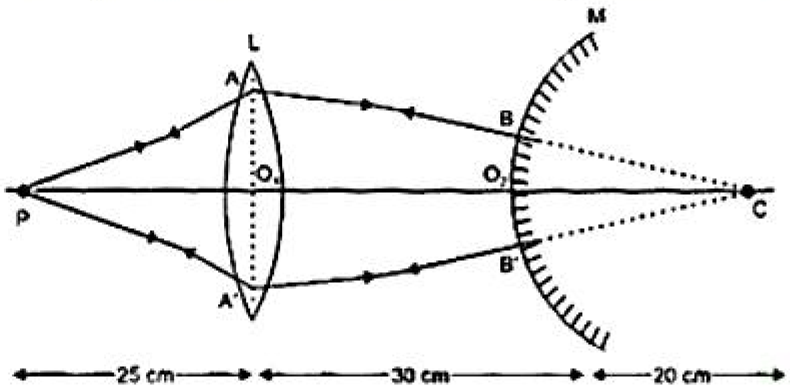
v. When electron remains between orbits its momentum is:
a. quantized
b. emitted
c. dequantized
d. none of the above

Section C

17. Define mobility of a charge carrier. Write the relation expressing mobility in terms of relaxation time. Give its SI unit.
18. 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.

OR

A convex lens and a convex mirror of radius of curvature 20 cm are placed coaxially with the convex mirror placed at a distance of 30 cm from the lens. For a point object, at a distance of 20 cm from the lens, the final image due to this combination coincides with the object itself. What is the focal length of the convex lens?

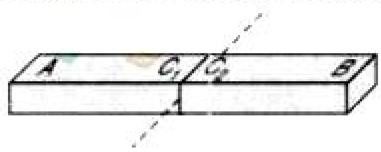


19. A charge Q is divided into two parts q and Q-q and separated by a distance R. When the force of repulsion between them will be maximum?

OR

Why can one ignore quantization of electric charge, when dealing with macroscopic i.e. large scale charges?

20. State Lenz's law. Give one example to illustrate this law.
21. An electron moves in a circle with uniform speed in a stationary magnetic field normal to the circle. If the field magnitude is made to increase with time, will the electron speed up or speed down? Will it continue to revolve in the same circle?
22. Differentiate between nuclear fission and fusion.
23. A concave lens produces a virtual and diminished image independent of the location of the object. Explain, why?
24. 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?

OR

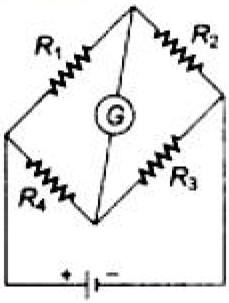
Why does a magnetic dipole possess potential energy, when placed at some inclination with the direction of the field?

25. i. The bluish colour predominates in clear sky.
ii. Violet colour is seen at the bottom of the spectrum when white light is dispersed by a prism.
State reasons to explain these observations.

Section D

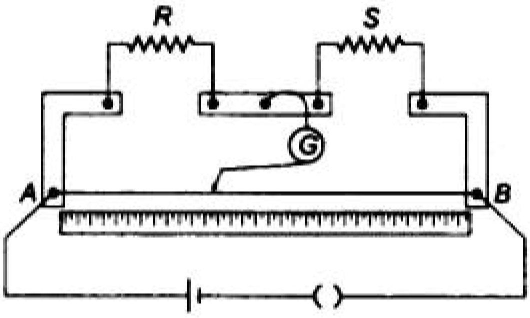
26. In a Young's double slit experiment, the two slits are kept 2 mm apart and the screen is positioned 140 cm away from the plane of the slits. The slits are illuminated with light of wavelength 600 nm. Find the distance of the third bright fringe, from the central maximum, in the interference pattern obtained on the screen.If the wavelength of the incident light were changed to 480 nm, find out the shift in the position of third bright fringe from the central maximum.

27. For the circuit diagram of a Wheatstone bridge shown in the figure, use Kirchhoff's laws to obtain its balance condition.

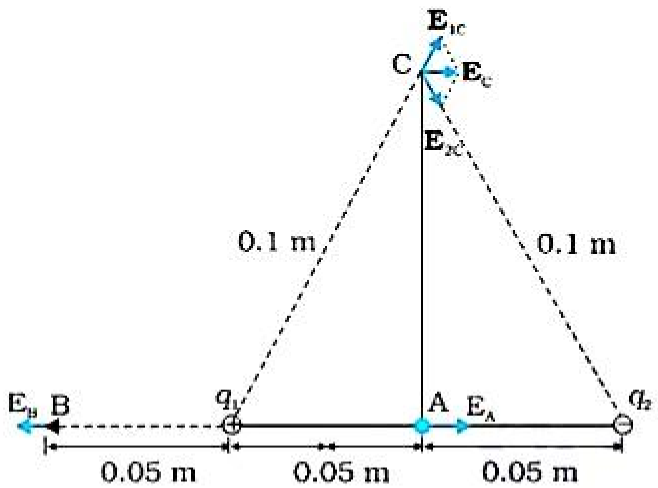


OR

In a meter bridge, the null point is found at a distance of 60 cm from A. If a resistance of 5Ω is connected in series with S, then null point occurs at 50.0 cm from A. Determine the values of R and S.



28. Two-point charges q_1 and q_2, of magnitude $+10^{-8}$ C and -10^{-8} C, respectively, are placed 0.1 m apart. Calculate the electric fields at points A, B, and C shown in fig.



OR

Two equally charged identical metal spheres A and B repel each other with a force 2.0×10^{-5} N. Another identical uncharged sphere C is touched to A and then placed at the mid point between A and B. What is the net electric force on C?

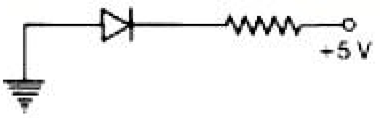
29. An electron and a proton are accelerated through the same potential. Which one of the two has (i) greater value of de-Broglie wavelength associated with it and (ii) less momentum? Justify your answer.
30. Deduce the expression for the torque experienced by a rectangular loop carrying a steady current I and placed in a uniform magnetic field B. Indicate the direction of the torque acting on the loop.

Section E

31. i. Explain with the help of a diagram the formation of depletion region and barrier potential in a p-n junction.
    ii. Draw the circuit diagram of a half-wave rectifier and explain its working.

OR

i. In the following diagram, is the junction diode forward biased or reverse biased?

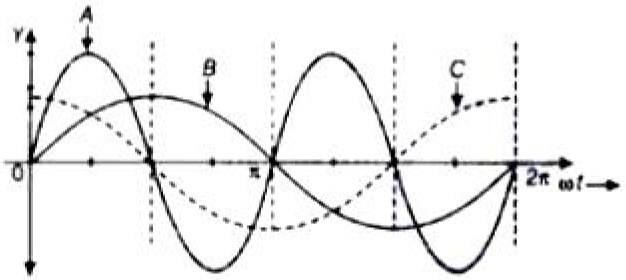


ii. Draw the circuit diagram of a full wave rectifier and state how it works?

32. 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, $\sqrt{2} = 1.414$).

OR

A device X is connected to an AC source, V = V_0 sin ωt. The variation of voltage, current and power in one cycle is shown in the following graph.



i. Identify the device X.
ii. Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit? Justify the answer.
iii. How does its impedance vary with the frequency of the AC source? Show graphically.
iv. Obtain an expression for the current in the circuit and its phase relation with AC voltage.

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 $\frac{\lambda}{3}$.

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Solution

Section A

1. The electric intensity will be zero at a point mid-way between the two charges.
2. We know that, $r_2 = n^2 r_1$

   For first excited state, n = 2. Therefore,

   $r_2 = 4 \times 5.3 = 21.2$ nm

OR

Given $\lambda_{\text{electron}} = \lambda_\alpha$

De-Broglie wavelength associated with a particle of mass m and energy E is given by:

$\lambda = \frac{h}{\sqrt{2mE}}$

$\therefore \frac{h}{\sqrt{2m_e E_e}} = \frac{h}{\sqrt{2m_\alpha E_\alpha}}$

That is the kinetic energy of electron and α-particle is in the inverse ratio of their masses.

3. A sustained interference pattern cannot be obtained by using two independent sources of light. It is because of the following reasons:
   - Two independent sources of light can't emit waves continuously.
   - The waves emitted by two independent sources of light do not have same phase or a constant phase difference
   - Two independent sources of light cannot be coherent, as their relative phases are changing randomly.
4. Huygens' principle is a geometrical construction, which is used to determine the new position of a wavefront at a later time from its given position at any instant. In other words, the principle gives a method to know as to how light spreads out in the medium.

OR

i. When source of light is a point source, the wavefront is spherical. Example - Light coming from an electric bulb.
ii. At very large distances from the source, a portion of spherical or cylindrical

wavefront appears to be plane wavefront. Example - Light coming from the sun.

5. The angle of incidence in denser medium, for which angle of refraction in rarer medium is 90°, is called critical angle.
6. Metal A has higher value of work function because the threshold frequency is greater for A.
7. The capacitance of a spherical conductor of radius r is given by
   C = $4 \pi \varepsilon_0 r$
   The radius of the spherical conductor having capacitance 1 F is given by
   r = $\frac{C}{4\pi\varepsilon_0}$ = $1 \times 9 \times 10^9 = 9 \times 10^9$ m
   = 9×10^6 km
   Since one cannot have a spherical conductor of such a big radius, it is not possible to make a spherical conductor of capacitance 1 F.

OR

The stretching of dielectric atoms due to displacement of charges in the atoms under the action of the applied electric field is called polarisation.

8. In the circuit containing two junction diodes D_1 and D_2, the diode D_2 is forward biased and D_1 is reverse biased. Therefore, the path of appreciable current will be from positive pole of the battery to its negative pole through resistance R and junction diode D_2.
9. The electric lines of force originate from positive charge and end at negative charge and are thus discontinuous curves. But as the isolated magnetic poles do not exist, the magnetic field lines are closed loops.
10. The reverse bias increases the potential barrier, as it aids it.
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. (c) A is true but R is false
    Explanation: A is true but R is false
14. (a) Both A and R are true and R is the correct explanation of A

Explanation: Both A and R are true and R is the correct explanation of A

Section B

15. i. (c) 10^{-6} F
    ii. (d) Larger plate area and shorter distance between plates
    iii. (c) potential energy.
    iv. (d)8μC
    v. (a) $\frac{Q^2}{2A\epsilon_0}$
16. i. (d) The position and velocity of the electrons in the orbit cannot be determined simultaneously
    ii. (c) A Nucleus
    iii. (c) both a and b
    iv. (d) A discrete spectrum
    v. (a) quantized

Section C

17. **Mobility** is formally defined as the value of the drift velocity per unit of electric field strength; thus, the faster the particle moves at a given electric field strength, the larger the **mobility**. Mobility is generally denoted by μ.

    $\therefore \quad \mu = v_d/E$ ...(i)

    The SI unit of mobility is $m^2\ V^{-1}\ s^{-1}$.

    Drift velocity in term of relaxation time,

    $v_d = \frac{-eE}{m}\tau$

    In magnitude, $v_d = \frac{eE}{m}\tau$ or $\frac{v_d}{E} = \frac{e\tau}{m}$

    $\mu = \frac{e\tau}{m}$ [From Eq. (i)]

    The faster the particle moves at a given electric field strength, the larger the mobility. The mobility of a particular type of particle in a given solid may vary with temperature.
18. 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.

OR

Here O_2C = 20 cm (the radius of curvature of the mirror)

u = -25 cm

v = +(30 + 20) = +50 cm

If f be the focal length of the lens, then

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

$= \frac{1}{50} - \frac{1}{(-25)} = \frac{1}{50} + \frac{1}{25} = \frac{3}{50}$

Thus,

$f = \frac{50}{3}$ = 16.67 cm

19. Let 'r' be the separation between the charges q and (Q-q).

The force of repulsion between them is,

$F = \frac{k(Q-q)q}{r^2} = \frac{k}{r^2}(Qq - q^2)$

Differentiate F w.r.t. q and setting it to zero we get,

$\frac{dF}{dq} = \frac{k}{r^2}\frac{d}{dq}(Qq - q^2) = 0$

$\Rightarrow \frac{k}{r^2}(Q - 2q) = 0$

$\Rightarrow Q - 2q = 0$

$\Rightarrow q = \frac{Q}{2}$

For this value of q, the force is extremum (minimum or maximum). The force will be maximum if the second differentiation of F is less than zero.

$\frac{d^2F}{dq^2} = \frac{-2k}{r^2} < 0$

Thus, the force of repulsion is maximum when q = $\frac{Q}{2}$

OR

In practice, the charge on a charged body is very large. On the other hand, the charge on an electron is very small. When electrons are added to a body (negatively charged body) or removed from a body (positively charged body), the change taking place in the total charge on the body is so small that the charge seems to be varying in a continuous manner. Therefore, quantization of electric charge can be ignored, when dealing with a large scale charged body.

20. According to this law "the direction of induced current in a closed circuit is always such as to oppose the cause that produces it."

$e=-\frac{d\phi}{dt}$

The negative sign expresses Lenz's law. It means that the induced emf is such that, the induced current opposes the change in flux if the circuit is closed.

Consider a bar magnet and a loop. The bar magnet experiences a repulsive force due to the current induced. Hence, some amount of work is done to move the magnet. The energy which is spent by the person in moving the magnet is dissipated by Joule's heating produced by induced current. Thus, in each case whenever there is a relative motion between a coil and the magnet, a force begins to act which opposes the relative motion. Therefore, to maintain the relative motion, a mechanical work must be done. This work appears in the form of the electric energy of the coil. Thus, Lenz's law is based on the conservation of energy.

21. As B increases with time, Lorentz force F = Bev, on the electron increases. As this force provides the necessary centripetal force ($F = mv^2/r$), therefore, the electron must speed up. Also, some energy is spent up in increasing B with time. The electron, therefore, should have higher energy by speeding up. Further, from

$F=\frac{mv^2}{r}=Bev$

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

The electron will not continue to revolve in a circle of the same radius, as rates of increase of B and v (with time) may be different.

22. Nuclear fission and fusion have the following points of differences:
    i. In a nuclear fission reaction, a heavy nucleus splits into two lighter nuclei; whereas in a nuclear fusion reaction, two light nuclei unite to form a heavier nucleus.
    ii. The energy released per nucleon is very high in case of nuclear fusion reaction in comparison to that in nuclear fission reaction.
    iii. The nuclear fusion reaction can be carried out only under very high temperature condition, while in case of nuclear fission reaction, there is no such requirement.

23. From the lens equation, we have

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

or $v=\frac{uf}{u+f}$

The focal length of a concave lens is negative. Since distance of a real object from the lens is also negative, it follows that v will also be negative. Therefore, a concave lens forms the image on the same side of the object. In other words, the image formed is always virtual.

Again, m = $\frac{f}{u+f}$

Since both f and u are negative, the value of m is positive and always less than 1 i.e. the image formed is always diminished.

Hence, a concave lens produces a virtual and diminished image independent of the position of the object.

24. 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.

OR

In equilibrium, a magnetic dipole always aligns itself along the direction of the magnetic field. When the magnetic dipole is displaced from the equilibrium position, a restoring torque acts on the dipole to bring it back. Therefore, to place the dipole at some inclination with the field, work has to be done against the restoring torque. This work done is stored in the dipole as its potential energy.

25. i. The intensity of scattered light varies inversely as fourth power of wavelength (i. e., $I \propto 1/\lambda^4$). In visible light, blue colour has minimum wavelength, so it is scattered most, that is why bluish colour predominates in a clear sky.
    ii. While light consists of infinite wavelengths starting from 400nm (violet) to 750nm (red). The refractive index of prism is maximum for violet and minimum for red; so prism separates constituent colours of white light and causes maximum deviation for violet colour as deviation increases with the refractive index. That is why violet colour is seen at the bottom of spectrum when white light is dispersed through a prism.

Section D

26. Given, d = 2 mm $= 2 \times 10^{-3} m$

D = 140 cm = 1.40 m

λ = 600 nm $= 600 \times 10^{-9} = 6 \times 10^{-7}$ m

Position of bright fringes is given by

$x_n = n\lambda \frac{D}{d}$

Distance of the third bright fringe is

$x_3 = 3\lambda \frac{D}{d}$

$\Rightarrow x_3 = 3 \times 6 \times 10^{-7} \times \frac{1.40}{2\times10^{-3}}$

$= 12.6 \times 10^{-4} = 1.26 \times 10^{-3} m$

= 1.26 mm

For λ = 480 nm $= 480 \times 10^{-9} = 4.8 \times 10^{-7} m$

Distance of the third bright fringe is

$x_3 = 3\lambda \frac{D}{d}$

$= 3 \times 4.8 \times 10^{-7} \times \frac{1.40}{2\times10^{-3}}$

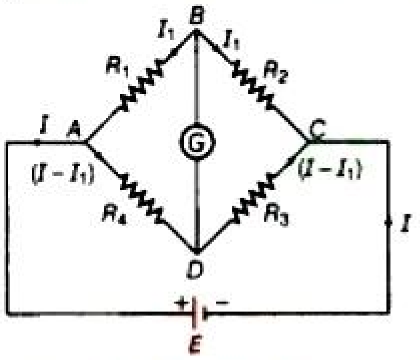
$= 10.08 \times 10^{-4} = 1.008 \times 10^{-3} m$

$= 1.01 \times 10^{-3} m$ = 1.01 mm

$\therefore$Shift in the position of third bright fringe

= 1.26 - 1.01 = 0.25 mm.

27. In balanced Wheatstone bridge if no current flow through galvanometer, that means while applying Kirchhoff's law, we can neglect this path. No current flows through the galvanometer G when circuit is balanced.



Applying Kirchhoff's second rule, we have

In mesh ABDA,

$\therefore -I_1 R_1 + (I - I_1) R_4 = 0$

$\Rightarrow I_1 R_1 = (I - I_1) R_4$ ....(i)

In mesh BCDB,

$-I_1 R_2 + (I - I_1) R_3 = 0$

$\Rightarrow I_1 R_2 = (I - I_1) R_3$ ...(ii)

On dividing Eq. (i) by Eq. (ii), we get

$\frac{I_1 R_1}{I_1 R_2} = \frac{(I - I_1) R_4}{(I - I_1) R_3} \Rightarrow \frac{R_1}{R_2} = \frac{R_4}{R_3}$

This is necessary and required balanced condition of balanced Wheatstone bridge.

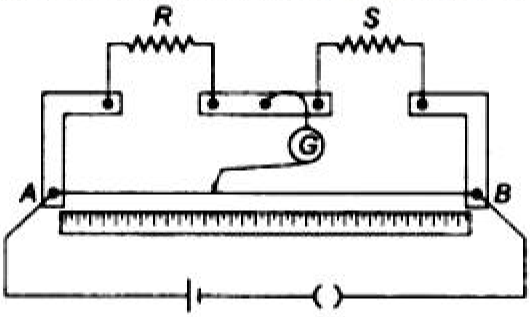
OR

The meter bridge works on the principle of Wheatstone bridge. At balance condition:

$\frac{R}{S} = \frac{l_1}{100 - l_1}$

where l_1 is distance measured from A to the Null point.

In a meter bridge, the null point is found at a distance of 60 cm from A.



Given: $l_1 = 60\ cm$

$\frac{R}{S} = \frac{60}{100-60} = \frac{60}{40} = \frac{3}{2}$

$\Rightarrow \frac{R}{S} = \frac{3}{2}$ ...(i)

Again, applying the condition when S and 5Ω are connected in series,

$\frac{R}{S'} = \frac{l_1}{100 - l_1}$ with $l_1 = 50\ cm$

and $S' = 5 + S$

$\frac{R}{S+5} = \frac{50}{50} \Rightarrow \frac{R}{S+5} = 1$ ...(ii)

From Equations , (i) and (ii), we get

$\frac{3}{2} S = S + 5 \Rightarrow \frac{3}{2} S - S = 5$

$\Rightarrow S = 10\Omega$

Substituting value of 'S' in (i),

$\frac{R}{S} = \frac{3}{2}$

$\Rightarrow \frac{R}{10} = \frac{3}{2}$

$\Rightarrow R = \frac{3 \times 10}{2}$

$\Rightarrow R = \frac{30}{2}$

$\Rightarrow R = 15\Omega$

28. The electric field due to a charge is given by the formula E=$q/4\pi \in 0(r^2)$. Thus, the

electric field vector E_{1A} at A due to the positive charge q_1 points towards the right and has a magnitude

$E_{1A} = \frac{(9\times10^9 Nm^2C^{-2})\times(10^{-8}C)}{(0.05m)^2} = 3.6 \times 10^4\ NC^{-1}$

The electric field vector E_{2A} at A due to the negative charge q_2 points towards the right and has the same magnitude. Hence the magnitude of the total electric field E_A at A is

$E_A = E_{1A} + E_{2A} = 7.2 \times 10^4\ NC^{-1}$

E_A is directed toward the right.

The electric field vector E_{1B} at B due to the positive charge q_1 points towards the left and has a magnitude

$E_{1B} = \frac{(9\times10^9 Nm^2C^{-2})\times(10^{-8}C)}{(0.05m)^2} = 3.6 \times 10^4\ NC^{-1}$

The electric field vector E_{2B} at B due to the negative charge q_2 points towards the right and has a magnitude

$E_{2B} = \frac{(9\times10^9 Nm^2C^{-2})\times(10^{-8}C)}{(0.15m)^2} = 4 \times 10^3\ NC^{-1}$

The magnitude of the total electric field at B is

$E_B = E_{1B} - E_{2B} = 3.2 \times 10^4\ NC^{-1}$

E_B is directed towards the left.

The magnitude of each electric field vector at point C, due to charge q_1 and q_2 is

$E_{1C} = E_{2C} = \frac{(9\times10^9 Nm^2C^{-2})\times(10^{-8}C)}{(0.10m)^2} = 9 \times 10^3\ NC^{-1}$

The directions in which these two vectors point are indicated in fig. The resultant of these two vectors is

$E_C = E_{1C}\cos\frac{\pi}{3} + E_{2C}\cos\frac{\pi}{3} = 9 \times 10^3\ NC^{-1}$

E_C points towards the right.

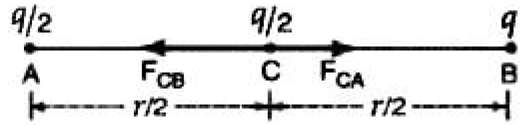
OR

Consider that two identical spheres A and B each having charge q are placed at a distance r apart as shown in Figure.

Now, $\mathbf{F} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q\times q}{r^2}$

$\therefore \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{r^2} = 2 \cdot 0 \times 10^{-5}$ .....(i)

When an identical uncharged sphere C is touched to A, both will share the charge on A equally i.e. each of the spheres A and C will, now, possess charge $\frac{q}{2}$.



Now, $F_{CA} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\frac{q}{2} \times \frac{q}{2}}{\left(\frac{r}{2}\right)^2}$

$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{r^2}$ (along CB)

and $\mathbf{F}_{CB} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\frac{q}{2} \times q}{\left(\frac{r}{2}\right)^2}$

$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{2q^2}{r^2}$ (along CA)

Since $F_{CB} > F_{CA}$, the resultant force on the sphere C is given by

$\mathbf{F}' = \mathbf{F}_{CB} - \mathbf{F}_{CA}$

$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{2q^2}{r^2} - \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{r^2}$

$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{r^2}$ (along CA)

Using the equation (i), we have

$F' = 2.0 \times 10^{-5}$ N (along CA)

29. i. From de-Broglie equation,

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$

As, $p = \sqrt{2mK}$ and K = qV

$\Rightarrow \quad \lambda = \frac{h}{\sqrt{2mqV}}$ ....(i)

$\lambda \propto \frac{1}{\sqrt{mq}}$

Ratio of wavelengths of electron and proton,

$\frac{\lambda_e}{\lambda_p} = \sqrt{\left(\frac{m_p}{m_e}\right)\left(\frac{q_p}{q_e}\right)}$

Ratio of mass of proton and electron,

$\frac{m_p}{m_e} = 1836$ (constant)

$\frac{q_p}{q_e} = 1$ (Both electron and proton have same charge)

$\Rightarrow \quad \frac{\lambda_e}{\lambda_p} = \sqrt{1836 \times 1}$

$\lambda_e \approx 42.8\lambda_p$ nearly

Electron have greater wavelength associated with it than that of proton.

ii. $\because \quad \lambda = \frac{h}{p}$ (de-Broglie equation)

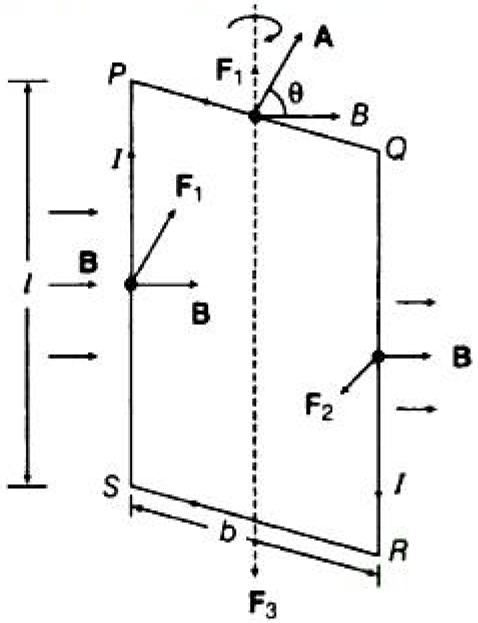
$\Rightarrow \quad p = \frac{h}{\lambda} \Rightarrow p \propto \frac{1}{\lambda} \Rightarrow \frac{p_e}{p_p} = \frac{\lambda_p}{\lambda_e}$

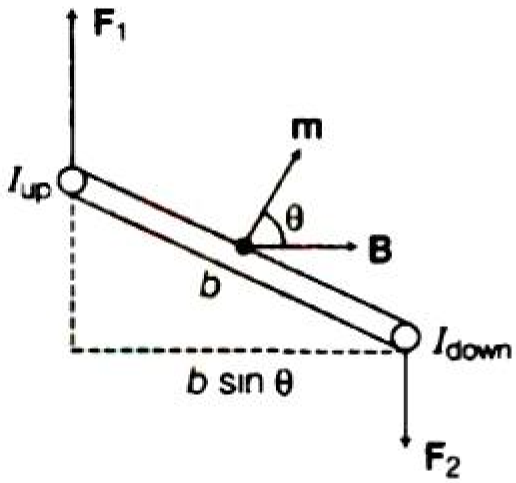
Now,

$\frac{\lambda_p}{\lambda_e} = \frac{1}{42.8} \Rightarrow \quad \frac{p_e}{p_p} = \frac{\lambda_p}{\lambda_e} = \frac{1}{42.8}$

Momentum of proton is nearly 42.8 times to that of momentum of electron. Thus, electron will have less momentum.

30. Let a current carrying rectangular loop PQRS is carrying a steady current I placed in a uniform magnetic field B keeping the axis of the coil perpendicular to the field as shown in figure. Let at any instant the area vector A makes an angle θ with the direction of magnetic field intensity B.





Let length and breadth of the coil are I and b respectively.

Now, magnetic force on PS arm of the coil is given by $F_1 = BIl \sin 90^\circ$ [$\because$ PS || axis of coil, $\therefore \theta = 90^\circ$]

F_1 = BIl ...... (i)

By Fleming's left hand rule, the direction of the above force is perpendicular to SP and B is along upward direction. Similarly, force on QR arm of the coil

F_2 = BIl sin 90° ..... (ii)

The direction of force is perpendicular to QR and B is along downward direction

$\because$ F_1 and F_2 are equal in magnitude and opposite in direction, parallel to each other acting on the loop forms a couple which try to rotate the coil.

Now, force on RS part of the coil

$F_3 = IBb\sin(90^\circ + \theta) \Rightarrow F_3 = IBb\cos\theta$

and also force on PQ part of the coil

$F_4 = IBb\sin(90^\circ - \theta) = IBb\cos\theta$

But by Fleming's left hand rule, F_3 and F_4 are equal in magnitude and opposite in direction along the same line of action. Therefore, they balance each other.

Now, torque due to F_1 and F_2 is given by

τ = force $\times$ perpendicular distance between lines of action of F_1 and F_2.

$\tau = F \times b\sin\theta$

But, $F_1 = F_2 = F = IBl, \therefore \tau = (IBl) \times (b\sin\theta)$

$\Rightarrow \tau = IB(lb)\sin\theta$

$\therefore \tau = IBA\sin\theta$

where, A = lb = area of coil.

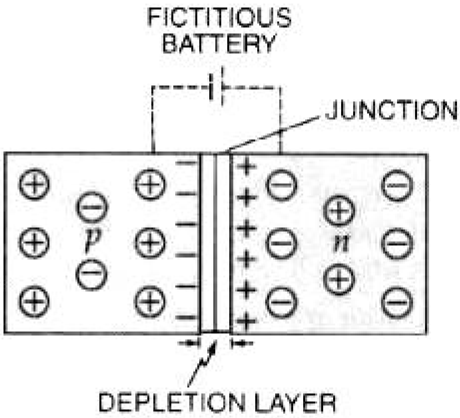
For N turns of the coil, we have

$\tau = NIAB\sin\theta$, this is the required expression of the torque in the current carrying rectangular loop.

Section E

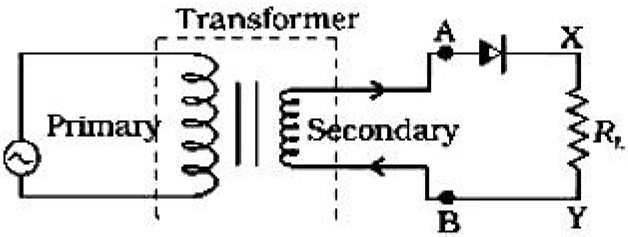
31. i. A p-n juntion is a basic semiconductor device.

   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.



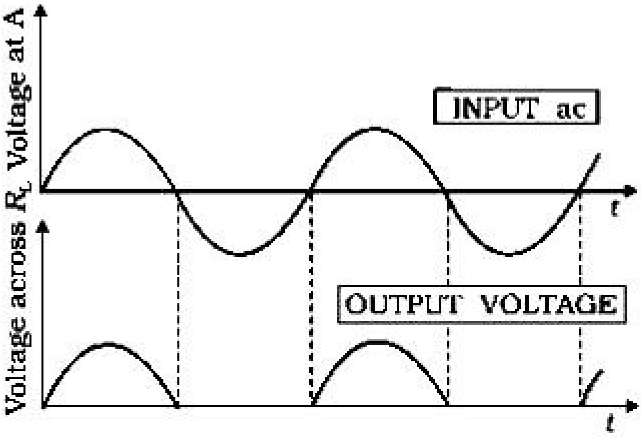
Due to the diffusion of holes and electrons, the two sections of the junction diode no longer remain neutral. The p-section of the junction diode becomes slightly negative, while the n-section is rendered positive. It appears as if some fictitious battery is connected across the junction with its negative pole connected to p-region and positive pole connected to n-region. The potential difference developed across the junction due to migration of majority charge carriers is called **potential barrier**. It opposes the further diffusion of charge carriers.

ii. The half-wave rectifier circuit is shown in the figure.



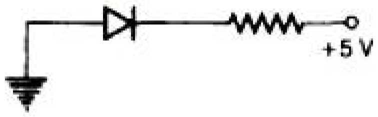
The secondary of a transformer supplies the desired ac voltage across terminals A and B. When the voltage at A is positive, the diode is forward biased and it conducts. When A is negative, the diode is reverse-biased and it does not conduct.
Therefore, in the positive half-cycle of a.c. there is a current through the load resistor R_L and we

get an output voltage, as shown in Fig., whereas there is no current in the negative halfcycle. In the next positive half-cycle, again we get the output voltage. Thus, the output voltage, though still varying, is restricted to only one direction and is said to be rectified. Since the rectified output of this circuit is only for half of the input ac wave it is called as half-wave rectifier. The input-output waveforms are shown in the Fig. below.



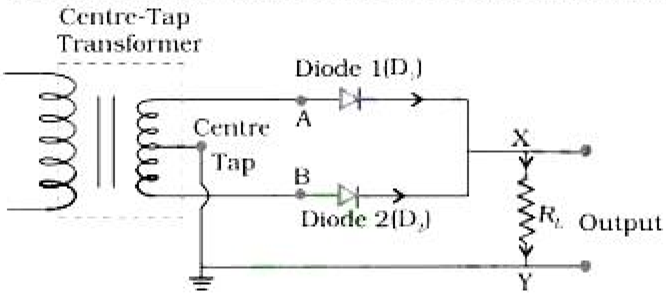
OR

i. In this case, the p-side is at 0V, whereas the n-side is at +5V. As, $V_p < V_n$, hence the diode is reverse biased.



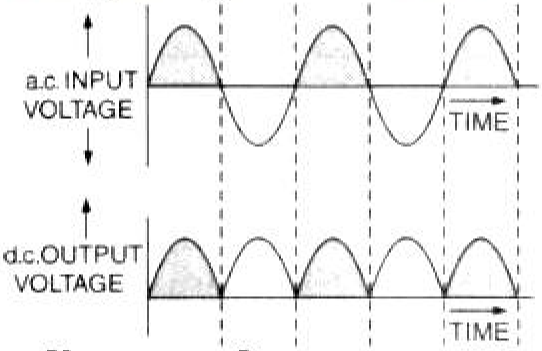
ii. A rectifier which rectifies both halves of each a.c. input cycle is called a full wave rectifier.

The circuit arrangement is shown in the figure.



Suppose the input voltage to A with respect to the centre tap at any instant is positive. It is clear that, at that instant, voltage at B being out of phase will be negative. So, diode D_1 gets forward biased and conducts (while D_2 being reverse biased is not conducting). Hence, during this positive half cycle we get an output current (and a output voltage across the load resistor R_L). In the course of the ac cycle when the voltage at A becomes negative with respect to centre tap, the voltage at B would be positive. In this part of the cycle diode D_1 would not conduct but diode D_2 would, giving an output current and output voltage (across R_L) during the negative half cycle of the input ac. Thus, we get output voltage during both the positive as well as the negative half of the cycle.

The input-output waveforms are shown in the figure.



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

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.

OR

i. Device X is a capacitor.

   As the current is leading voltage by $\frac{\pi}{2}$ radians and it happens only then when an ac source is connected with a pure capacitive circuit.

ii. Curve A represents power, Curve B represents voltage and Curve C represents current.

   As, V(t) = $V_0 \sin \omega t$

   Current, I(t) = $I_0 \cos \omega t$, with $I_0 = \frac{V_0}{X_C}$ (X_C being capacitive reactance)

   As, in the case of capacitor,

   $I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$ [current is leading the voltage]

   Average power, $P = V(t)I(t) = \frac{V_0 I_0}{2} \cos \phi$

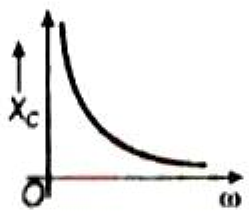
   where, ϕ = phase difference

iii. As, X_C = capacitive reactance = $\frac{1}{C\omega}$

   where ω is angular frequency and C being capacitance of the capacitor.

   So, reactance or impedance decreases with increase in frequency.

   Graph of X_C versus ω is shown below:



iv. For a capacitor fed with an AC supply,

   $V = \frac{q}{C}$ or $q = CV = CV_0 \sin \omega t$

   $\therefore \quad I = \frac{dq}{dt} = V_0 \omega C \cos \omega t = \frac{V_0}{X_C} \sin\left(\omega t + \frac{\pi}{2}\right)$, since $\omega C = \frac{1}{X_C}$

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.