Class XII Session 2024-25
Subject - Physics
Sample Question Paper - 9

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

General Instructions:

1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. All the sections are compulsory.
4. **Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, **Section B** contains five questions of two marks each, **Section C** contains seven questions of three marks each, **Section D** contains two case study based questions of four marks each and **Section E** contains three long answer questions of five marks each.
5. There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.
6. Use of calculators is not allowed.

Section A

1. The resistivity of a semiconductor at room temperature is in between: **[1]**

a) 10^{-3} to 10^{6} Ω cm
b) 10^{10} to 10^{12} Ω cm
c) 10^{-2} to 10^{-5} Ω cm
d) 10^{6} to 10^{8} Ω cm

2. If the percentage change in current through a resistor is 1%, then the change in power through it would be: **[1]**

a) 0.5%
b) 1%
c) 2%
d) 1.7%

3. A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will: **[1]**

a) Become infinite
b) Become zero
c) Reduce
d) Remain same as in air

4. A frog can be levitated in a magnetic field produced by a current in a vertical solenoid placed below the frog. This is possible, because the body of the frog behaves as **[1]**

a) paramagnetic
b) ferromagnetic
c) anti-ferromagnetic
d) diamagnetic

5. Three condensers of capacity 2 μF , 4 μF and 8 μF respectively, are first connected in series and then **[1]**

connected in parallel. The ratio of the equivalent capacitance in the two cases will be

a) 7 : 3
b) 3 : 7
c) 4 : 49
d) 49 : 4

6. The resistance of a galvanometer is 50Ω and the current required to give full scale deflection is $100\mu A$. In order to convert it into an ammeter for reading up to 10 A, it is necessary to put a resistance of **[1]**

a) $5 \times 10^{-2}\Omega$
b) $5 \times 10^{-5}\Omega$
c) $5 \times 10^{-4}\ \Omega$
d) $5 \times 10^{-3}\Omega$

7. If the rotational velocity of dynamo armature is doubled, then induced emf will become: **[1]**

a) two times
b) half
c) unchanged
d) four times

8. The susceptibility of a magnetic substance is found to depend on temperature and the strength of the magnetising field. The material is a: **[1]**

a) diamagnet
b) superconductor
c) ferromagnet
d) paramagnet

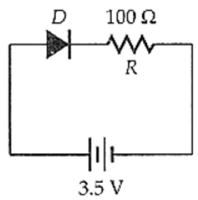
9. In Young's double-slit experiment, the intensity of light at a point on the screen where the path difference is λ is k (λ being the wavelength of light used). The intensity at a point where the path difference is $\frac{\lambda}{4}$, will be **[1]**

a) k
b) $\frac{k}{4}$
c) $\frac{k}{2}$
d) zero

10. A semi-circular arc of radius 'a' is charged uniformly and the charge per unit lengths is λ. The electric field at the centre is: **[1]**

a) $\frac{\lambda}{2\pi\varepsilon_0 a^2}$
b) $\frac{\lambda}{4\pi\varepsilon_0 a}$
c) $\frac{\lambda}{2\pi\varepsilon_0 a}$
d) $\frac{\lambda^2}{2\pi\varepsilon_0 a}$

11. In the given figure, a diode D is connected to an external resistance R = 100Ω and an emf of 3.5 V. If the barrier potential developed across the diode is 0.5 V, the current in the circuit will be **[1]**



a) 40 mA
b) 30 mA
c) 35 mA
d) 20 mA

12. How will the image formed by a convex lens be affected if the central portion of the lens is wrapped in a black paper? **[1]**

a) No image is formed by the remaining portion of the lens
b) Full image will be formed but will be less bright
c) Two images will be formed
d) Central portion of the image will be absent

13. **Assertion (A):** In photoemissive cell inert gas is used. **[1]**

Reason (R): inert gas in the photoemissive cell gives greater current.

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 but R is true.

14. **Assertion:** Positive charge always moves from a higher potential point to a lower potential point. **[1]**

Reason: Electric potential is a vector quantity.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

15. **Assertion (A):** In Young's double-slit experiment if wavelength of incident monochromatic light is just doubled, number of bright fringe on the screen will increase. **[1]**

Reason (R): Maximum number of bright fringe on the screen is inversely proportional to the wavelength of light used.

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 but R is true.

16. **Assertion (A):** The dc and ac both can be measured by a hot wire instrument. **[1]**

Reason (R): The hot wire instrument is based on the principle of magnetic effect of current.

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 but R is true.

Section B

17. Which of the following electromagnetic waves has (a) minimum wavelength, and (b) minimum frequency? Write one use of each of these two waves. **[2]**

Infrared waves, Microwaves, γ-rays and X-rays

18. **[2]**

a. Show that the time period (T) of oscillations of a freely suspended magnetic dipole of magnetic moment (m) in a uniform magnetic field (B) is given by $T = 2\pi\sqrt{\frac{I}{mB}}$, where I is a moment of inertia of the magnetic dipole.

b. Identify the following magnetic materials:

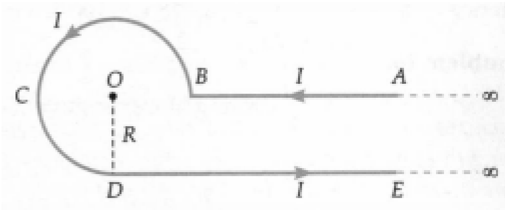
i. A material having susceptibility (χ_m) = -0.00015.

ii. A material having susceptibility (χ_m) = 10^{-5}.

19. Explain the variation of resistivity with temperature in pure-semiconductors. **[2]**

20. Briefly explain Geiger-Marsden experiment. Show the variation of the number of particles scattered (N) with scattering angle (θ) in this experiment. What is the main conclusion that can be inferred from this plot? **[2]**

21. A current I is flowing in an infinitely long conductor bent into the shape shown in Fig. If the radius of the curved part is R, find the magnetic field at the centre O. **[2]**

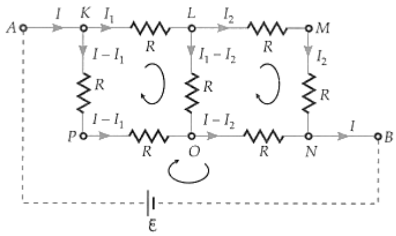


OR

A deuteron and an alpha particle having same momentum are in turn allowed to pass through a magnetic field $\vec{B}$, acting normal to the direction of motion of the particles. Calculate the ratio of the radii of the circular paths described by them.

Section C

22. Find the equivalent resistance between the terminals A and B in the network shown in Figure. Given each resistor R is 10 Ω. **[3]**



23. With the help of a circuit diagram, explain how two p-n junction diodes along with a centre tapped transformer can be used as a full wave rectifier. **[3]**

24. An alpha particle is accelerated through a potential difference of 100 V. Calculate: **[3]**

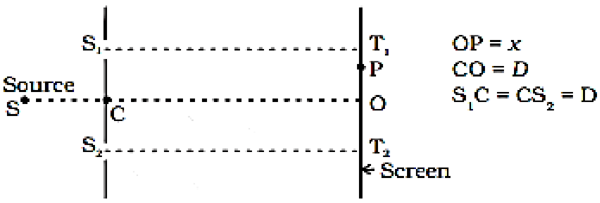
    i. The speed acquired by the alpha particle, and
    ii. The de-Broglie wavelength associated with it.

    (Take mass of alpha particle = 6.4×10^{-27} kg)

25. Draw a plot showing the variation of binding energy per nucleon with mass number A. Write two important conclusions which you can draw from this plot. Explain with the help of this plot, the release in energy in the processes of nuclear fusion and fission. **[3]**

26. It is found experimentally that 13.6 eV energy is required to separate a hydrogen atom into a proton and an electron. Compute the orbital radius and the velocity of the electron in a hydrogen atom. **[3]**

27. Consider a two-slit interference arrangements (Figure) such that the distance of the screen from the slits is half the distance between the slits. Obtain the value of D in terms of λ such that the first minima on the screen fall at a distance D from the center O. **[3]**



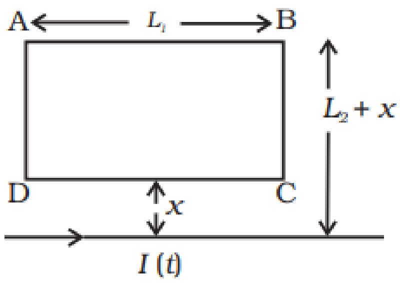
28. **[3]**

    a. A toroidal solenoid with an air core has an average radius of 0.15 m, area of cross section $12 \times 10^{-4} m^2$ and 1200 turns. Obtain the self inductance of the toroid. Ignore field variation across the cross section of the toroid.
    b. A second coil of 300 turns is wound closely on the toroid above. If the current in the primary coil is increased from zero to 2.0 A in 0.05 s, obtain the induced emf in the secondary coil.

OR

A rectangular loop of wire ABCD is kept close to an infinitely long wire carrying a current $I(t) = I_0 (1 - \frac{t}{T})$ for

$0 \leq t \leq T$ and I(0) = 0 for t > T (Figure). Find the total charge passing through a given point in the loop, in time T. The resistance of the loop is R.



Section D

29. **Read the text carefully and answer the questions:** **[4]**

In an electromagnetic wave both the electric and magnetic fields are perpendicular to the direction of propagation, that is why electromagnetic waves are transverse in nature. Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields. Energy density of an electromagnetic waves is the energy in unit volume of the space through which the wave travels.

(a) The electromagnetic waves propagated perpendicular to both $\vec{E}$ and $\vec{B}$. The electromagnetic waves travel in the direction of

a) $\vec{E} \cdot \vec{B}$
b) $\vec{B} \cdot \vec{E}$
c) $\vec{E} \times \vec{B}$
d) $\vec{B} \times \vec{E}$

(b) Fundamental particle in an electromagnetic wave is

a) photon
b) phonon
c) electron
d) proton

(c) Electromagnetic waves are transverse in nature is evident by

a) diffraction
b) interference
c) polarisation
d) reflection

OR

The electric and magnetic fields of an electromagnetic waves are

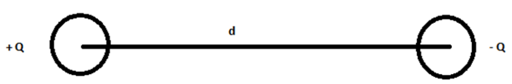
a) in opposite phase and parallel to each other
b) in phase and parallel to each other.
c) in phase and perpendicular to each other
d) in opposite phase and perpendicular to each other

(d) For a wave propagating in a medium, Name the property that is independent of the others.

a) frequency
b) wavelength
c) velocity
d) all these depend on each other

30. **Read the text carefully and answer the questions:** **[4]**

Electric dipole consist of a pair of equal and opposite point charges separated by a small distance and its strength is measured by the dipole moment. The field around the dipole in which the electric effect of the dipole can be experienced is called the dipole field.



(a) The electric dipole moment is:

a) a scalar quantity
b) neither scalar nor vector quantity
c) a vector quantity
d) A Plane quantity

(b) Electric field due to the electric dipole is

a) cylindrically symmetric
b) spherically symmetric
c) symmetric
d) asymmetric

(c) The SI unit of dipole moment is:

a) C/m
b) C-m
c) c/m^2
d) $C\text{-}m^2$

(d) Charges ± 20 nC are separated by 5mm. calculate the magnitude of dipole moment:-

a) 10^{-7} C-m
b) 10^{10} C-m
c) 10^{-10} C-m
d) 10^{-8} C-m

OR

When an electric dipole is placed in a uniform electric field, it experiences

a) Neither any force nor any torque
b) Force but no torque
c) Force as well as torque
d) Torque but no net force

Section E

31. Draw a ray diagram to show the formation of real image of the same size as that of the object placed in front of a converging lens. Using this ray diagram establish the relation between u, v and f for this lens. **[5]**

OR

You have learned in the text how Huygens' principle leads to the laws of reflection and refraction. Use the same principle to deduce directly that a point object placed in front of a plane mirror produces a virtual image whose distance from the mirror is equal to the object distance from the mirror.

32. A capacitor of capacitance C_1 is charged to a potential V_1 while another capacitor of capacitance C_2 is charged to a potential difference V_2. The capacitors are now disconnected from their respective charging batteries and connected in parallel to each other. **[5]**

i. Find the total energy stored in the two capacitors before they are connected.
ii. Find the total energy stored in the parallel combination of two capacitors.
iii. Explain the reason for the difference of energy in parallel combination in comparison to the total energy before they are connected

OR

Define the terms (i) capacitance of a capacitor (ii) dielectric strength of a dielectric. When a dielectric is inserted between the plates of a charged parallel plate capacitor, fully occupying the intervening region, how does the polarization of the dielectric medium affect the net electric field? For linear dielectrics, show that the introduction of a dielectric increases its capacitance by a factor κ, characteristic of the dielectric.

33. a. Derive the expression for the current flowing in an ideal capacitor and its reactance when connected to an ac source of voltage $V = V_o \sin \omega t$. **[5]**

b. Draw its phasor diagram.

c. If resistance is added in series to capacitor what changes will occur in the current flowing in the circuit and phase angle between voltage and current.

OR

i. An ac source generating a voltage $V = V_0 \sin \omega t$ is connected to a capacitor of capacitance C. Find the expression of the current I flowing through it. Plot a graph of V and I versus ωt to show that the current is $\frac{\pi}{2}$ ahead of the voltage.

ii. A resistor of 200 Ω and a capacitor of 15 μF are connected in series to a 220 V, 50 Hz ac source. Calculate the current in the circuit and the rms voltage across the resistor and the capacitor. Why the algebraic sum of these voltages is more than the source voltage?

Solution

Section A

1. **(a)** 10^{-3} to 10^{6} Ω cm

   Explanation: Resistivity of a semiconductor at room temp, is in between 10^{-3} to 10^{6} Ω cm.

2. **(c)** 2%

   Explanation: Power, $P = I^2R$

   $\therefore \frac{\Delta P}{P} \times 100 = 2\frac{\Delta I}{I} \times 100 + \frac{\Delta R}{R} \times 100$

   = 2 × 1% + 0 = 2%

3. **(a)** Become infinite

   Explanation: $\frac{1}{f} = (\frac{\mu_2}{\mu_1} - 1)(\frac{1}{R_1} - \frac{1}{R_2})$

   Since, $\mu_2 = \mu_1$,

   $\frac{1}{f} = 0,\ hence\ f = \infty$

4. **(d)** diamagnetic

   Explanation: To levitate a body, a force must be applied on it which at least balances the body's weight. Since weight will always pull the frog down, the magnetic force on the frog due to the vertical solenoid placed below it must act in the upward direction. Thus, the frog is repelled by the magnetic field. Diamagnetic substances are the only substances which are repelled by a magnetic field. This shows that the body of the frog behaves diamagnetically.

5. **(c)** 4 : 49

   Explanation: $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{2} + \frac{1}{4} + \frac{1}{8} = \frac{7}{8};\ \ C_s = \frac{8}{7}\mu F;$

   $C_p = C_1 + C_2 + C_3 = 2 + 4 + 8 = 14\mu F;$

   $\frac{C_s}{C_p} = \frac{\frac{8}{7}}{14} = \frac{4}{49}$

6. **(c)** $5 \times 10^{-4}\ \Omega$

   Explanation: $I_g = 10^{-4}$A

   I = 10 A; G = 50Ω

   $S = \frac{I_g \times G}{(I - I_g)}$

   $= 5 \times 10^{-4}\ \Omega$

7. **(a)** two times

   Explanation: $\varepsilon = NBA\omega \sin \omega t$ i.e., $\varepsilon \propto \omega$

   $\frac{\varepsilon_2}{\varepsilon_1} = \frac{2\omega}{\omega} = 2$

8. **(d)** paramagnet

   Explanation: The susceptibility of a paramagnetic substance depends both on the temperature and strength of the magnetising field.

9. **(c)** $\frac{k}{2}$

   Explanation: Path difference λ implies a maximum, so I_{max} = k

   $I = I_{max} \cos^2 \frac{\phi}{2} = k \cos^2 \left(\frac{1}{2} \cdot \frac{2\pi}{\lambda} \cdot \frac{\lambda}{4}\right)$

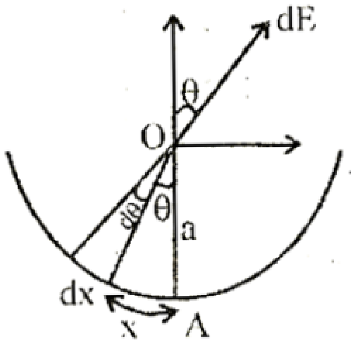
   $= k \cos^2 \frac{\pi}{4} = k\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{k}{2}$

10.

(c) $\frac{\lambda}{2\pi\varepsilon_0 a}$

Explanation: λ = linear charge density;

Charge on elementary portions is given by dq = λdx



Electric field at O is given by , $dE = \frac{\lambda dx}{4\pi\varepsilon_0 a^2}$

Horizontal electric field, i.e., perpendicular to AO, will cancelled.

Hence, net electric field = addition of all electrical fields in direction of AO

$= \sum \mathrm{dE} \cos\theta$

$\Rightarrow E = \int \frac{\lambda dx}{4\pi\varepsilon_0 a^2} \cos\theta$

Also, $\mathrm{d}\theta = \frac{\mathrm{dx}}{\mathrm{a}}$ or $\mathrm{dx} = \mathrm{ad}\theta$

$E = \int_{-\pi/2}^{\pi/2} \frac{\lambda \cos\theta d\theta}{4\pi\varepsilon_0 a} = \frac{\lambda}{4\pi\varepsilon_0 a} [\sin\theta]_{-\pi/2}^{\frac{\pi}{2}}$

$= \frac{\lambda}{4\pi\varepsilon_0 a} [1 - (-1)] = \frac{\lambda}{2\pi\varepsilon_0 a}$

11.

(b) 30 mA

Explanation: I = $\frac{V_{\text{net}}}{R} = \frac{3.5 - 0.5}{100}\ \mathrm{A} = \frac{3}{100}\ \mathrm{A}$ = 30 mA

12.

(b) Full image will be formed but will be less bright

Explanation: Image will be formed at the same position and same height but intensity of image formed will be less hence its brightness will be less as less number of light rays will form the image. Light rays from the covered portion will not contribute to image formation.

13. **(a)** Both A and R are true and R is the correct explanation of A.

Explanation: The photoemissive cell contains two electrodes are enclosed in a glass bulb which may be evacuated or contain an inert gas at low pressure. An inert gas in the cell gives greater current but causes a time lag in the response of the cell to very rapid changes of radiation which may make it unsuitable for some purpose.

14.

(c) Assertion is correct statement but reason is wrong statement.

Explanation: If two points P and Q in an electric field are separated by an infinitesimal distance Δx and have a potential difference ΔV between them, E= $-\frac{\Delta V}{\Delta x}$. Here, negative sign implies that $\vec{E}$ has got a direction opposite to the potential gradient, i.e, in the direction of $\vec{E}$, the potential decreases, i.e, positive charge always moves from a higher potential point to a lower potential point.

15. **(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.

16.

(c) A is true but R is false.

Explanation: Both ac and dc produce heat, which is proportional to the square of the current. The reversal of direction of current in ac is immaterial so far as production of heat is concerned.

Section B

17. The minimum wavelength or Maximum frequency has maximum energy and vice versa, γ- Ray has maximum energy so it has a minimum wavelength and Microwaves have minimum energy so it has a maximum frequency.

Use of electromagnetic waves:

Infrared waves: Heat-sensitive thermal imaging cameras, Remote controls.

Microwaves: microwave radio relay networks, radar, satellite, and spacecraft communication.

γ -rays: Used as tracers in medicine, Astronomy.

X-rays: checking fracture

18. a. Let us consider a uniform magnetic field $\vec{B}$ exists in the region, in which a magnet of dipole moment $\vec{m}$ is placed. The dipole is making small angle θ with the magnetic field. The torque acts on the magnet is given by

$\vec{\tau} = \vec{m} \times \vec{B}$

= mB sin θ In magnitude, τ = mB sin θ

= -mB sin θ ($\because \theta$ in small) ...(i)

Also the torque on dipole try to restore its initial position i.e., along the direction of magnetic field. (I = moment of inertia)

In equilibrium

$I\frac{d^2\theta}{dt^2} = -mB\sin\theta$ ...(ii)

Negative sign implies that restoring torque is in opposition to deflecting torque.

$\frac{d^2\theta}{dt^2} = \frac{-mB}{I}\theta$ ...(iii)

Comparing with equation of angular SHM

$\frac{d^2\theta}{dt^2} = -\omega^2\phi$ ...(iv)

We have

$\omega^2 = \frac{mB}{I} \Rightarrow \omega = \sqrt{\frac{mB}{I}}$

$\Rightarrow \frac{2\pi}{T} = \sqrt{\frac{mB}{I}} \Rightarrow \frac{T}{2\pi} = \sqrt{\frac{I}{mB}}$

$T = 2\pi\sqrt{\frac{I}{mB}}$

b. i. Diamagnetic substance.

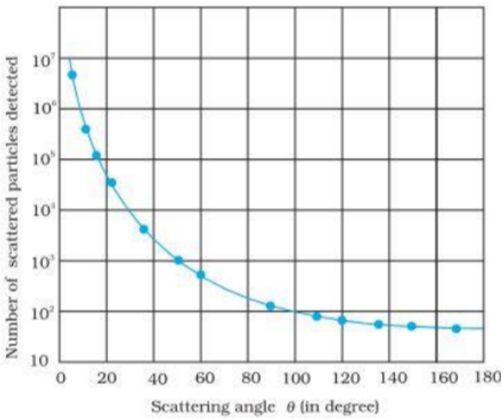
ii. Paramagnetic substance.

19. The resistivity of a semiconductor is given by

$\rho = \frac{1}{\sigma} = \frac{1}{e(n_e\mu_e + n_h\mu_h)}$

As the temperature increases, the mobilities μ_e and μ_h of electrons and holes decrease due to the increase in their collision frequency. But due to the small energy gap of semiconductors, more and more electrons $\left(n \propto e^{-E_g/k_BT}\right)$ from the valence band cross over to the conduction band. The increase in carrier concentrations, n_e and n_h is so large that decrease in the values of μ_e and μ_h has no influence. The overall effect is that conductivity increases or resistivity decreases with the increase of temperature.

20. The alpha-particles emitted by a radioactive source were allowed to fall on a thin foil of gold. The scattered alpha-particles were observed through a rotatable detector consisting of zinc sulphide screen and a microscope. The scattered alpha-particles on striking the screen produced brief light flashes.



Conclusion: The existence of positively charged nucleus inside an atom and provide an upper limit to the size of the nucleus.

21. As the point O lies on the straight part AB, So

$B_{AB} = 0$

$B_{BCD} = \frac{\mu_0 I}{4\pi R} \cdot \frac{3\pi}{2}$, acting normally outward

$B_{DE} = \frac{\mu_0 I}{4\pi R}(\sin 90^\circ + \sin 0^\circ) = \frac{\mu_0 I}{4\pi R}$, acting normally outward

Total magnetic field at the centre O

$B = B_{AB} + B_{BCD} + B_{DE}$

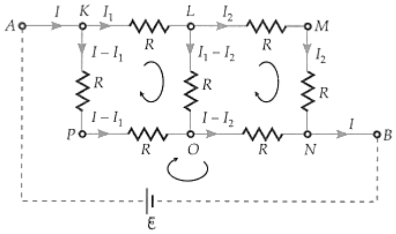
$= 0 + \frac{\mu_0 I}{4\pi R} \cdot \frac{3\pi}{2} + \frac{\mu_0 I}{4\pi R}$
or $B = \frac{\mu_0 I}{4\pi R}\left(\frac{3\pi}{2} + 1\right)$, acting normally outward.

OR

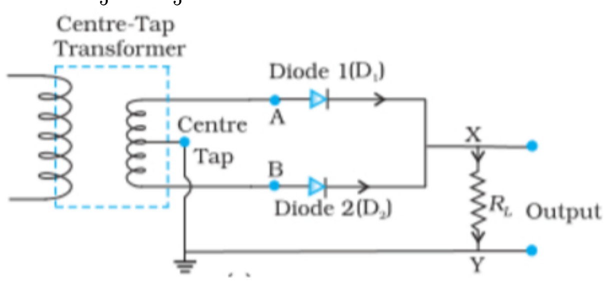
$R = \frac{mv}{qB}$
$R = \frac{mv}{qB} = \frac{\rho}{qB}$
Now, $\frac{q_d}{q_\alpha} = \frac{e}{2e} = \frac{1}{2}$
$\therefore \frac{r_d}{r_\alpha} = \frac{q_\alpha}{q_d} = \frac{2}{1}$

Section C

22. Imagine a battery of emf ε, having no internal resistance, connected between the points A and B. The distribution of current through various branches is as shown in Figure.



Applying Kirchhoff's second law to loop KLOPK, we get
$I_1R + (I_1 - I_2)R - 2(I - I_1)R = 0$
or $4I_1 - I_2 = 2I$ ...(i)
Similarly, from the loop LMNOL, we have
$2I_2R - (I - I_2)R - (I_1 - I_2)R = 0$
or $- I_1 + 4 I_1 = I$ ...(ii)
From the loop AKPONBEA, we have
$2 (I - I_1) R + (I - I_2) R = \varepsilon$ ...(iii)
Solving equations (i) and (ii), we get
$I_1 = \frac{3}{5}I$ and $I_2 = \frac{2}{5}I$
Substituting these values in equation (iii), we get
$2\left(I - \frac{3}{5}I\right)R + \left(I - \frac{2}{5}I\right)R = \varepsilon$
or $\frac{7}{5}IR = \varepsilon$ ...(iv)
If R' is the equivalent resistance between A and B, then
$IR' = \varepsilon$ ...(v)
From (iv) and (v), $IR' = \frac{7}{5}IR$
or $R' = \frac{7}{5}R = \frac{7}{5} \times 10 = 14\Omega$

23. 

Explanation
The circuit diagram is as shown above.
During positive half of the AC input, diode D1 gets forward biased and conducts and diode D2 gets reverse biased.
During negative half of the AC input, diode D2 gets forward biased and conducts; and diode D1 gets reverse biased.
So, output is obtained during both positive and negative half of the cycle in the same direction.

24. i. $\frac{1}{2}mv^2 = qV$
$\frac{1}{2}mv^2 = 2e \times 100$
or, $\frac{1}{2}mv^2 = 2e \times 100$
or, $mv^2 = 400$ eV

or, v = $\sqrt{\frac{400eV}{m}}$

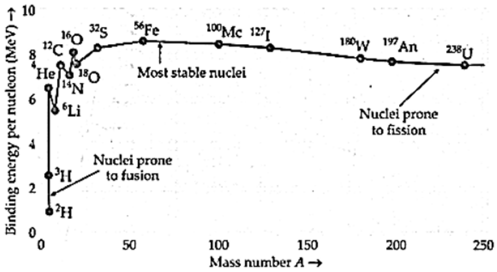
or, v = $\sqrt{\frac{400\times1.6\times10^{-19}}{6.4\times10^{-27}}}$

$\therefore$ v = 10^5 m/s

ii. de-Broglie wavelength = λ = $\frac{h}{\sqrt{2mqV}}$

Or, λ = $\frac{6.6\times10^{-34}}{\sqrt{2\times6.4\times10^{-27}\times2\times1.6\times10^{-19}\times100}}$

$\therefore \lambda$ = 1.03 $\times$ 10^{-12} m

25. 

Binding energy per nucleon as a function of mass number A.

Two important conclusions from this graph are:

i. Nuclear forces non-central and short ranged force.

ii. Nuclear forces between proton-neutron and neutron-neutron are strong and attractive in nature.

Explanation of Nuclear Fission: When a heavy nucleus (A $\geq$ 235 say) breaks into two lighter nuclei (nuclear fission), the binding energy per nucleon increases i.e, nucleons get more tightly bound. This implies that energy would be released in nuclear fission.

Explanation of Nuclear Fusion: When two very light nuclei (A $\leq$ 10) join to form a heavy nucleus, the binding is energy per nucleon of fused heavier nucleus more than the binding energy per nucleon of lighter nuclei, so again energy would be released in nuclear fusion.

26. Total energy of the electron in hydrogen atom is –13.6 eV = –13.6 $\times$ 1.6 $\times$ 10^{-19} J = –2.2 $\times 10^{-18}$ J.

Thus from Eq., we have

$-\frac{e^2}{8\pi\varepsilon_0 r}$ = E

This gives the orbital radius

$r=-\frac{e^2}{8\pi\varepsilon_0 E}=-\frac{\left(9\times10^9\text{Nm}^2/\text{C}^2\right)\left(1.6\times10^{-19}\text{C}\right)^2}{(2)\left(-2.2\times10^{-18}\text{J}\right)}$

= 5.3 $\times$ 10^{-11} m

The velocity of the revolving electron can be computed from Eq. with m = 9.1 $\times$ 10^{-31} kg,

$\frac{1}{2}mv^2=\frac{e^2}{4\pi\epsilon_0 r^2}$ thus velocity of electron is given by :-

$v=\frac{e}{\sqrt{4\pi\varepsilon_0 mr^2}}=2.2\times10^6\text{m/s}$

27. According to θ

d = D (Given) ...(i)

$D=\frac{1}{2}d$ (Given) ...(ii)

d = 2D

Path difference at P = S_2P - S_1P

Path difference $p=\sqrt{D^2+\left(x+\frac{d}{2}\right)^2}-\sqrt{D^2+\left(x-\frac{d}{2}\right)^2}$

Substitute the value of d and x from (i) and (ii)

$=\sqrt{D^2+(D)+D)^2}-\sqrt{D^2+(D-D)^2}$

$=\sqrt{5D^2}-\sqrt{D^2}$

$p=D(\sqrt{5}-1)$

The path difference for nth dark fringe from central maxima O is $(2n-1)\frac{\lambda}{2}$

$\therefore$ For 1st minima $p=\frac{\lambda}{2}$

Put the value of p in (iii)

$\frac{\lambda}{2} = D(\sqrt{5} - 1)$
$D = \frac{\lambda}{2(\sqrt{5}-1)}$
Rationalizing the denominator, we get,
$D = \frac{\lambda}{2(\sqrt{5}-1)} \times \frac{(\sqrt{5}+1)}{(\sqrt{5}+1)} = \frac{(2.236+1)}{2\times(5-1)}\lambda = \frac{3.236}{2\times4}\lambda$
$= \frac{3.236}{8}\lambda = 0.404\lambda$

28. a. $B = \mu_0 n_1 I = \frac{\mu_0 N_1 I}{l} = \frac{\mu_0 N_1 I}{2\pi r}$
Total magnetic flux, $\phi_B = N_1 BA = \frac{\mu_0 N_1^2 IA}{2\pi r}$
But $\phi_B = LI$
$\therefore L = \frac{\mu_0 N_1^2 A}{2\pi r}$
Or $L = \frac{4\pi\times10^{-7}\times1200\times1200\times12\times10^{-4}}{2\pi\times0.15}$
$= 2.3 \times 10^{-3} H$ = 2.3 mH
b. $|E| = \frac{d}{dt}(\phi_2)$ where ϕ_2 is the total magnetic flux linked with the second coil.
$|E| = \frac{d}{dt}(N_2 BA) = \frac{d}{dt}\left[N_2 \frac{\mu_0 N_1 I}{2\pi r} A\right]$
$|E| = \frac{\mu_0 N_1 N_2 A}{2\pi r}\frac{dI}{dt}$
$|E| = \frac{4\pi\times10^{-7}\times1200\times300\times12\times10^{-4}\times2}{2\pi\times0.15\times0.05}$ = 0.023 V

OR

To find the charge that passes through the circuit first we have to find the relation between instantaneous current and instantaneous magnetic flux linked with it. The emf induced can be obtained by differentiating the expression of magnetic flux linked w.r.t. t and then applying Ohm's law, we get A rectangular loop of wire ABCD is kept close to an infinitely long wire carrying a current
$I = \frac{E}{R} = \frac{1}{R}\frac{d\phi}{dt}$
According to the problem electric current is given as a function of time.
$I(t) = \frac{dQ}{dt}$ or $\frac{dQ}{dt} = \frac{1}{R}\frac{d\phi}{dt}$
Integrating the variable separately in the form of the differential equation for finding the charge Q that passed in time t, we have
$Q(t_1) - Q(t_2) = \frac{1}{R}[\phi(t_1) - \phi(t_2)]$
$\phi(t_1) = L_1 \frac{\mu_0}{2\pi}\int_x^{L_2+x}\frac{dx'}{x'}I(t_1)$ $[\phi_m = \vec{B}\cdot\vec{A} = \frac{\mu_0 I}{2\pi} l \int_{x_0}^{x}\frac{dr}{r} = \frac{\mu_0 Il}{2\pi}\ln\frac{x}{x_0}$ $]$
$= \frac{\mu_0 L_1}{2\pi} I(t_1)\ln\frac{L_2+x}{x}$
Therefore the magnitude of charge is
$Q = \frac{1}{R}[\phi(T) - \phi(0)]$
$Q = \frac{\mu_0 L_1}{2\pi}\ln\frac{L_2+x}{x}[I(T) - I(0)]$
Now I(T) = I_1 and I(0) = 0
$\therefore \quad Q = \frac{\mu_0 L_1}{2\pi} I_1 \ln\left(\frac{L_2+x}{x}\right)$
This is the required expression.

Section D

29. **Read the text carefully and answer the questions:**
In an electromagnetic wave both the electric and magnetic fields are perpendicular to the direction of propagation, that is why electromagnetic waves are transverse in nature. Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields. Energy density of an electromagnetic waves is the energy in unit volume of the space through which the wave travels.

(i) **(c)** $\vec{E} \times \vec{B}$
Explanation: Electromagnetic waves propagate in the direction of $\vec{E} \times \vec{B}$.

(ii) **(a)** photon
Explanation: Photon is the fundamental particle in an electromagnetic wave.

(iii) **(c)** polarisation
Explanation: Polarisation establishes the wave nature of electromagnetic waves.

OR

(c) in phase and perpendicular to each other

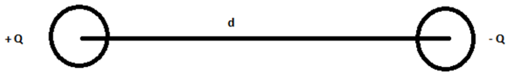
Explanation: The electric and magnetic fields of an electromagnetic wave are in phase and perpendicular to each other.

(iv) **(a)** frequency

Explanation: Frequency ν remains unchanged when a wave propagates from one medium to another. Both wavelength and velocity get changed.

30. **Read the text carefully and answer the questions:**

Electric dipole consist of a pair of equal and opposite point charges separated by a small distance and its strength is measured by the dipole moment. The field around the dipole in which the electric effect of the dipole can be experienced is called the dipole field.



(i) **(c)** a vector quantity

Explanation: a vector quantity

(ii) **(a)** cylindrically symmetric

Explanation: cylindricaly symmetric

(iii) **(b)** C-m

Explanation: C-m

(iv) **(c)** 10^{-10} C-m

Explanation: 10^{-10} C-m

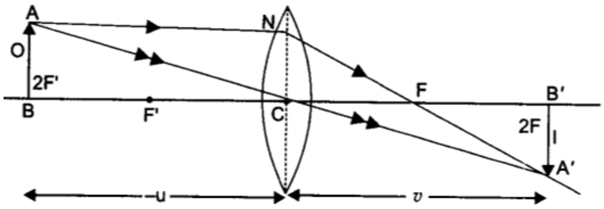
OR

(d) Torque but no net force

Explanation: Torque but no net force

Section E

31. **Thin Lens Formula :** Suppose an object AB of finite size is placed normally on the principal axis of a thin convex lens (fig.). A ray AP starting from A parallel to the principal axis, after refraction through the lens, passes through the second focus F. Another ray AC directed towards the optical centre C of the lens, goes straight undeviated. Both the rays meet at A' Thus A' is the real image of A. The perpendicular A' B' dropped from A' on the principal axis is the whole image of AB.



Let distance of object AB from lens = u

Distance of image A' B' from lens = v

Focal length of lens = f. We can see that triangles ABC and A' B' C' are similar

$\frac{AB}{A'B'} = \frac{CB}{CB'}$ ...(i)

Similarly triangles PCF and A' B' F are similar

$\frac{PC}{A'B'} = \frac{CF}{FB'}$

But PC = A B

$\frac{AB}{A'B'} = \frac{CF}{FB'}$ ...(ii)

From (i) and (ii), we get $\frac{CB}{CB'} = \frac{CF}{FB'}$ ...(iii)

From sign convention, CB = -u, CB' = v, CF = f

and FB' = CB' - CF = v - f

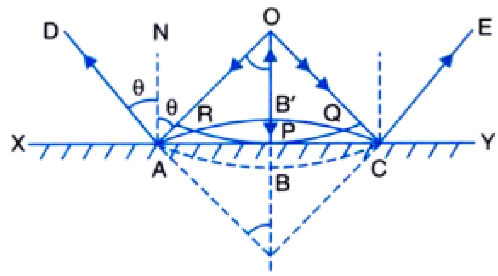
Substituting this value in (iii), we get, $-\frac{u}{v} = \frac{f}{v-f}$

or -u(v - f) = vf or -uv + uf = vf

Dividing throughout by uvf, we get $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ ...(iv)

OR

We are given a plane mirror XY and let, O be a point object at a distance OP, in front of the plane mirror. A part RPQ of the wavefront touches the plane mirror at P and from this point, spherical wavefronts start emanating. Whereas disturbance from R and Q continues moving forward, along with the normal rays OR and OQ, that reflects back v. When, disturbances from R, P, and Q reach the mirror at A, B' and C respectively, reflected spherical wavefront is formed.



The reflected wavefront AB'C appears to start from I. Hence, I become a virtual image for 0 as a real point object. Draw AN normal to XY, hence parallel to OP.

Now, OA is the incident ray (being normal to incident wavefront ABC) and AD is the reflected ray (being normal to reflected wavefront AB'C).

Thus, $\angle \mathrm{OAN} = \angle \mathrm{DAN} = \theta$ [i = r]

But, $\angle OAN$ = alternate $\angle \mathrm{AOP}$

and $\angle \mathrm{DAN}$ = corresponding $\angle \mathrm{AlP}$

$\therefore \quad \angle \mathrm{AOP} = \angle \mathrm{AlP}$

$\angle \mathrm{AIP} = \angle \mathrm{AOP}$ (each θ)

$\angle AP| = \angle APO = 90^\circ$ (each 90^o)

AP is common to both

Δ_s become congruent

Hence, PI = PQ

i.e., a normal distance of the image from the mirror = normal distance of the object from the mirror.

Thus, a virtual image is formed as much behind the mirror as the object in front of it.

32. i. Total energy stored in the two capacitors before they are connected,

$u_i = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2$

ii. After the two capacitors are connected in parallel, the common potential is

$V = \frac{\text{Total charge}}{\text{Total capacitance}} = \frac{q_1+q_2}{C_1+C_2} = \frac{C_1V_1+C_2V_2}{C_1+C_2}$

Total energy stored in the parallel combination,

$U_f = \frac{1}{2}(C_1+C_2)V^2 = \frac{1}{2}(C_1+C_2)\left(\frac{C_1V_1+C_2V_2}{C_1+C_2}\right)^2$

$= \frac{1}{2}\frac{(C_1V_1+C_2V_2)^2}{C_1+C_2}$

iii. Clearly, $U_f < U_i$. Thus the total energy of the parallel combination is less than the sum of the energies stored in the two capacitors before they are connected. During sharing of charges, some energy is lost as heat due to the flow of charges in connecting wires.

OR

i. Capacitance of a capacitor is defined as the ratio of the electric charge on the capacitor to the electric potential of capacitor due to it's charge.

ii. Dielectric strength of a dielectric is defined as the maximum value of electric field that can be applied to the dielectric without it's electric breakdown.

When a dielectric slab is introduced in between the plates of capacitor, the electric field gets reduced.

Consider a parallel plate capacitor with vacuum in between it's plates. The capacitor is charged up with battery such that electric field is set up between it's plates.

Then, $E^\circ = \sigma\varepsilon^\circ$

where, σ is the surface charge density of the plates.

Now, as soon as the dielectric is introduced in between the plates each molecule of the dielectric get's polarised. Charges are induced on the surface of the dielectric and, these induced charges set up an electric field E_p inside the dielectric.

Therefore, the resultant electric field gets reduced and is given as

$E = E^o - E_p$

When there is vaccum in between the plates, capacitance is given by C = ε°Ad .

When, dielctric is inserted in between the plates, Capacitance increases by a factor of K.

where, K is the dielectric constant.

Capacitance becomes C = Kε°Ad.

33. a. We have V= V_o sin ωt.

Also, v = $\frac{q}{c}$; q = charge on capacitor

$v_0 \sin\omega t = \frac{q}{c}$

or, q = $cv_0 \sin\omega t$

$\therefore$ I = $\frac{dq}{dt} = \frac{d}{dt}$ $(CV_0 \sin\omega t) = cv_0 \sin\omega t \cdot \omega$

$\therefore$ I = $\frac{v_o}{\frac{1}{\omega c}} \sin\left(\omega t + \frac{\pi}{2}\right)$

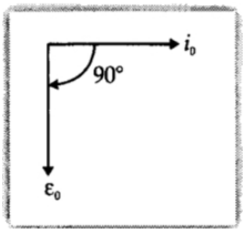
Max. current, $I_o = \frac{v_o}{\frac{1}{\omega c}} \times 1$ when sin $\left(\omega t + \frac{\pi}{2}\right)$ = 1

$\therefore$ I = I_o sin $\left(\omega t + \frac{\pi}{2}\right)$

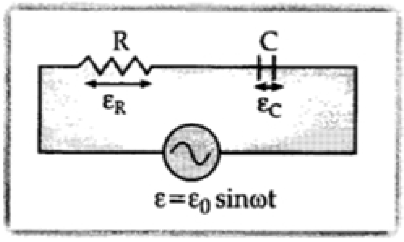
Comparing with ohm's law: I = $\frac{V}{R}$ to equation $I_o = \frac{v_o}{\frac{1}{\omega c}}$

We have, capacitive reactance, $x_C = \frac{1}{\omega c}$

b. Phasor diagram:



c. A resistor is now connected with the capacitor in series:



Peak voltage drop across R is i_0R

Peak voltage drop across C is i_0 X_C.

Voltage a cross R is in phase with the current.

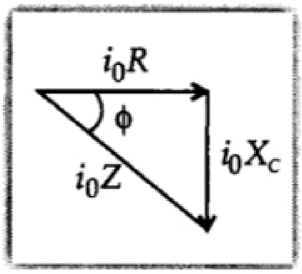
Voltage across C lags the current by 90^o.

So, the voltage drops across R and across C are not in phase. They are out of phase by 90^o.

So, $\varepsilon_0 = \sqrt{(i_0 R)^2 + (i_0 X_C)^2}$

$\therefore$ $i_0 = \frac{V_0}{\sqrt{R^2 + X_C^2}}$

The phase angle is



Phase Angle = ϕ = $\tan^{-1} \frac{X_C}{R}$

OR

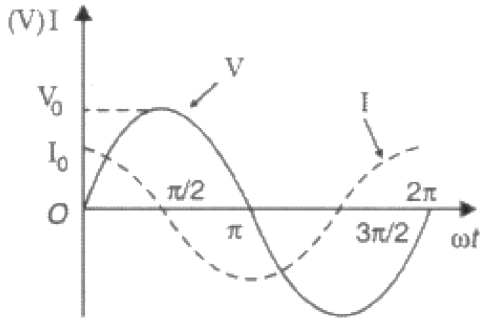
i. V = V_0 sin ωt, V = $\frac{Q}{C}$

A.C. source containing capacitor: Let a source of alternating e.m.f. V=$V_m$sinωt be connected to a capacitor of capacitance C only.

$l = \frac{dQ}{dt}$

$I_0 = \frac{V_0}{\left(\frac{1}{\omega C}\right)}$

I = I_0 sin $\left(\omega t + \frac{\pi}{2}\right)$



ii. $X_C = \frac{1}{2\pi f C}$ = 212.3 Ω

Z = $\sqrt{R^2 + X_C^2}$ = 291.5 Ω

$I_{rms} = \frac{V_{rms}}{Z} = \frac{220}{291.5}$ = 0.755 A

V_R (rms) = 151 V

V_C (rms) = 160.3 V

Two voltages are out of phase, hence they are added vectorially.