SAMPLE PAPER - 1

Class 12 - Physics

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

General Instructions:

1. There are 35 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. All the sections are compulsory.
3. Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

Section A

1. What is the packing fraction of a bcc lattice? **[1]**

a) $\frac{\pi\sqrt{3}}{4}$ b) $\frac{\pi\sqrt{3}}{8}$

c) $\frac{2\pi\sqrt{3}}{8}$ d) $\frac{\pi\sqrt{2}}{8}$

2. A wind-powered generator converts wind energy into electrical energy. Assume that the generator converts a fixed fraction of the wind energy intercepted by its blades into electrical energy. For wind speed v, the electrical power output will be proportional to: **[1]**

a) v^3 b) v

c) v^4 d) v^2

3. In a vessel of depth 15 cm, liquid is poured till the liquid level appears to be at half the depth. The liquid level is 5 cm from the top. Calculate the refractive index of the liquid, **[1]**

a) 1.5 b) 3.0

c) 1.7 d) 1.33

4. At absolute zero, Si acts as a: **[1]**

a) insulator b) metal

c) semiconductor d) none of these

5. Potential at a point x-distance from the centre inside the conducting sphere of radius R and charged with charge Q is: **[1]**

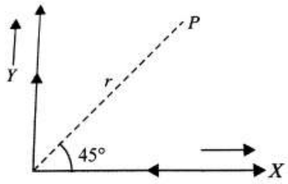
a) $\frac{Q}{R}$

b) xQ

c) $\frac{Q}{x}$

d) $\frac{Q}{x^2}$

6. Current I flows through a long conducting wire bent at right angles as shown in the figure. The magnetic field at a point P on the right bisector of the angle XOY at a distance r from O is: **[1]**



a) $\frac{2\mu_0 I}{\pi r}$

b) $\frac{\mu_0 I}{4\pi r}(\sqrt{2}+1)$

c) $\frac{\mu_0 I}{\pi r}$

d) $\frac{\mu_0}{4\pi} \times \frac{2I}{r}(\sqrt{2}+1)$

7. The flux linked with a circuit is given by: $\phi = t^3 + 3t - 7$. The graph between t (x-axis) and induced emf (y-axis) will be a: **[1]**

a) parabola not through the origin

b) straight line through the origin

c) straight line with negative intercept

d) straight line with positive intercept

8. The de Broglie wavelength of an electron in the first Bohr orbit is equal to: **[1]**

a) half the circumference of first orbit

b) circumference of the first orbit

c) one-fourth circumference of first orbit

d) twice the circumference of first orbit

9. Newton has postulated his corpuscular theory on the basis of: **[1]**

a) Newton's ring

b) dispersing of light

c) rectilinear propagation of light

d) colour due to thin film

10. Charge motion with in the Gaussian surface gives changing physical quantity as: **[1]**

a) electric flux

b) Gaussian surface area

c) electric field

d) charge

11. The unit cubic cell of A1 has a lattice parameter equal to 4.5×10^{-10} metre. The number of unit cells in an aluminium foil of volume 1×10^{-6} metre^3 is: **[1]**

a) 10^{-8}

b) 10^{8}

c) 10^{-24}

d) 10^{24}

12. For a normal eye, the cornea of eye provides a converging power of 40 D and the least converging power of the eye lens behind the cornea is 20 D. Using this information, the distance between the retina and the cornea-eye lens can be estimated to be: **[1]**

a) 2.5 cm

b) 5 cm

c) 1.5 m

d) 1.67 m

13. Photoelectrons are emitted by a metal surface only when **[1]**

a) light is incident at an angle greater than the critical angle

b) the wavelength of the incident light exceeds a certain minimum value

c) frequency of the incident light exceeds a certain minimum value

d) metal is initially charged

14. Four equal charges q are placed at four corners of a cube of side a each. Work done in carrying a charge - q from its centre to infinity is: **[1]**

a) $\frac{q^2}{2\pi\varepsilon_0 a}$

b) $\frac{\sqrt{2}q^2}{\pi\varepsilon_0 a}$

c) zero

d) $\frac{\sqrt{2}q^2}{\pi\varepsilon_0 a}$

15. In a double-slit experiment, when light of wavelength 400 nm was used, the angular width of the first minima formed on a screen placed 1m away, was found to be 0.2^o. What will be the angular width of the first minima, if the entire experimental apparatus is immersed in water? ($\mu_{\text{water}} = \frac{4}{3}$) **[1]**

a) 0.15^o

b) 0.266^o

c) 0.05^o

d) 0.1^o

16. **Assertion (A):** Neutrons penetrate matter more readily as compared to protons. **[1]**
Reason (R): Neutrons are slightly more massive than protons.

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.

17. **Assertion (A):** Accelerated charge radiate electromagnetic waves. **[1]**
Reason (R): As the wave propagate through the space, the oscillating electric and magnetic field regenerate each other.

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.

18. **Assertion:** Diamagnetic materials can exhibit magnetism. **[1]**
Reason: Diamagnetic materials have permanent magnetic dipole moment.

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) If both assertion and reason are false.

Section B

19. Determine the number density of donor atoms which have to be added to an intrinsic germanium semiconductor to produce an n-type semiconductor of conductivity 5 Ω^{-1} cm^{-1}, given that the mobility of electron in n-type Ge is 3900 cm^2 /Vs. Neglect the contribution of holes to conductivity. **[2]**

20. Calculate the period of revolution of an electron revolving in the first orbit of the hydrogen atom. Given the radius of the first orbit $= 0.53\dot{A}$ and $c = 3 \times 10^8$ ms^{-1} **[2]**

21. An EM wave, Y_1, has a wavelength of 1 cm while another EM wave, Y_2, has a frequency of 10^{15} Hz. Name these two types of waves and write one useful application for each. **[2]**

OR

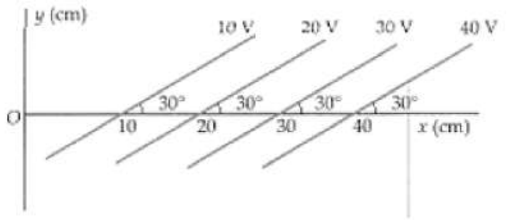
The charge on a parallel plate capacitor varies as $q = q_0 \cos 2\pi\nu t$. The plates are very large and close together (area = A, separation = d). Neglecting the edge effects, find the displacement current through the capacitor?

22. Find the maximum wavelength of electromagnetic radiation which can create a hole-electron pair in germanium. The band gap in germanium is 0.65 eV. **[2]**

23. To what potential we must charge n insulated sphere of radius 14 cm so that the surface charge density is equal to 1μ Cm^{-2}? **[2]**

OR

Figure shows some equipotential surfaces. What can you say about the magnitude and direction of the electric field?



24. X-rays fall on a photosensitive surface to cause photoelectric emission. Assuming that the work-function of the surface can be neglected, find the relation between the de-Broglie wavelength (λ) of the electrons emitted to the energy (E) of the incident photons. Draw the graph for λ as function of E. **[2]**

25. If both the number of protons and neutrons in a nuclear reaction is conserved, in what way is mass converted into energy (or vice versa)? Explain giving one example. **[2]**

Section C

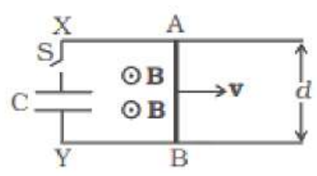
26. Using Bohr's postulates of the atomic model, derive the expression for radius of nth electron orbit. Hence, obtain the expression for Bohr's radius. **[3]**

27. **[3]**
    i. Write two points to distinguish between interference and diffraction fringes.
    ii. In Young's double-slit experiment, fringes are obtained on a screen placed at a certain distance away from the slits. If the screen is moved by 5 cm towards the slits, the fringe width changes by 30 μm. Given that the slits are 1 mm apart, calculate the wavelength of the light used.

28. A metallic rod of length l and resistance R is rotated with a frequency ν, with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius l, about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis is present everywhere. **[3]**
    i. Derive the expression for the induced emf and the current in the rod.
    ii. Due to the presence of the current in the rod and of the magnetic field, find the expression for the magnitude and direction of the force acting on this rod.
    iii. Hence obtain the expression for the power required to rotate the rod.

OR

Find the current in the sliding rod AB (resistance = R) for the arrangement shown in Figure. B is constant and is out of the paper. Parallel wires have no resistance. v is constant. Switch S is closed at time t = 0.



29. i. How are electromagnetic waves produced? **[3]**

ii. How do you convince yourself that electromagnetic waves carry energy and momentum?

OR

Name the EM waves in the wavelength range 10 nm to 10^{-3} nm. How are these waves generated? Write their two uses.

30. A short bar magnet placed with its axis at 30° with a uniform external magnetic field of 0.16 T experiences a torque of magnitude 0.032 J. **[3]**

a. Estimate the magnetic moment of the magnet.

b. If the bar were free to rotate, which orientations would correspond to its

i. stable, and

ii. unstable equilibrium?

What is its potential energy in the field for cases (i) and (ii)?

Section D

31. i. Obtain the expression for the torque $\vec{\tau}$ experienced by an electric dipole of dipole moment $\vec{p}$ in a uniform electric field, $\vec{E}$. **[5]**

ii. What will happen if the field were not uniform?

OR

i. Define electric flux. Write its SI unit. Gauss' law in electrostatics is true for any closed surface, no matter what its shape or size is. Justify this statement with the help of a suitable example.

ii. Use Gauss' law to prove that the electric field inside a uniformly charged spherical shell is zero.

32. a. Define magnifying power of a reflecting type telescope. Write its expression. **[5]**

b. A small telescope has an objective lens of focal length 150 cm and an eyepiece of focal length 5 cm. If this telescope is used to view a 100 m high tower 3 km away, find the height of the final image when it is formed 25 cm away from the eyepiece.

OR

a. Draw a labelled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision.

b. The total magnification produced by a compound microscope is 20. The magnification produced by the eyepiece is 5. The microscope is focused on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm. Calculate the focal length of the objective and the eyepiece.

33. A dry cell of emf 1.5 V and internal resistance 0.10 Ω is connected across a resistor in series with a very low resistance ammeter. When the circuit is switched on, the ammeter reading settles to a steady value of 2.0 A What is the steady: **[5]**

i. rate of chemical energy consumption of the cell,

ii. rate of energy dissipation inside the cell,

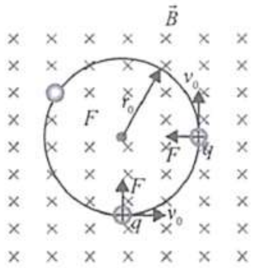
iii. rate of energy dissipation inside the resistor,

iv. power output of the source?

Section E

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

An electron with speed $v_0 << c$ moves in a circle of radius r_0 in a uniform magnetic field. This electron is able to traverse a circular path as magnetic field is perpendicular to the velocity of the electron. A force acts on the particle perpendicular to both $\vec{v}_0$ and q. This force continuously deflects the particle sideways without changing its speed and the particle will move along a circle perpendicular to the field. The time required for one revolution of the electron is T_0.



(i) If the speed of the electron is doubled to $2v_0$ What will be the radius of the circle if the initial radius is r_0?

(ii) If the speed of particle gets doubled, what will be the new time period of particle?

(iii) A charged particles is projected in a magnetic field $\vec{B} = (2\hat{i} + 4\hat{j}) \times 10^2$ T. The acceleration of the particle is found to be $\vec{a} = (x\hat{i} + 2\hat{j})\text{ms}^{-2}$. Find the value of x

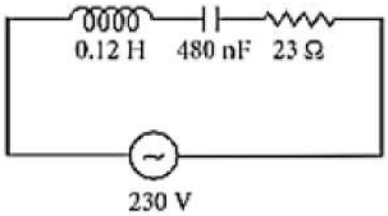
OR

What will be the trajectory of electron If the direction of velocity of the electron makes an acute angle with the direction of magnetic field?

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

When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. We cannot have resonance in a RL or RC circuit.

A series LCR circuit with L = 0.12H, C = 480 nF, R = 23 Ω is connected to a 230 V variable frequency supply.



(i) Find the value of source frequency for which current amplitude is maximum.

(ii) What will be the value of maximum current?

(iii) Find the value of maximum power.

OR

What is the Q-factor of the given circuit?

Solution

SAMPLE PAPER - 1

Class 12 - Physics

Section A

1. **(b)** $\frac{\pi\sqrt{3}}{8}$

   Explanation: Packing fraction for a bcc lattice,

   $= \frac{2\times\frac{4}{3}\pi r^3}{a^3} = \frac{2\times\frac{4}{3}\pi\left(\frac{\sqrt{3}a}{4}\right)^3}{a^3} = \frac{\pi\sqrt{3}}{8}$

2. **(a)** v^3

   Explanation: Power, p = $\vec{F}\cdot\vec{v}$ = Fv

   F = $v\left(\frac{dm}{dt}\right) = v\left\{\frac{d(\rho\times\text{ volume})}{dt}\right\}$ (ρ = density)

   $\therefore \quad F = \rho v\left[\frac{d(\text{ Volume})}{dt}\right]$ = ρvAv = ρAv^2

   Power, P = ρav^3 or P $\propto$ v^3

3. **(d)** 1.33

   Explanation: 1.33

4. **(a)** insulator

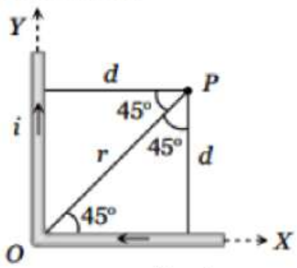
   Explanation: At absolute zero, Si acts as an insulator due to the absence of free electrons in the conduction band.

5. **(a)** $\frac{Q}{R}$

   Explanation: The potential at any point inside the charged spherical conductor equals to the potential at the surface of the conductor i.e. $\frac{Q}{R}$

6. **(d)** $\frac{\mu_0}{4\pi}\times\frac{2I}{r}(\sqrt{2}+1)$

   Explanation:

   By using B = $\frac{\mu_0}{4\pi}\cdot\frac{i}{r}(\sin\phi_1+\sin\phi_2)$,

   from figure d = r sin $45^\circ = \frac{r}{\sqrt{2}}$

   Magnetic field due to each wire at

   PB = $\frac{\mu_0}{4\pi}\cdot\frac{i}{(\frac{r}{\sqrt{2}})}(\sin 45^\circ+\sin 90^\circ)$

   = $\frac{\mu_0}{4\pi}\cdot\frac{i}{r}(\sqrt{2}+1)$

   Hence net magnetic field at P

   B_{net} = $2\times\frac{\mu_0}{4\pi}\cdot\frac{i}{r}(\sqrt{2}+1)$

   = $\frac{\mu_0}{4\pi}\times\frac{2I}{r}(\sqrt{2}+1)$

7. **(a)** parabola not through the origin

   Explanation: ϕ = t^3 + 3t - 7

   $\therefore$ Induced emf, e = $-\frac{d\phi}{dt}$,= -($3t^2$ - 2) = $-3t^2$ -3

   At t = 0; e = -3 V

   Therefore, shape of graph will be a parabola not through origin.

8. **(b)** circumference of the first orbit

   Explanation: $\lambda = \frac{h}{mv}$

   According to Bohr's theory:

$mvr_0 = \frac{h}{2\pi}$

or $\frac{h}{mv} = 2\pi r_0$

= circumference of the first orbit.

9. **(c)** rectilinear propagation of light

Explanation: rectilinear propagation of light

10. **(c)** electric field

Explanation: electric field

11. **(d)** 10^{24}

Explanation: Lattice parameter = a, i.e., a = 4.5×10^{-10}m

Volume of the unit cell = a^3

$\therefore a^3 = (4.5 \times 10^{-10})^3 = 91 \times 10^{-30}\ m^3$

Volume of foil = 91×10^{-6} m3

$\therefore$ Number of unit cells = $\frac{91\times10^{-6}}{91\times10^{-30}} = 10^{24}$

12. **(d)** 1.67 m

Explanation: Converging power of cornea, P_c = + 40 D

Least converging power of eye lens, P_e = +20 D

Power of the eye lens, P = $P_C + P_e$ = 40D + 20D = 60D

f = $\frac{1}{P} = \frac{1}{60\text{D}} = \frac{1}{60}\text{m} = \frac{100}{60}\text{cm} = \frac{5}{3}\text{cm}$

Distance between the retina and cornea eye lens

= Focal length of the eye lens = $\frac{5}{3}$ cm = 1.67 cm

13. **(c)** frequency of the incident light exceeds a certain minimum value

Explanation: Photoelectrons are emitted by a metal surface only when frequency of the incident light exceeds a certain threshold value.

14. **(b)** $\frac{\sqrt{2}q^2}{\pi\varepsilon_0 a}$

Explanation: $\frac{\sqrt{2}q^2}{\pi\varepsilon_0 a}$

15. **(a)** 0.15^o

Explanation: In air angular fringe width is given by $\theta_0 = \frac{\beta}{D}$

Angular fringe width in water,

$\theta_w = \frac{\beta}{\mu D} = \frac{\theta_0}{\mu}$

= $\frac{0.2^\circ}{\left(\frac{4}{3}\right)}$ = 0.15^o

16. **(b)** Both A and R are true but R is not the correct explanation of A.

Explanation: Both A and R are true but R is not the correct explanation of A.

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

Explanation: Consider a charge oscillating with some frequency. This oscillating charge produces an oscillating electric field in space, which produces an oscillating magnetic field, which in turn, is a source of oscillating electric field and so on. The oscillating electric and magnetic field thus regenerate each other, as the wave propagate through the space.

18. **(d)** If both assertion and reason are false.

Explanation: Diamagnetic materials have L = 0, S = 0 and J = 0. They have no magnetic dipole moment. The given reason is wrong.

Section B

19. Here $\sigma = 5\Omega^{-1}\ \text{cm}^{-1}$, μ_e = 3900 $cm^2\ V^{-1}\ s^{-1}$, n_e = ?

If we neglect the contribution of holes to conductivity, then

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

$\therefore$ Electron density,

$n_e = \frac{\sigma}{e\mu_e} = \frac{5}{1.6\times10^{-19}\times3900}$ cm^{-3}

$= 8.01 \times 10^{15}$ cm^{-3}

20. Velocity of electron in nth orhit = $\frac{1}{137} \cdot \frac{c}{n}$

Period of revolution of an electron in fifst orbit,

$T = \frac{2\pi r}{v} = \frac{2\pi r\times137\times n}{c}$

$= \frac{2\times3.14\times0.53\times10^{-10}\times137\times1}{3\times10^8}$ s

1.52×10^{-16} s. $[\because n = 1]$

21. **Y_1 Microwaves:** Microwave oven, Aircraft Navigator, It is used in radar communication.

Y_2 Ultraviolet waves: Sterilize surgical instruments, food preservation, or any other.

OR

The displacement current in a capacitor is equal to the conduction current of the capacitor.

Displacement current, $I_d = I_c$

The displacement current through the capacitor is given by

$I_d = I_c = \frac{dq}{dt}$ ....(i)

Here we are given, $q = q_0 \cos 2\pi\nu t$

Putting this value in Eq (i), we get

$I_d = I_c = - q_0 \sin 2\pi\nu t \times 2\pi\nu$

$I_d = I_c = -2\pi\nu q_0 \sin 2\pi\nu t$

22. Here $E_g = 0.65$ eV = $0.65 \times 1.6 \times 10^{-19}$ J

This is the minimum energy required to push an electron from valence to the conduction band or to create a hole-electron pair. Hence required maximum wavelength $\lambda_{\max}$ is given by

$E_g = \frac{hc}{\lambda_{\max}}$

or $\lambda_{\max} = \frac{hc}{E_g}$

$= \frac{6.6\times10^{-34}\times3\times10^8}{0.65\times1.6\times10^{-19}}$

$= 1.9 \times 10^{-6}$ m

23. Here r = 14 cm = 14×10^{-2} m,

$\sigma = 1\ \mu$ $Cm^{-2} = 10^{-6}$ Cm^{-2}

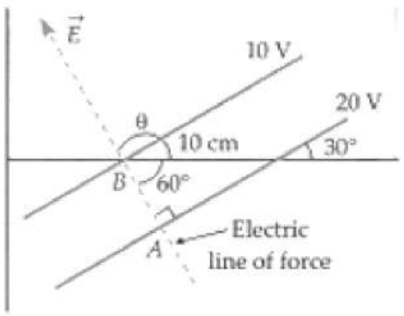
$\therefore V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{4\pi r^2\sigma}{r} = \frac{1}{4\pi\varepsilon_0} \cdot 4\pi r\sigma$

$= 9 \times 10^9 \times 4 \times \frac{22}{7} \times 14 \times 10^{-2} \times 10^{-6}$ V

= 15840 V

OR

As shown in Fig. consider two consecutive equipotential surfaces. The electric field is normal to the equipotential surfaces and always directed from higher potential to lower potential.



The normal distance between two consecutive equipotential surfaces is dr = AB = 10 cm $\times$ cos 60° = 5 cm $\left[\frac{AB}{10 \text{ cm}} = \cos 60^\circ\right]$

Also dV = 10 - 20 = -10 V

$\therefore E = -\frac{dV}{dr} = -\frac{-10 \text{ V}}{5\times10^{-2} \text{ m}} = 200 \text{Vm}^{-1}$

Angle made by $\vec{E}$ with positive X-axis is

$\theta = 180 - 60° = 120°$

24. According to the Einstein and photoelectric equation,

$KE_{max} = h\nu - \phi = E - \phi$

Thus, $E = KE_{max} + \phi$

Given $\phi = 0$

So, $E = K_{max}$

$E = \frac{p^2}{2m}$

Thus, $p = \sqrt{2mE}$

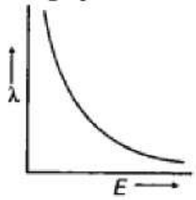
de-Broglie wavelength is given by

$\lambda = \frac{h}{p}$ ....(i) here h is the Planck constant

Substituting the value of p, we get

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

The graph between wavelength and Energy is shown in the figure below.



25. $_1^2H + _1^2H \rightarrow _2^3He + _0^1n +$ energy

If we take the above example, we observe that the proton number and neutron number get conserved. We see that the total rest mass of neutron and protons will be similar on both sides in a nuclear reaction. Further, it is examined that the total binding energy of nuclei on the left side should not be same as that of right-hand side where the difference between binding energies will result in the release of energy in a reaction.

Section C

26. Let e, m and v be respectively the charge, mass and velocityof the electron and r the radius of the orbit.

The positive charge on the nucleus is Ze, where Z is the atomic number (in case of hydrogen atom, Z = 1). As, the centripetal force is provided by the electrostatic force of attraction, we have

$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{(Ze)\times e}{r^2}$ or $mv^2 = \frac{Ze^2}{4\pi\varepsilon_0 r}$ ....(i)

From the first postulate of Bohr's atomic model, the angular momentum of the electron is

$mvr = n\frac{h}{2\pi}$ ....(ii)

where, n (= 1, 2, 3, ...) is principal quantum number.

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

$r = n^2 \frac{h^2\varepsilon_0}{\pi m Z e^2}$ ....(iii)

This is the equation for the radii of the permitted orbits.

Bohr's Radius: The radius of the first orbit (n = 1) of hydrogen atom (Z = 1) will be

$r = \frac{h^2\varepsilon_0}{\pi m e^2}$

This is called Bohr's radius and its value is 0.53 $\overset{o}{A}$

Since $r_n \propto n^2$, the radius of the second orbit of hydrogen atom will be $(4\times 0.53)\overset{o}{A}$ and that of the third orbit $(9 \times 0.53)\overset{o}{A}$ and can be extended for other orbits according to formula.

27. i. Any two points of difference

Interference	Diffraction
Fringes are equally spaced.	Fringes are not equally spaced.
Intensity is same for all maxima.	Intensity falls as we go to successive maxima away from the centre.
Superposition of two waves originating from two narrow slits.	Superposition of a continuous family of waves originating from each point on a single slit.

ii. Let D be the distance of the screen from the plane of the slits.

We have d= 1mm $=10^{-3}$ m.

Fringe width, $\beta=\frac{\lambda D}{d}$
In the first case $\beta=\frac{\lambda D}{d}$ or $\beta d=\lambda D$ ...(i)
In the second case $\left(\beta-30\times10^{-6}\right)=\frac{\lambda(D-0.05)}{d}$
or $\left(\beta-30\times10^{-6}\right)d=\lambda(D-0.05)$ ...(ii)
Subtracting (ii) from (i) we get
$30\times10^{-6}\times d=\lambda\times0.05$
$\therefore\lambda=\frac{30\times10^{-6}\times10^{-3}}{5\times10^{-2}}\mathrm{m}$
$\therefore\lambda=6\times10^{-7}\mathrm{m}$ = 600 nm

28. i. In the one revolution, change of area,
$dA=\pi l^2$
$\therefore$ Change of magnetic flux in one revolution of the rod,
$d\phi_B=\vec{B}\cdot d\vec{A}=BdA\cos0^\circ=B\pi l^2$
(Given, magnetic field intensity, $\vec{B}$ is parallel to change in area, $d\vec{A}$)
If period of revolution is T,
a. Induced emf (e) = $\frac{d\phi}{dt}=\frac{B\pi l^2}{T}=B\pi l^2\nu$ $(\because\nu=\frac{1}{T})$
b. Induced current in the rod,
$I=\frac{e}{R}=\frac{\pi\nu Bl^2}{R}$
(Given R = resistance of the rod)
ii. Magnitude of force acting on the rod,
$|\vec{F}|=|I(\vec{l}\times\vec{B})|=BIlsin90^0=\frac{\pi\nu B^2l^3}{R}$
The external force required to rotate the rod opposes the Lorentz force acting on the rod, i.e external force acts in the direction opposite to the Lorentz force.
iii. Power required to rotate the rod,
$P=\vec{F}.\vec{v}=Fvcos0^0=\frac{\pi\nu B^2l^3v}{R}$

OR

This is the similar problem as we discussed above. Here, a conductor of length d moves with speed v, perpendicular to the magnetic field B as shown in figure. Due to this a motional emf is induced across two ends of rod (e = vBd). since, switch S is closed at time t = 0, capacitor is charged by this potential difference. Let Q (t) be the charge on the capacitor and current flows from A to B. Now, the induced current
$I=\frac{dQ}{dt}=\frac{Bvd}{R}-\frac{Q}{RC}$
$\frac{Q}{RC}+\frac{dQ}{dt}=\frac{Bvd}{R}$
$Q+RC\frac{dQ}{dt}=vBCd$ (Let vBdC = A).......(1)
$Q+RC\frac{dQ}{dt}=A$
$\frac{dQ}{A-Q}=\frac{1}{RC}dt$
By integrating we have
$\int_0^Q\frac{dQ}{A-Q}=\frac{1}{RC}\int_0^t dt=-[\ln(A-Q)-\ln A]=\frac{t}{RC}$
$\ln\frac{A-Q}{A}=-\frac{t}{RC}$
$\frac{A-Q}{A}=e^{-t/RC}$ (by taking exponential on both sides)
$Q=A(1-e^{-t/RC})$
Current in the rod is given by :-
$I=\frac{dQ}{dt}=\frac{d}{dt}\left[A\left(1-e^{-t/RC}\right)\right]$
$=-A\left(e^{-t/RC}\right)\left(-\frac{1}{RC}\right)$ thus from 1st equation
$I=\frac{vBd}{R}e^{-t/RC}$

29. i. The oscillating charge produces an oscillating or time-varying electric field and an oscillating electric field produces a time-varying magnetic field which then produces an oscillating emf. An oscillating voltage (emf) produces an oscillating magnetic field and so on. This, in turn, produces an oscillating electric field and so on. Thus oscillating electric and magnetic fields regenerate each other and as a result, an electromagnetic wave is produced and the wave propagates through space. In this

way, the oscillating charges produce an electromagnetic wave. Vibrations of electric and magnetic fields are mutually perpendicular to each other and also perpendicular to the direction of propagation of the wave

ii. According to quantum theory, electromagnetic radiation is made up of massless particles called photons. The momentum of the photon is expressed as

$p = \frac{E}{c}$

Where p and E are momentum and energy carried by the electromagnetic radiation or photons respectively and c = speed of light.

Thus, electromagnetic waves carry energy and momentum.

OR

X-rays: wavelength 10^{-12}m - 10^{-8} m, frequency 10^{20} - 10^{16}Hz

Generation: X-radiation occurs due to electron transitions among upper and lower energy levels of heavy elements excited by electron bombardment or rapid deceleration of electrons.

Uses:

a. Used in medicine and dentistry
b. Mammograms use X-rays to identify breast cancer. Because X-rays damage or destroy living tissues and organisms, care must be taken to avoid unnecessary or over exposure.

30. a. Here $\theta = 30^o$, B = 0.16T, τ = 0.032 J

Magnetic moment,

m = $\frac{\tau}{B\sin\theta} = \frac{0.032}{0.16\times\sin 30^\circ}$ = 0.40 JT^{-1}

b. Potential energy of the dipole in a magnetic field $\vec{B}$ is given by

$U = -\vec{m}\cdot\vec{B} = -mB\sin\theta$

i. The bar will be in stable equilibrium when its magnetic moment $\vec{m}$ is parallel to $\vec{B}$ (θ = 0°). Its potential energy is then minimum and is given by

U_{min} = -mB cos 0^o = -mB

= -0.40 $\times$ 0.16 = -0.064 J

ii. The bar will be in unstable equilibrium when $\vec{m}$ is antiparallel to $\vec{B}$ (θ =180°). Its potential energy is then maximum and is given by

U_{max} = -mB cos 180^o = + mB = +0.064 J

Section D

31. i. Let us consider two charges +q and -q separated by a distance 2a.Obtaining expression for torque $\vec{\tau}$ experienced by electric dipole in uniform electric field

Effect of non-uniform electric field

a. Force on + q, $\vec{F}$ = q $\vec{E}$

Force on -q, F = -q $\vec{E}$

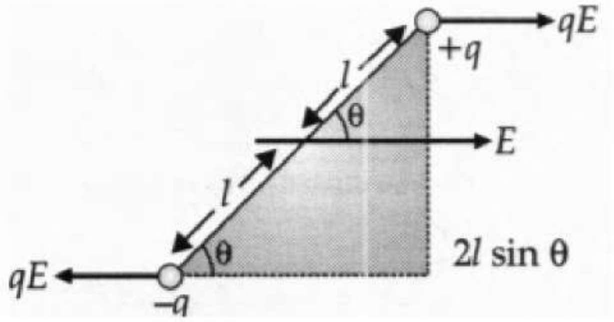
Magnitude of torque $\vec{\tau}$ = qE $\times$ 2asin θ

= 2qaEsin θ

$\vec{\tau}$ = $\vec{p} \times \vec{E}$

here p is the dipole moment.

ii. If the electric field is non-uniform, the dipole experiences a translatory force as well as a torque.

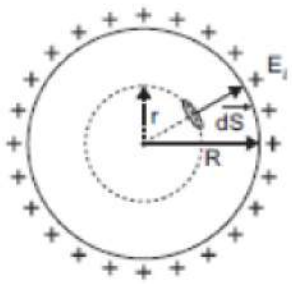


Consider electric dipole kept in a uniform electric field. Consider electric dipole kept in a uniform electric field at an angle θ where a dipole experience a torque, so, the torque generated by parallel forces qE will act as a couple as

$|\vec{\tau}| = qE2l\sin\theta$
= pE sin θ [as p = 2ql]
$|\vec{\tau}| = |\vec{p} \times \vec{E}|$
When the field is non-uniform, the force acting on both ends will not be equal, hence they result in a mixture of couple and net force. With this, dipole experiences rotational as well as linear force.

OR

i. The electric flux through an area is defined as the electric field multiplied by the area of the surface projected on a plane, perpendicular to the field. Its S.I. unit is voltmeter (V_m) or Newton metre square per coulomb ($Nm^2\ C^{-1}$). The given statement is justified because while measuring the flux, the surface area is more important than its volume on its size.
ii. Electric field inside the shell:



The charge resides on the surface of a conductor. Thus, a hollow charged conductor is equivalent to a charged spherical shell. Let's consider a spherical Gaussian surface of radius (r < R). If E is the electric field inside the shell, then by symmetry electric field strength has the same magnitude E_i on the Gaussian surface and is directed radially outward.

Electric flux through the Gaussian surface is given by,
$= \int_s \vec{E}_i \cdot d\vec{S}$
$= \int E_i dS \cos 0 = E_i.4\pi r^2$
Now, Gaussian surface is inside the given charged shell, so charge enclosed by Gaussian surface is zero.
Therefore, using Gauss's theorem, we have
$\int_S \vec{E}_i \cdot d\vec{S} = \frac{1}{\epsilon_0} \times$ charge enclosed
$\Rightarrow E_i \cdot 4\pi r^2 = \frac{1}{\epsilon_0} \times 0$
$\Rightarrow E_i = 0$

Thus, electric field at each point inside a charged thin spherical shell is zero.

32. a. Magnifying power of reflecting type telescope is the ratio of the angle subtended at the eye by the image to the angle subtended at the unaided eye by the object.
Mathematically, we can write
$m = \frac{f_0}{f_e}$ Or $m = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$
where, f_o is the focal length of the objective, f_e is the focal length of the eye-piece.

b. Using, the lens equation for objective lens,
$\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0}$
$\Rightarrow \frac{1}{150} = \frac{1}{v_0} - \frac{1}{-3\times10^5}$
$\Rightarrow \frac{1}{150} - \frac{1}{3\times10^5} = \frac{1}{v_o}$
$\Rightarrow v_o = \frac{3\times10^5}{1999} = 150$ cm
Hence, magnification due to the objective lens is given by,
$m_o = \frac{\mathbf{v_o}}{\mathbf{u_o}} = \frac{150\times10^{-2}}{3000} = \frac{10^{-2}}{20}$
$\Rightarrow m_o = 0.05 \times 10^{-2}$

Now, using lens formula for eye-piece, we get
$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e}$
$\Rightarrow \frac{1}{5} = \frac{1}{-25} - \frac{1}{u_e}$
$\Rightarrow u_e = \frac{-25}{6}$ cm
Therefore, magnification due to eyepiece $m_e = \frac{-25}{-\frac{25}{6}} = 6$ cm

Hence, total magnification, $m = m_e \times m_o$

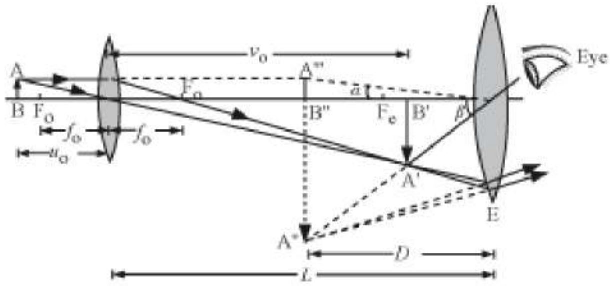
$m = 6 \times 5 \times 10^{-4}$

$= 30 \times 10^{-4}$

So, size of final image = $30 \times 10^{-4} \times 100$ m = 30 cm

OR

a.



where AB = object, A'B' = image formed by objective, A"B" = image formed by eyepiece

L is the separation between the eyepiece and the objective,

f_0 is the focal length of the objective,

f_e is the focal length of the eyepiece,

D is the least distance for clear vision

b. For the least distance of clear vision, the total magnification is given by:

$m = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right) = m_o \cdot m_e$ ...(i)

Also, the given magnification for the eyepiece:

$m_e = 5 = \left(1 + \frac{D}{f_e}\right)$

$\Rightarrow 5 = 1 + \frac{20}{f_e}$

$\Rightarrow f_e = 5$ cm

Substituting the value of m and m_e in equation (i), we get:

$m = m_0 \cdot m_e$

$\Rightarrow m_o = \frac{m}{m_e} = \frac{20}{5} = 4$

Now, we have:

$m_o = \frac{L}{|f_o|}$

$\Rightarrow f_0 = \frac{14}{4} = 3.5$ cm

33. Here $\varepsilon = 1.5$ V, r = 0.10 Ω, I = 2.0 A

i. Rate of chemical energy consumption of the cell

$= \varepsilon I = 1.5 \text{ V} \times 2.0 \text{ A} = 3.0$ W

ii. Rate of energy dissipation inside the cell

$= I^2 r = (2)^2 \times 0.10 \text{ W} = 0.40$ W.

iii. Rate of energy dissipation inside the resistor

$= \varepsilon I - I^2 r = 3.0 - 0.40 = 2.6$ W.

iv. Power output of the source

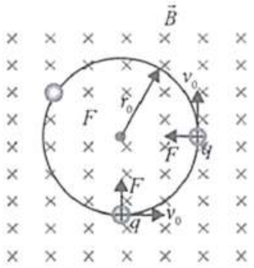
= Power input to the external circuit

$= \varepsilon I - I^2 r = 2.6$ W

Section E

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

An electron with speed $v_0 << c$ moves in a circle of radius r_0 in a uniform magnetic field. This electron is able to traverse a circular path as magnetic field is perpendicular to the velocity of the electron. A force acts on the particle perpendicular to both $\vec{v}_0$ and q. This force continuously deflects the particle sideways without changing its speed and the particle will move along a circle perpendicular to the field. The time required for one revolution of the electron is T_0.



(i) $2r_0$

As, $r_0 = \frac{mv}{qB} \Rightarrow r' = \frac{m(2v_0)}{qB} = 2r_0$

(ii) T_0

As, T = $\frac{2\pi m}{qB}$

Thus, it remains same as it is independent of velocity.

(iii) As F $\perp$ B

Hence, a $\perp$ B

$\therefore \vec{a} \cdot \vec{B} = 0$

$\Rightarrow (x\hat{i} + 2\hat{j}) \cdot (2\hat{i} + 4\hat{j})$ = 0

2x + 8 = 0 $\Rightarrow$ x = -4 ms^{-2}

OR

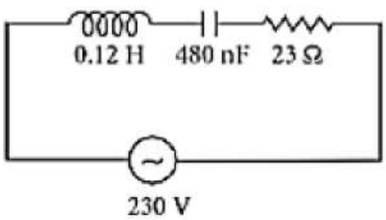
If the charged particle has a velocity not perpendicular to $\vec{B}$, then the component of velocity along $\vec{B}$ remains unchanged as the motion along the $\vec{B}$ will not be affected by $\vec{B}$.

Then, the motion of the particle in a plane perpendicular to $\vec{B}$ is as before circular one. Thereby, producing helical motion.

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

When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. We cannot have resonance in a RL or RC circuit.

A series LCR circuit with L = 0.12H, C = 480 nF, R = 23 Ω is connected to a 230 V variable frequency supply.



(i) Here, L = 0.12 H, C = 480 nF = 480 $\times$ 10^{-9} F, R = 23Ω, V = 230 V

$V_0 = \sqrt{2} \times 230$ = 325.22 V

$I_0 = \frac{V_0}{\sqrt{R^2+\left(\omega L-\frac{1}{\omega C}\right)^2}}$

At resonance, $\omega L - \frac{1}{\omega C}$ = 0

$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.12\times480\times10^9}}$ = 4166.67 rad s^{-1}

$v_R = \frac{4166.67}{2\times3.14}$ = 663.48 Hz

(ii) Current, $I_0 = \frac{V_0}{R} = \frac{325.22}{23}$ = 14.14 A

(iii) Maximum power, $P_{max} = \frac{1}{2}(I_0)^2 R$

$= \frac{1}{2} \times (14.14)^2 \times 23$ = 2299.3 W

OR

Quality factor Q = $\frac{X_L}{R} = \frac{\omega_r L}{R} = \frac{4166.67\times0.12}{23}$ = 21.74