Class XII Session 2024-25
Subject - Physics
Sample Question Paper - 5

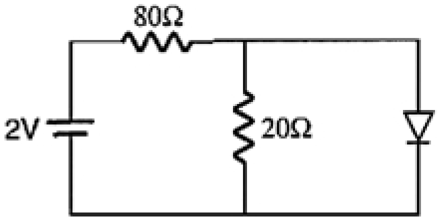
Time Allowed: 3 hours **Maximum Marks: 70**

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. In the circuit shown, the current through the ideal diode is: **[1]**



a) 100 mA　　b) 20 mA

c) 25 mA　　d) 75 mA

2. $m^2V^{-1}s^{-1}$ is the SI unit of which of the following? **[1]**

a) Potential gradient　　b) Mobility

c) Drift velocity　　d) Resistivity

3. For a glass prism, the angle of minimum deviation will be smallest for the light of **[1]**

a) blue colour　　b) yellow colour

c) green colour　　d) red colour.

4. A bar-magnet of the pole-strength 2 Amp-m is kept in a magnetic field of induction 4×10^{-5} Wb/m^2 such that the axis of the magnet makes an angle 30° with the direction of the field. If the couple acting on the magnet is **[1]**

found to be 80 × 10^{-7} Nm, then the distance between the poles of the magnet is:

a) 20 cm
b) 4 m
c) 2 m
d) 8 m

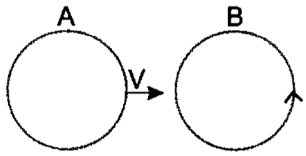
5. A proton is about 1840 times heavier than an electron. When it is accelerated by a potential difference of 1 kV, its kinetic energy will be: **[1]**

a) 920 keV
b) $\frac{1}{1840}$keV
c) 1 keV
d) 1840 keV

6. An electron with velocity $\vec{v} = \left(v_x\hat{i} + v_y\hat{j}\right)$ moves through a magnetic field $\vec{B} = \left(B_x\hat{i} - B_y\hat{j}\right)$. The force $\vec{F}$ on the electron is : (e is the magnitude of its charge) **[1]**

a) $e\left(v_xB_y - v_yB_x\right)\hat{k}$
b) $-e\left(v_xB_y - v_yB_x\right)\hat{k}$
c) $-e\left(v_xB_y + v_yB_x\right)\hat{k}$
d) $e\left(v_xB_y + v_yB_x\right)\hat{k}$

7. There are two coils A and B as shown in the figure. A current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counter clockwise. B is kept stationary when A moves. We can infer that **[1]**



a) there is a constant current in the counterclockwise direction in A.
b) there is a constant current in the clockwise direction in A.
c) there is a varying current in A.
d) there is no current in A.

8. A bar magnet having a magnetic moment of 2 × 10^4 JT^{-1} is free to rotate in a horizontal plane. A horizontal magnetic field B = 6 × 10^{-4} T exists in the space. The work done in taking the magnet slowly from a direction parallel to the field to a direction 60° from the field is **[1]**

a) 0.6 J
b) 12 J
c) 2 J
d) 6 J

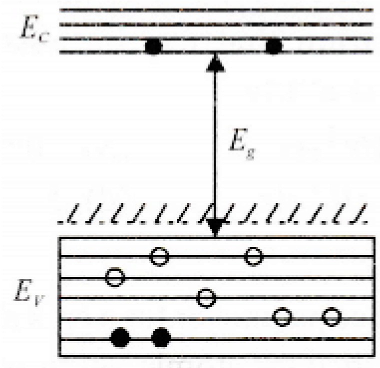
9. Phase difference between any two points of a wavefront is **[1]**

a) π
b) 0
c) $\frac{\pi}{4}$
d) $\frac{\pi}{2}$

10. When 10^{19} electrons are removed from a neutral metal plate, the electric charge on it is **[1]**

a) -1.6 C
b) 10^{+19} C
c) +1.6 C
d) 10^{-19} C

11. In the energy band diagram of a material as given below, the open circles and filled circles denote holes and electrons respectively. The material is a/an **[1]**



a) insulator

b) metal

c) p-type semiconductor

d) n-type semiconductor

12. The minimum distance between an object and its real image formed by a convex lens of focal length f is: **[1]**

a) 4f

b) f

c) 2f

d) 3f

13. **Assertion (A):** When ultraviolet light is incident on a photocell, its stopping potential is V_0 and the maximum kinetic energy of the photoelectrons is K_{max}. When the ultraviolet light is replaced by X-rays, both V_0 and K_{max}. increase. **[1]**

Reason (R): Photoelectrons are emitted with speeds ranging from zero to a maximum value because of the range of frequencies present in the incident light.

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:** When a capacitor is filled completely with a metallic slab its capacity becomes very large. **[1]**
Reason: Dielectric constant for metal is zero.

a) Both A and R are true and R is the correct explanation of A

b) Both A and R are true but R is NOT the correct explanation of A

c) A is true but R is false

d) A is false and R is also false

15. **Assertion (A):** According to Huygen's principle, no backward wave-front is possible. **[1]**
Reason (R): Amplitude of secondary wavelet is proportional to $(1 + \cos\theta)$ where θ is the angle between the ray at the point of consideration and the direction of secondary wavelet.

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):** Faraday's laws are consequences of the conservation of energy. **[1]**
Reason (R): In a purely resistive AC circuit, the current lags behind the emf in phase.

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. Compare the following: **[2]**

i. Wavelengths of the incident solar radiation absorbed by the earth's surface and the radiation re-radiated by the earth.

ii. Tanning effect produced on the skin by UV incident directly on the skin and that coming through glass window.

18. A sample of paramagnetic salt contains 2.0×10^{24} atomic dipoles each of dipole moment 1.5×10^{-23} JT^{-1}. The sample is placed under homogeneous magnetic field of 0.84 T and cooled to the temperature of 4.2 K. The degree of magnetic saturation achieved is equal to 15%. What is the total dipole moment of the sample for a magnetic field of 0.98 T and a temperature of 2.8 K (assume Curie's law)? **[2]**

19. Distinguish between intrinsic and extrinsic semiconductors. Although in an extrinsic semiconductor $n_e \neq n_h$, yet it is electrically neutral. Why? **[2]**

20. Explain why the spectrum of hydrogen atom has many lines, although a hydrogen atom contains only one electron. **[2]**

21. Answer the following: **[2]**

a. Magnetic field lines can be entirely confined within the core of a toroid, but not within a straight solenoid. Why?

b. Does a bar magnet exert a torque on itself due to its own field? Justify your answer.

c. When an electron revolves around a nucleus, obtain the expression for the magnetic moment associated with it.

OR

a. It is not advisable to use a galvanometer as such to measure current directly. Why?

b. Why should the value of resistance connected in parallel to a galvanometer be low?

c. Is the reading shown by an ammeter in a circuit less than or more than the actual value of current flowing in the circuit? Why?

Section C

22. **[3]**

a. Write the relationship between mobility and drift velocity in a current carrying conductor.

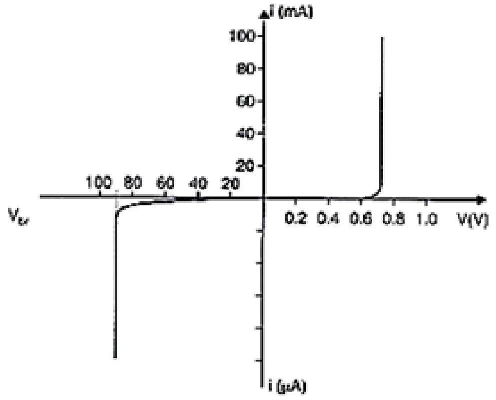
b. Two aluminium wires have their lengths in the ratio 2 : 3 and radii in the ratio 1 : 3. These are connected in parallel across a battery of emf E and of negligible internal resistance. Find the ratio of drift velocities of the electrons in the two wires.

23. The following figure shows the V-I characteristics of a semiconductor diode. **[3]**

i. Identify the semiconductor diode used.

ii. Draw the circuit diagram to obtain the given characteristics of this device.

iii. Briefly explain how this diode can be used as a voltage regulator.



24. Write the basic features of the photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based. **[3]**

25. Calculate and compare the energy released by **[3]**

a. fusion of 1.0 kg of hydrogen deep within Sun and

b. the fission of 1.0 kg of ^{235}U in a fission reactor.

26. An electron in a hydrogen atom makes transitions from orbits of higher energies to orbits of lower energies. **[3]**

a. When will such transitions result in (a) Lyman (b) Balmer series?

b. Find the ratio of the longest wavelength in Lyman series to the shortest wavelength in Balmer series.

27. In a single slit diffraction experiment, a slit of width d is illuminated by red light of wavelength 650 nm. For what value of d will **[3]**

i. the first minimum fall is at an angle of diffraction of 30°and

ii. the first maximum fall is at an angle of diffraction of 30°?

28. A coil of cross-sectional area A lies in a uniform magnetic field B with its plane perpendicular to the field. In this position the normal to the coil makes an angle of 0° with the field. The coil rotates at a uniform rate to complete one rotation in time T. Find the average induced emf in the coil during the interval when the coil rotates: **[3]**

i. from 0° to 90°position

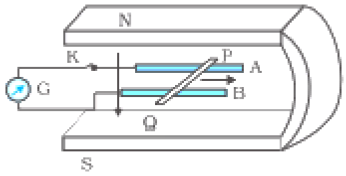
ii. from 90° to 180° position

iii. from 180° to 270° and

iv. from 270° to 360°

OR

Figure shows a metallic rod PQ of length l, resting on the smooth horizontal rails AB positioned between the poles of a permanent magnet. The rails, the rod, and the magnetic field are in three mutually perpendicular directions. A galvanometer G connects the rails through a switch K. Assume the magnetic field to be uniform. Given the resistance of the closed-loop containing the rod is R.



i. Suppose K is open and the rod is moved with a speed v in the direction shown. Find the polarity and magnitude of induced emf.

ii. With K open and the rod moving uniformly, there is no net force on the electrons in the rod PQ even though they do experience a magnetic force due to the motion of the rod. Explain.

iii. What is the induced emf in the moving rod if the magnetic field is parallel to the rails instead of being perpendicular?

Section D

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

An electromagnetic wave transports linear momentum as it travels through space. If an electromagnetic wave transfers a total energy U to a surface in time t, then total linear momentum delivered to the surface is $p = \frac{U}{c}$. When an electromagnetic wave falls on a surface, it exerts pressure on the surface. In 1903, the American scientists Nichols and Hull succeeded in measuring radiation pressures of visible light where other had failed, by making a detailed empirical analysis of the ubiquitous gas heating and ballistic effects.

(a) The pressure exerted by an electromagnetic wave of intensity I(W m^{-2}) on a non-reflecting surface is (c is the velocity of light)

a) $\frac{I}{c}$
b) $\frac{I}{c^2}$
c) Ic^2
d) Ic

(b) Light with an energy flux of 18 W/cm^2 falls on a non-reflecting surface at normal incidence. The pressure exerted on the surface is:

a) 2 N/m^2
b) 6×10^{-4} N/m^2
c) 2×10^{-4} N/m^2
d) 6 N/m^2

(c) Radiation of intensity 0.5 W m^{-2} are striking a metal plate. The pressure on the plate is

a) 0.212×10^{-8} N m^{-2}
b) 0.132×10^{-8} N m^{-2}
c) 0.166×10^{-8} N m^{-2}
d) 0.083×10^{-8} N m^{-2}

OR

The radiation pressure of the visible light is of the order of

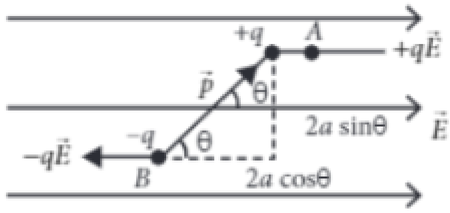
a) 10^{-4} N/m
b) 10^{-6} N/m^2
c) 10^{-8} N
d) 10^{-2} N m^2

(d) A point source of electromagnetic radiation has an average power output of 1500 W. The maximum value of electric field at a distance of 3 m from this source (in V m^{-1}) is

a) 500
b) $\frac{500}{3}$
c) $\frac{250}{3}$
d) 100

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

When electric dipole is placed in uniform electric field, its two charges experience equal and opposite forces, which cancel each other and hence net force on electric dipole in uniform electric field is zero. However these forces are not collinear, so they give rise to some torque on the dipole. Since net force on electric dipole in uniform electric field is zero. so no work is done in moving the electric dipole in uniform electric field. However some work is done in rotating the dipole against the torque acting on it.



(a) The dipole moment of a dipole in a uniform external field $\vec{E}$ is $\vec{P}$. Then the torque $\vec{\tau}$ acting on the dipole is

a) $\vec{\tau} = 2(\vec{P} + \vec{E})$
b) $\vec{\tau} = \vec{P} \cdot \vec{E}$
c) $\vec{\tau} = (\vec{P} + \vec{E})$
d) $\vec{\tau} = \vec{P} \times \vec{E}$

(b) An electric dipole consists of two opposite charges, each of magnitude 1.0 μC separated by a distance of 2.0 cm. The dipole is placed in an external field of 10^5 NC^{-1}. The maximum torque on the dipole is

a) 4×10^{-3} Nm
b) 2×10^{-3} Nm
c) 1×10^{-3} Nm
d) 0.2×10^{-3} Nm

(c) Torque on a dipole in uniform electric field is minimum when θ is equal to

a) 0^o
b) 90^o
c) 180^o
d) Both 0^o and 180^o

(d) When an electric dipole is held at an angle in a uniform electric field, the net force F and torque τ on the dipole are

a) F = 0, τ = 0
b) $F \neq 0, \tau \neq 0$
c) F $\neq$ 0, τ = 0
d) F = 0, $\tau \neq 0$

OR

An electric dipole of moment p is placed in an electric field of intensity E. The dipole acquires a position such that the axis of the dipole makes an angle θ with the direction of the field. Assuming that the potential energy of the dipole to be zero when $\theta = 90^o$, the torque and the potential energy of the dipole will respectively be

a) pE sin θ, - pE cos θ
b) pE cos θ, -pE sin θ
c) pE sin θ, 2pE cos θ
d) pE sin θ, -2pE cos θ

Section E

31. i. Draw a ray diagram showing the image formation by a compound microscope. Obtain the expression for total magnification when the image is formed at infinity. **[5]**

ii. How does the resolving power of a compound microscope get affected, when
1. focal length of the objective is decreased.
2. the wavelength of light is increased ? Give reasons to justify your answer.

OR

i. Using Huygens's construction of secondary wavelets explains how a diffraction pattern is obtained on a screen due to a narrow slit on which a monochromatic beam of light is incident normally.

ii. Show that the angular width of first diffraction fringe is half that of the central fringe.

iii. Explain why the maxima at $\theta = \left(n + \frac{1}{2}\right) \frac{\lambda}{a}$ become weaker and weaker with increasing n.

32. Two charged conducting spheres of radii a and b are connected to each other by a wire. What is the ratio of electric fields at the surfaces of the two spheres? Use the result obtained to explain why charge density on the sharp and pointed ends of a conductor is higher than on its flatter portions. **[5]**

OR

Two parallel metal plates P and Q are inserted at equal distances into a plane capacitor as shown in fig. Plates A and B of the capacitor are connected to a battery of e.m.f. V.

a. What are the potentials of the four plates?

b. How will the potentials of plates P and Q and the intensities of the fields in each of the three spaces change after plates P and Q have been connected by a wire?

c. What will happen to the charges on plates A and B, when plates P and Q are connected with a wire?

d. Will there be charges on the plates P and Q after connecting them with a wire?

33. i. An alternating voltage $V = V_m \sin \omega t$ applied to a series L-C-R circuit derives a current given by $I = I_m \sin(\omega t + \phi)$. Deduce an expression for the average power dissipated over a cycle. **[5]**

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

OR

a. Draw graphs showing the variations of inductive reactance and capacitive reactance with the frequency of the applied ac source.

b. Draw the phasor diagram for a series RC circuit connected to an ac source.

c. An alternating voltage of 220 V is applied across a device X, a current of 0.25 A flows, which lag behind the applied voltage in phase by $\frac{\pi}{2}$ radian. If the same voltage is applied across another device Y, the same current flows but now it is in phase with the applied voltage.

i. Name the devices X and Y.

ii. Calculate the current flowing in the circuit when the same voltage is applied across the series combination of X and Y.

Solution

Section A

1.

(c) 25 mA

Explanation: The given diode is ideal and forward-biased so there is short circuit. No current flow through the 20 Ω and whole current flow through the short circuit. The current flow through the circuit is, I = $\frac{2V}{80\Omega}$ = 25 mA

2.

(b) Mobility

Explanation: The charge carrier in most metals is the negatively charged electron. The mobility of the charge carrier is defined as the drift velocity of the charge carrier per unit electric field. It is denoted by μ and$\mu = v_d/E$ is given as. The Sl unit of μ is m2V-1s-1.

3.

(d) red colour.

Explanation: For a glass prism, the angle of minimum deviation will be smallest for the light of red color.

As wavelength of red color is maximum among all, hence, $\mu \propto \frac{1}{\lambda}$, hence $\mu$is smaller. As μ decreases, angle of deviation decreases.

4. **(a)** 20 cm

Explanation: $\tau = q_m \times 2l \times B\sin\theta$

$\therefore$ 2l = $\frac{\tau}{q_m \times B\sin\theta}$

= $\frac{80\times10^{-7}}{2\times4\times10^{-5}\times\sin30^\circ}$ = 0.20 m = 20 cm

5.

(c) 1 keV

Explanation: K.E. gained = qV = e × 1 kV = 1 keV

6.

(d) $e\left(v_x B_y + v_y B_x\right)\hat{k}$

Explanation: $e\left(v_x B_y + v_y B_x\right)\hat{k}$

The force is given as -e (v×B).

7. **(a)** there is a constant current in the counterclockwise direction in A.

Explanation: there is a constant current in the counterclockwise direction in A.

8.

(d) 6 J

Explanation: W = $mB\left(\cos\theta_1 - \cos\theta_2\right)$

= 2 × 10^4 × 6 × 10^{-4} (cos 0° - cos 60°) = 6J

9.

(b) 0

Explanation: Wavefront is the locus of all points those are in same phase.

10.

(c) +1.6 C

Explanation: q = ne = 10^{19} × 1.6 × 10^{-19} C = +1.6 C

11.

(c) p-type semiconductor

Explanation: One can see in the figure that number of holes are greater than number of electrons. Hence it is p−type semi conductor.

12. **(a)** 4f

Explanation: 4f

13.

(c) A is true but R is false.

Explanation: We know that

$eV_0=K_{max}=h\nu-\phi$

where ϕ is the work function.

Hence, as ν increases (note that the frequency of X-rays is greater than that of U.V. rays), both V_0 and K_{max} increase.

So, A is true but R is false.

14.

(d) A is false and R is also false

Explanation: A is false and R is also false

15.

(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.

16.

(c) A is true but R is false.

Explanation: Faraday's laws of electromagnetic induction are consequences of the conservation of energy. It involves only the transformation of energy into electrical energy. In a purely resistive circuit, current and voltage are in the same phase.

Section B

17. i. Radiation re-radiated by earth has greater wavelength

ii. Tanning effect is significant for direct UV radiation due to high intensity ; but it is negligible for radiation coming through the glass.

18. Dipole moment of each atomic dipole,

$m = 1.5 \times 10^{-23}\ JT^{-1}$

Total number of atomic dipoles, $N = 2.0 \times 10^{24}$

Initial total magnetic moment at temperature $T_1 = 4.2$ K is

$M_1 = 15\%$ of mN

$= \frac{15}{100} \times 1.5 \times 10^{-23} \times 2.0 \times 10^{24}\ JT^{-1} = 4.5\ JT^{-1}$

According to Curie's law,

$M = \text{ Constant } \times \frac{B}{T}$

$\therefore \frac{M_2}{M_1} = \frac{B_2}{B_1} \times \frac{T_1}{T_2}$

Now $B_1 = 0.84$ T, $T_1 = 4.2$ K, $B_2 = 0.98$ T, $T_2 = 2.8$ K

Hence the final dipole moment at temperature $T_2 = 2.8$ K is

$M_2 = M_1 \times \frac{B_2}{B_1} \times \frac{T_1}{T_2} = 4.5 \times \frac{0.98}{0.84} \times \frac{4.2}{2.8} JT^{-1}$

$= 7.9\ JT^{-1}$

19. **Intrinsic semiconductors:** are pure semiconductors while extrinsic semiconductors are doped with either trivalent or pentavalent impurities.

Extrinsic semiconductor: maintains an overall charge neutrality as the charge of additional charge carriers is just equal and opposite to that of the ionised cores in the lattice.

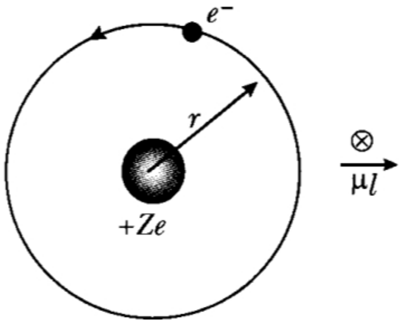
20. A source of hydrogen spectrum has billions of hydrogen atoms. Each hydrogen atom has many stationary states. All possible transitions can occur from any higher level to any lower level. This gives rise to a large number of spectral lines.

21. a. If field lines were extremely confined between two ends of a straight solenoid, the flux through the cross section at each end would be non zero. But the flux of field B through any closed surface must always be zero, For a toroid this difficulty is absent.

b. No, there is no force on torque on an element due to the field produced by that element itself.

c. $I = \frac{e}{T}, T = \frac{2\pi r}{v}$

$I = \frac{ev}{2\pi r}, \mu = I\pi r^2 = \frac{evr}{2}$



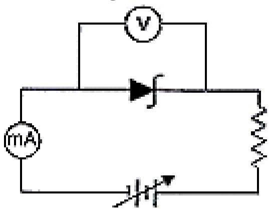
OR

a. It will not measure accurate value of current because its high resistance will affect the current in the circuit.
b. To reduce the galvanometer resistance a small resistance is connected in parallel.
c. It is less than the actual value of current because it has some resistance which consume some energy and hence the reading shown by an ammeter in a circuit less than the actual value of current flowing in the circuit.

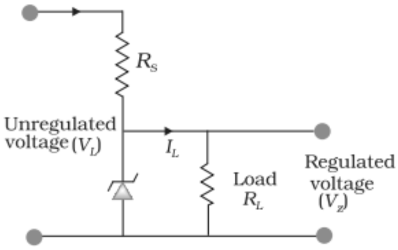
Section C

22. a. $\mu = \frac{V_d}{E}$
b. $V_d = \frac{e\tau E}{m} = \frac{e\tau V}{ml}$
$\frac{V_{d1}}{V_{d2}} = \frac{l_2}{l_1} = \frac{3}{2}$
Hence, the ratio of drift velocities of the electrons in the two wires is 3:2

23. i. The semiconductor diode whose V-I characteristic is shown in figure is Zener diode.
ii. Circuit diagram to obtain the given characteristic is shown in figure.



iii. The circuit of Zener diode used as voltage regulator is shown in figure.



The unregulated dc voltage (filtered output of a rectifier) is connected to the Zener diode through a series resistance R_s such that the Zener diode is reverse biased.
If the input voltage increases, the current through R_s and Zener diode also increases. This increases the voltage drop across R_s without any change in the voltage across the Zener diode. This is because in the breakdown region, Zener voltage remains constant even though the current through the Zener diode changes. Similarly, if the input voltage decreases, the current through R_s and Zener diode also decreases. The voltage drop across R_s decreases without any change in the voltage across the Zener diode. Thus any increase/decrease in the input voltage results in, increase/decrease of the voltage drop across R_s without any change in voltage across the Zener diode. Thus the Zener diode acts as a voltage regulator.

24. The basic features of the photon picture of e.m. radiation are as follows:
i. Light is composed of discrete packets of energy called quanta or photons.
ii. Each photon carries an energy E $(= h\nu)$ and momentum p (= h / λ), which depend on the frequency ν of the incident radiation and not on its intensity.
iii. During the collision of a photon with an electron, the total energy of the photon gets absorbed by the electron.
iv. Photoelectric emission from the metal surface occurs due to the absorption of a photon by an electron.

25. a. Mass of hydrogen, m = 1kg = 1000 g
Since 1 mole of hydrogen contains 6.023×10^{23} atoms which are equivalent to 1g of hydrogen then, 1kg of hydrogen contains,

N = 6.023 × 10^{23} × 1000 = 6.023 × 10^{26} atoms

In sun, 4 hydrogen atoms, ${}_1^1\mathrm{H}$ combine to form one helium atom, ${}_2^4\mathrm{He}$ in fusion process which releases 26 MeV of energy.

Thus,

The energy released from the fusion of 1kg of hydrogen is,

$E = \frac{N}{4} \times 26 = \frac{6.023 \times 10^{23}}{4} \times 26 \times 10^3 \mathrm{MeV}$ ...(1)

$= \frac{156.598 \times 10^{26}}{4} \mathrm{MeV} = 39.1495 \times 10^{26}$ MeV

b. Mass of uranium, m = 1kg = 1000 g

Since 1 mole of Uranium contains 6.023 × 10^{23} atoms which are equivalent to 235 g of Uranium then, 1kg of Uranium contains,

N = $\frac{1000}{235}$ × 6.023 × 10^{23} = 25.63 × 10^{23}

During fission reaction of 1 atom of ${}_{92}^{235}U$ releases 200 MeV of energy.

Thus,

The energy released from fission of 1kg of Uranium is,

E = N × 200 = 25.63 × 10^{23} × 200 MeV = 5.106 × 10^{26} MeV ...(2)

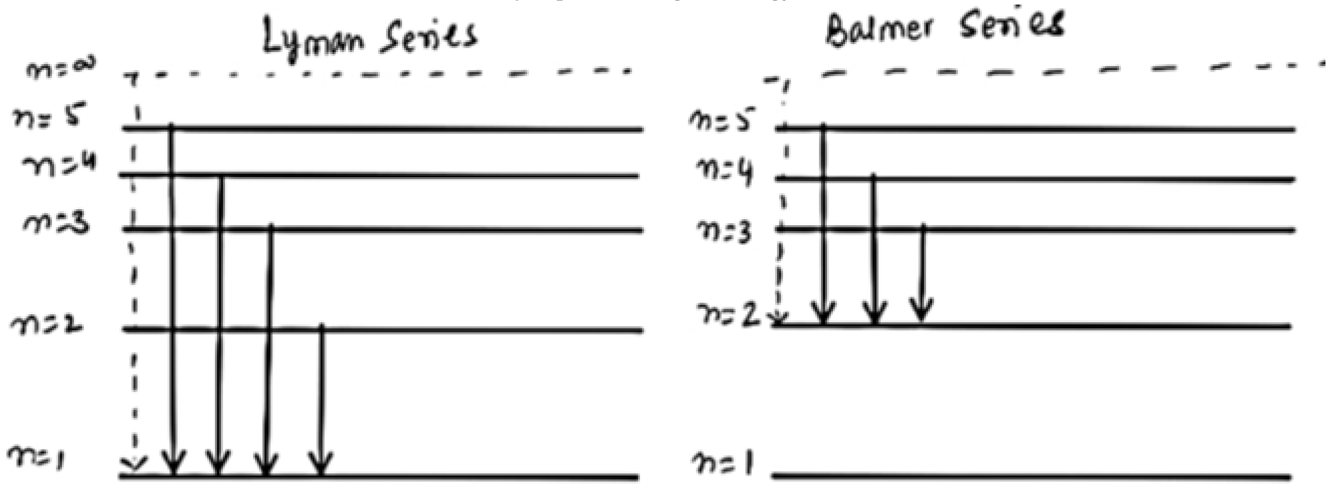
Divide (1) by (2) we get,

$x = \frac{39.1495 \times 10^{26}}{5.106 \times 10^{26}} = 7.67 \approx 8$

Hence, the energy released in fusion is 8 times the energy released in fission.

26. a. Transition result in Lyman series if electron will jump from a higher energy orbit to n = 1 orbit

Transition result in Balmer series if electron will jump from a higher energy orbit to n = 2 orbit



b. Longest wavelength in Lyman Series

$\frac{1}{\lambda_L} = R \cdot \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}$

Shorted wavelength in Balmer Series

$\frac{1}{\lambda_S} = R\left[\frac{1}{{n_1}^2} - \frac{1}{n_2^2}\right] = R\left[\frac{1}{2^2} - \frac{1}{\infty}\right] = \frac{R}{4}$

Ratio $\frac{\lambda_2}{\lambda_S} = \frac{4}{3R} \times \frac{R}{4} = \frac{1}{3}$

27. i. In single slit diffraction pattern, first minimum occurs at $d \sin\theta = \lambda$ [θ and λ are diffraction angle and wavelength of the light used]

$\therefore$ Slit width, $d = \frac{\lambda}{\sin\theta}$ ....(a)

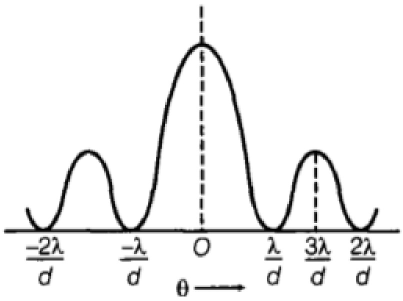
Given, $\lambda = 650 \times 10^{-9} \mathrm{m}\ and\ \theta = 30^\circ$

Now from equation (a) we get slit width, $d = \frac{650 \times 10^{-9}}{\sin 30^\circ} = \frac{650}{(1/2)} \times 10^{-9}$

$= 1300 \times 10^{-9}$ m

$\therefore d = 1.3 \times 10^{-6} \mathrm{m} = 1.3\ \mu m$

ii. In single slit diffraction pattern, maximum and minima occurs as per the below diagram -



Now for first maximum,

$d\sin\theta = \frac{3\lambda}{2}\left[using,\ d\sin\theta = (2n+1)\frac{\lambda}{2}\right]$

where, n = 1(for first maximum)

$\Rightarrow \quad d = \frac{3\lambda}{2\sin\theta}$

where, $\theta = 30^\circ, \lambda = 650 \times 10^{-9}\text{m}$

$\therefore d = \frac{3\lambda}{2\sin\theta}$

$= \frac{3\times650\times10^{-9}}{2\times\sin30^\circ}$

$= 1950 \times 10^{-9}\text{m}$

$\therefore d = 1.95 \times 10^{-6}\text{m} = 1.95\ \mu m$

28. i. For rotation from 0^o to 90^o

ϕ_1 = BA cos 0^o = BA, ϕ_2 = BA cos 90^o = 0, t = $\frac{T}{4}$

$\therefore$ Average induced emf,

$\varepsilon = -\frac{\phi_2-\phi_1}{t} = -\frac{0-BA}{T/4} = \frac{4BA}{T}$.

ii. For rotation from 90^o to 180^o

ϕ_1 = BA cos 90^o = 0, ϕ_2 = BA cos 180^o = -BA, t = $\frac{T}{4}$

$\therefore \varepsilon = -\frac{-BA-0}{T/4} = \frac{4BA}{T}$

iii. For rotation from 180^o to 270^o

ϕ_1 = BA cos180^o = -BA, ϕ_2 = BA cos 270^o = 0, t = $\frac{T}{4}$

$\therefore \varepsilon = -\frac{0+BA}{T/4} = -\frac{4BA}{T}$

iv. For rotation from 270^o + 360^o

ϕ_1 = BA cos 270^o = 0, ϕ_2 = BA cos 360^o = BA, t = $\frac{T}{4}$

$\therefore \varepsilon = -\frac{BA-0}{T/4} = -\frac{4BA}{T}$

As the sense of the induced emf in the second half rotation is opposite to that in the first half rotation, the induced current will change its direction after first-half rotation.

OR

i. e = Bvl

P is a positive end

Q is a negative end

ii. Magnetic force is cancelled by the electric force set-up due to the excess charge of opposite nature at both ends of the rod.

There is no net force on the electrons in rod PQ when key K is open and the rod is moving uniformly. This is because the magnetic force is cancelled by the electric force set-up due to the excess charge of opposite nature at both ends of the rods.

iii. Induced emf is zero as a motion of rod not cutting field lines.

In this case, no emf is induced in the coil because the motion of the rod does not cut across the field lines. Or when the permanent magnet is rotated in vertical position the field becomes parallel to rails. The motion of the rod will not cut across the lines of the field. so no emf is produced.

Section D

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

An electromagnetic wave transports linear momentum as it travels through space. If an electromagnetic wave transfers a total energy U to a surface in time t, then total linear momentum delivered to the surface is p = $\frac{U}{c}$. When an electromagnetic wave falls on a surface, it exerts pressure on the surface. In 1903, the American scientists Nichols and Hull succeeded in measuring radiation pressures of visible light where other had failed, by making a detailed empirical analysis of the ubiquitous gas heating and ballistic effects.

(i) **(a)** $\frac{I}{c}$

Explanation: Pressure exerted by an electromagnetic radiation, $P = \frac{I}{c}$

(ii) **(b)** 6×10^{-4} N/m^2

Explanation: $P_{\text{rad}} = \frac{\text{Energy flux}}{\text{Speed of light}} = \frac{18 \text{ W/cm}^2}{3 \times 10^8 \text{ m/s}}$

$= \frac{18 \times 10^4 \text{ W/m}^2}{3 \times 10^8 \text{ m/s}} = 6 \times 10^{-4}$ N/m^2

(iii) **(c)** 0.166×10^{-8} N m^{-2}

Explanation: $P = \frac{I}{c} = \frac{0.5}{3 \times 10^8} = 0.166 \times 10^{-8}$ N m^{-2}

OR

(b) 10^{-6} N/m^2

Explanation: The radiation pressure of visible light

$= 7 \times 10^{-6}$ N/m^2

(iv) **(d)** 100

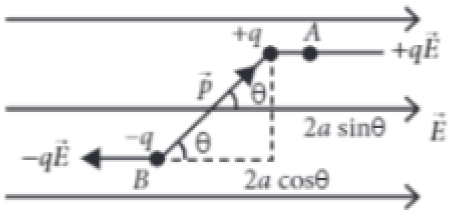
Explanation: Intensity of EM wave is given by $I = \frac{P}{4\pi R^2}$ $V_{av} = \frac{1}{2}\varepsilon_0 E_0^2 \times c$

$\Rightarrow E_0 = \sqrt{\frac{P}{2\pi R^2 \varepsilon_0 c}} = \sqrt{\frac{1500}{2 \times 3.14(3)^2 \times 8.85 \times 10^{-12} \times 3 \times 10^8}}$

$= \sqrt{10,000} = 100$ V m^{-1}

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

When electric dipole is placed in uniform electric field, its two charges experience equal and opposite forces, which cancel each other and hence net force on electric dipole in uniform electric field is zero. However these forces are not collinear, so they give rise to some torque on the dipole. Since net force on electric dipole in uniform electric field is zero. so no work is done in moving the electric dipole in uniform electric field. However some work is done in rotating the dipole against the torque acting on it.



(i) **(d)** $\vec{\tau} = \vec{P} \times \vec{E}$

Explanation: As τ = either force $\times$ perpendicular distance between the two forces

= qaE sin θ or τ = PE sin θ

or $\vec{P} \times \vec{E}$ ($\because$ qa = P)

(ii) **(b)** 2×10^{-3} Nm

Explanation: The maximum torque on the dipole in an external field is given by

τ = pE = q(2a) $\times$ E

Here, q = $1\mu\text{C} = 10^{-6}\text{C}$, 2a = 2 cm = 2×10^{-2} m, E = 10^5 NC^{-1}, τ = ?

$\therefore \tau = 10^{-6} \times 2 \times 10^{-2} \times 10^5 = 2 \times 10^{-3}$ Nm

(iii) **(d)** Both 0^o and 180^o

Explanation: When θ is 0 or 180^o, the τ is minimum, which means the dipole moment should be parallel to the direction of the uniform electric field.

(iv) **(d)** F = 0, $\tau \neq 0$

Explanation: Net force is zero and torque acts on the dipole, trying to align p with E.

OR

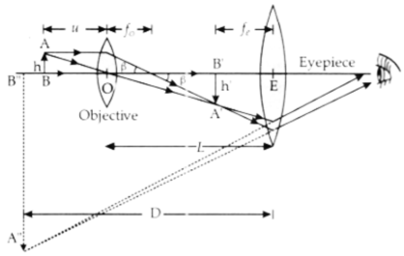
(a) pE sin θ, - pE cos θ

Explanation: Torque, τ = pE sin θ and potential energy

U = -pE cos θ

Section E

31. i. The ray diagram, showing image formation by a compound microscope, is given below ;-



ii. Linear Magnification due to objective lens is given by $= \frac{\tan\beta}{\tan\alpha}$

$\tan\beta = \frac{h'}{L} = \frac{h}{f_o}$

$\frac{h'}{h} = \frac{L}{f_0}$

(where the distance between the second focal point of the objective and the first focal point of the eyepiece is called the tube length of the compound microscope and is denoted by L) The eyepiece will act as a simple microscope, hence we may use the formula of magnification by a simple microscope for normal adjustment.

$m_e = \frac{D}{f_e}$

Total magnification, m = $m_o \times m_e$

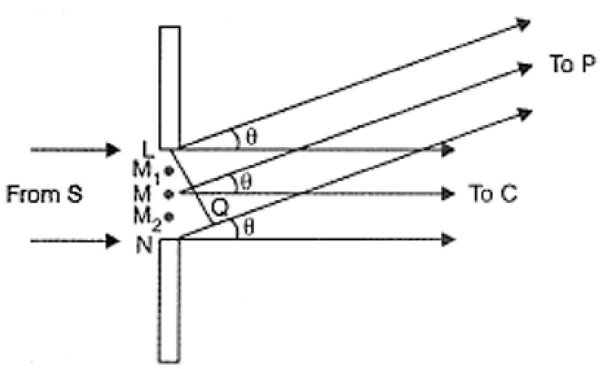
$= \frac{L}{f_o} \times \frac{D}{f_e} d_{\min}$

a. From the equation, it is clear that resolving power increases when the focal length of the objective is decreased. This is because the minimum separation, d_{min} decreases when f is decreased.

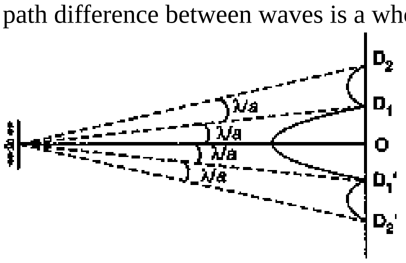
b. Resolving power decreases when the wavelength of light is increased. This is because the minimum separation, d_{min} increases when λ is increased.

OR

i. We can regard the total contributions of the wavefront LN at some point P on the screen, as the resultant effect of the superposition of its wavelets like LM, MM_2, M_2N. These have to be superposed taking into account their proper phase differences.



We, therefore, get maxima and minima, i.e., a diffraction pattern, on the screen. **Maxima and minima** are produced when the path difference between waves is a whole number of wavelengths or an odd number of half wavelengths respectively.

ii. 

Conditions for first minima on the screen

asin $\theta = \lambda$

$\Rightarrow \quad \theta = \frac{\lambda}{a}$

$\therefore$ Angular width of the central fringe on the screen (from the figure)

$= 2\theta = \frac{2\lambda}{a}$

Angular width of first diffraction fringe (From fig)

$= \frac{\lambda}{a}$

For the first diffraction, the angular width of the fringe is half that of the central fringe.

iii. Maxima becomes weaker and weaker with increasing n. This is because the effective part of the wavefront, contributing to the maxima becomes smaller and smaller, with increasing n.

32. Suppose that two connected conducting spheres of radii a and b possess charges $q_1$and q_2 respectively. On the surface of the two spheres, the potential will be

$V_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{a}$

$V_2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{b}$

Till the potentials of two conductors become equal, the flow of charges continues.

Thus, $V_1 = V_2$

$\frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{a} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{b}$

$\frac{q_1}{q_2} = \frac{a}{b}$

Now, the electric field on the two spheres is given as

$E_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{a^2}$

$E_2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{b^2}$

or $\frac{E_1}{E_2} = \frac{q_1}{q_2} \cdot \frac{b^2}{a^2} = \frac{a}{b} \cdot \frac{b^2}{a^2} = \frac{b}{a}$

Therefore, b : a is the ratio of the electric field of the first sphere to that of the second sphere.

The surface charge densities of the two spheres are given as

$\sigma_1 = \frac{q_1}{4\pi a^2}$ (As the charges are distributed uniformly over the surfaces of conducting spheres)

$\sigma_2 = \frac{q_2}{4\pi b^2}$

$\therefore \frac{\sigma_1}{\sigma_2} = \frac{q_1}{q_2} \cdot \frac{b^2}{a^2} = \frac{a}{b} \cdot \frac{b^2}{a^2} = \frac{b}{a}$

Therefore, the surface charge densities are inversely related with the radii of the sphere. The surface charge density on the sharp and pointed ends of a conductor is higher than on its flatter portion since a flat portion may be taken as a spherical surface of large radius and a pointed portion as that of small radius.

OR

a. The plates P and Q divide the space between the plates A and B in three equal parts. Since V = Ed, the potentials of the plates A, P, Q, and B will be respectively V, 2V/3, V/3 and 0.

b. When the plates P and Q are connected with a wire, the space between the plates A and B gets divided into two equal parts. Hence, the potentials of plates A, P, Q, and B will be respectively V, V/2, V/2 and 0.

Since the potential difference between the plates A and P; and between the plates, Q and B have increased from V/3 to V/2, the electric field between these plates will increase. As the potential difference the plates P and Q is zero, the electric field will also be zero.

c. Since the potential difference between the plates A and P and between the plates Q and B have increased, the charge on the plates A and B will increase.

d. Yes, the plate P will have a positive charge and the plate Q will have a negative charge.

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

$V = V_m \sin \omega t$ and

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

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

The instantaneous power is given by

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

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

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

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

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

$dW = Pdt$

$\Rightarrow dW = VIdt$

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

$W = \int_0^T VIdt$

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

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

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

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

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

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

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

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

This is the required expression.

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

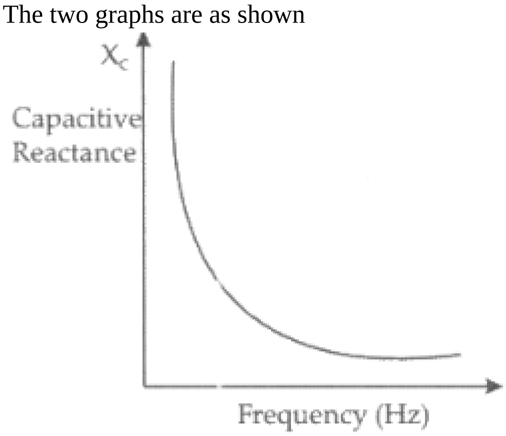
where, R = resistance and Z = impedance of the circuit.

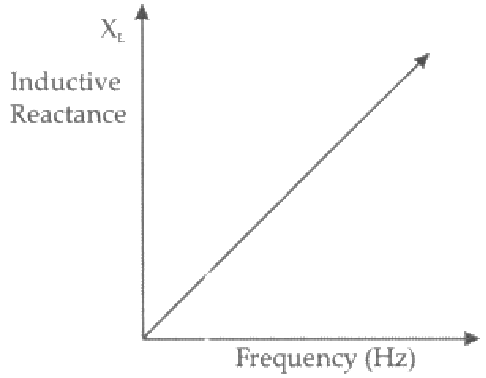
Low power factor ($\cos\phi$) implies lower ohmic resistance which implies larger power loss in power system (transmission line), because in power system power, P $\propto \frac{1}{R}$.

OR

a. Drawing the two graphs the graph shows the variation of capacitive resistance with frequency and inductive resistance with frequency.

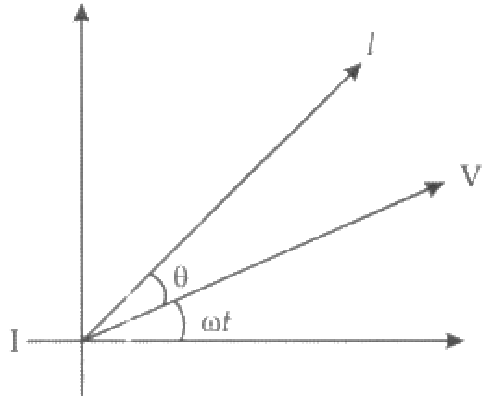
The two graphs are as shown





b. Drawing the phaser diagram

(the current leads the voltage by an angle θ where $0 < \theta < \frac{\pi}{2}$) . The required phaser diagram is as shown.



[Here, $\theta = \tan^{-1}\left[\frac{1}{\omega CR}\right]$

c.

i. In device X:

Current lags behind the voltage by $\frac{\pi}{2}$

$\therefore$ X is an inductor.

In device Y:

Current in phase with the applied voltage.

$\therefore$ Y is resistor.

ii. We are given that

$0.25 = \frac{220}{X_L}$

or $X_L = \frac{220}{0.25}\Omega = 880\ \Omega$

Also $0.25 = \frac{220}{X_R}$

$\therefore X_R = \frac{220}{0.25}\Omega = 880\ \Omega$

For the series combination of X and Y,

Equivalent impedance = $\sqrt{X_L^2 + X_R^2} = (880\sqrt{2})\Omega$

$\therefore$ Current flowing $\frac{220}{880\sqrt{2}}$ A = 0.177 A