Class XII Session 2026-27
Subject - Physics
Sample Question Paper - 10

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. To produce n-type crystal, Ge or Si may be doped with a substance that is **[1]**

   a) pentavalent b) tetravalent

   c) trivalent d) divalent

2. A n-type silicon sample of width $4 \times 10^{-3}\ m$, thickness $25 \times 10^{-5}\ m$ and length $6 \times 10^{-2}\ m$ carries a current of 4.8 mA when the voltage is applied across the length of the sample. If the free electron density is $10^{22}\ m^{-3}$, then how much time does it take for the electrons to travel the full length of the sample? Given that charge on an electron $e = 1.6 \times 10^{-19} C$. **[1]**

   a) 0.03 s b) 0.02 s

   c) 0.04 s d) 0.01 s

3. When a wave undergoes reflection at an interface from rarer to denser medium, change in its phase is: **[1]**

   a) $\frac{\pi}{2}$ b) $\frac{\pi}{4}$

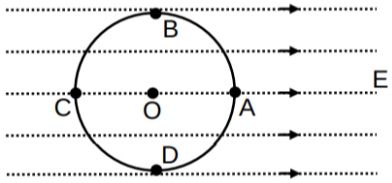
   c) 0 d) π

4. An iron needle is kept near a strong bar magnet. It will experience **[1]**

a) neither a force nor a torque.
b) a torque and no force.
c) a force of attraction and a torque.
d) a force of attraction and no torque.

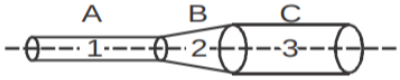
5. The electric field in a region surrounding the origin is uniform and along the x axis. A small circle is drawn with the centre at the origin cutting the axis at points A, B, C and D having coordinates $(a, 0), (0, a), (-a, 0)$ and (0, -a), respectively, as shown in figure. **[1]**

Then the potential is minimum at:



a) A
b) B
c) D
d) C

6. A long, straight, hollow conductor (tube) carrying a current has two sections A and C of unequal cross-section joined by a conical section B. 1, 2 and 3 are points on a line parallel to the axis of the conductor at certain distance. The magnetic fields at 1,2 and 3 have magnitudes B_1, B_2 and B_3: **[1]**



a) $B_1 < B_2 < B_3$
b) $B_1 = B_2 \neq B_3$
c) $B_1 = B_2 = B_3$
d) B_2 cannot be found unless the dimensions of the section B are known

7. If N is the number of turns in a coil, the value of self-inductance varies as **[1]**

a) N
b) N^2
c) N^{-2}
d) N^0

8. The magnetic susceptibility for a diamagnetic material is **[1]**

a) small and positive
b) large and positive
c) small and negative
d) large and negative

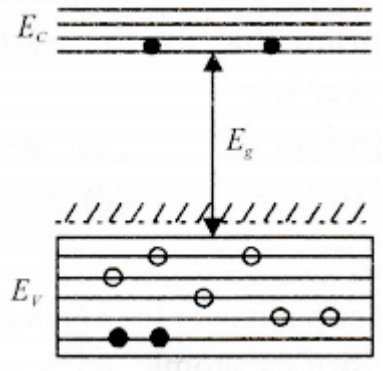
9. The optical path difference is defined as $\Delta x = \frac{2\pi}{\lambda}$. What are the dimensions of the optical path difference? **[1]**

a) $[ML^0T^2]$
b) $[ML^{-2}T]$
c) $[M^1L^{-1}T^0]$
d) $M^0L^{-1}T^0$

10. What is the flux through a cube of side a if a point charge q is at one of its corners? **[1]**

a) $\frac{2q}{\varepsilon_0}$
b) $\frac{q}{2\varepsilon_0}$
c) $\frac{q}{8\varepsilon_0}$
d) $\frac{q}{\varepsilon_0}$

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) p-type semiconductor
c) n-type semiconductor
d) metal

12. Which of the following principle is used in optical fibre? **[1]**

a) Interference
b) Diffraction
c) Total internal reflection
d) Scattering

13. **Assertion (A):** Though the light of a single frequency (monochromatic) is incident on metal, the energies of emitted photoelectrons are different. **[1]**
Reason (R): The energy of electrons emitted from inside the metal surface is lost in a collision with the other atoms in the metal.

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:** Lines of force are perpendicular to the conductor surface. **[1]**
Reason: The general electric field is perpendicular to the equipotential surface.

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):** Wavefront emitted by a point source of light in an isotropic medium is spherical. **[1]**
Reason (R): Isotropic medium has same refractive index in all directions.

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):** Capacitor serves as a block for dc and offers an easy path to ac. **[1]**
Reason (R): Capacitive reactance is inversely proportional to frequency.

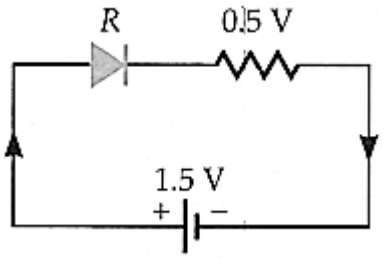
a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false. d) A is false but R is true.

Section B

17. Find the wavelength of the electromagnetic waves of frequency 4×10^9 Hz in free space. Give its two applications. **[2]**

18. A p-n junction diode when forward biased has a drop of 0.5 V which is assumed to be independent of the current. The current in excess of 10 mA through the diode produces a large Joule heating which damages (burns) the diode. If we want to use a 1.5 V battery to forward bias the diode, what should be the value of the resistor used in series with the diode so that the maximum current does not exceed 5 mA? **[2]**



19. The energy of an electron in an orbit of Bohr hydrogen atom is -3.4 eV. Find its angular momentum. **[2]**

20. A straight solenoid of length 50 cm has 1000 turns and a mean cross-sectional area of 2×10^{-4} m^2. It is placed with its axis at 30°, with a uniform magnetic field of 0.32 T. Find the torque acting on the solenoid when a current of 2A is passed through it. **[2]**

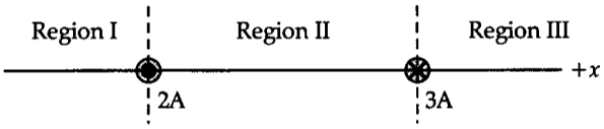
OR

An iron ring having 500 turns of wire and a mean diameter of 12 cm carries a current of 0.3 A. The relative permeability of iron is 600. What is the magnetic flux density in the core? What is the magnetisation field intensity? What part of the flux density is due to the electronic loop currents in the core?

21. An electric charge moving in a direction making an angle $\theta(\neq 90^o)$ with the direction of magnetic field follows a helical path. Why? **[2]**

OR

Two straight infinitely long wires are fixed in space so that the current in the left wire is 2 A and directed out of the plane of the page and the current in the right wire is 3 A and directed into the plane of the page. In which region(s) is/are there a point on the x-axis, at which the magnetic field is equal to zero due to these currents carrying wires? Justify your answer.



Section C

22. Distinguish between emf (ε) and terminal voltage (V) of a cell having internal resistance r. Draw a plot showing the variation of terminal voltage (V) versus the current (I) drawn from the cell. Using this plot, show how does one can determine the internal resistance of the cell? **[3]**

23. Ultra-violet light of wavelength 200 nm from a source is incident on a metal surface. If the stopping potential is -2.5 V, **[3]**

a. Calculate the work function of the metal, and

b. How would the surface respond to a high intensity red light of wavelength 6328 A produced by a laser?

24. With the help of a suitable diagram, describe briefly the two important processes involved in the formation of a p-n junction. Define the terms depletion region and potential barrier. **[3]**

25. Define the terms (i) mass defect (ii) binding energy for a nucleus and state the relation between the two for a given nuclear reaction for which the B.E. / nucleon of the product nucleus/nuclei is more than that for the original nucleus/nuclei. Is this nuclear reaction exothermic or endothermic in nature? Justify your choice. **[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. Define the term mutual inductance between the two coils. Obtain the expression for mutual inductance of a pair of long co-axial solenoids each of length l and radii r_1 and r_2 ($r_2 > > r_1$). The total number of turns in the two solenoids are N_1 and N_2 respectively. **[3]**

OR

i. Define the term self-inductance and write its S.I. unit.

ii. Obtain the expression for the mutual inductance of two long co-axial solenoids S_1 and S_2 wound one over the other, each of length L and radii r_1 and r_2 and n_1 and n_2 number of turns per unit length, when a current I is set up in the outer solenoid S_2.

28. Explain how Newton's Corpuscular theory predicts the speed of light in a medium, say water, to be greater than the speed of light in vacuum. Is the prediction confirmed by the experimental determination of speed of light in water? If not, which alternative picture of light is consistent with experiment? **[3]**

Section D

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

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

(a) Which wavelength of the Sun is used finally as electric energy?
radio waves, infrared waves, visible light, microwaves

a) infrared waves b) radio waves

c) microwaves d) visible light

(b) Which of the following electromagnetic radiations have the longest

wavelength?

X-rays, γ-rays, microwaves, radiowaves

a) γ-rays b) X-rays

c) microwaves d) radiowaves

(c) Which one of the following is not electromagnetic in nature?

X-rays, gamma rays, cathode rays, infrared rays

a) infrared rays b) gamma rays

c) cathode rays d) X-rays

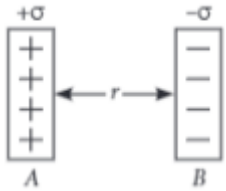
(d) Which of the following has minimum wavelength?

X-rays, ultraviolet rays, γ-rays, cosmic rays

a) ultraviolet rays b) X-rays

c) cosmic rays d) γ-rays

30. Surface charge density is defined as charge per unit surface area of surface charge distribution. i.e., $\sigma = \frac{dq}{dS}$. Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs having magnitude of 17.0×10^{-22} Cm^{-2} as shown. The intensity of electric field at a point is $E = \frac{\sigma}{\varepsilon_0}$, where ε_0 = permittivity of free space. **[4]**



i. What is E in the outer region of the first plate? (2)

ii. What is E in the outer region of the second plate? (1)

iii. What is E between the plates? (1)

Section E

31. i. A coin is placed inside a denser medium. Why does it appear to be raised? Obtain an expression for the height through which the object appears to be raised in terms of refractive index of the medium and real depth. **[5]**

ii. A compound microscope consists of an objective lens of focal length 2 cm and an eyepiece of focal length 6.25 cm separated by a distance of 15 cm. How far from the objective should an object be placed in order to obtain the final image at the least distance of distinct vision (25 cm)? Calculate the magnifying power of the microscope.

OR

i. Describe briefly how a diffraction pattern is obtained on a screen due to a single narrow slit illuminated by a monochromatic source of light. Hence, obtain the conditions for the angular width of secondary maxima and secondary minima.

ii. Two wavelengths of sodium light of 590 nm and 596 nm are used in turn to study the diffraction taking place at a single slit of aperture $2 \times 10^{-6} m$. The distance

between the slit and the screen is 1.5m. Calculate the separation between the positions of first maxima of the diffraction pattern obtained in the two cases.

32. a. Derive the expression for the electric potential due to an electric dipole at a point on its axial line. **[5]**

b. Depict the equipotential surfaces due to an electric dipole.

OR

i. Derive an expression for potential energy of an electric dipole $\vec{p}$ in an external uniform electric field $\vec{E}$. When is the potential energy of the dipole (1) maximum, and (2) minimum?

ii. An electric dipole consists of point charges -1.0 pC and +1.0 pC located at $(0, 0)$ and (3 mm, 4 mm) respectively in x - y plane. An electric field $\vec{E} = \left(\frac{1000V}{m}\right)\hat{i}$ is switched on in the region. Find the torque $\vec{\tau}$ acting on the dipole.

33. i. Draw a labelled diagram of a step-up transformer and describe its working principle. Explain any three causes for energy losses in a real transformer. **[5]**

ii. A step-up transformer converts a low voltage into high voltage. Does it violate the principle of conservation of energy? Explain.

iii. A step-up transformer has 200 and 3000 turns in its primary and secondary coils respectively. The input voltage given to the primary coil is 90 V. Calculate:

1. The output voltage across the secondary coil
2. The current in the primary coil if the current in the secondary coil is 2.0 A.

OR

i. Write the function of a transformer. State its principle of working with the help of a diagram. Mention various energy losses in this device.

ii. The primary coil of an ideal step-up transformer has 100 turns and transformation ratio is also 100. The input voltage and power are respectively 220 V and 1100 W. Calculate

a. number of turns in secondary
b. current in primary
c. voltage across secondary
d. current in secondary
e. power in secondary

Solution

Section A

1. **(a)** pentavalent
   Explanation:
   When a pentavalent impurity, such as arsenic or antimony or phosphorus is added to a pure semiconductor, the number of free electrons become more than the holes in the semiconductor and such an extrinsic semiconductor is called n-type semiconductor.

2. **(b)** 0.02 s
   Explanation:
   To find the time it takes for electrons to travel the full length of the n-type silicon sample, we first need to calculate the drift velocity of the electrons. The drift velocity v_d can be determined using the formula: $I = n \cdot A \cdot e \cdot v_d$ where: - I is the current (4.8 mA or 4.8×10^{-3} A), - n is the free electron density ($10^{22}\, m^{-3}$), - A is the cross-sectional area of the sample, - e is the charge of an electron ($1.6 \times 10^{-19}\, C$), - v_d is the drift velocity.
   First, we calculate the cross-sectional area A:
   $A = \text{width} \times \text{thickness} = (4 \times 10^{-3}\, m) \times (25 \times 10^{-5}\, m) = 1 \times 10^{-7}\, m^2$
   Now, substituting the values into the current formula:
   $4.8 \times 10^{-3} = (10^{22}) \cdot (1 \times 10^{-7}) \cdot (1.6 \times 10^{-19}) \cdot v_d$
   Calculating the right side: $4.8 \times 10^{-3} = 1.6 \times 10^{-4} \cdot v_d$
   Now, solving for v_d: $v_d = \frac{4.8 \times 10^{-3}}{1.6 \times 10^{-4}} = 30\, m/s$
   Next, we find the time t it takes for electrons to travel the full length of the sample (0.06 m):
   $t = \frac{\text{length}}{v_d} = \frac{6 \times 10^{-2}\, m}{30\, m/s} = 0.002\, s = 0.02\, s$
   This calculation shows that the time taken for the electrons to travel the full length of the sample is 0.02 seconds.

3. **(d)** π
   Explanation:
   When a wave is reflected into rarer medium from the surface of a denser medium, it undergoes a phase change of π radian.

4. **(c)** a force of attraction and a torque.
   Explanation:
   A force of attraction and a torque

5. **(a)** A
   Explanation:
   The electric potential in a uniform electric field decreases in the direction of the field. Since the electric field is directed along the x-axis, the potential will be lowest at the point where the x-coordinate is maximized, which is point A at (a, 0). Points B, C, and D have either zero or negative x-coordinates, leading to higher potential values compared to point A.
   Therefore, the potential is minimum at point A.

6.

(c) $B_1 = B_2 = B_3$

Explanation:

The solution states that the magnetic fields at points 1, 2, and 3 are equal, which is correct due to the properties of a long, straight conductor carrying a steady current. According to Ampère's law, the magnetic field around a long straight conductor is uniform and depends only on the distance from the wire, not on the shape or size of the conductor. Since points 1, 2, and 3 are all at the same distance from the axis of the conductor, they will experience the same magnetic field strength, leading to the conclusion that $B_1 = B_2 = B_3$.

7.

(b) N^2

Explanation:

Self-inductance,

$L = \frac{\mu_0 N^2 A}{l}$

i.e., $L \propto N^2$

8.

(c) small and negative

Explanation:

Small and negative.

9.

(d) $M^0L^{-1}T^0$

Explanation:

$\Delta x = \frac{2\pi}{\lambda}$

$\Rightarrow [\Delta x] = \frac{1}{[L]} = [M^0L^{-1}T^0]$

10.

(c) $\frac{q}{8\varepsilon_0}$

Explanation:

When the charge q is placed at one corner of the cube, only one-eighth of the flux emerging from the charge q passes through the cube.

$\therefore \phi_E = \frac{q}{8\varepsilon_0}$

11.

(b) 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.

(c) Total internal reflection

Explanation:

Total internal reflection principle is used in optical fibre.

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

Explanation:

The energy of electrons just after they absorb photons incident on the metal surface may be lost in a collision with other atoms in the metal before the electron is ejected out of the metal which results in the ejected photoelectrons with different energies despite monochromatic incident radiation.

14. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.
Explanation:
Assertion and reason both are correct statements and reason is correct explanation for assertion.

15. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation:
If a medium has same refractive index at every point in all directions, then the wavefront obtained from a point source in such a medium is spherical since wave travels in all direction with same speed. Such a medium is known as isotropic medium. So, the assertion and reason both are true and the reason explains the assertion properly.

16. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation:
The capacitive reactance of the capacitor is given by $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$
So this is infinite for dc (f = 0) and has a very small value for ac. Therefore a capacitor blocks dc.

Section B

17. Wavelength,
$\lambda = \frac{c}{v} = \frac{3\times10^8}{4\times10^9} = \frac{3}{40}$ m = 0.075 m
These are microwaves which are used
i. in radar systems for aircraft navigation.
ii. in microwave ovens.

18. Here V_D = 0.5 V, V = 1.5 V, I = 5 mA = 5 $\times$ 10^{-3}, R = ?
The voltage equation for the diode circuit is
IR + V_D = V
or 5 $\times$ 10^{-3} A $\times$ R + 0.5 V = 1.5 V
or R = 200 Ω

19. $E_n = -\frac{13.6}{n^2}eV$
$n^2 = \frac{-13.6}{-3.4} = 4$
$n = 2$
Angular momentum
$L = \frac{nh}{2\pi}$
$L = \frac{h}{\pi} = \frac{6.63\times10^{-34}}{3.14} = 2.11 \times 10^{-34} Js$

20. Torque of solenoid is given by
τ = MB sin θ
= (NIA) B sin θ
= $1000 \times 2 \times 2 \times 10^{-4} \times 0.32 \times \frac{1}{2}$
= 0.064 Nm

OR

Here N = 500, D = 12cm = 0.12 m, I = 0.3 A, μ_r = 600
Magnetising field intensity,
H = nI = $\frac{N}{l} \cdot I = \frac{N}{\pi D} \cdot I = \frac{500\times0.3}{\pi\times0.12}$
= 397.9 A turns m^{-1}

Magnetic flux density, B = $\mu H = \mu_r \mu_0 H$

= $600 \times 4\pi \times 10^{-7} \times 397.9$ = 0.3 Wbm^{-1}

Flux density due to electronic current loop is

$\mu_0 M = B - \mu_0 H$ = $0.3 - 4\pi \times 10^{-7} \times 397.9$

= 0.3 - 0.0005 = 0.2995 Wbm^{-2}

21. When a charge moves with velocity v making an angle ϕ with the direction of the magnetic field, the component of velocity v sin ϕ (perpendicular to the magnetic field) makes the charge move along a circular path, while the component of velocity v cos ϕ (along the magnetic field) drifts the charge along the direction of the field. As a result, the path of the charge becomes helical.

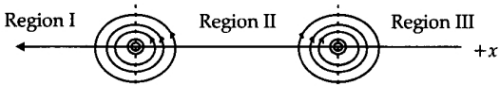
OR

Magnetic field strength at a point P (where the resultant magnetic field is zero), at a distance r due to

left wire = $B_1 = \frac{\mu_0 I_1}{2\pi r}$

right wire = $B_2 = \frac{\mu_0 I_2}{2\pi r}$

The fields are oppositely directed.



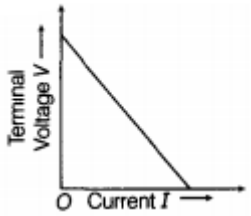
Since, $I_2 > I_1$, the point P cannot be in region II or III. It will be in the region I.

Section C

22. Difference between emf (ε) and terminal voltage (V)

emf	**Terminal voltage**
It is the potential difference between two terminals of the cells when no current is flowing through it.	It is the potential difference between two terminals when current passes through it.
It is the cause.	It is the effect.

Following plot is showing variation of terminal voltage versus the current.



Note:- Negative slope gives internal resistance, where

$V = \varepsilon - Ir$

Or $r = \frac{\varepsilon - V}{I}$

23. a. λ = 200 nm, stopping potential = -2.5 V

K.E. = 2.5 $\times$1.6 $\times$ 10^{-19} J = 4 $\times 10^{-19}$ J

E = hv = $h\frac{c}{\lambda}$

= $\frac{6.63\times10^{-34}\times3\times10^{8}}{200\times10^{-9}}$

= 9.945 $\times$ 10^{-19} J

Work function = E - eV

= (9.945 $\times$ 10^{-19} - 4 $\times 10^{-19}$)J

= 5.595 $\times$ 10^{-19} J

b. Wavelength of red light = 6328 $\mathring{A}$

E = hv = $h\frac{c}{\lambda}$

$= \frac{6.63\times10^{-34}\times3\times10^{8}}{6328\times10^{-10}}$

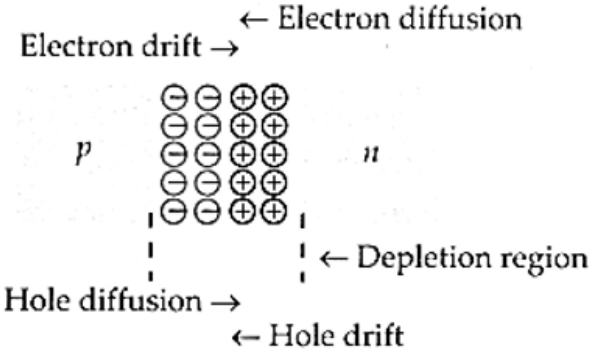
$= 0.00314 \times 10^{-16}$ J

$= 3.14 \times 10^{-19}$ J

Energy of red light < work function of metal surface

∴ No emission of photoelectrons takes place.

24. **Formation of depletion region and potential barrier in a junction diode:** Two important processes involved during the formation of p-n junction are diffusion and drift. Due to the concentration gradient across the p- and n-sides of the junction holes diffuse from p-side to n-side and electrons diffuse from n-side to p-side of the junction. This movement of charge carriers gives rise to diffusion current across the p-n junction. This process leaves behind -ve acceptor ions on the p-side and +ve donor ions on the n-side of the junction. The space charge region on either side of the junction which gets devoid of mobile charge carriers and has only immobile ions is called the depletion layer.



The accumulation of negative charges in the p-region and positive charges in the n-region sets up a potential difference across the junction. This is called barrier potential because it opposes the further diffusion of electrons and holes across the junction.

25. i. Mass defect (ΔM), of any nucleus ${}^{A}_{Z}X$ is the difference in the mass of the nucleus (= M) and the sum of masses of its constituent nucleons (= M').

$\Delta M = M' - M$

$= [Zm_p + (A - Z)m_n] - M$

where m_p and m_n denote the mass of the proton and the neutron respectively.

ii. Binding energy is the energy required to separate a nucleus into its constituent nucleons. Or Nuclear binding energy is the minimum energy that would be required to disassemble the nucleus of an atom into its component parts. These component parts are neutrons and protons, which are collectively called nucleons. The relation between the two is

B.E. = ΔMc^2

iii. There is a release of energy, i.e., the reaction is exothermic.

Reason: Increase in B.E/nucleon implies that mass has been converted into energy. This would result in the release of energy.

26. Total energy of the electron in hydrogen atom is –13.6 eV = $-13.6 \times 1.6 \times 10^{-19}$ J = -2.2×10^{-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 = 9.1×10^{-31} kg,

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

$v = \frac{e}{\sqrt{4\pi\varepsilon_0 mr^2}} = 2.2 \times 10^6 \text{m/s}$

27. A coil B kept near another coil A has magnetic flux passing through it when kept near coil A. The ratio of magnetic flux through the coil B to the current in the coil A is called as mutual inductance of coils. or **Mutual Inductance** is the interaction of one coils magnetic field on another coil as it induces a voltage in the adjacent coil

$M_{12} = \frac{\phi_2}{i}$

Let S_1 carries a current i.

Magnetic field inside S_1 will be $B = \frac{\mu_o N_1 i}{l}$

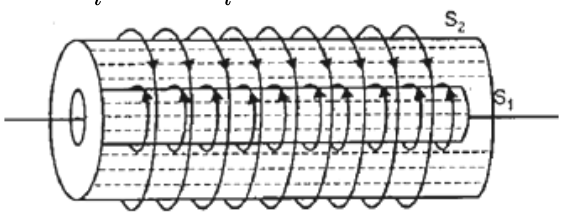
Flux through each turn of S_2 is $\phi = B \times \pi r_2^2$

$\phi = \frac{\mu_o N_1 \pi r_2^2 i N_2}{l}$

Flux through each turn of S_2 is $\phi_B = \phi N_2$

$\phi_B = \frac{\mu_o N_1 \pi r_2^2 i N_2}{l}$

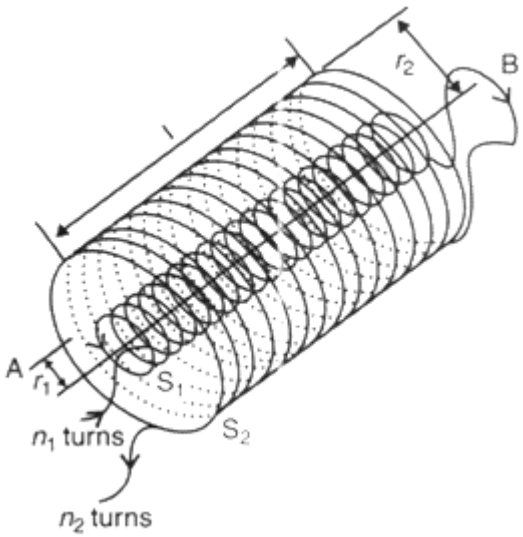
$M = \frac{\phi_B}{i} = \frac{\mu_o N_1 N_2 \pi r_2^2}{l}$



OR

i. Self-Inductance is the property by which an opposing induced emf is produced in a coil due to a change in current, or magnetic flux, linked with the coil.
The S.I. unit of self-inductance is Henry (H).

ii. In this question, a long co-axial solenoids S_1 and S_2 wound one over the other, each of length L and radii r_1 and r_2 and n_1 and n_2 number of turns per unit length, when a current I is set up in the outer solenoid S_2.



Let a current l_2 flow in the secondary coil

$\therefore B_2 = \frac{\mu_0 N_2 i_2}{l}$

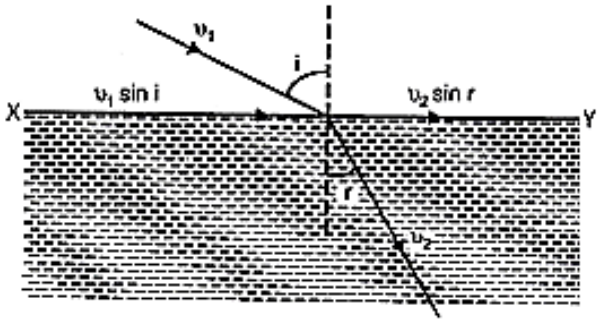
$\therefore$ Flux linked with the primary coil = $\frac{\mu_0 N_2 N_1 A_1 i_2}{l}$

$= M_{12} i_2$

Hence, $M_{12} = \frac{\mu_0 N_2 N_1 A_2}{l}$

$\mu_0 n_2 n_1 A_1 l \left(n_1 = \frac{N_1}{l}; n_2 = \frac{N_2}{l}\right)$

28. According to Newton's Corpuscular theory of light, when corpuscles of light strike the interface XY, figure separating a denser medium from a rarer medium, the component of their velocity along XY remains the same.



If v_1 is velocity of light in rarer medium (air),

v_2 is velocity of light in denser medium (water),

i is the angle of incidence,

r is angle of refraction,

Then component of v_1 along XY = v_1 sin i

Component of v_2 along XY = v_2 sin r

As v_1 sin i = v_2 sin r

$\therefore \frac{v_2}{v_1} = \frac{\sin i}{\sin r} = \mu$

As $\mu > 1 \therefore v_2 > v_1$

i.e. light should travel faster in water than in air. This prediction of Newton's theory is opposite to the experiment result.

Huygens wave theory predicts that $v_2 < v_1$, which is consistent with experiment.

Section D

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

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

(a) **(a)** infrared waves
Explanation:
Infrared rays can be converted into electric energy as in solar cell.

(b) **(d)** radiowaves
Explanation:
Radiowaves have longest wavelength.

(c) **(c)** cathode rays
Explanation:
Cathode rays are invisible fast moving streams of electrons emitted by the cathode of a discharge tube which is maintained at a pressure of about 0.01 mm of mercury.

(d) **(d)** γ-rays
Explanation:
γ-rays have minimum wavelength.

30. i. There are two plates A and B having surface charge densities, $\sigma_A = 17.0 \times 10^{-22}$ C/m^2 on B, respectively. According to Gauss' theorem, if the plates have same surface charge density but

having opposite signs, then the electric field in region I is zero.

$E_I = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$

ii. The electric field in region III is also zero.

$E_{III} = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$

iii. In region II or between the plates, the electric field.

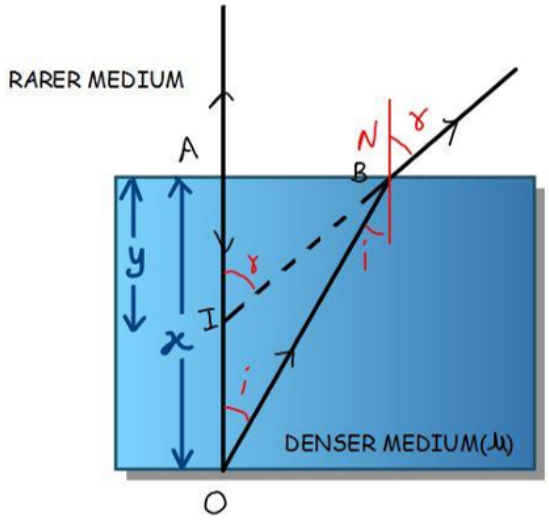
$E_{II} = E_A - E_B = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$

$= \frac{\sigma\left(\sigma_A \text{ or } \sigma_B\right)}{\varepsilon_0} = \frac{17.0\times10^{-22}}{8.85\times10^{-12}}$

$E = 1.9 \times 10^{-10}\ NC^{-1}$

Section E

31. i. Due to refraction of light



In $\triangle$OAB,

$\sin i = \frac{AB}{OB}$

In $\triangle$IAB, $\sin r = \frac{AB}{IB}$

According to Snell's law

$\frac{1}{\mu} = \frac{\sin i}{\sin r} = \frac{IB}{OB}$ When angles are small, OB $\approx$ OA and IB $\approx$ IA

$\mu = \frac{OA}{IA} = \frac{x}{y}$

Height through which object is raised = x - y

$= x - \frac{x}{\mu}$

$= x\left(1 - \frac{1}{\mu}\right)$

ii. $f_0 = 2$ cm

$f_e = 6.25$ cm

$L = v_0 + |u_e| = 15$ cm

$v_e = -25$ cm

$\frac{1}{V_e} - \frac{1}{u_e} = \frac{1}{f_e}$;

$\frac{1}{-25} - \frac{1}{u_e} = \frac{1}{6.25}$

$u_e = -5$ cm

Now, $L = v_0 + |-5| = 15$ cm

$V_o = 10$ cm

Now, $\frac{1}{f_o} = \frac{1}{V_o} - \frac{1}{u_o}$

$u_0 = 2.5$ cm

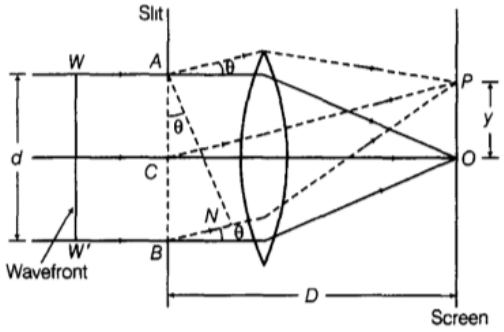
MP = $\frac{V_o}{u_o}\left[1+\frac{D}{f_o}\right]$

= -20

OR

i. A single narrow slit is illuminated by a monochromatic source of light. The diffraction pattern is obtained on the screen placed in front of the slits. There is a central bright region called as central maximum. All the waves reaching this region are in phase hence the intensity is maximum. On both side of central maximum, there are alternate dark and bright regions, the intensity becoming weaker away from the center. The intensity at any point P on the screen depends on the path difference between the waves arising from different parts of the wave-front at the slit.

Diffraction of light at a single slit A parallel beam of light with a plane wavefront WW' is made to fall on a single slit AB. As width of the slit AB = dis of the order of wavelength of light, therefore, diffraction occurs on passing through the slit.



The wavelets from the single wavefront reach the centre O on the screen in same phase and hence, interfere constructively to give central maximum (bright fringe).

The diffraction pattern obtained on the screen consists of a central bright band having alternate dark and weak bright band of decreasing intensity on both sides.

Consider a point P on the screen at which wavelets travelling in a direction making an angle θ with CO are brought to focus by the lens. The wavelets from points A and B will have a path difference equal to BN.

From the right angled ΔANB, we have BN = AB sinθ or BN = d sinθ.

To establish the condition for secondary minima, the slit is divided into 2,4,6... equal parts such that corresponding wavelets from parts such that corresponding wavelets from successive regions interfere with path difference $\lambda/2$

or for nth secondary minlmum.the slit can be divided into 2n equal parts. Hence, for nth secondary minimum, path difference= $= d\sin\theta_n = n\lambda$.

or $\sin\theta_n = \frac{n\lambda}{d}(n = 1, 2, 3, \ldots)$

To establish the condition for secondary maxima, the slit is divided into 3,5,7... equal parts such that corresponding wavelets from alternate regions interfere with path difference of A./2 or for nth secondary maximum, the slit can be divided into (2n+ 1)equal parts.

Hence, for nth secondary maximum

$d\sin\theta_n = (2n+1)\frac{\lambda}{2}$ (n = 1, 2, 3,...)

ii. For $\lambda_1 = 590\text{mm}$

Location of 1 maxima $y_1 = (2n+1)\frac{D\lambda_1}{2d}$

If $n = 1 \Rightarrow y_1 = \frac{3D\lambda_1}{2d}$

For $\lambda_2 = 596\text{nm}$

Location of III maxima

$y_2 = (2n+1)\frac{D\lambda_2}{2d}$, if n = 1

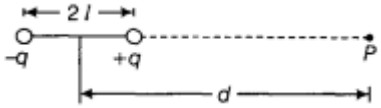
$\Rightarrow y_2 = \frac{3D\lambda_2}{2d}$

$\therefore$ Path difference $= y_2 - y_1 = \frac{3D}{2d}(\lambda_2 - \lambda_1)$

$= \frac{3\times1.5}{2\times2\times10^{-6}}(596-590)\times10^{-9}$

$= 6.75\times10^{-3}\text{m}$

32. a. Let electric potential is to be determined at a point P lying on the axis of an electric dipole of dipole length 2l at a distance d from the centre of the dipole as shown in the figure.



Potential at P due to +q charge of the dipole $= \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{(d-l)}$

Potential at P due to -q charge of the dipole

$= \frac{1}{4\pi\varepsilon_0}\frac{-q}{(d+l)}$

Total potential at P due to both the charges of the dipole

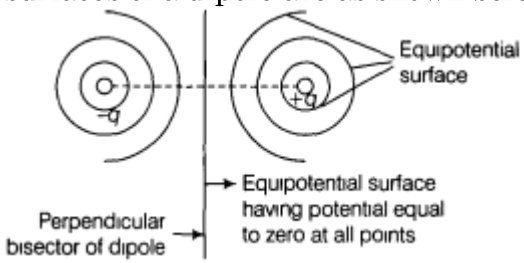
$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(d-l)}-\frac{1}{(d+l)}\right]$

$= q\times\frac{2l}{4\pi\varepsilon_0}\times\frac{1}{(d^2-l^2)} = \frac{p}{4\pi\varepsilon_0}\times\frac{1}{(d^2-l^2)}$

where, the scalar value of dipole moment (p) = q × 2l

If l << d, then neglecting l^2 we get, the final value of the electric potential to be, $V = \frac{1}{4\pi\varepsilon_0}\frac{p}{d^2}$

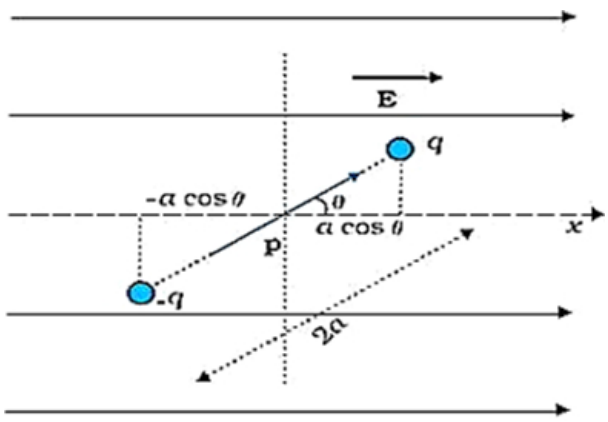
b. An electric dipole consists of two equal and opposite charges separated by some distance. Equipotential lines and electric field are always perpendicular to each other. Equipotential surfaces of a dipole are as shown below:



Potential of points lying on the perpendicular bisector surface will be zero.

OR

i.



The amount of work done in rotating the dipole from $\theta = \theta_0$ to $\theta = \theta_1$ by the external torque

$W = \int_{e_0}^{\theta_1}\tau_{ext}\,d\theta$

$= \int_{\theta_0}^{a} pE\sin\theta d\theta$

$W = pE\left(\cos\theta_0-\cos\theta_1\right)$

For $\theta_0 = \frac{\pi}{2}$ and $\theta_1 = \theta$

$= pE\left(\cos\frac{\pi}{2}-\cos\theta\right)$

$U(\theta) = -pE\cos\theta = -\vec{p}\cdot\vec{E}$

1. Potential energy is maximum when:
   $\vec{p}$ is antiparallel to $\vec{E}$
2. Potential energy is minimum when:
   $\vec{p}$ is along to $\vec{E}$

ii. **Dipole Moment Calculation:**

The charge q = 1.0×10^{-12}C.

Separation vector $\vec{d}$ = (3 mm, 4 mm) = (3×10^{-3} m, 4×10^{-3} m)

Dipole moment $\vec{p} = q\vec{d}$ = ($1.0 \times 10^{-12} \times 3 \times 10^{-3}$, $1.0 \times 10^{-12} \times 4 \times 10^{-3}$) = ($3.0 \times 10^{-15}$, 4.0×10^{-15}) C.m.

Torque Calculation:

Electric field $\vec{E} = 1000\hat{i}\ \text{V/m}$

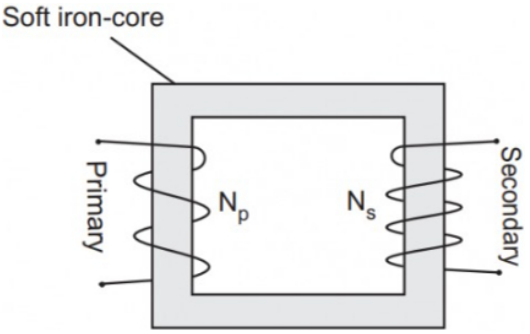
Torque $\vec{\tau} = \vec{p} \times \vec{E}$

$$\vec{\tau} = \left(3.0 \times 10^{-15}\,\hat{i} + 4.0 \times 10^{-15}\,\hat{j}\right) \times 1000\hat{i} = \left(4.0 \times 10^{-15} \times 1000\right)\hat{k}$$

$$\vec{\tau} = 4.0 \times 10^{-12}\ \text{N} \cdot \text{m}\hat{k}$$

The torque is $\vec{\tau} = 4.0 \times 10^{-12}\ \text{N} \cdot \text{m}\hat{k}$

33. i.



The working principle of transformer is mutual induction.

When an alternating voltage is applied to the primary, the resulting current produces an alternating magnetic flux which links the secondary and induces an emf in it.

Causes of energy losses

a. **Copper Losses (I^2R Losses):**
   Explanation: These losses occur due to the resistance of the wire in the coils. When current flows through the wire, some energy is dissipated as heat due to the resistance.
   Mitigation: Using thicker wires with lower resistance and cooling mechanisms can help reduce these losses.

b. **Core Losses (Iron Losses):**
   Explanation: Core losses include hysteresis loss and eddy current loss. Hysteresis loss occurs due to the lagging of magnetic domains behind the changing magnetic field. Eddy current loss is caused by circulating currents induced within the core material due to the changing magnetic field.
   Mitigation: Using laminated silicon steel cores reduces eddy currents, and using materials with low hysteresis loss minimizes core losses.

c. **Leakage Flux:**
   Explanation: Not all magnetic flux produced by the primary coil links with the secondary coil. Some flux "leaks" and does not contribute to energy transfer between coils, leading to inefficiency.
   Mitigation: Improving core design and using better core materials can help reduce leakage flux.

ii. A step-up transformer does not violate the conservation of energy. It increases voltage by decreasing current proportionally. The power input (low voltage, high current) equals the

power output (high voltage, low current), ensuring energy conservation. The transformer merely transfers energy, with losses typically due to inefficiencies.

iii. 1. $\frac{V_s}{V_P} = \frac{N_s}{N_P}$

$V_s = \frac{N_s}{N_P} \times V_P = \frac{3000}{200} \times 90$

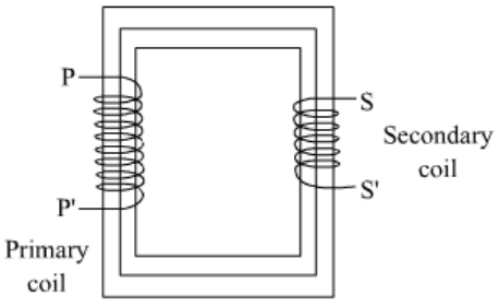
$V_s = 1350$ V

2. $\frac{I_P}{I_s} = \frac{N_s}{N_P}$

$I_P = \frac{3000}{200} \times 2 = 30$ A

OR

i. A transformer is a device that changes a low alternating voltage into a high alternating voltage or vice versa. The transformer works on the principle of mutual induction. A changing alternate current in the primary coil produces a changing magnetic field, which induces a changing alternating current in the secondary coil.



Energy losses in the transformer:

a. Flux leakage due to poor structure of the core and air gaps in the core.

b. Loss of energy due to heat produced by the resistance of the windings.

c. Eddy currents due to alternating magnetic flux in the iron core, which leads to loss of energy due to heat.

d. Hysterisis, frequent and periodic magnetisation and demagnetisation of the core, leading to loss of energy due to heat.

ii. a. Now,

$N = \frac{N_s}{N_p}$

$\Rightarrow \frac{N_S}{100} = 100$

$\Rightarrow N_S = 10000$ turns

b. Current in primary is given by,

$I_P V_P = P$

$\Rightarrow I_P = \frac{1100}{220} = 5A$

c. Voltage across secondary is given by,

$\frac{V_s}{V_p} = \frac{N_s}{N_p} = N$

$\Rightarrow V_S = 100 \times 220 = 22000$ V

d. Current in secondary is given by

$V_S I_S = P$

$\Rightarrow I_S = \frac{P}{V_s} = \frac{1100}{22000} = 0.05$ A

e. In an ideal transformer,

Power in secondary = Power in primary = 1100 W