ISC EXAMINATION PAPER – 2025
PHYSICS PAPER–1
Class–12^{th}
(Solved)

Maximum Marks: 70 | *Time Allotted: Three Hours* | *Reading Time: Additional Fifteen Minutes*

Instructions to Candidates:

1. You are allowed an **additional fifteen minutes** for **only** reading the question paper.
2. You must **NOT** start writing during reading time.
3. This question paper has **11 printed pages and one blank page.**
4. There are **twenty questions** in this paper. Answer *all* questions.
5. There are **four** sections in the paper: **A, B, C** and **D. Internal choices** have been provided in **two questions** each in **Sections B, C** and **D.**
6. **Section A** consists of one question having fourteen sub-parts of **one mark** each.
7. While attempting **Multiple Choice Questions** in Section A, you are required to **write only ONE option as the answer.**
8. **Section B** consists of **seven questions** of **two marks** each.
9. **Section C** consists of **nine questions** of **three marks** each.
10. **Section D** consists of **three questions** of **five marks** each.
11. The intended marks for questions are given in brackets [].
12. A list of useful constants and relations is given at the end of this paper.
13. A simple scientific calculator without a programmable memory may be used for calculations.

SECTION–A (14 MARKS)

Question 1

(A) In questions (i) to (vii) given below, choose the correct alternative (a), (b), (c) or (d).

(i) When a battery is connected between the terminals P and Q, as shown in *Figure 1* below, it is found that no current flows through 5Ω resistor. Then, the value of resistor X is: **[1]**

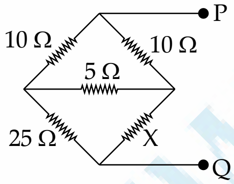


Figure 1

(a) 10 Ω **(b)** 20 Ω
(c) 25 Ω **(d)** 45 Ω

(ii) The **relative permeability** of substance 'X' is slightly less than one and that of substance 'Y' is slightly more than one. Then: **[1]**

(a) 'X' is paramagnetic and 'Y' is ferromagnetic.
(b) 'X' is diamagnetic and 'Y' is ferromagnetic.
(c) 'X' is paramagnetic and 'Y' is diamagnetic.
(d) 'X' is diamagnetic and 'Y' is paramagnetic.

(iii) If **kinetic energy** of moving electrons is made four times, then their **de Broglie wavelength** becomes: **[1]**

(a) eight times. **(b)** four times.
(c) two times. **(d)** half.

(iv) A student has made connections, as shown in *Figure 2* below, so that the wires MN and ST **repel** each other. But it is observed that they are attracting each other. What change should the student make for the wires to repel each other? **[1]**

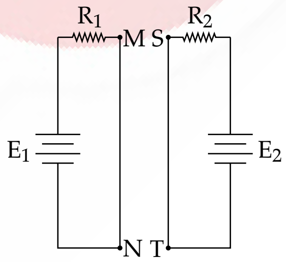


Figure 2

(a) Reverse the terminals of batteries E_1 and E_2.
(b) Reverse the terminals of battery E_1 or E_2.
(c) Choose supply voltage such that $E_1 = E_2$.
(d) Add key and ammeter to the circuit.

(v) N-type semiconductor is that which has: **[1]**

(a) majority of holes as charge carriers.
(b) majority of free electrons as charge carriers.
(c) trivalent element added as an impurity.
(d) an equal number of holes and free electrons.

(vi) Given below are two statements marked, Assertion and Reason. Read the two statements and choose the correct option. **[1]**

Assertion: When a convex lens made of glass is completely immersed in water, its focal length increases.

Reason: Refractive index of glass with respect to water is greater than that of glass with respect to air.

(a) Both Assertion and Reason are true and Reason is the correct explanation for Assertion.

(b) Both Assertion and Reason are true but Reason is not the correct explanation for Assertion.

(c) Assertion is true and Reason is false.

(d) Both Assertion and Reason are false.

(vii) Given below are two statements marked, Assertion and Reason. Read the two statements and choose the correct option. **[1]**

Assertion: Diffraction of light is difficult to observe in everyday situations but can be observed in laboratory conditions.

Reason: To produce diffraction of waves, size of an obstacle must be comparable to the wavelength of the waves.

(a) Both Assertion and Reason are true and Reason is the correct explanation for Assertion.

(b) Both Assertion and Reason are true but Reason is not the correct explanation for Assertion.

(c) Assertion is true and Reason is false.

(d) Both Assertion and Reason are false.

(B) Answer the following questions briefly:

(i) How does the resistance of a semiconductor crystal vary with its temperature? **[1]**

(ii) ***Figure 3*** below shows an ideal transformer. Explain why current flowing through secondary coil is greater than that in primary coil. **[1]**

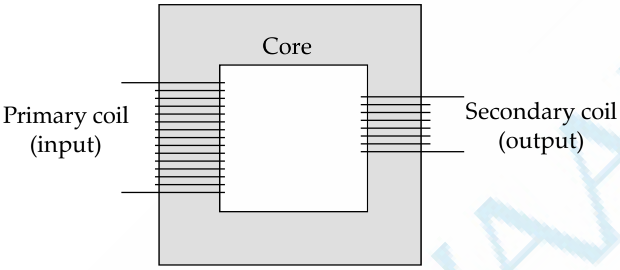


Figure 3

(iii) State ***any one*** difference between a primary rainbow and a secondary rainbow. **[1]**

(iv) **Hubble** telescope employs a large parabolic mirror as an objective. State ***any one*** advantage of using a **mirror** in place of a lens in such a telescope. **[1]**

(v) Name ***any one*** phenomenon where moving particles behave like waves. **[1]**

(vi) What is the minimum energy a gamma ray (γ) photon should possess to produce an electron – positron pair? **[1]**

(vii) In an energy band diagram of a certain material, forbidden band is **absent**. Identify this material. **[1]**

SECTION–B (14 MARKS)

Question 2 **[2]**

(i) **(a)** What is the effect on **capacitance** of a **parallel plate** capacitor if the distance between its plates is increased?

(b) How will **capacitance** of a capacitor change if a dielectric slab is introduced between its plates?

OR

(ii) ***Figures 4*** and ***5*** represent the combination of two identical cells having negligible internal resistance.

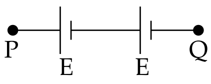


Figure 4

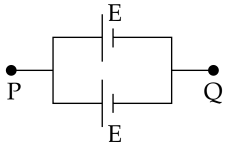


Figure 5

(a) In which of the two combinations, emf of the battery is **greater**?

(b) When a resistor '*R*' is connected between the terminals P and Q, I_1 and I_2 are the currents flowing through '*R*' in ***Figure 4*** and ***Figure 5*** respectively. Obtain the ratio $\frac{I_1}{I_2}$.

Question 3 **[2]**

In case of a **short** electric dipole:

(i) What is the **locus** of a point having zero potential?

(ii) If electric field intensity at a point in axial position is E_1 and at an **equidistant** point in equatorial position is E_2, what is the ratio $\frac{E_1}{E_2}$?

Question 4 **[2]**

(i) ***Figure 6*** below shows an electric circuit.

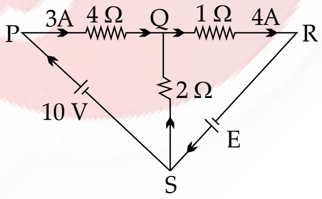


Figure 6

Apply **Kirchhoff's** laws to calculate:

(a) current '*I*' flowing through the 2 Ω resistor.

(b) emf of the cell '*E*'.

OR

(ii) In a **potentiometer** experiment, a cell of emf 1.25 V gives a balance point at 35 cm mark of the wire. If this cell is replaced by another cell, the balance point is at 63 cm mark. Calculate the **emf** of the second cell.

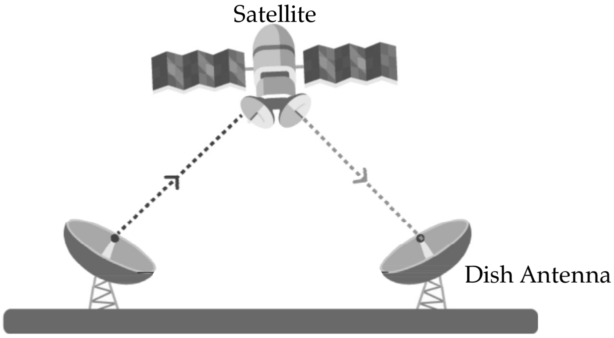
Question 5 **[2]**

Magnetic field at the **centre** of a circular coil is B. Calculate the magnetic field at the **same** point when **each** of the current, number of turns of the coil and its radius is doubled.

Question 6 **[2]**

The objective of a telescope consists of two lenses kept in contact. One lens has an optical power of +2.0 D whereas the other lens has an optical power of −1.5 D. Calculate **focal length** of the objective.

Question 7 **[2]**



(i) **Name** the electromagnetic wave travelling from the **satellite** to the **dish antenna** shown in the image above.

(ii) If the wavelength of an electromagnetic wave is 6 nm, what is its **frequency**?

Question 8 **[2]**

With reference to **photoelectric effect**, define the terms:

(i) Threshold frequency.

(ii) Work function.

SECTION – C (27 MARKS)

Question 9 **[3]**

An infinite plane metallic sheet having surface charge density '$+\sigma$' is placed in vacuum. P is a point at a small distance 'r' to its right.

(i) Write an expression for **intensity** of electric field at point P.

(ii) Now, an identical charged sheet having surface charge density '$-\sigma$' is placed parallel to the first sheet such that the point P is to its **left** at the same distance 'r'. (The point P lies between the two plates.)

(a) What is the **resultant intensity** of electric field at point P?

(b) What is its direction?

Question 10 **[3]**

(i) Harry sets up a circuit as shown in ***Figure 7*** below. He measures potential difference 'V' across the variable resistor R with an instrument Y. He also measures current 'I' flowing through R with another instrument X.

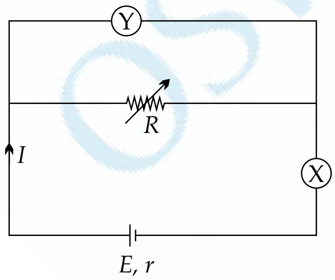
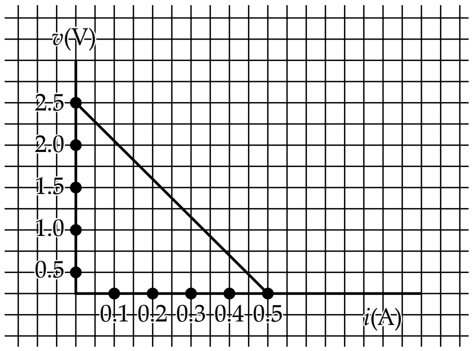


Figure 7

(a) Identify the instruments X and Y.

(b) Using the graph of V against I shown below, calculate

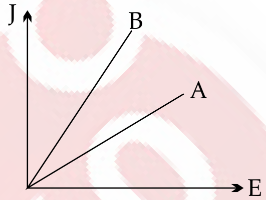


(1) emf (E) of the cell.

(2) Internal resistance (r) of the cell.

OR

(ii) The graph below shows the variation of current density (J) with electric field (E) applied to two different metallic wires A and B.



(a) Which one of the wires, A or B, has higher **resistivity**?

(b) For a certain value of electric field (E), in which wire 'A' or 'B' is drift velocity greater? Give a reason for your answer.

Question 11 **[3]**

A galvanometer having a resistance of 20 Ω shows a full scale deflection with a current of 1 mA. How can it be converted into a **voltmeter** with a range of 0–10 V?

Question 12 **[3]**

(i) Two infinitely long straight wires PQ and RS carrying currents I_1 and I_2 respectively are kept 10 cm apart in **vacuum**. Calculate **magnetic field** (B) at the point X shown in ***Figure 8*** below.

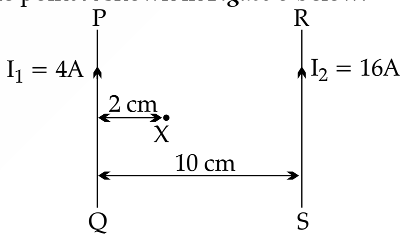


Figure 8

OR

(ii) An electron and a proton are moving along the **+X axis**. If an external magnetic field B = 0.314 T is applied along **−Z axis**:

(a) What is the **path** followed by the **electron** due to the magnetic field?

(b) Calculate the **frequency** of revolution of the **proton**.

Question 13 **[2]**

A convex lens having small focal length is to be used as a **magnifying glass** (simple microscope) to obtain an image of a small diamond. If the image lies at least distance of distinct vision (D):

(i) Where will you keep the diamond to obtain its image at D?

(ii) State ***any two*** characteristics of the image formed by the magnifying glass.

Question 14 **[3]**

A parallel beam of light is travelling **obliquely** from an optically rarer medium to an optically denser medium.

(i) Draw a **labelled** diagram showing incident and refracted wavefronts. Mark angle of incidence as ***'i'*** and angle of refraction as ***'r'***.

(ii) Use **Huygen's wave theory** to prove **Snell's law**.

Question 15 **[3]**

For any prism, show that refractive index *'n'* of its material is given by:

$$n = \frac{\sin\left(\frac{A + \Delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

where the terms have their usual meaning.

Question 16 **[3]**

Two identical rectangular slits 5 mm apart are illuminated with a monochromatic light of wavelength 600 nm. The screen is kept 1.2 m away from the slits.

(i) Calculate the **distance** between the 5^{th} bright fringe (band) on **one side** and the 3^{rd} bright fringe on the **other side** of the central bright band.

(ii) What will be the **change** in the interference pattern if the given light is replaced with monochromatic light of wavelength 500 nm?

Question 17 **[3]**

(i) Plot a **labelled** graph of **stopping potential** (V_S) versus **frequency** (f) of incident UV radiation.

(ii) State how the value of **Planck's constant** can be determined from this graph.

SECTION–D (15 MARKS)

Question 18 **[5]**

(i) (a) ***Figure 9*** shows a metallic rod AB of length l = 3 m moving in an (external uniform magnetic field, **B** = $\left(\frac{1}{\pi}\right)$ T which is directed into the plane of this paper.

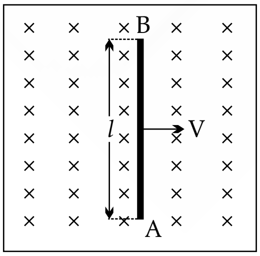


Figure 9

If the position of the rod changes with time as $x = \pi t$, where x is in metre and t is in second, then:

(1) Calculate the **motional emf** developed in the rod.

(2) **Name** the law used to find the direction of induced current.

(b) When current flowing through a solenoid decreases from 15 A to 0 in 0.2 s, an emf of 30 V is induced in it. Calculate the **coefficient of self-inductance** of the solenoid.

OR

(ii) An alternating emf $E = 5.0 \sin(314\,t)$V is applied to a circuit containing a resistor connected in series with an unknown component X.

The current in the circuit is found to be $I = 3.0 \sin\left(314t - \frac{\pi}{3}\right)$ A.

(a) Identify the component X.

(b) Calculate rms value (I_{rms}) of the current flowing through the circuit.

(c) Find the frequency of the source.

(d) Calculate power factor.

(e) Find the impedance (Z) of the circuit.

Question 19 **[5]**

(i) (a) Show that radius (r_n) of the n^{th} **Bohr orbit** varies directly with square of the **principal quantum number (*n*)** of the orbit.

(b) (1) Where does **nuclear fusion** reaction take place continuously in the Universe?

(2) What is meant by "**Mass defect**" of a nucleus?

OR

(ii) (a) A group of students went on an educational tour to **Bhabha Atomic Research Centre**, Mumbai. They visited various nuclear reactors like Apsara, Cirus, Zerlina and Dhruv and observed that Apsara was a swimming pool type reactor. The teacher explained how water slows down fast moving neutrons and absorbs the heat produced in the reactor.

(1) What is the use of a nuclear reactor?

(2) What is the name given to a material which slows down fast moving neutrons?

(3) State how a nuclear reactor can be shut down in case of an emergency.

(b) (1) What is meant by the statement: 'Angular momentum of an orbiting electron is **quantised**'?

(2) What is the **physical significance** of the fact that total energy of an orbiting electron is negative?

Question 20 **[5]**

When a television set (scientifically known as a television receiver) is opened, many components like semiconductor diodes, transistors, capacitors, resistors, etc. can be observed on its motherboard. There are different types of diodes like photo diode, Zener diode, LED, etc. found in the T.V. set. With the help of these components, a television receives audio as well as video signals.

(i) A semiconductor diode has two types of semiconducting materials: 'P' type and 'N' type. What is the difference between them?

(ii) Draw a **labelled** diagram of a **full wave rectifier**. Show graphically how its output voltage varies with time.

(iii) What type of diode can be used as a **voltage regulator**?

USEFUL CONSTANTS AND RELATIONS

1.	Speed of light in vacuum	c	=	3×10^{8} ms^{-1}
2.	Charge of a proton	e	=	1.6×10^{-19}C
3.	Mass of a proton	m_{ρ}	=	1.67×10^{-27} kg
4.	Permeability of vacuum	μ_0	=	$4\pi \times 10^{-7}$ Hm^{-1}
5.	1 nm		=	10^{-9}m
6.	π		=	3.14

■■

ANSWERS

SECTION—A (14 MARKS)

Answer 1

A. (i)Option (c) is correct.

Explanation: As no current is flowing through the middle arm of 5 Ω resistor, so the circuit represents a balanced wheatstone bridge. So

$$\frac{X}{25} = \frac{10}{10}$$

$$X = \frac{10 \times 25}{10} = 25\,\Omega$$

(ii) Option (d) is correct.

Explanation: Substance X (μ_r<1): Diamagnetic (weakly repelled by magnetic fields).

Substance Y (μ_r>1) : Paramagnetic (weakly attracted by magnetic fields).

(iii) Option (d) is correct.

Explanation: The de Broglie wavelength (λ) of a particle is given by:

$$\lambda = \frac{h}{p}$$

Since momentum p is related to kinetic energy K as:

$$p = \sqrt{2mK}$$

Substituting this into the de Broglie equation:

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

Now, if the kinetic energy is made four times (i.e. $K'=4K$):

Then, new wavelength λ' will be,

$$\lambda' = \frac{h}{\sqrt{2m(4K)}} = \frac{h}{2\sqrt{2mK}}$$

$$\lambda' = \frac{\lambda}{2}$$

(iv) Option (b) is correct.

Explanation: If the wires are attracting each other instead of repelling, it means that the currents are flowing in the same direction. To correct this, the student should reverse the current direction in either MN or ST by swapping the connections at the power source.

(v) Option (b) is correct.

Explanation: An N-type semiconductor is created by doping a pure semiconductor (like silicon or germanium) with a pentavalent impurity (such as phosphorus or arsenic). This doping process introduces extra free electrons, which become the majority charge carriers.

(vi) Option (c) is correct.

Explanation: Assertion is true because focal length of a lens depends on the refractive index contrast between the lens material (glass) and the surrounding medium (air or water). Since the refractive index of water (≈1.33) is closer to that of glass (≈1.5) than air (≈1.0), the lens bends light less in water, leading to an increase in focal length.

Reason is false. The refractive index of glass with respect to water is approximately 1.12 and the refractive index of glass with respect to air is 1.5.

(vii) Option (a) is correct.

Explanation: Assertion is true because the diffraction occurs when light waves bend around obstacles or pass through small openings. However, in everyday life, most objects are much larger than the wavelength of visible light (which is in the range of 400–700 nm), making diffraction effects very small and difficult to notice. In a controlled laboratory setup (such as a single-slit experiment), conditions can be adjusted to make diffraction clearly visible.

Reason is also true because the diffraction is most noticeable when the size of the obstacle or aperture is comparable to or smaller than the wavelength of the wave. Since visible light has a very small wavelength, we need tiny slits or edges (in the micrometer range) to observe significant diffraction effects.

The Reason correctly explains why diffraction of light is difficult to observe in everyday life but visible in the lab.

B. (i) At higher temperatures, more electrons gain thermal energy and jump from the valence band to the conduction band, increasing the number of free charge carriers (electrons and holes). More free charge carriers lead to higher conductivity and thus lower resistance.

(ii) In a step-down transformer, the secondary current is greater than the primary current due to the conservation of energy. Since the transformer reduces voltage in the secondary coil, the current must increase to keep power constant, as per the formula:

$$V_p I_p = V_s I_s$$

(iii) Primary Rainbow: It is brighter and has red on the outer edge and violet on the inner edge.

Secondary Rainbow: It is fainter and has colours reversed (red on the inner edge and violet on the outer edge).

(iv) No Chromatic Aberration – Unlike lenses, mirrors do not suffer from chromatic aberration (colour distortion) because they reflect all wavelengths of light equally

(v) One phenomenon where moving particles behave like waves is electron diffraction.

(vi) The minimum energy a gamma-ray photon should possess to produce an electron-positron pair is at least 1.022 MeV.

(vii) If the forbidden band is absent in the energy band diagram, the material is a conductor (metal).

SECTION—B (14 MARKS)

Answer 2

(i)(a) The capacitance C of a parallel plate capacitor is given by the formula:

$$C = \varepsilon_0 A / d$$

Since, capacitance is inversely proportional to the plate separation d, increasing d leads to a decrease in capacitance.

(b) The capacitance of a parallel plate capacitor is given by:

$$C = \varepsilon_0 \varepsilon_r A/d$$

When a dielectric slab is inserted, the dielectric constant ε_r increases. Since, capacitance is directly proportional to ε_r, the capacitance increases.

OR

(ii)(a) The emf of the battery is greater in Figure 4, as the cells are in series, adding their emf values.

(b) Using formula

$$I = E_{net}/R$$

For Figure 4

$$E_{net} = E + E = 2E$$

(the cells are in series and their total voltage is added)

$$I_1 = 2E/R$$

For Figure 5

$$E_{net} = E$$

(the cells are in parallel, so the voltage remains the same)

$$I_2 = E/R$$

Hence, I_1/I_2 = 2:1

Answer 3

(i) The locus of points with zero potential is a plane passing through the centre of the dipole, perpendicular to the dipole axis.

(ii) The electric field at an axial position (along the dipole axis) is:

$$E_{axial} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{r^3}$$

The electric field at an equatorial position (perpendicular to the dipole axis) is:

$$E_{equatorial} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{p}{r^3}$$

Taking the ratio:

$$\frac{E_{axial}}{E_{equatorial}} = \frac{\frac{2p}{r^3}}{\frac{p}{r^3}} = 2:1$$

So, the ratio $E_1 : E_2 = 2:1$.

Answer 4

(i) Using Kirchhoff's Current Law (KCL) at junction Q:

Total current entering junction = Total current leaving junction

$$I + 3\text{A} = 4\text{A}$$

$$I = 4\text{A} - 3\text{A} = 1\text{A}$$

(ii) Apply Kirchhoff's Voltage Law (KVL) in loop PQRSP

Starting at P, moving along PQRSP:

$(3\text{ A} \times 4\ \Omega) + (4\text{ A} \times 1\ \Omega) - E - 10\text{ V} = 0$

$12\text{ V} + 4\text{ V} - 10\text{ V} = E$

$$E = 6\text{ V}$$

OR

(ii) Given: $E_1 = 1.25$ V (emf of the first cell)

$L_1 = 35$ cm (balance length for the first cell)

Let E_2 = emf of the second cell, to be found

$L_2 = 63$ cm (balance length for the second cell)

In a potentiometer experiment, the emf of a cell is directly proportional to the balancing length of the wire, given by:

$$\frac{E_1}{E_2} = \frac{L_1}{L_2}$$

Putting values,

$$\frac{1.25}{E_2} = \frac{35}{63}$$

$$E_2 = 1.25 \times \frac{63}{35}$$

$$E_2 = 1.25 \times 1.8$$

$$E_2 = 2.25\text{ V}$$

Answer 5

The magnetic field at the centre of a circular coil carrying current is given by:

$$B = \frac{\mu_0 NI}{2R}$$

If each of N, I, and R is doubled, we replace them as:

$$N' = 2N$$

$$I' = 2I$$

$$R' = 2R$$

Using the modified formula:

$$B' = \frac{\mu_0 (2N)(2I)}{2(2R)}$$

$$B' = \frac{4\mu_0 NI}{4R}$$

$$B' = \frac{4}{2}B$$

$$B' = 2B$$

Hence, the magnetic field at the centre will be two times of the initial magnetic field.

Answer 6

Given for the objective lens of telescope,

Power of 1st lens (P_1) = +2.0 D

Power of 2nd lens (P_2) = −1.5 D

For two lenses in contact, the total power is given by:

$$P_{total} = P_1 + P_2$$

Putting values,

$$P_{total} = 2.0 - 1.5 = 0.5\text{D}$$

Using relation between focal length and power of lens

$$f_{total} = \frac{1}{P_{total}} = \frac{1}{0.5} = 2.0\text{ m}$$

Hence, the focal length of the objective is 2.0 metres.

Answer 7

(i) The electromagnetic wave travelling from the satellite to the dish antenna is a microwave.

(ii) Given

$\lambda = 6$ nm $= 6 \times 10^{-9}$ m (wavelength)

$c = 3.0 \times 10^8$ m/s (speed of light)

using the wave equation:

$$c = \lambda f$$

Rearranging, $f = c/\lambda$

putting values

$$f = 3.0 \times 10^8 / 6 \times 10^{-9}$$

$$f = 5.0 \times 10^{16} \text{ Hz}$$

Hence, the frequency of the wave is 5.0×10^{16} Hz

Answer 8

(i) The threshold frequency is the minimum frequency of incident light required to eject electrons from the surface of a metal in the photoelectric effect. It is denoted by f_0.

(ii) The work function is the minimum energy required to eject an electron from the surface of a metal. It is denoted by φ_0.

SECTION–C (27 MARKS)

Answer 9

(i) For an infinite plane sheet of charge with surface charge density σ, the electric field intensity at a point near the sheet is given by:

$$E = \frac{\sigma}{2\varepsilon_0}$$

directed away from the sheet (to the right).

(ii)(a) For two oppositely charged parallel sheets, the electric field between them adds up (same direction). The total field is:

$$E_{\text{resultant}} = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

(b) The positive sheet (+σ) produces an electric field to the right. The negative sheet (–σ) produces an electric field to the right. Since both fields add up, the resultant field is to the right.

Answer 10

(i) **(a)** Instrument Y (measuring potential difference *V*) → Voltmeter

Instrument X (measuring current *I*) → Ammeter

(b)(1) The emf (*E*) of the cell is the y-intercept of the graph (when $I = 0$).

From the graph:

At $I=0$, $V = 2.5$ V

So, emf $E = 2.5$ V

(2) Using formula, $V = E - I \times r$

Rearrange for *r*:

$r = (E - V)/I$

From the graph, at $I=0.5$ A, $V=0$ V

$$r = \frac{2.5\text{V} - 0\text{V}}{0.5\text{A}}$$

$$r = \frac{2.5\text{V}}{0.5\text{A}} = 5\Omega$$

OR

(ii)(a) From Ohm's law in microscopic form:

$$J = \sigma E$$

The slope of the graph *J* vs *E* gives the conductivity σ of the material.

Wire A has a lower slope (lower σ), meaning it has a higher resistivity ρ.

(b) Drift velocity v_d is given by:

$$J = nqv_d$$

For a given *E*, the wire with the greater current density (*J*) has a greater drift velocity (assuming *n* is the same).

Drift velocity is greater in wire B because it has a higher current density for the same electric field.

Answer 11

The resistance of the galvanometer $G = 20\Omega$

The maximum current through the galvanometer $I_g = 1.0$ mA $= 1.0 \times 10^{-3}$ A

The maximum voltage we want to measure with the voltmeter $V = 10$ V

When a galvanometer is converted into a voltmeter by adding a series resistance *R*, the total voltage across the combination can be expressed as:

$$V = I_g(R + G)$$

$$R + G = \frac{V}{I_g}$$

Thus,

$$R = \frac{V}{I_g} - G$$

$$R = \frac{10}{1.0 \times 10^{-3} \text{ A}} - 20\ \Omega$$

$$R = 10{,}000\ \Omega - 20\ \Omega = 9{,}980\ \Omega$$

Answer 12

Given data:

Current in wire PQ: $I_1 = 4$ A (upward)

Current in wire RS: $I_2 = 16$ A (upward)

Distance between PQ and RS : $d = 10$ cm $= 0.1$ m

Distance of point X from PQ : $d_1 = 2$ cm $= 0.02$ m

Distance of point X from RS : $d_2 = 8$ cm $= 0.08$ m

Permeability of free space: $\mu_0 = 4\pi \times 10^{-7}$ Tm/A

Magnetic field due to PQ at X

Magnetic field at a point due to a current-carrying wire is given by:

$$B_1 = \frac{\mu_0 I_1}{2\pi d_1}$$

Substituting values:

$$B_1 = \frac{4\pi \times 10^{-7} \times 4}{2\pi \times 0.02}$$

$$B_1 = \frac{16 \times 10^{-7}}{0.04}$$

$B_1 = 4 \times 10^{-5}$ T

Using Right-Hand Rule, the field due to PQ at X is into the page.

Magnetic field due to RS at X

Similarly, for wire RS:

$$B_2 = \frac{\mu_0 I_2}{2\pi d_2}$$

$$B_2 = \frac{4\pi \times 10^{-7} \times 16}{2\pi \times 0.08}$$

$$B_2 = \frac{64 \times 10^{-7}}{0.16}$$

$$B_1 = 4 \times 10^{-5}\text{T}$$

Using the Right-Hand Rule, the field due to RS at X is out of the page.

Net magnetic field at X

Since, the two fields are equal and opposite in direction, they cancel each other out, so:

$$B_{net} = 0 \text{ T}$$

OR

(ii)(a) Given that the electron and proton are moving along the +X axis and the magnetic field is along the –Z axis. Applying Fleming's left hand rule, as the electron has a negative charge ($q = -e$), the force will be in the –Y direction. The force due to the magnetic field acts as a centripetal force, causing the electron to move in a circular path in the XY plane.

(b) Given data:

- Magnetic field: B = 0.314 T
- Charge of proton: $q = e = 1.6 \times 10^{-19}$C
- Mass of proton: $m_p = 1.67 \times 10^{-27}$ kg

The frequency of circular motion (cyclotron frequency) of a charged particle in a magnetic field is given by:

$$f = \frac{qB}{2\pi m}$$

Substituting the values:

$$f = \frac{(1.6\times10^{-19})(0.314)}{2\pi(1.67\times10^{-27})}$$

$$f = \frac{5.024\times10^{-20}}{10.486\times10^{-27}}$$

$f = 4.79 \times 10^6$ Hz

Answer 13

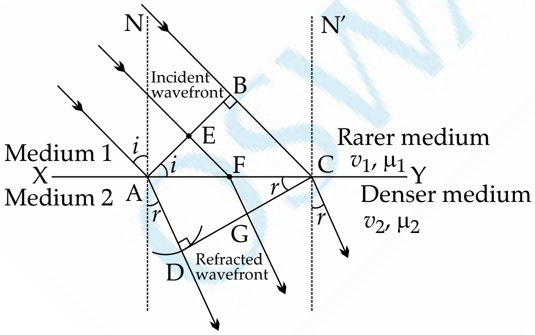
(i) To obtain the image at the least distance of distinct vision (D), the object (diamond) should be placed between the focus (*F*) and the optical centre (O) of the convex lens.

(ii) Characteristics of the image formed by a magnifying glass

1. Virtual and erect – The image is formed on the same side as the object and cannot be captured on a screen.
2. Magnified – The image appears larger than the actual object, which helps in detailed observation.

Answer 14

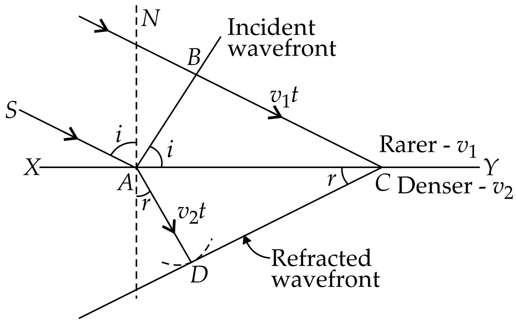
(i)



(ii) Consider a plane wavefront AB incident on a plane surface XY separating two media 1 and 2 as shown.

Let v_1 and v_2 be the velocities of light in the two media, with $v_1 < v_2$.

The wavefront first strikes at point A and then at the successive points towards C. According to Huygens' principle, from each point on AC, the secondary wavelets start growing in the second medium with speed v_2.



Let the disturbance take time t to travel from B to C, then $BC = v_1t$. During the time the disturbance from B reaches the point C, the secondary wavelets from point A must have spread over a hemisphere of radius $AD = v_2t$ in the second medium. The tangent plane CD drawn from point C over this hemisphere of radius v_2t will be the new refracted wavefront.

Let the angles of incidence and refraction be i and r respectively.

From right ΔABC, we have

$$\sin\angle BAC = \sin i = \frac{BC}{AC}$$

From right ΔADC, we have

$$\sin\angle DCA = \sin r = \frac{AD}{AC}$$

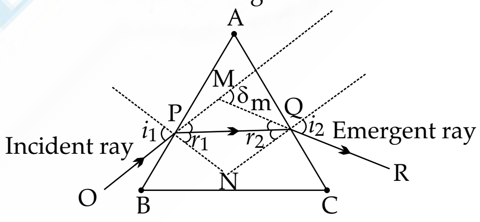
$$\frac{\sin i}{\sin r} = \frac{BC}{AD} = \frac{v_1t}{v_2t}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = {}^1\mu_2 \text{ (a constant)}$$

This proves Snell's law of refraction.

Answer 15

With reference to the figure



OP is the incidence ray which is making an angle i_1 with the normal, and QR is the emergent ray which makes an angle i_2 with the normal.

Let A and n be the angle of prism and refractive index respectively.

In the case of minimum deviation, $\angle r_1 = \angle r_2 = \angle r$

The angle $\quad A = \angle r_1 + \angle r_2$

$A = \angle r + \angle r = \angle 2r$

Thus $\quad \angle r = \dfrac{A}{2}$

Also, $\quad A+\delta = i_1 + i_2$

However, for minimum deviation we have $i_1 + i_2 = 2i$

$$A + \delta_m = 2i$$

$$i = \frac{A+\delta_m}{2}$$

According to Snell's law, the refractive index of a medium

$$n = \frac{\sin i}{\sin r} = \frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}}$$

Thus, $$n = \frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}}$$

Hence the relation between angle of incidence, angle of minimum deviation and refractive index of the material is obtained.

Answer 16

(i) Given Data:

Distance between the slits: d=5 mm = 5×10^{-3}m

Wavelength of light: λ=600 nm = 600×10^{-9}m

Distance between slits and screen: D=1.2 m

Bright fringe positions: 5th bright fringe on one side and 3rd bright fringe on the other.

In Young's double-slit experiment, the fringe width (distance between consecutive bright fringes) is given by:

$$y = \lambda D/d$$

Substituting the values:

$$y = \frac{(600\times10^{-9})(1.2)}{5\times10^{-3}}$$

$$y = \frac{7.2\times10^{-7}}{5\times10^{-3}} = 1.44\times10^{-4}\text{m} = 0.144 \text{ mm}$$

Now, the position of the n^{th} bright fringe is:

$$y_n = n\cdot y$$

For the 5th bright fringe:

$$y_5 = 5 \times 0.144 = 0.72 \text{ mm}$$

For the 3rd bright fringe on the other side:

$$y_3 = 3 \times 0.144 = 0.432 \text{ mm}$$

Thus, the total distance between them:

$$\Delta y = y_5 + y_3 = 0.72 + 0.432 = 1.152 \text{ mm}$$

(ii) If the light wavelength is changed to 500 nm (500×10^{-9} m), the fringe width becomes:

$$y' = \frac{\lambda' D}{d}$$

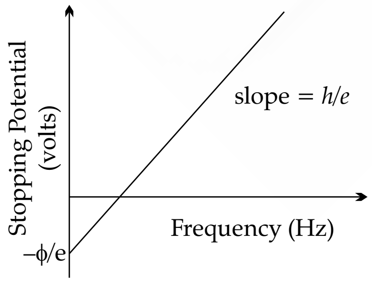
$$y' = \frac{(500\times10^{-9})(1.2)}{5\times10^{-3}}$$

$$y' = \frac{6.0\times10^{-7}}{5\times10^{-3}} = 1.2\times10^{-4}\text{m} = 0.12 \text{ mm}$$

Since, the fringe width is directly proportional to the wavelength, reducing the wavelength from 600 nm to 500 nm, results in smaller fringe widths, meaning the bright fringes will be closer together and the overall pattern will become more compact.

Answer 17

(i)



(ii) From the equation:

$$V_s = \frac{h}{e}f - \frac{\phi}{e}$$

The slope of the graph gives h/e

Since, e (electron charge) = 1.6×10^{-19} C, we can determine h as:

h = slope × e

By calculating the slope from two points on the straight-line graph:

$$\text{slope} = \frac{\Delta V_s}{\Delta f}$$

$$h = e \times \frac{\Delta V_s}{\Delta f}$$

Thus, Planck's constant h can be determined from the slope of the graph.

SECTION–D (15 MARKS)

Answer 18

(i)(a) Given:

Length of the rod (l) = 3 m

Magnetic field (B) = $\frac{1}{\pi}$ T (directed into the plane)

The position of the rod is given by $x = \pi t$

The velocity of the rod is $v = \frac{dx}{dt} = \pi$

The motional EMF (ε) is given by $\varepsilon = Bvl$

Substituting the given values: $\varepsilon = \left(\frac{1}{\pi}\right) \times \pi \times 3 = 3$ V

Therefore, the motional EMF induced in the rod is 3 volts.

(2) The direction of induced current in the rod can be determined using Fleming's Right-Hand Rule.

Since, the rod is moving perpendicular to the magnetic field directed into the plane, the induced current will flow from A to B in the rod.

(b) Given data:

- Initial current: I_i = 15 A
- Final current: I_f = 0 A
- Time interval: dt = 0.2 s
- Induced emf: ε = 30 V

The self-induced emf (ε) in a solenoid is given by Faraday's law of electromagnetic induction:

$$30 = -L \times \frac{(0-15)}{0.2}$$

$$30 = -L \times \left(\frac{-15}{0.2}\right)$$

$$30 = -L \times (-75)$$

$$L = \frac{30}{75} = 0.4\text{H}$$

OR

(ii)(a) The current lags the voltage by $\frac{\neq}{3}$, so the component X must be an inductor (L).

(b) The rms (root mean square) value of current is given by:

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

$$I_{rms} = \frac{3.0}{\sqrt{2}} = \frac{3.0}{1.414} \approx 2.12\text{A}$$

(c) We know that angular frequency and frequency are related to:

$$\omega = 2\pi f$$
$$314 = 2\pi f$$
$$f = 314/2\pi = 50 \text{ Hz}$$

So, the frequency of the source is 50 Hz.

(d) Power factor (cos θ)is given by:

$$\text{Cos}\,\theta = \cos\left(\frac{\pi}{3}\right) = \frac{1}{2} = 0.5$$

(e) Impedance is given by Ohm's law for AC circuits:

$$Z = \frac{E_0}{I_0}$$

Substituting values:

$$Z = \frac{5.0}{3.0} \approx 1.67\ \Omega$$

Answer 19

(i)(a) For a circular orbit of the electron,

$$\frac{mv^2}{r} = \frac{kZe \cdot e}{r^2} = \frac{kZe^2}{r^2}$$

Or,

$$r = \frac{kze^2}{mv^2} \quad \text{....(i)}$$

Using Bohr's quantisation condition for angular momentum,

$$L = mvr = \frac{nh}{2\pi}$$

Or,

$$r = \frac{nh}{2\neq mv} \quad \text{....(ii)}$$

$$\frac{kZe^2}{mv^2} = \frac{nh}{2\neq nv}$$

$$v = \frac{2\neq kZe^2}{nh}$$

$$\therefore \quad \text{r} = \frac{nh}{2\pi m} \cdot \frac{nh}{2\pi kZe^2}$$

$$= \frac{n^2h^2}{4\neq^2 mkZe^2}$$

This shows that $r \propto n^2$.

(b)(1) Nuclear fusion occurs continuously in stars, including our Sun. In stars, hydrogen nuclei (protons) fuse to form helium, releasing a tremendous amount of energy in the process. This energy powers the Sun and other stars, making them shine.

(2) The mass defect (Δm) is the difference between the sum of the masses of individual nucleons (protons and neutrons) in a nucleus and the actual mass of the nucleus.

$$\Delta m = (Zm_p + Nm_n) - M$$

where:

- Z = Number of protons
- m_p = Mass of a proton
- N = Number of neutrons
- m_n = Mass of a neutron
- M = Actual mass of the nucleus

OR

(ii) (a) (1) A nuclear reactor is used to:

- Generate electricity by controlling nuclear fission reactions.
- Produce radioactive isotopes for medical and industrial applications.
- Conduct scientific research in nuclear physics.
- Power naval vessels, such as submarines and aircraft carriers.

(2) The material that slows down fast neutrons is called a moderator. Examples of moderators:

- Heavy water (D_2O)
- Graphite
- Ordinary water (H_2O)

(3) A nuclear reactor can be shut down in an emergency by inserting control rods completely into the reactor core. Control rods are made of neutron-absorbing materials like boron or cadmium.

(b)(1) This means that an electron cannot have any arbitrary value of angular momentum; instead, it is restricted to discrete (quantised) values.

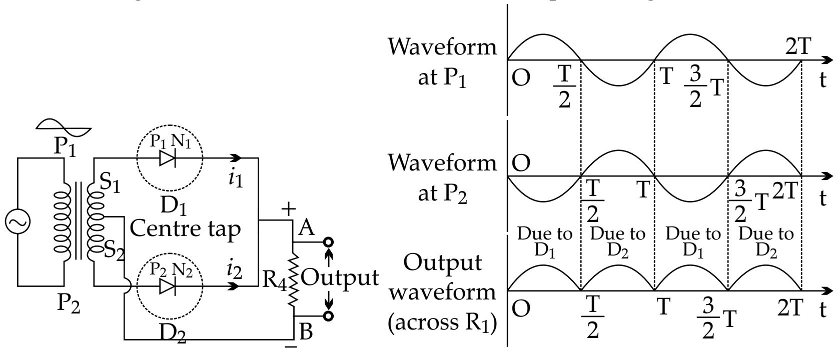
(2) Negative energy implies that the electron requires external energy to escape the atom, leading to concepts like ionisation energy.

Answer 20

(i)

Property	P-Type Semiconductor	N-Type Semiconductor
Dopant Used	Trivalent impurity (e.g., boron, gallium)	Pentavalent impurity (e.g., phosphorus, arsenic)
Majority Charge Carriers	Holes (positive charge carriers)	Electrons (Negative charge carriers)
Minority Charge Carriers	Electrons	Holes
Charge Flow Mechanism	Due to movement of holes	Due to movement of free electrons
Nature of Conductivity	Accepts electrons (deficiency of electrons)	Donates electrons (excess electrons)

(ii) Labelled diagram of a full wave rectifier with its output voltage varies with time.



(iii) A Zener Diode is used as a voltage regulator because:

- It operates in reverse breakdown region and maintains a constant voltage across its terminals.
- Even if the input voltage fluctuates, it provides a stable output voltage.