UP Board Class 12 Physics 2024 (Code 346 FX) Question Paper with Solutions

General Instructions

(i) This booklet contains 9 questions, each provided with a complete, step-by-step solution.

(ii) It has multiple-choice questions as well as questions that need a written answer.

(iii) Attempt each question on your own before reviewing the given solution.

1(a). In lens maker formula $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$, which focal length is used?

(A)

Always first

(B)

Always second

(C)

First or second any one

(D)

None of these

Correct Answer: (B)

Always second

Solution:

Step 1: The lens maker's formula is given as:

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Step 2: Here, R_1 and R_2 are the radii of curvature of the two lens surfaces. The sign convention is used to determine which radius corresponds to the first and second surfaces.

Step 3: Generally, the formula considers the second focal length in practical applications as it corresponds to the image formation side.

$\therefore$ The correct answer is Always second.

Always second

Quick Tip: Always consider the lens maker's formula with proper sign convention and determine the focal length based on whether the lens is convex or concave.

1(b). What is the nature of n-type semiconductor?

(A)

Negatively charged

(B)

Positively charged

(C)

Neutral

(D)

None of these

Correct Answer: (C)

Neutral

Solution:

Step 1: An n-type semiconductor is created by doping a pure semiconductor with elements having more electrons.

Step 2: Despite having free electrons, the overall charge of the semiconductor remains neutral because the number of positive protons in the nuclei balances the charge.

Quick Tip: N-type semiconductors are neutral overall, even though they contain free electrons as charge carriers.

1(c). In nuclear reaction, $^{15}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + P$, what is P?

(A)

Proton

(B)

Deuteron

(C)

Alpha particle

(D)

Electron

Correct Answer: (A)

Proton

Solution:

Step 1: Analyze the given nuclear reaction:

$$^{15}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + P$$

Step 2: By balancing atomic and mass numbers:

$$7 + 0 = 6 + X \quad \Rightarrow \quad X = 1 \quad \text{(Proton)}$$

$$15 + 1 = 14 + Y \quad \Rightarrow \quad Y = 2 \quad \text{(Mass of proton)}$$

$\therefore$ The correct answer is Proton.

Proton

Quick Tip: In nuclear reactions, balance both atomic and mass numbers to identify unknown particles.

1(d). The equivalent resistance of 5 equal resistances connected in series and parallel are R_1 and R_2 respectively. If $R_1 = nR_2$, then what will be the possible value of n?

(A) $\frac{1}{25}$

(B) $\frac{1}{5}$

(C) 5

(D) 25

Correct Answer: (D) 25

Solution:

Step 1: Equivalent resistance for resistors in series:

$$R_1 = 5R$$

Step 2: Equivalent resistance for resistors in parallel:

$$\frac{1}{R_2} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} + \frac{1}{R} + \frac{1}{R}$$

$$R_2 = \frac{R}{5}$$

Step 3: Given $R_1 = nR_2$:

$$5R = n \cdot \frac{R}{5}$$

$$n = 25$$

$\therefore$ The correct answer is 25.

$$\boxed{25}$$

Quick Tip: For resistors in series, simply add their resistances; for parallel resistors, sum their reciprocals and take the inverse.

1(e). Which of the following is the unit of electric flux?

(A) \text{volt Ã— second}

(B) \text{volt Ã— metre}

(C) \text{coulomb Ã— second}

(D) \text{coulomb Ã— metre}

Correct Answer: (B) \text{volt Ã— metre}

Solution:

Step 1: Electric flux is given by the formula:

$$\Phi_E = \mathbf{E} \cdot \mathbf{A}$$

Step 2: The unit of electric field E is volt per metre (V/m), and the unit of area A is metre squared (m^2).

$$\text{Unit of flux} = \left(\frac{\text{volt}}{\text{metre}}\right) \times \text{metre}^2 = \text{volt} \times \text{metre}$$

$\therefore$ The correct answer is volt Ã— metre.

$\boxed{\text{volt Ã— metre}}$

Quick Tip: Remember that electric flux is the product of electric field strength and surface area, leading to the unit **volt × metre**.

1(f). If the resistance of ammeter and milli-ammeter are x_1 and x_2 respectively, then:

(A) $x_1 > x_2$

(B) $x_1 = x_2$

(C) $x_1 < x_2$

(D) $x_1 \geq x_2$

Correct Answer: (C) $x_1 < x_2$

Solution:

Step 1: An ammeter is designed to measure larger currents with lower resistance, whereas a milli-ammeter measures smaller currents and therefore requires higher sensitivity.

Step 2: Since a milli-ammeter is more sensitive, it has higher internal resistance compared to an ammeter.

$$\therefore x_1 < x_2$$

$$\boxed{x_1 < x_2}$$

Quick Tip: Milli-ammeters have higher resistance than regular ammeters because they are designed for lower current measurements.

2(a). Write the relation between SI and MKS units of electric power.

Correct Answer: —

Solution:

Step 1: In the SI system, electric power is measured in watts (W), where:

$$1 \text{ watt} = 1 \text{ joule/second}$$

Step 2: In the MKS system, power is also expressed in terms of mechanical energy per unit time, which leads to the same value.

$$\therefore \text{The relation is } 1 \text{ watt} = 1 \text{ joule per second.}$$

$$\boxed{1 \text{ watt} = 1 \text{ joule/second}}$$

Quick Tip: Power in the SI and MKS systems is numerically the same, with both units related to energy conversion per second.

2(b). Which type of field is produced around a current carrying conductor and why?

Correct Answer: —

Solution:

Step 1: When current flows through a conductor, it generates a magnetic field around it according to Ampere's circuital law. **Step 2:**

The right-hand rule helps determine the direction of the magnetic field, which forms concentric circles around the conductor.

∴ The field produced is a magnetic field.

Magnetic field

Quick Tip: Use the right-hand thumb rule to determine the direction of the magnetic field around a current-carrying conductor.

2(c). If ε_0 and μ_0 represent permittivity and permeability of free space, then $\frac{1}{\sqrt{\varepsilon_0\mu_0}}$ represents which physical quantity?

Correct Answer: —

Solution:

Step 1: The speed of electromagnetic waves in free space is given by the formula:

$$c = \frac{1}{\sqrt{\varepsilon_0\mu_0}}$$

Step 2: The values of permittivity ε_0 and permeability μ_0 in free space determine the propagation speed of light.

∴ The correct answer is the speed of light.

Speed of light

Quick Tip: The relation $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$ is fundamental in electromagnetism and defines the speed of light in vacuum.

2(d). How are optical ray and wavefront related with each other?

Correct Answer: —

Solution:

Step 1: A wavefront represents the locus of points having the same phase in a wave. **Step 2:** An optical ray indicates the direction of propagation of the wave. **Step 3:** The optical ray is always perpendicular to the wavefront at any given point.

∴ The correct answer is: An optical ray is perpendicular to the wavefront.

An optical ray is perpendicular to the wavefront

Quick Tip: To understand wave behavior, remember that optical rays are always normal to wavefronts, following Huygens' principle.

2(e). Define energy band in solids.

Correct Answer: —

Solution:

Step 1: In solids, atomic energy levels overlap due to the close proximity of atoms, forming continuous ranges called energy bands.

Step 2: The two main types of bands in a solid are the valence band (occupied by electrons) and the conduction band (where free electrons exist). **Step 3:** The gap between these bands determines the electrical properties of the material.

∴ Energy bands define the allowed energy levels in a solid.

Energy bands are ranges of electron energy levels in solids.

Quick Tip: In semiconductors and insulators, the energy gap between valence and conduction bands determines their conductivity.

2(f). Who discovered the photoelectric effect?

Correct Answer: —

Solution:

Step 1: The photoelectric effect is the phenomenon in which light incident on a metal surface ejects electrons. **Step 2:** Albert Einstein explained this effect by proposing the quantization of light energy in the form of photons. **Step 3:** This discovery confirmed the particle nature of light and won Einstein the Nobel Prize in Physics in 1921.

∴ The correct answer is: Albert Einstein.

Albert Einstein

Quick Tip: Remember that the photoelectric effect supports the quantum theory of light, leading to the concept of photons.

3(a). A capacitor of capacity $10\,\mu F$ is charged with a source of 2 volt. Calculate (i) the energy obtained from the source and (ii) the energy stored in the capacitor.

Correct Answer: —

Solution:

Step 1: The total energy supplied by the source is calculated using:

$$\text{Energy} = CV^2$$

$$= (10 \times 10^{-6})(2)^2$$

$$= 4 \times 10^{-5}\,\text{J}$$

Step 2: The energy stored in the capacitor is:

$$\text{Stored Energy} = \frac{1}{2}CV^2$$

$$= \frac{1}{2}(10 \times 10^{-6})(2)^2$$

$$= 2 \times 10^{-5}\,\text{J}$$

$\therefore$ The correct answers are $4 \times 10^{-5}\,\text{J}$ and $2 \times 10^{-5}\,\text{J}$.

$$\boxed{4 \times 10^{-5}\,\text{J},\ 2 \times 10^{-5}\,\text{J}}$$

Quick Tip: In capacitors, only half of the energy supplied by the source is stored; the rest is dissipated in the circuit.

3(b). A cell has electromotive force 1.5 volt and internal resistance 0.2 ohm. It is connected with an external resistance of 2.8 ohm. Calculate (i) the potential difference across the open ends of the cell and (ii) the current obtained from the cell.

Correct Answer: —

Solution:

Step 1: Using Ohm's Law, total resistance is:

$$R_{\text{total}} = 0.2 + 2.8 = 3\,\Omega$$

Step 2: The current obtained from the cell:

$$I = \frac{E}{R_{\text{total}}} = \frac{1.5}{3} = 0.5\,A$$

Step 3: Potential difference across the terminals:

$$V = E - Ir = 1.5 - (0.5 \times 0.2)$$

$$= 1.4\,V$$

$\therefore$ The correct answers are 1.4 V and 0.5 A.

$$\boxed{1.4\,\text{V},\ 0.5\,\text{A}}$$

Quick Tip: Always include internal resistance when calculating the total circuit resistance in practical cells.

3(c). If wavelength λ represents wave property and momentum p represents the particle property, then what will the expressions $\lambda = \frac{h}{p}$ and $p = \frac{h}{\lambda}$ represent?

Correct Answer: —

Solution:

Step 1: The expression $\lambda = \frac{h}{p}$ represents the de Broglie wavelength, which describes the wave nature of particles. **Step 2:** The expression $p = \frac{h}{\lambda}$ represents the particle's momentum derived from its wavelength.

∴ The correct answers are de Broglie wavelength and momentum.

de Broglie wavelength, momentum

Quick Tip: De Broglie's equation shows the wave-particle duality, linking wavelength with momentum.

3(d). If the mass defect of a nucleus is 2×10^{-6} kg, then calculate its binding energy in (i) joule and (ii) electron-volt.

Correct Answer: —

Solution:

Step 1: The binding energy is calculated using Einsteinâ€™s equation:

$$E = mc^2$$

$$= (2 \times 10^{-6})(3 \times 10^{8})^2$$

$$= 1.8 \times 10^{11}\ \text{J}$$

Step 2: Converting joules to electron-volts:

$$1\ \text{J} = 6.24 \times 10^{18}\ \text{eV}$$

$$E = 1.8 \times 10^{11} \times 6.24 \times 10^{18}$$

$$= 1.12 \times 10^{30}\ \text{eV}$$

$\therefore$ The correct answers are 1.8×10^{11} J and 1.12×10^{30} eV.

$$\boxed{1.8 \times 10^{11}\ \text{J},\ 1.12 \times 10^{30}\ \text{eV}}$$

Quick Tip: Use $E = mc^2$ to calculate binding energy, and remember the conversion factor $1\ \text{J} = 6.24 \times 10^{18}$ eV.

4(a).

On which factors and how do the following depend?

(i) Internal resistance of cell
(ii) Resistance of conductor

Correct Answer: —

Solution:

i. Internal resistance of cell Step 1: The internal resistance of a cell depends on several factors:

$$r \propto \frac{\text{distance between electrodes}}{\text{area of electrodes}}$$

- It increases if the distance between electrodes increases.
- It decreases if the cross-sectional area of electrodes increases.
- It depends on the electrolyte's concentration and nature.

Thus, the internal resistance can be minimized by using a highly conductive electrolyte and optimizing electrode placement.

Factors: Distance, area, electrolyte nature, and temperature

ii. Resistance of conductor

Step 1: The resistance of a conductor is given by:

$$R = \rho \frac{L}{A}$$

where: - R is resistance,
- ρ is resistivity,
- L is length,
- A is cross-sectional area.

Step 2: Factors affecting resistance: - It increases with an increase in length (L).
- It decreases with an increase in cross-sectional area (A).
- Different materials have different resistivities.
- Resistance increases with temperature due to an increase in resistivity.

Therefore, resistance can be controlled by choosing appropriate materials and dimensions.

Factors: Length, cross-sectional area, material, and temperature

Quick Tip: To reduce conductor resistance, choose materials with low resistivity and increase the cross-sectional area.

4(b). A plane electromagnetic wave is represented by the equation

$$E = 100\cos(6 \times 10^8 t + 4x)\,\text{volt/metre}.$$

Calculate the following:
(i) The refractive index of the medium
(ii) The velocity of electromagnetic wave in the medium
(iii) The expression for magnetic field

Correct Answer: —

Solution:

i. The refractive index of the medium Step 1: The given equation of the wave is:

$$E = 100\cos(6 \times 10^8 t + 4x)$$

Step 2: Comparing with the general wave equation $E = E_0\cos(\omega t + kx)$, we get:

$$\omega = 6 \times 10^8, \quad k = 4$$

Step 3: Using the relation $v = \frac{\omega}{k}$:

$$v = \frac{6 \times 10^8}{4} = 1.5 \times 10^8\ \text{m/s}$$

Step 4: The refractive index is:

$$n = \frac{c}{v} = \frac{3 \times 10^8}{1.5 \times 10^8} = 2$$

$$\boxed{n = 2}$$

ii. The velocity of electromagnetic wave in the medium Step 1: From the previous step, we obtained the velocity as:

$$v = \frac{\omega}{k} = 1.5 \times 10^8 \text{ m/s}$$

$$\boxed{v = 1.5 \times 10^8 \text{ m/s}}$$

iii. The expression for magnetic field Step 1: In an electromagnetic wave, the magnetic field B is related to the electric field E by:

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

Step 2: Substituting the given electric field expression:

$$B = \frac{100}{3 \times 10^8} \cos(6 \times 10^8 t + 4x)$$

$$B = \frac{E_0}{c} \cos(6 \times 10^8 t + 4x)$$

$$\boxed{B = \frac{E_0}{c} \cos(6 \times 10^8 t + 4x)}$$

Quick Tip: For plane electromagnetic waves, the velocity can be calculated using $v = \frac{\omega}{k}$ and the magnetic field using $B = \frac{E}{c}$.

4(c).

Explain the difference between the following substances with the help of examples:

(i) Paramagnetic
(ii) Diamagnetic
(iii) Ferromagnetic

Correct Answer: —

Solution:

i. Paramagnetic Substances

Step 1: Paramagnetic materials have unpaired electrons in their atomic structure, which cause weak attraction to external magnetic fields.

Step 2: They have a small and positive magnetic susceptibility and align weakly with the applied magnetic field. **Examples:** Aluminum, Platinum, Oxygen.

Weak attraction, e.g., Aluminum

ii. Diamagnetic Substances

Step 1: Diamagnetic materials have all paired electrons, causing them to create an induced magnetic field in the opposite direction to the applied field.

Step 2: They have a small and negative magnetic susceptibility and are weakly repelled by the applied magnetic field.

Examples: Copper, Gold, Bismuth.

Weak repulsion, e.g., Copper

iii. Ferromagnetic Substances

Step 1: Ferromagnetic materials have domains of atoms that align strongly with an external magnetic field, creating a strong attraction.

Step 2: They have high positive susceptibility and retain magnetization even after removing the external field.

Examples: Iron, Nickel, Cobalt.

Strong attraction, e.g., Iron

Quick Tip: Ferromagnetic materials retain magnetism, while paramagnetic and diamagnetic materials do not.

4(d). The angle of prism is equal to its minimum deviation angle (δ_m). In minimum deviation condition, calculate the following:

(i) The angle of incidence

(ii) The angle of refraction

(iii) The refractive index of the material of the prism.

Correct Answer: —

Solution:

i. The angle of incidence Step 1: At minimum deviation condition, the angle of incidence i is related to the prism angle A and minimum deviation angle δ_m by:

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

Step 2: Given $A = \delta_m$, we substitute:

$$i = A + \frac{A}{2} = \frac{3A}{2}$$

$$\boxed{i = \frac{3A}{2}}$$

ii. The angle of refraction Step 1: At minimum deviation, the refracted ray passes symmetrically through the prism, meaning:

$$r = \frac{A}{2}$$

$$\boxed{r = \frac{A}{2}}$$

iii. The refractive index of the material of the prism Step 1: The refractive index n of the prism material is given by:

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

Step 2: Since $A = \delta_m$:

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

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

$$\boxed{n = \frac{\sin A}{\sin\left(\frac{A}{2}\right)}}$$

Quick Tip: In minimum deviation condition, the refracted ray is symmetric inside the prism, and refractive index can be calculated using the formula $n = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$.

4(e). What are forward biasing and reverse biasing in *p-n* junction? Explain the difference between forward current and reverse current.

Correct Answer: —

Solution:

Step 1: Forward Biasing In forward biasing, the external voltage applied reduces the potential barrier of the depletion region, allowing current to flow easily through the junction.

- The positive terminal of the battery is connected to the *p*-side, and the negative terminal to the *n*-side.
- As the barrier potential decreases, more charge carriers (electrons and holes) cross the junction.
- The current increases exponentially with applied voltage.

Example: Forward biasing is used in rectifiers and LEDs. Current in forward bias }

Forward bias allows current flow.

Step 2: Reverse Biasing In reverse biasing, the external voltage increases the potential barrier, preventing the flow of majority carriers and widening the depletion region.

- The positive terminal is connected to the *n*-side, and the negative terminal to the *p*-side.
- Only a small leakage current flows due to minority carriers.

- Beyond a certain voltage, breakdown occurs, causing a large current to flow.

Example: Reverse biasing is used in Zener diodes and photodiodes.

$$\text{Reverse current } I_R \approx 0$$

$$\boxed{\text{Reverse bias restricts current flow.}}$$

Step 3: Difference Between Forward and Reverse Current

Forward Current	Reverse Current
$Large current flow$	$Very small current flow (leakage current)$
$Depletion region shrinks$	$Depletion region widens$
$Used in conduction applications$	$Used for blocking applications$

Quick Tip: In practical applications, forward biasing allows current flow in diodes, while reverse biasing is used for blocking and sensing applications.

5(a). A proton, a deuteron and an alpha particle of same velocity enter perpendicularly in an uniform magnetic field of 10^5 tesla. Calculate the ratio of their time periods of revolution.

Correct Answer: —

Solution:

Step 1: The time period of a charged particle in a magnetic field is given by the formula:

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

Step 2: Given that the velocity and magnetic field are the same for all particles, the ratio of time periods depends on the ratio $\frac{m}{q}$. **Step 3:** The mass and charge values of the particles:

$$\text{Proton: } m_p, \quad q_p = e$$

$$\text{Deuteron: } m_d = 2m_p, \quad q_d = e$$

$$\text{Alpha particle: } m_\alpha = 4m_p, \quad q_\alpha = 2e$$

Step 4: Using the formula $T \propto \frac{m}{q}$:

$$\frac{T_{\text{proton}}}{T_{\text{deuteron}}} = \frac{m_p/e}{2m_p/e} = \frac{1}{2}$$

$$\frac{T_{\text{proton}}}{T_\alpha} = \frac{m_p/e}{4m_p/2e} = \frac{1}{4}$$

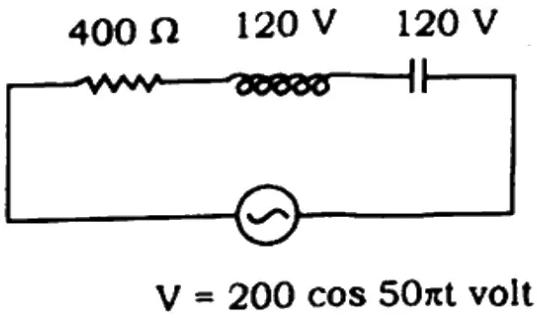
Thus, the ratio of time periods is:

$$1 : 2 : 4$$

$$\boxed{1 : 2 : 4}$$

Quick Tip: The time period of a charged particle in a magnetic field is proportional to the mass-to-charge ratio $\frac{m}{q}$.

5(b).



Calculate the following for given circuit :

i) Current in the circuit

ii) The potential across resistance

iii) The phase difference between the potentials across inductor and capacitor.

Correct Answer: –

Solution:

Step 1: Read the circuit:

The figure shows a resistor of $400\ \Omega$, an inductor and a capacitor in series with an AC source $V = 200\cos 50\pi t$ volt. The voltage across the inductor is marked 120 V and the voltage across the capacitor is also marked 120 V. The source has peak value $V_0 = 200$ V.

Step 2: Key idea:

In a series LCR circuit the same current flows through every element. The voltage across the resistor is in phase with this current. The voltage across the inductor leads the current by $90°$, and the voltage across the capacitor lags the current by $90°$. So the two reactive voltages point in exactly opposite directions.

Here $V_L = V_C = 120$ V, so they cancel each other completely. The circuit is at resonance, where $X_L = X_C$ and the impedance is $Z = R$.

Step 3: Impedance and current (part i):

The impedance of a series LCR circuit is:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Since $X_L = X_C$, we get:

$$Z = R = 400\ \Omega$$

The peak current is the peak source voltage divided by the impedance:

$$I_0 = \frac{V_0}{Z} = \frac{200}{400} = 0.5\ \text{A}$$

The rms value of this current is $I_{rms} = \frac{0.5}{\sqrt{2}} \approx 0.35$ A.

Step 4: Potential across the resistance (part ii):

By Ohm's law for the resistor:

$$V_R = I_0 R = 0.5 \times 400 = 200\ \text{V}$$

This is the peak value. It equals the peak source voltage, which must happen because the inductor and capacitor voltages cancel. The rms value is $200/\sqrt{2} \approx 141$ V.

Step 5: Phase difference between inductor and capacitor voltages (part iii):

Take the current as reference. The inductor voltage leads it by 90° and the capacitor voltage lags it by 90°. So the phase difference between them is:

$$\phi = 90^\circ - (-90^\circ) = 180^\circ = \pi \text{ rad}$$

The two voltages are in opposite phase.

Final Answer:

(i) The current is 0.5 A (peak), about 0.35 A rms. (ii) The potential across the resistance is 200 V (peak). (iii) The phase difference between the inductor and capacitor voltages is π (180°).

$$\boxed{I_0 = 0.5 \text{ A}, \quad V_R = 200 \text{ V}, \quad \phi = \pi}$$

Quick Tip: The inductor and capacitor voltages are equal and opposite, so the circuit is at resonance and $Z = R$. Then $I_0 = V_0/R$, $V_R = V_0$ and the phase difference is π.

5(c). In a spherical mirror, the distance between the focus point and centre of curvature is 20 cm. Calculate the following and write their names: (i) The distance of pole of mirror from its focal point.
(ii) The distance of pole of mirror from its centre of curvature.
\vspace{0.5cm} **(i) The distance of pole of mirror from its focal point**

Correct Answer: —

Solution:

Step 1: The focal length f of a spherical mirror is the distance between the pole and the focal point.

Step 2: Given that the distance between the focus and centre of curvature is 20 cm, we know that:

$$f = 20\,\text{cm}$$

$$\boxed{20\,\text{cm (Focal length)}}$$

(ii) The distance of pole of mirror from its centre of curvature

Solution:

Step 1: The radius of curvature R is the distance between the pole and the centre of curvature.

Step 2: Since the focal length is given as $f = 20\,\text{cm}$, we use the relation:

$$R = 2f$$

Step 3: Substituting the given value:

$$R = 2 \times 20 = 40\,\text{cm}$$

$$\boxed{40\,\text{cm (Radius of curvature)}}$$

Quick Tip: In spherical mirrors, the focal length is half of the radius of curvature, given by $f = \frac{R}{2}$. The radius of curvature is always twice the focal length in spherical mirrors.

5(d). What is meant by threshold wavelength λ_0 and threshold frequency ν_0 in photoelectric effect? On which factors do the saturation current and the value of cut-off voltage depend?

Correct Answer: —

Solution:

Step 1: Threshold Wavelength and Threshold Frequency **Threshold Wavelength:** Threshold wavelength λ_0 is the longest wavelength of incident light that can cause photoemission. It is related to the work function ϕ of the material by the equation:

$$\lambda_0 = \frac{hc}{\phi}$$

If the wavelength λ of the incident light is greater than λ_0, photoemission does not occur.

Threshold Frequency: Threshold frequency ν_0 is the minimum frequency of the incident light required to eject electrons from the metal surface. It is given by:

$$\nu_0 = \frac{\phi}{h}$$

If the frequency ν of the incident light is less than ν_0, no photoelectric emission occurs.

$$\boxed{\lambda_0 = \frac{hc}{\phi}, \quad \nu_0 = \frac{\phi}{h}}$$

\

Step 2: Factors affecting Saturation Current and Cut-off Voltage **Saturation Current:** Saturation current is the maximum current obtained when all photoelectrons emitted from the surface reach the anode.

It depends on: - **Intensity of Incident Light:** As the intensity increases, more photons strike the surface, resulting in the emission of more electrons.

$$\text{Saturation current} \propto \text{Intensity of light}$$

Cut-off Voltage: Cut-off voltage (stopping potential) is the minimum negative potential required to stop the photoelectrons from reaching the anode.

It depends on: - **Frequency of Incident Light:** Higher frequency photons carry more energy, requiring a higher cut-off voltage to stop the electrons. Using Einstein's photoelectric equation:

$$eV_{\text{cut-off}} = h\nu - \phi$$

$$\boxed{\text{Saturation current} \propto \text{intensity}, \quad V_{\text{cut-off}} \propto \text{frequency}.}$$

Quick Tip: Remember: Saturation current depends on light intensity, whereas cut-off voltage is determined by light frequency and the material's work function.

5(e). What is *p-n* junction rectifier? Draw circuit diagram of (i) half-wave rectifier (HWR) and (ii) full-wave rectifier (FWR). (i) Half-Wave Rectifier (HWR)

Correct Answer: —

Solution:

Step 1: In a half-wave rectifier, a single diode is used to allow the flow of current only during the positive half of the AC input. **Step 2:**

During the negative half-cycle, the diode blocks the current flow.

HWR allows current in one half-cycle.

(ii) Full-Wave Rectifier (FWR) % Solution **Solution: Step 1:** A full-wave rectifier uses two diodes (center-tap transformer) or four diodes (bridge rectifier) to allow current in both positive and negative cycles. **Step 2:** This results in a pulsating DC output.

FWR allows current in both half-cycles.

Quick Tip: A half-wave rectifier uses one diode, while a full-wave rectifier uses two or four diodes for continuous current flow.

OR

Compare *n*-type and *p*-type semiconductors on the basis of following :
i) The nature of doping material
ii) Majority and minority charge carriers
iii) The relation between conductivity and mobility.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:
Pure silicon or germanium is an intrinsic semiconductor. Adding a small amount of a suitable impurity (doping) raises its conductivity a lot. The type of impurity decides whether the result is n-type or p-type.

Step 2: Nature of doping material (part i):
For an n-type semiconductor, we dope Si or Ge with a pentavalent

impurity such as phosphorus, arsenic or antimony. Each impurity atom has 5 valence electrons. Four of them form bonds, and the fifth is left almost free. Such an atom is called a donor.
For a p-type semiconductor, we dope with a trivalent impurity such as boron, aluminium or gallium. Each impurity atom has 3 valence electrons, so one bond is left incomplete. This gap is a hole, and the atom is called an acceptor.

Step 3: Majority and minority carriers (part ii):
In an n-type semiconductor, the donors supply many free electrons. So electrons are the majority carriers and holes are the minority carriers, with $n_e \gg n_h$.
In a p-type semiconductor, the acceptors create many holes. So holes are the majority carriers and electrons are the minority carriers, with $n_h \gg n_e$.
In both types the crystal as a whole stays electrically neutral, because the doped atoms are neutral.

Step 4: Conductivity and mobility (part iii):
Mobility μ is the drift speed gained per unit electric field. The conductivity of a semiconductor has an electron part and a hole part:

$$\sigma = e\,(n_e\mu_e + n_h\mu_h)$$

For n-type, $n_e \gg n_h$, so the electron term dominates:

$$\sigma_n \approx e\,n_e\mu_e$$

For p-type, $n_h \gg n_e$, so the hole term dominates:

$$\sigma_p \approx e\,n_h\mu_h$$

In general, electron mobility is larger than hole mobility, so for the same doping level an n-type sample conducts better than a p-type sample.

Final Answer:

An n-type semiconductor uses a pentavalent (donor) impurity, has electrons as majority carriers and holes as minority carriers, and $\sigma \approx en_e\mu_e$. A p-type semiconductor uses a trivalent (acceptor) impurity, has holes as majority carriers and electrons as minority carriers, and $\sigma \approx en_h\mu_h$.

$$\boxed{\sigma_n \approx e\, n_e\mu_e, \qquad \sigma_p \approx e\, n_h\mu_h}$$

Quick Tip: n-type: pentavalent donor, electrons majority, $\sigma \approx en_e\mu_e$. p-type: trivalent acceptor, holes majority, $\sigma \approx en_h\mu_h$.

6. When a capacitor of capacity C is charged with charge q and potential difference V, the electric field E and the electrostatic energy U is obtained between plates of capacitor. If the capacitor is disconnected from the source and a slab of medium having the same thickness and dielectric constant k is introduced completely between the plates, calculate the new values of the following:

(i)Capacity

(ii) Potential difference

(iii) Charge

(iv) Electric field

(v) Electrostatic potential energy

(i) Capacity

Correct Answer: —

Solution:

Step 1: The capacitance of a parallel plate capacitor with dielectric is given by:

$$C' = kC$$

$$\boxed{C' = kC}$$

(ii) Potential Difference % Correct Answer **Correct Answer:** $V' = \frac{V}{k}$ % Solution **Solution: Step 1:** Since the capacitor is disconnected, the charge remains constant. Using the formula:

$$V' = \frac{q}{C'} = \frac{q}{kC}$$

$$V' = \frac{V}{k}$$

$$\boxed{V' = \frac{V}{k}}$$

(iii) Charge % Correct Answer **Correct Answer:** $q' = q$ (remains constant) % Solution **Solution: Step 1:** As the capacitor is disconnected, the charge remains the same:

$$q' = q$$

$$\boxed{q' = q}$$

(iv) Electric Field % Correct Answer **Correct Answer:** $E' = \frac{E}{k}$ % Solution **Solution: Step 1:** The electric field is given by:

$$E = \frac{V}{d}$$

Step 2: Substituting the new potential difference:

$$E' = \frac{V'}{d} = \frac{V}{kd}$$

$$E' = \frac{E}{k}$$

$$\boxed{E' = \frac{E}{k}}$$

(v) Electrostatic Potential Energy % Correct Answer **Correct Answer:** $U' = \frac{U}{k}$ % Solution **Solution: Step 1:** Electrostatic potential energy is given by:

$$U = \frac{1}{2}CV^2$$

Step 2: Substituting new values:

$$U' = \frac{1}{2}kC\left(\frac{V}{k}\right)^2$$

$$U' = \frac{U}{k}$$

$$\boxed{U' = \frac{U}{k}}$$

Quick Tip: When a dielectric is inserted, the capacitance increases by a factor of k, while the potential and electric field decrease proportionally.

OR

What is the main difference between a cell and a battery? In which conditions do the following combinations of cells become useful and why?

(i) Series combination

(ii) Parallel combination

(iii) Mixed combination

Correct Answer: —

Solution:

A cell is a single electrochemical unit that converts chemical energy into electrical energy, while a battery consists of multiple cells connected together to provide higher voltage or current.

Step 1: A **cell** generates electrical energy from a chemical reaction within a single unit.

Step 2: A **battery** consists of multiple interconnected cells to provide higher output for more demanding applications.

Cell: Single unit, Battery: Multiple cells

(i) Series Combination

Solution: In a series combination, the voltages add up while the current remains the same.

Step 1: Cells are connected end-to-end, with the positive terminal of one connected to the negative terminal of the next.

Step 2: The total voltage is:

$$V_{\text{total}} = V_1 + V_2 + V_3 + \ldots$$

Step 3: This configuration is useful when high voltage is required, such as in electronic circuits.

Used for high voltage applications.

(ii) Parallel Combination

Solution: In a parallel combination, the current increases while the voltage remains the same.

Step 1: Cells are connected with all positive terminals together and all negative terminals together.

Step 2: The total current is:

$$I_{\text{total}} = I_1 + I_2 + I_3 + \ldots$$

Step 3: This configuration is useful when a higher current capacity is needed, such as in power backup systems.

Used for high current applications.

(iii) Mixed Combination

Solution: Step 1: In mixed combination, cells are connected in both series and parallel configurations.

Step 2: This provides an increase in both voltage and current, depending on the number of cells.

Step 3: It is useful in applications where both high voltage and current are needed, such as in electric vehicles.

Used for balanced voltage and current applications.

Quick Tip: Series combination increases voltage, parallel combination increases current, and mixed combination balances both.

7. The focal lengths of a convergent and a divergent lens are f_1 and f_2 respectively. If the lenses are placed in contact, then in the following conditions of combination, write the nature of the combined lens and also draw the ray diagram: (i) $f_1 > f_2$
(ii) $f_1 < f_2$
(iii) $f_1 = f_2$
(i) Condition: $f_1 > f_2$

Correct Answer: —

Solution:

Step 1: The effective focal length of the lens combination is given by:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

Step 2: Since $f_1 > f_2$ and f_2 is negative for a diverging lens:

$$\frac{1}{F} = \frac{1}{f_1} - \frac{1}{|f_2|}$$

Step 3: If f_1 dominates, the net effect is converging.

Combination acts as a converging lens.

(ii) Condition: $f_1 < f_2$

Solution:

Step 1: Using the same formula:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

Step 2: If $f_1 < f_2$, the negative focal length of the diverging lens dominates.

$$\frac{1}{F} < 0$$

Step 3: The net effect is a diverging lens.

Combination acts as a diverging lens.

(iii) Condition: $f_1 = f_2$

Solution:

Step 1: Using the lens formula:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

Step 2: If f_1 and f_2 are equal in magnitude but opposite in sign:

$$\frac{1}{F} = 0 \Rightarrow F = \infty$$

Step 3: The combination acts as a plane parallel glass.

Combination acts as a plane glass.

Quick Tip: The focal length of a lens combination is determined by the sum of reciprocals of individual focal lengths.

OR

Compare the Astronomical Telescope and Compound Microscope on the basis of the following:

(i) Components

(ii)Magnifying power

Explain with reason whether any one of the above devices can be used as the other device.

(i) Components

Correct Answer: —

Solution:

An astronomical telescope consists of an objective lens and an eyepiece with a longer focal length, while a compound microscope consists of an objective lens and an eyepiece with a shorter focal length.

Astronomical Telescope: - Used for viewing distant objects. -

Objective lens: Large aperture, long focal length.

Eyepiece lens: Shorter focal length for magnification.

Compound Microscope: - Used for viewing tiny nearby objects. -

Components

Objective lens: Short focal length, higher magnification.

Eyepiece lens: Further magnifies the intermediate image.

Telescope: Long focal length, Microscope: Short focal length.

(ii) Magnifying Power % Solution **Solution:**

The magnifying power of an astronomical telescope is the ratio of

focal lengths, while for a compound microscope, it is the product of magnifications of the objective and eyepiece lenses.

Astronomical Telescope:

$$\text{Magnifying Power} = \frac{f_{\text{objective}}}{f_{\text{eyepiece}}}$$

Compound Microscope:

$$\text{Magnifying Power} = m_{\text{objective}} \times m_{\text{eyepiece}}$$

Conclusion: - Telescope magnifies distant objects by collecting more light. - Microscope magnifies small objects by successive magnification.

Telescope: Focal length ratio, Microscope: Successive magnification.

(iii) Can one device be used as the other? % Solution

Solution: A telescope is designed for distant objects with long focal length, while a microscope is designed for close objects with short focal length. The image formation principles and optical configurations are different, making them unsuitable for interchange.

Thus, one cannot be used as the other.

Telescope and microscope serve distinct purposes.

Quick Tip: Remember: Telescopes are for distant objects with long focal lengths, while microscopes magnify tiny objects with short focal lengths.

8. Represent the variation of binding energy per nucleon with mass number. On the basis of it, explain the following: (i) Nuclear fission
(ii) Nuclear fusion
(iii) Nuclear energy

Correct Answer: —

Solution:

Step 1: The binding energy per nucleon varies with mass number.

Step 2: The curve shows that lighter nuclei and very heavy nuclei have lower binding energy, while medium-sized nuclei (e.g., iron) have the highest binding energy, making them more stable.

$$\boxed{\text{Most stable nucleus: Fe } (A = 56)}$$

(i) Nuclear Fission

Solution:
Nuclear fission is the process where a heavy nucleus splits into smaller nuclei, releasing energy.
Step 1: Heavy elements such as uranium-235 split into lighter elements when bombarded with neutrons.

Step 2: This process releases energy due to the increase in binding energy per nucleon.

$$\boxed{\text{Heavy nucleus} \rightarrow \text{Two lighter nuclei} + \text{Energy}}$$

(ii) Nuclear Fusion

Solution: Nuclear fusion is the process where lighter nuclei combine to form a heavier nucleus, releasing energy.

Step 1: Light elements such as hydrogen nuclei fuse together under high temperature and pressure to form helium.

Step 2: This results in a release of energy due to an increase in binding energy per nucleon.

$$\boxed{\text{Light nuclei} \rightarrow \text{Heavier nucleus} + \text{Energy}}$$

(iii) Nuclear Energy

Solution: Nuclear energy is the energy released during fission or fusion due to changes in binding energy.

Step 1: The energy released during fission and fusion reactions is calculated using Einstein's equation:

$$E = mc^2$$

Step 2: This energy is harnessed in nuclear reactors and stars.

$$\boxed{\text{Energy is released due to mass defect.}}$$

Quick Tip: Nuclear fusion occurs in stars, while nuclear fission is used in power plants.

OR

The energy of a hydrogen atom in an energy state is −3.4 electron-volts. For an electron in this energy state, calculate the following: (i) Binding energy
(ii) Ionization potential
(iii) The number of energy states
(iv) The angular momentum
(v) Kinetic energy
(i) Binding Energy

Correct Answer: —

Solution:

Binding energy is the energy required to remove the electron from the given state.

$$\text{Binding energy} = 3.4 \text{ eV}$$

$$\boxed{3.4 \text{ eV}}$$

(ii) Ionization Potential % Solution **Solution:** Ionization potential is the energy required to ionize the atom by removing an electron from the current state.

$$\text{Ionization potential} = 3.4 \text{ eV}$$

$$\boxed{3.4 \text{ eV}}$$

(iii) The Number of Energy States % Solution **Solution:** The number of possible states for an electron in the nth energy level is given by:

$$\text{Number of states} = n^2$$

For $n = 2$:

$$2^2 = 4$$

$$\boxed{4}$$

(iv) The Angular Momentum % Solution **Solution:** The angular momentum of an electron in the nth orbit is:

$$L = n\hbar$$

For $n = 2$:

$$L = 2\hbar$$

$$\boxed{2\hbar}$$

(v) Kinetic Energy % Solution **Solution:** In hydrogen atoms, kinetic energy in an energy state is numerically equal to the binding energy.

$$\text{Kinetic Energy} = 3.4 \text{ eV}$$

$$\boxed{3.4 \text{ eV}}$$

Quick Tip: For hydrogen atoms, ionization energy equals the binding energy in a given state.

9. On what factors does the magnetic flux linked with a coil depend? Explain the induced electromotive force on the basis of the following:

(i) Cause

(ii) Magnitude

(iii) Direction

Correct Answer: —

Solution:

Step 1: Magnetic flux (Φ) linked with a coil depends on:

$$\Phi = BA\cos\theta$$

where:

- B = Magnetic field strength
- A = Area of the coil
- θ = Angle between the field and the normal to the coil

Flux depends on $B, A,$ and θ.

(i) Cause

Solution: The changing magnetic field causes an induced electromotive force (EMF).

Step 1: According to Faraday's law, EMF is induced when the magnetic flux through a coil changes with time.

$$\mathcal{E} = -\frac{d\Phi}{dt}$$

Changing flux induces EMF.

(ii) Magnitude

Solution: The magnitude of induced EMF is proportional to the rate of change of flux.

Step 1: Using Faraday's law, the magnitude of the induced EMF is:

$$|\mathcal{E}| = \left|\frac{d\Phi}{dt}\right|$$

Step 2: Faster changes in flux result in higher EMF.

$$\boxed{\mathcal{E} \propto \frac{d\Phi}{dt}}$$

(iii) Direction

Solution: The direction of induced EMF is given by Lenz's Law.

Step 1: According to Lenz's Law, the induced EMF opposes the change in magnetic flux.

Step 2: The negative sign in Faraday's law signifies this opposition.

$$\mathcal{E} = -\frac{d\Phi}{dt}$$

Opposes the flux change.

Quick Tip: Remember, a change in flux induces an EMF that opposes the cause producing it.

OR

On what principle does the transformer work? State the following conditions for an ideal transformer:

(i) Leakage of magnetic flux

(ii) Resistance of primary coil

(iii) Resistance of secondary coil

(iv)Dissipation of power

Correct Answer: —

Solution:

A transformer works on the principle of electromagnetic induction.

Step 1: An alternating current in the primary coil creates a changing magnetic field.

Step 2: This varying magnetic flux induces an EMF in the secondary coil according to Faraday's law.

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

Transformer works on mutual induction.

(i) Leakage of magnetic flux

Solution: There should be no flux leakage; all flux should link both coils.

Step 1: Ideally, all magnetic flux produced by the primary coil should pass through the secondary coil.

Zero flux leakage for ideal transformer.

(ii) Resistance of primary coilSolution: The primary coil should have zero resistance.

Step 1: An ideal transformer assumes no resistive losses in the primary coil to prevent energy dissipation.

Zero resistance in the primary coil.

(iii) Resistance of secondary coil

Solution: The secondary coil should also have zero resistance.

Step 1: In an ideal transformer, the secondary coil is assumed to be perfect, with no resistance.

Zero resistance in the secondary coil.

(iv) Dissipation of power

Solution:

There should be no power loss in an ideal transformer.

Step 1: In an ideal transformer, the entire power input is transferred to the output. **Step 2:** Efficiency is 100%, meaning no loss due to resistance, flux leakage, or core losses.

No power dissipation in ideal transformer.

Quick Tip: An ideal transformer assumes perfect energy transfer with no losses.