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

collegedunia

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). The Louis de Broglie wavelength of a particle having kinetic energy E is:

(A) $\lambda = \frac{h}{\sqrt{2mE}}$

(B) $\lambda = \frac{h}{\sqrt{mE}}$

(C) $\lambda = \frac{\sqrt{2mE}}{h}$

(D) $\lambda = \frac{\sqrt{mE}}{h}$

Correct Answer: (A) $\lambda = \frac{h}{\sqrt{2mE}}$

Solution:

The de Broglie wavelength λ of a particle with kinetic energy E is given by the relation:

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

where h is Planckâ€™s constant, m is the mass of the particle, and E is its kinetic energy.

Correct Answer: (A) $\lambda = \frac{h}{\sqrt{2mE}}$.

Quick Tip: The de Broglie wavelength is inversely related to the square root of the particleâ€™s kinetic energy and its mass.

1(b). If drift velocity of electron be v_d and intensity of electric field E, then which relation among the following obeys Ohm's law?

(A) $v_d \propto E^2$

(B) $v_d =$ Constant

(C) $v_d \propto E$

(D) $v_d \propto \sqrt{E}$

Correct Answer: (C) $v_d \propto E$

Solution:

The path of scattered α-particles in Rutherford scattering is hyperbolic. When an α-particle is scattered by a nucleus, the path is determined by the repulsive electrostatic force, resulting in a hyperbolic trajectory.

Quick Tip:

Ohms law states that the drift velocity of charge carriers is proportional to the applied electric field, leading to a constant current for a given resistance.

1(c).

The path of scattered α-particle is:

(A) Circular

(B) Parabolic

(C) Elliptical

(D) Hyperbolic

Correct Answer: (D) Hyperbolic

Solution:

The path of scattered α-particles in Rutherford scattering is hyperbolic. When an α-particle is scattered by a nucleus, the path is determined by the repulsive electrostatic force, resulting in a hyperbolic trajectory.

Quick Tip: The scattering of particles by nuclei follows hyperbolic paths due to the inverse square law of electrostatic forces.

1(d).

The maximum focal length of convex lens is for:

(A) Blue light

(B) Green light

(C) Red light

(D) Yellow light

Correct Answer: (C) Red light

Solution:

The focal length of a lens is dependent on the wavelength of the light passing through it. For a convex lens, the focal length is greatest for red light, as it has the longest wavelength.

Quick Tip: Light with longer wavelengths, like red light, tends to have the largest focal length in a convex lens, due to its lesser refraction compared to shorter wavelengths.

1(e).

The power consumed in alternating current in a circuit containing only a capacitor will be:

(A) $P = -1$

(B) $P = 0$

(C) $P = +1$

(D) None of the above

Correct Answer: (B) $P = 0$

Solution:

In a purely capacitive AC circuit, the power consumed is zero. The voltage and current are out of phase by 90Â°, resulting in no net power dissipation.

Quick Tip: In a purely capacitive circuit, the current leads the voltage by 90Â°, meaning no real power is consumed; all power is reactive.

1(f).

Force of 80 Newton works between two point charges placed at a fixed distance apart in air. When these charges are placed at the same distance apart in a dielectric medium, then the force of 8 Newton works on it. The dielectric constant of the medium will be:

(A) $K = -10$

(B) $K = 10$

(C) $K = 0.01$

(D) $K = -0.01$

Correct Answer: (B) $K = 10$

Solution:

The force between two point charges is related to the dielectric constant K of the medium by the formula:

$$F_{\text{medium}} = \frac{F_{\text{air}}}{K}.$$

Given that the force in air is 80 N and the force in the dielectric medium is 8 N:

$$8 = \frac{80}{K} \quad \Rightarrow \quad K = \frac{80}{8} = 10.$$

Quick Tip: The force between two charges decreases in a dielectric medium by a factor equal to the dielectric constant K, which is always greater than 1 for materials other than air.

2(a).

Find the ratio of the focal length of lens in air and that of lens when it is immersed in liquid.

Correct Answer: —

Solution:

The focal length of a lens in air is given by the lens formula:

$$\frac{1}{f_{\text{air}}} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right),$$

where μ is the refractive index of the material of the lens, and R_1 and R_2 are the radii of curvature of the lens. When the lens is immersed in a liquid of refractive index μ_{liquid}, the focal length is:

$$\frac{1}{f_{\text{liquid}}} = (\mu_{\text{lens}} - \mu_{\text{liquid}})\left(\frac{1}{R_1} - \frac{1}{R_2}\right).$$

The ratio of the focal lengths is:

$$\frac{f_{\text{air}}}{f_{\text{liquid}}} = \frac{\mu_{\text{lens}} - 1}{\mu_{\text{lens}} - \mu_{\text{liquid}}}.$$

Quick Tip: The focal length of a lens changes when it is immersed in a medium due to the change in the relative refractive index.

2(b).

In hydrogen atom, what is the ionization potential of the electron in the ground state?

Correct Answer: —

Solution:

The ionization potential (IP) is the energy required to remove an electron from the ground state of an atom. For a hydrogen atom, the ionization potential is given by:

$$\text{IP} = \frac{13.6\,\text{eV}}{1^2} = 13.6\,\text{eV}.$$

Correct Answer: The ionization potential of the electron in the ground state of a hydrogen atom is 13.6 eV.

Quick Tip: The ionization potential for hydrogenâ€™s ground state is a fundamental constant, directly related to the Rydberg constant.

2(c).

Write the definition and dimensional formula of electrical conductivity.

Correct Answer: —

Solution:

Electrical conductivity (σ) is the ability of a material to conduct an electric current. It is the reciprocal of resistivity (ρ), and its unit is

Siemens per meter (S/m).

$$\sigma = \frac{1}{\rho}.$$

The dimensional formula of electrical conductivity is:

$$[\sigma] = M^1L^{-3}T^3A^{-2}.$$

Quick Tip: The higher the electrical conductivity, the better the material is at conducting electricity, with metals typically having high conductivity.

2(d).

Which value of current does the ammeter used in A.C. circuit measure?

Correct Answer: —

Solution:

An ammeter in an AC circuit measures the **rms (root mean square)** value of the alternating current. The rms value gives an equivalent DC value that produces the same power dissipation as the AC.

Quick Tip: The rms value of an AC current or voltage is the value of a steady DC that would provide the same power in a resistive circuit.

2(e).

How much charge is there on a hole? Draw the circuit symbol of p-n junction diode.

Correct Answer: —

Solution:

A hole behaves as a positive charge carrier in a semiconductor, and its charge is equal in magnitude to the charge of an electron but with opposite sign:

$$\text{Charge on a hole} = +e = 1.6 \times 10^{-19}\ \text{C}.$$

The circuit symbol of a p-n junction diode is:

Quick Tip: A hole represents the absence of an electron in a semiconductor, but it effectively behaves like a positive charge carrier.

2(f).

Between radio waves and microwaves, which one has a higher frequency?

Correct Answer: —

Solution:

Microwaves have a higher frequency than radio waves. The frequency range for microwaves is approximately 3×10^9 Hz to 3×10^{12} Hz,

while the frequency of radio waves ranges from about 30 Hz to 3×10^9 Hz.

Quick Tip: Electromagnetic waves are categorized by their frequency, with microwaves falling in the higher-frequency range compared to radio waves.

3(a).

Define the mass defect and binding energy of nucleus.

Correct Answer: —

Solution:

- Mass defect: The mass defect is the difference between the mass of a fully assembled nucleus and the sum of the individual masses of its constituent protons and neutrons. It represents the mass converted into energy during the formation of the nucleus.

Mass Defect = (sum of masses of individual nucleons) − mass of the nucleus.

- Binding energy: The binding energy of a nucleus is the energy required to break it apart into its constituent nucleons (protons and neutrons). It is equal to the energy equivalent of the mass defect.

$$E_b = \Delta m \cdot c^2,$$

where Δm is the mass defect, and c is the speed of light.

Quick Tip: The mass defect is related to the binding energy, which can be found using Einstein's famous equation, $E = mc^2$.

3(b).

A double concave lens has to be made from crown glass. How much should the radii of surfaces of lens be kept to make the power of lens -2.5 D? Refractive index of crown glass is 1.65.

Correct Answer: —

Solution:

The power of a lens is given by the lens formula:

$$P = \frac{1}{f},$$

where f is the focal length of the lens. The focal length for a lens with radii of curvature R_1 and R_2 is given by the lensmaker's formula:

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

where μ is the refractive index of the material of the lens. Since it is a double concave lens, R_1 is negative and R_2 is also negative. Given the power $P = -2.5\,\text{D}$, the focal length is:

$$f = \frac{1}{P} = -0.4\,\text{m}.$$

Substituting the known values, we can find the radii of the surfaces using the lensmaker's formula.

Quick Tip: For a concave lens, both radii of curvature are negative, and the formula for the focal length is derived using the refractive index and surface curvatures.

3(c).

Explain the operation of p-n junction diode in forward bias.

Correct Answer: —

Solution:

When a p-n junction diode is connected in forward bias, the positive terminal of the external voltage source is connected to the p-type semiconductor, and the negative terminal is connected to the n-type semiconductor. This causes the following: - The applied voltage reduces the width of the depletion region as the holes from the p-side and the electrons from the n-side are pushed towards the junction. - If the forward voltage exceeds the threshold voltage (typically 0.7V for silicon diodes), the barrier potential is overcome, and current begins to flow through the diode. This allows current to pass easily through the diode in the direction of the applied voltage.

Quick Tip: In forward bias, the current flows through the diode only after the applied voltage exceeds the threshold potential barrier.

3(d).

What is the effect on range and sensitivity of an ammeter when the value of its shunt resistance increases?

Correct Answer: —

Solution:

- Range: Increasing the shunt resistance decreases the total resistance of the circuit, which increases the maximum current (or range) that can be measured by the ammeter. In other words, a higher shunt resistance extends the range of the ammeter. - Sensitivity: Increasing the shunt resistance reduces the sensitivity of the ammeter. This is because the current is divided between the ammeter and the shunt, and with a higher shunt resistance, the current through the ammeter decreases.

Quick Tip: The shunt resistance helps to protect the ammeter from high currents, but increasing it reduces the meter's sensitivity while increasing its measuring range.

4(a).

If a thin prism of glass is immersed in water, then prove that the minimum deviation produced by the prism becomes one-fourth with respect to air. Given refractive index of glass with respect to air = $\frac{3}{2}$ and that of water with respect to air = $\frac{4}{3}$.

Correct Answer: —

Solution:

The minimum deviation δ produced by a prism is given by:

$$\sin\left(\frac{\delta_{\text{min}}}{2}\right) = \frac{\mu_{\text{prism}} - 1}{2} \sin\left(\frac{A}{2}\right),$$

where μ_{prism} is the refractive index of the material of the prism and A is the angle of the prism. When the prism is immersed in air, the refractive index is $\mu_{\text{glass}} = \frac{3}{2}$, and in water, the refractive index of the glass relative to water becomes:

$$\mu_{\text{glass-water}} = \frac{\mu_{\text{glass}}}{\mu_{\text{water}}} = \frac{\frac{3}{2}}{\frac{4}{3}} = \frac{9}{8}.$$

Now, considering the angle of the prism and its effect on minimum deviation, we can show that the minimum deviation when immersed in water becomes one-fourth that in air:

$$\delta_{\text{min-water}} = \frac{\delta_{\text{min-air}}}{4}.$$

Quick Tip: The refractive index changes the angle of refraction and hence the deviation when immersed in different media.

4(b).

Discuss the significance of displacement current and find the phase difference between it and the conduction current.

Correct Answer: —

Solution:

- Displacement current: Displacement current is the current that appears to flow in the space between the plates of a capacitor when the electric field between the plates is changing. It was introduced by Maxwell to account for the continuity equation in varying electric

fields. The displacement current I_d is related to the rate of change of the electric flux Φ_E as:

$$I_d = \varepsilon_0 \frac{d\Phi_E}{dt} = \varepsilon_0 A \frac{dE}{dt},$$

where A is the area of the plates, and E is the electric field. - Phase difference between displacement current and conduction current: In an alternating current circuit involving a capacitor, the conduction current and the displacement current are in phase. This means the peak values occur at the same time, resulting in no phase difference.

Quick Tip: In capacitive circuits with AC, the displacement current plays an important role in continuity by balancing the conduction current.

4(c). Explain nuclear fission and nuclear fusion with examples.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

Both processes are nuclear reactions in which a small part of the mass is converted into energy. The mass lost is called the mass defect Δm, and the energy released is $E = \Delta m\, c^2$. In fission a heavy nucleus breaks up, and in fusion light nuclei join.

Step 2: Nuclear Fission:

Nuclear fission is the splitting of a heavy nucleus (for example $^{235}_{92}\mathrm{U}$) into two medium-sized nuclei, accompanied by the release of two or three neutrons and a large amount of energy (about 200 MeV per

fission).
Example:

$$^{235}_{92}\text{U} + ^{1}_{0}n \rightarrow ^{141}_{56}\text{Ba} + ^{92}_{36}\text{Kr} + 3\,^{1}_{0}n + 200\ \text{MeV}$$

The neutrons released can cause further fissions, so a chain reaction is possible. This is the principle of nuclear reactors and the atom bomb.

Step 3: Nuclear Fusion:
Nuclear fusion is the combining of two light nuclei to form a heavier nucleus with release of energy. It needs a very high temperature (of the order of 10^7 K) so that the nuclei can overcome their electrostatic repulsion.
Example:

$$^{2}_{1}\text{H} + ^{2}_{1}\text{H} \rightarrow ^{3}_{2}\text{He} + ^{1}_{0}n + 3.27\ \text{MeV}$$

Fusion is the source of the energy of the Sun and stars and the principle of the hydrogen bomb.

Step 4: Final Answer:
Fission is the splitting of a heavy nucleus into lighter nuclei, as in $^{235}_{92}\text{U} + ^{1}_{0}n \rightarrow ^{141}_{56}\text{Ba} + ^{92}_{36}\text{Kr} + 3\,^{1}_{0}n + 200$ MeV. Fusion is the joining of light nuclei into a heavier one, as in $^{2}_{1}\text{H} + ^{2}_{1}\text{H} \rightarrow ^{3}_{2}\text{He} + ^{1}_{0}n + 3.27$ MeV.

Quick Tip: Fission splits a heavy nucleus; fusion joins light nuclei. Both release energy from the mass defect.

4(d).

A plastic ball P of mass 3.2×10^{-15} kg is suspended between two horizontal parallel charged plates in a balanced state. How many electrons on the ball will be increased or decreased? ($g = 10\,\text{m/s}^2$)

Correct Answer: —

Solution:

The plastic ball P is in a balanced state, meaning the gravitational force mg acting downwards is balanced by the electric force qE acting upwards.

$$mg = qE \quad \Rightarrow \quad q = \frac{mg}{E}.$$

The electric field E between the plates is given by:

$$E = \frac{\text{Potential Difference}}{\text{Distance}} = \frac{1000}{0.02} = 50000\,\text{V/m}.$$

Substituting values:

$$q = \frac{(3.2 \times 10^{-15})(10)}{50000} = 6.4 \times 10^{-19}\,\text{C}.$$

The charge of a single electron is $e = 1.6 \times 10^{-19}$ C. The number of electrons n added to the ball can be calculated as:

$$n = \frac{q}{e} = \frac{6.4 \times 10^{-19}}{1.6 \times 10^{-19}} = 4.$$

Thus, the ball must gain **4 electrons**.

Quick Tip: To calculate the number of electrons added or removed, use $n = \frac{q}{e}$, where q is the charge and e is the charge of an electron.

4(e). What are electromagnetic waves? Draw their propagation diagram. Show the electric field amplitude and magnetic field amplitude in propagation diagram.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

Light, radio waves and X-rays are all the same kind of wave, called an electromagnetic wave. Such a wave is made of an electric field and a magnetic field that keep changing with time and carry energy through space.

Step 2: Define electromagnetic waves.

An electric charge that is accelerated produces a changing electric field. A changing electric field produces a changing magnetic field, and a changing magnetic field produces a changing electric field again.

This chain keeps going and the disturbance moves forward by itself. The moving pair of fields is called an electromagnetic wave.

Key properties of these waves:

1. The electric field $\vec{E}$ and the magnetic field $\vec{B}$ are perpendicular to each other and also perpendicular to the direction of travel. So the wave is transverse.

2. $\vec{E}$ and $\vec{B}$ are in the same phase. They become zero together and reach their maximum values together.

3. They need no material medium. In vacuum they travel at the speed $c = 3 \times 10^8$ m/s.

Step 3: Write the equations of the wave.

Let the wave travel along the x-axis, with $\vec{E}$ along the y-axis and $\vec{B}$ along the z-axis. Then

$$E_y = E_0 \sin(kx - \omega t), \qquad B_z = B_0 \sin(kx - \omega t)$$

Here E_0 is the amplitude of the electric field and B_0 is the amplitude of the magnetic field. The two amplitudes are linked by $E_0 = cB_0$.

Step 4: Draw the propagation diagram.

Take the x-axis as the direction in which the wave travels. The wave moves along the x-axis. The solid curve is the electric field, which oscillates along y with maximum value (amplitude) E_0. The dashed curve is the magnetic field, which oscillates along z with maximum value (amplitude) B_0. Both curves cross zero at the same points, which shows they are in phase.

Final Answer:

An electromagnetic wave is a transverse wave of in-phase, mutually perpendicular electric and magnetic fields that travels in vacuum at c. The diagram shows E with amplitude E_0 along y and B with amplitude B_0 along z, moving along x.

$$\boxed{E_0 = c\,B_0, \quad \vec{E} \perp \vec{B} \perp \text{direction of propagation}}$$

Quick Tip: An electromagnetic wave is a transverse wave of oscillating electric and magnetic fields, perpendicular to each other and to the direction of travel, with $E_0 = cB_0$. Draw E along one axis and B along the perpendicular axis, both varying along the line of travel, and label the amplitudes E_0 and B_0.

5(a).

Define interference. Mention the condition for constructive and destructive interference.

Correct Answer: —

Solution:

- Interference: Interference is the phenomenon in which two or more waves superpose to form a resultant wave. This effect occurs when the waves meet in such a way that they combine to form either a stronger or weaker wave. - Condition for Constructive Interference: When two waves meet such that their displacements are in the same direction, the resultant amplitude is the sum of the amplitudes of the two waves. The condition for constructive interference is:

$$\Delta\phi = 2n\pi \quad (n = 0, 1, 2, \ldots)$$

where $\Delta\phi$ is the phase difference between the two waves. - Condition for Destructive Interference: When the displacements of the two waves are in opposite directions, the resultant amplitude is the difference of the two amplitudes. The condition for destructive interference is:

$$\Delta\phi = (2n + 1)\pi \quad (n = 0, 1, 2, \ldots)$$

Quick Tip: For constructive interference, the phase difference must be an integer multiple of 2π, and for destructive interference, it must be an odd multiple of π.

5(b).

The atomic mass of ^{16}O is 16.0000 amu. Calculate its binding energy per nucleon. Mass of electron = 0.00055 amu, mass of proton = 1.007593 amu, mass of neutron = 1.008982 amu, and 1 amu = 931 MeV.

Correct Answer: –

Solution:

- Step 1: Calculate the mass defect The mass of the oxygen atom is given as 16.0000 amu. For the calculation, we assume that oxygen has 8 protons and 8 neutrons (since ^{16}O is the isotope with a mass number 16). The total mass of the nucleons is:

$$\text{Total mass} = (8 \times \text{mass of proton}) + (8 \times \text{mass of neutron}) + (\text{mass of electron})$$

$$= (8 \times 1.007593) + (8 \times 1.008982) + (8 \times 0.00055) = 16.152744\,\text{amu}.$$

Now, the mass defect Δm is:

$$\Delta m = (\text{Total mass of nucleons}) - (\text{Atomic mass}) = 16.152744 - 16.0000 = 0.152744\,\text{amu}.$$

- Step 2: Calculate the binding energy To find the binding energy, we use the equivalence $E = \Delta m \cdot c^2$, where 1 amu = 931 MeV.

$$\text{Binding energy} = 0.152744 \times 931 = 142.5\,\text{MeV}.$$

- Step 3: Calculate binding energy per nucleon Since the oxygen nucleus contains 16 nucleons, the binding energy per nucleon is:

$$\text{Binding energy per nucleon} = \frac{142.5}{16} = 8.91\,\text{MeV}.$$

Quick Tip: The binding energy of a nucleus is a measure of how stable the nucleus is; more binding energy indicates a more stable nucleus.

5(c).

Determine the nature of force acting between two parallel current-carrying conductors when:
(i) Current is in the same direction in conductors,
(ii) Current is in the opposite direction in conductors.

Correct Answer: —

Solution:

- For same direction of current: When two parallel conductors carry current in the same direction, they experience an attractive force due to the magnetic fields around them. According to Ampere's law, the force per unit length between the two conductors is:

$$F = \frac{\mu_0 I_1 I_2}{2\pi r},$$

where I_1 and I_2 are the currents, r is the distance between the conductors, and μ_0 is the permeability of free space. - For opposite direction of current: When the currents are in opposite directions, the force between the conductors is repulsive, and the formula remains the same but with a change in direction, which indicates a repulsive interaction.

Quick Tip: The nature of the force between two current-carrying conductors depends on whether the currents flow in the same or opposite

directions.

5(d).

Establish the relation between resistances of arms of Wheatstone bridge in balanced condition.

Correct Answer: —

Solution:

In a Wheatstone bridge, there are four resistances R_1, R_2, R_3, R_4, and a galvanometer G is connected between the junctions of R_1 & R_2 and R_3 & R_4. The bridge is said to be balanced when the galvanometer shows zero current, i.e., there is no potential difference across it. The relation for balance condition is:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}.$$

In this condition, the ratios of the resistances in the two halves of the bridge are equal.

Quick Tip: In the balanced Wheatstone bridge, the galvanometer shows zero current and provides a relation between the resistances.

OR

The resistance of a wire is 16 ohms. By melting it, the wire is stretched to half of its original length. What will be the resistance of the new wire?

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

The resistance of a wire depends on its length and its area of cross-section. When a wire is melted and drawn into a new shape, no metal is lost, so its volume stays the same. If the length changes, the area must change in the opposite way.

Step 2: Key Formula or Approach:

1. Resistance: $R = \rho\frac{L}{A}$, where ρ is the resistivity, which stays the same because the material is the same.
2. Volume stays fixed: $AL = A'L'$.

Step 3: Write what is given.

Original resistance $R = 16\ \Omega$, original length L and original area A.

The wire is stretched so that the new length is half of the original: $L' = \frac{L}{2}$.

Step 4: Find the new area.

Using constant volume,

$$A'L' = AL \Rightarrow A' \cdot \frac{L}{2} = AL \Rightarrow A' = 2A$$

So the area becomes double when the length becomes half.

Step 5: Find the new resistance.

$$R' = \rho\frac{L'}{A'} = \rho\frac{L/2}{2A} = \frac{1}{4}\rho\frac{L}{A} = \frac{R}{4}$$

$$R' = \frac{16}{4} = 4\ \Omega$$

Final Answer:

The new wire has one-fourth of the original resistance.

$$\boxed{R' = 4\ \Omega}$$

Quick Tip: At constant volume $R \propto L^2$. The length becomes half, so R becomes one-fourth: $R' = 16/4 = 4\ \Omega$.

5(e).

Obtain the expression for capacity of a parallel plate capacitor. How will the capacity of the capacitor be increased?

Correct Answer: —

Solution:

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

$$C = \frac{\varepsilon_0 A}{d},$$

where ε_0 is the permittivity of free space, A is the area of each plate, and d is the separation between the plates. - To increase the capacitance: - Increase the area A of the plates. - Decrease the distance d between the plates. - Use a dielectric material between the

plates, which increases the permittivity, making the capacitance larger by a factor of K, the dielectric constant of the material.

Quick Tip: Capacitance increases with increasing plate area or decreasing plate separation, or by introducing a dielectric.

6.

What is Bohr's quantum condition postulate? How is it explained by de Broglie? What are the shortcomings of Bohr's atomic model?

Correct Answer: —

Solution:

- Bohr's Quantum Condition Postulate: Bohr's quantum condition postulates that the angular momentum L of an electron revolving in a circular orbit around the nucleus is quantized and is given by:

$$L = n\hbar, \quad n = 1, 2, 3, \ldots$$

where $\hbar = \frac{h}{2\pi}$ is the reduced Planckâ€™s constant, and n is a positive integer known as the quantum number. This postulate leads to the quantization of energy levels in an atom. - Explanation by de Broglie: Louis de Broglie extended Bohrâ€™s model by suggesting that the electron itself exhibits wave-like properties. According to de Broglie, the electron moves as a standing wave, and the wavelength λ of the electron is related to its momentum p by:

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

where m is the mass and v is the velocity of the electron. In Bohrâ€™s model, the condition for standing waves on an orbit leads to the quantization of angular momentum $L = n\hbar$, which is in agreement with Bohrâ€™s postulate. - Shortcomings of Bohr's Atomic Model: 1. Bohr's model could not explain the spectra of atoms with more than one electron. 2. It does not account for the fine structure of spectral lines (which arises from relativistic and spin effects). 3. Bohrâ€™s model is inconsistent with the uncertainty principle proposed by Heisenberg, which implies that the position and momentum of an electron cannot both be known precisely. 4. It could not explain the Zeeman effect (splitting of spectral lines in the presence of a magnetic field).

Quick Tip: Bohrâ€™s model explains the quantization of energy levels in atoms but fails to explain phenomena involving multiple electron atoms or relativistic effects.

OR

Energy of a particle at absolute temperature T is of the order of kT. Calculate the wavelength of thermal neutrons at 27Â°C. Find the energy of a photon having the same wavelength. Here, k is the Boltzmann constant.

Correct Answer: —

Solution:

- Step 1: Find the thermal energy at 27Â°C. The average thermal energy of a particle is given by $E \sim kT$, where k is the Boltzmann constant and T is the temperature in Kelvin. - Temperature in Kelvin is:

$$T = 27 + 273 = 300\,\text{K}.$$

The Boltzmann constant $k = 1.38 \times 10^{-23}\,\text{J/K}$, so the energy of the particle is:

$$E = kT = (1.38 \times 10^{-23}) \times 300 = 4.14 \times 10^{-21}\,\text{J}.$$

- Step 2: Calculate the de Broglie wavelength of a neutron. The wavelength of the neutron is given by de Broglie's relation:

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

where $p = mv$ is the momentum and h is Planck's constant. The kinetic energy of the thermal neutron is $E = \frac{1}{2}mv^2$, so the velocity is:

$$v = \sqrt{\frac{2E}{m}}.$$

Thus, the wavelength is:

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

Substituting the values of $h = 6.626 \times 10^{-34}\,\text{J.s}$, and the mass of a neutron $m \approx 1.675 \times 10^{-27}\,\text{kg}$:

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 1.675 \times 10^{-27} \times 4.14 \times 10^{-21}}} \approx 1.56 \times 10^{-10}\,\text{m} = 0.156\,\text{nm}.$$

- Step 3: Energy of a photon having the same wavelength. The energy of a photon E_{photon} is related to the wavelength λ by:

$$E_{\text{photon}} = \frac{hc}{\lambda},$$

where $c = 3 \times 10^8\,\text{m/s}$ is the speed of light. Substituting the values:

$$E_{\text{photon}} = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{0.156 \times 10^{-9}} \approx 1.27 \times 10^{-16}\ \text{J}.$$

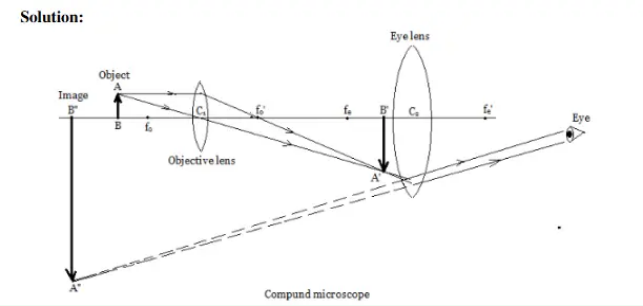
Quick Tip: The wavelength of thermal particles is related to their temperature, and de Broglie wavelength can be applied even for non-light particles like neutrons.

7.

By drawing a ray diagram, explain the formation of image in a compound microscope. Establish the formula for magnifying power for it.

Correct Answer: —

Solution:



Ray diagram and Explanation: In a compound microscope, an objective lens and an eyepiece are used. The object is placed at a distance between the focal point and the objective lens. The image formed by the objective is real and inverted, and it acts as the object for the eyepiece. The eyepiece forms a virtual, magnified image of the real image created by the objective. - Magnifying power formula: The

magnifying power M of the compound microscope is the product of the magnification by the objective lens M_1 and the magnification by the eyepiece M_2:

$$M = M_1 \times M_2 = \frac{D}{f_o} \times \frac{L}{f_e},$$

where: - f_o is the focal length of the objective lens, - f_e is the focal length of the eyepiece, - L is the length of the microscope tube, - D is the near point of the eye (usually taken as 25 cm for normal vision).

Quick Tip: The magnifying power of a compound microscope depends on both the objective lens and the eyepiece.

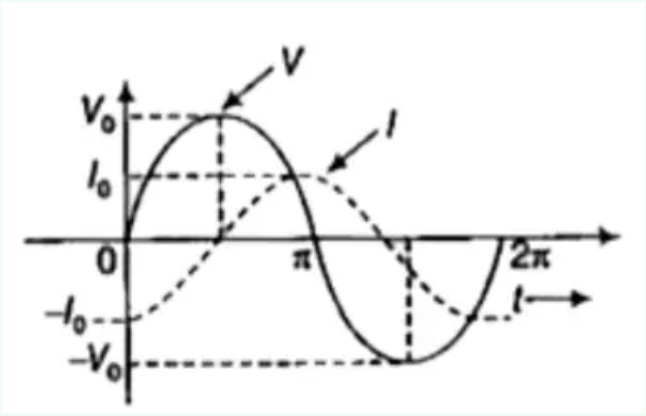
OR

In a circuit, the equation for alternating voltage V is represented by $V = 40\sin(100\pi t)$ volt. Here t is in seconds. Draw the time-voltage (t-V) graph with proper scale for one cycle. Calculate the root mean square value of voltage.

Correct Answer: —

Solution:

- Time-Voltage graph:



The voltage equation is $V = 40\sin(100\pi t)$. This represents a sinusoidal voltage, and the time period T is:

$$T = \frac{1}{f} = \frac{1}{50} = 0.02 \text{ seconds.}$$

The graph will have a peak voltage of 40 V, oscillating between +40 V and -40 V, completing one cycle every 0.02 seconds. - Root Mean Square (RMS) value: The RMS value of a sinusoidal voltage is given by:

$$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}}.$$

Substituting $V_{\text{max}} = 40$:

$$V_{\text{rms}} = \frac{40}{\sqrt{2}} \approx 28.28 \text{ V.}$$

Quick Tip: For a sinusoidal voltage, the RMS value is the effective value that gives the same heating effect as a DC voltage of the same value.

8.

What is atomic model of magnetism? Differentiate between paramagnetic, diamagnetic, and ferromagnetic substances on this basis. Also, give one example of each.

Correct Answer: —

Solution:

- Atomic Model of Magnetism: The atomic model of magnetism is based on the behavior of atomic magnetic moments, which arise from the motion of electrons (both orbital motion and spin). The magnetic properties of a material depend on how these magnetic moments align and interact. A material can exhibit different types of magnetism depending on the alignment of these moments. - Types of Magnetism:
1. Paramagnetic Substances:
- In paramagnetic materials, the magnetic moments of individual atoms tend to align with an external magnetic field but do not stay aligned when the external field is removed.
- These materials have a weak, positive susceptibility to magnetism.
- The atomic magnetic moments are typically not in alignment with each other due to thermal motion.
- Example: Aluminum. 2. Diamagnetic Substances:
- Diamagnetic materials do not have permanent atomic magnetic moments. When subjected to a magnetic field, they produce an opposing magnetic field and are repelled by the external field.
- These materials have a negative, weak susceptibility to magnetism.
- Example: Bismuth. 3. Ferromagnetic Substances:
- Ferromagnetic materials have permanent magnetic moments even without an external magnetic field. These magnetic moments can align to create a strong net magnetic moment, even without an external field.
- They exhibit strong positive magnetic susceptibility and can retain their magnetization even after the external magnetic field is removed.
- Example: Iron.

Quick Tip: Paramagnetic and ferromagnetic materials exhibit attraction to magnetic fields, while diamagnetic materials are repelled.

OR

There is minimum deviation of light ray on passing through a prism (n = $\sqrt{3}$). If the angle of incidence is twice the angle of refraction for this ray, then what will be the angle of prism and the angle of refraction?

Correct Answer: —

Solution:

Let the angle of incidence be i and the angle of refraction be r. We are given that:

$$i = 2r.$$

Let the angle of the prism be A, the refractive index $n = \sqrt{3}$, and the minimum deviation angle be D. For minimum deviation in a prism, the angle of incidence i and the angle of refraction r are equal. Using the following relation for minimum deviation:

$$D = i + r - A.$$

Since at minimum deviation $i = r$, we have:

$$D = 2r - A.$$

The refractive index n is related to the prism angle A and the minimum deviation D by:

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

Substituting $n = \sqrt{3}$ and solving for A and D, we get:

$$A = 60^\circ \quad \text{and} \quad r = 15^\circ.$$

Quick Tip: For minimum deviation, the angle of incidence is equal to the angle of refraction in a prism.

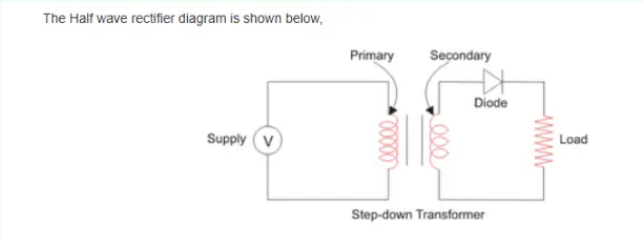
9.

Compare features of p-type and n-type semiconductors. Draw circuit diagram of half-wave rectifier of p-n junction diode and explain it.

Correct Answer: —

Solution:

Feature	p-type Semiconductor	n-type Semiconductor
Doping Element	Trivalent impurity (eg Boron)	Pentavalent impurity (eg Phosphorus)
Majority Carriers	Holes (+ve charge)	Electrons (-ve charge)
Minority Carriers	Electrons	Holes
Conductivity Type	due to holes	due to free electrons
Charge Carrier Movement	Holes towards the -ve terminal	Electrons towards the +ve terminal



Explanation of Half-Wave Rectifier:

1. **Working Principle:** A half-wave rectifier converts AC voltage into pulsating DC using a single p-n junction diode.
2. **Positive Half Cycle:** During the positive half-cycle of AC input, the diode is forward biased and allows current to flow through the load resistor (R_L).
3. **Negative Half Cycle:** During the negative half-cycle, the diode is

reverse biased and blocks current flow, resulting in no output.
4. **Output Waveform:** The output consists of only the positive half-cycles of the AC input, producing a pulsating DC voltage.

Quick Tip: A half-wave rectifier only uses one half-cycle of AC input, leading to high ripple content in the output. A capacitor filter can be used to smooth the output voltage.

OR

State Gauss's Law in electrostatics. Using it (i) find electric field due to a point source charge q and (ii) deduce Coulomb's law between source charge q and test charge q_0.

Correct Answer: —

Solution:

- Gauss's Law in Electrostatics: Gauss's law states that the electric flux through a closed surface is proportional to the enclosed electric charge. It is given by:

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0},$$

where:
- Φ_E is the electric flux,
- $\vec{E}$ is the electric field,
- $d\vec{A}$ is the differential area element on the closed surface,
- q_{enc} is the total charge enclosed within the surface,
- ϵ_0 is the permittivity of free space. - (A) Electric Field due to a Point

Source Charge q: Consider a spherical Gaussian surface with a radius r centered at a point charge q. Applying Gauss's law, we get:

$$E \cdot 4\pi r^2 = \frac{q}{\epsilon_0},$$

where E is the electric field at distance r from the charge. Solving for E, we get:

$$E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}.$$

- (B) Deduce Coulombâ€™s Law: Using the expression for E, the force on a test charge q_0 placed in the electric field E is given by:

$$F = q_0 \cdot E = q_0 \cdot \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}.$$

This is Coulombâ€™s law, which states that the force between two point charges q and q_0 separated by a distance r is:

$$F = \frac{1}{4\pi\epsilon_0} \cdot \frac{q \cdot q_0}{r^2}.$$

Quick Tip: Gauss's law provides a direct method for deriving Coulombâ€™s law by calculating the electric field due to a point charge.