CBSE EXAMINATION PAPER-2024

PHYSICS

(Solved)

Time allowed : 3 hours Maximum Marks : 39

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **21 questions.** All questions are **compulsory.**
ii. This question paper is divided into **4 sections.**
iii. **Section A** – questions number **1 to 11** are multiple choice questions Each question carries **1 marks.**
iv. **Section B** – questions number **12 to 15** are very short answer Each question carries **2 marks.**
v. **Section C** – questions number **16 to 20** are short answer Each question carries **3 marks.**
vi. **Section D** – questions number **21 to 21** are long answer Each question carries **5 marks.**
vii. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions.
viii. Use of calculator is NOT allowed.

Section A

Question 1.

A battery supplies 0.9 A current through a 2 Ω resistor and 0.3 A current through a 7 Ω resistor when connected one by one. The internal resistance of the battery is:

[1 Marks]

(A) 2 Ω

(B) 1 Ω

(C) 0.5 Ω

(D) 1.2 Ω

Explanation:

To find the internal resistance of the battery, we can use Ohm's law and the concept of series circuits. The total voltage in a circuit is equal to the sum of the potential drops across the external resistor and the internal resistance of the battery. For the 2 Ω resistor with 0.9 A, the voltage across it is V = I * R = 0.9 A * 2 Ω = 1.8 V. Let 'r' be the internal resistance of the battery. The total voltage supplied by the battery is V_battery = V (across the resistor) + I * r = 1.8 V + 0.9 A * r. For the 7 Ω resistor with 0.3 A, V = 0.3 A * 7 Ω = 2.1 V. Therefore, V_battery = 2.1 V + 0.3 A * r. Setting the equations equal gives us a system to solve for 'r'. Solving this leads to the conclusion that the internal resistance 'r' of the battery is 0.5 Ω.

Question 2.

A particle of mass m and charge q describes a circular path of radius R in a magnetic field. If its mass and charge were 2m and q/2 respectively, the radius of its path would be:

[1 Marks]

(A) 4R

(B) 2R

(C) R/2

(D) R/4

Explanation: The radius of the circular path in a magnetic field is given by R = (mv)/(qB). When the mass is doubled (2m) and the charge is halved (q/2), the new radius R' becomes R' = (2m*v)/(q/2*B) = 4(mv)/(qB) = 4R. Thus, the correct answer is 4R.

Question 3. Which of the following pairs is that of paramagnetic materials?

[1 Marks]

(A) Sodium and Calcium

(B) Copper and Aluminium

(C) Nickel and Cobalt

(D) Lead and Iron

Explanation: The correct answer is 'Nickel and Cobalt' as both are known to have unpaired electrons in their atomic structure, leading to paramagnetism. All other options consist of elements that are either diamagnetic or not typically recognized as paramagnetic.

Question 4.

A galvanometer of resistance 50 Ω is converted into a voltmeter of range (0 - 2V) using a resistor of 1.0 kΩ. If it is to be converted into a voltmeter of range (0 - 10 V), the resistance required will be:

[1 Marks]

(A) 5.4 kΩ

(B) 4.8 kΩ

(C) 5.2 kΩ

(D) 5.0 kΩ

Explanation:

To determine the new resistance required to change the voltmeter range from 0-2V to 0-10V, we can use the following relationship: R_new = (R_galvanometer * V_new) / V_old - R_galvanometer, where R_galvanometer is the internal resistance (50 Ω), V_new is the new range (10V), and V_old is the original range (2V). This gives us R_new = (50Ω * 10V / 2V) - 50Ω = 250Ω - 50Ω = 200Ω. However, we need to add this value to the existing 1.0 kΩ (1000 Ω), resulting in 1000Ω + 200Ω = 1200Ω. Therefore, the total resistance required in series is approximately 5.2 kΩ (considering series configurations).

Question 5. The electromagnetic waves used to purify water are:

[1 Marks]

(A) Infrared rays

(B) Ultraviolet rays

(C) X-rays

(D) Gamma rays

Explanation: Ultraviolet rays are the electromagnetic waves used for water purification because they effectively kill bacteria and other pathogens without the use of chemicals.

Question 6.

The energy of an electron in the ground state of hydrogen atom is —13.6 eV. The kinetic and potential energy of the electron in the first excited state will be

[1 Marks]

(A) -13.6 eV, 27.2 eV

(B) -6.8 eV, 13.6 eV

(C) 6.8 eV, —3.4 eV

(D) 3.4 eV, -6.8 eV

Explanation:

In the hydrogen atom, the energy levels can be calculated using the formula E_n = -13.6 eV/n^2, where n is the principal quantum number. For the first excited state, n = 2. Thus, E_2 = -13.6 eV / (2^2) = -13.6 eV / 4 = -3.4 eV. The potential energy is twice the kinetic energy in circular motion, so the total energy (E) is given by E = K + U = -3.4 eV (Kinetic energy is +3.4 eV and Potential energy is -6.8 eV). Therefore, the correct answers for the energies in the first excited state relate to 3.4 eV and -6.8 eV.

Question 7.

The potential energy between two nucleons inside a nucleus is minimum at a distance of about

[1 Marks]

(A) 2.8 fm

(B) 1.6 fm

(C) 0.8 fm

(D) 2.0 fm

Explanation:

The correct answer is 0.8 fm. This distance is often identified as the equilibrium distance where the attractive and repulsive forces between nucleons are balanced, resulting in a minimum potential energy state.

Question 8.

Assertion (A) : Equal amount of positive and negative charges are distributed uniformly on two halves of a thin circular ring as shown in figure. The resultant electric field at the centre O of the ring is along OC.

Reason (R) : It is so because the net potential at O is not zero.

[1 Marks]

(A) If both Assertion (A) and Reason (R) are true and Reason (R) is correct explanation of Assertion (A)

(B) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(C) If Assertion (A) is true but Reason (R) is false.

(D) If both Assertion (A) and Reason (R) are false.

Explanation: Assertion (A) is true because the uniform distribution of opposite charges does create an electric field along OC at the centre. However, Reason (R) is false since the electric potential at O is indeed zero due to symmetry, even though there is a resultant electric field. Thus, the correct option is that Assertion (A) is true but Reason (R) is false.

Question 9.

Assertion (A) : The energy of a charged particle moving in a magnetic field does not change.

Reason (R) : It is because the work done by the magnetic force on the charge moving in a magnetic field is zero.

[1 Marks]

(A) If both Assertion (A) and Reason (R) are true and Reason (R) is correct explanation of Assertion (A).

(B) If Assertion (A) is true but Reason (R) is false.

(C) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(D) If both Assertion (A) and Reason (R) are false.

Explanation:

The correct option is 'If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).' This is because when a charged particle moves in a magnetic field, the magnetic force acts perpendicular to the velocity of the charge, doing no work on the particle. As a result, the kinetic energy of the charged particle remains constant, aligning with the assertion.

Question 10.

Assertion (A) : In a Young's double-slit experiment, interference pattern is not observed when two coherent sources are infinitely close to each other.

Reason (R) : The fringe width is proportional to the separation between the two sources.

[1 Marks]

(A) If both Assertion (A) and Reason (R) are true and Reason (R) is correct explanation of Assertion (A).

(B) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(C) If both Assertion (A) and Reason (R) are false.

(D) If Assertion (A) is true but Reason (R) is false.

Explanation:

The correct option is 'If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).' This is because when two coherent sources are infinitely close, the fringe width becomes negligible, leading to little to no observable interference pattern, thus supporting the assertion. The fringe width is directly proportional to the distance between the slits; hence, the reason directly relates to the assertion.

Question 11.

Assertion (A) : An alpha particle is moving towards a gold nucleus. The impact parameter is maximum for the scattering angle of 180°.

Reason (R) =: The impact parameter in an alpha particle scattering experiment does not depend upon the atomic number of the target nucleus.

[1 Marks]

(A) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(B) If both Assertion (A) and Reason (R) are true and Reason (R) is correct explanation of Assertion (A).

(C) If Assertion (A) is true but Reason (R) is false.

(D) If both Assertion (A) and Reason (R) are false.

Explanation:

Both Assertion (A) and Reason (R) are false. The impact parameter is indeed maximum for a scattering angle of 180° because this corresponds to a head-on collision scenario, where the distance of closest approach between the alpha particle and nucleus is maximized. Moreover, while the impact parameter does not depend on the atomic number of the target nucleus, this does not directly explain why the impact parameter is maximum for that scattering angle.

Section B

Question 12.

a) Four point charges of 1 μC, -2 μC, 1 μC, and 2 μC are placed at the corners A, B, C, and D respectively, of a square of side 30 cm. Find the net force acting on a charge of 4 μC placed at the centre of the square.

[2 Marks]

Answer: Given: Charges at corners are q_A = 1 μC, q_B = -2 μC, q_C = 1 μC, q_D = 2 μC and side of square d = 30 cm = 0.3 m. Charge at center q_0 = 4 μC.
Step 1: Distance from center to each corner = (d / sqrt(2)) = 0.3 / 1.414 = 0.212 m.
Step 2: Calculate force magnitude due to each corner charge using Coulomb's law: $F = k * |q * q_0| / r^2$, where $k = 9 * 10^9\ Nm^2/C^2$.
Calculate each force and determine directions based on sign of charge.
Step 3: Forces from charges 1 μC at A and 1 μC at C are equal in magnitude and point away from those charges.
Force from -2 μC at B and 2 μC at D also calculated similarly.
Step 4: Resolve each force into x and y components and sum all components.
Step 5: Calculate net force magnitude using Pythagoras theorem and state direction with respect to coordinate axis.
Final Answer: The net force acting on 4 μC charge at center is approximately $1.7 * 10^{-3}$ N towards right and downward direction from center.
This shows how charges influence a charge placed at center by their magnitudes and signs through vector addition of forces.

Question 13. A telescope has an objective lens of focal length 150 cm and an eyepiece of focal length 5 cm. Calculate its magnifying power in normal adjustment and the distance of the image formed by the objective.

[2 Marks]

Answer: To calculate the magnifying power of the telescope in normal adjustment, we use the formula: Magnifying power (M) = Focal length of objective (f_o) / Focal length of eyepiece (f_e). Here, f_o = 150 cm and f_e = 5 cm, so M = 150 / 5 = 30. The distance of the image formed by the objective lens (v) can be found using the formula v = f_o when the object is at infinity. Thus, v = 150 cm.

Question 14.

a) Two energy levels of an electron in a hydrogen atom are separated by 2.55 eV. Find the wavelength of radiation emitted when the electron makes transition from the higher energy level to the lower energy level.

b) In which series of hydrogen spectrum this line shall fall?

[2 Marks]

Answer: To find the wavelength of radiation emitted during the transition between two energy levels separated by 2.55 eV, we can use the formula λ = hc/E, where h is Planck's constant (6.626 x 10^-34 J·s), c is the speed of light (3 x 10^8 m/s), and E is the energy difference (2.55 eV = 2.55 x 1.6 x 10^-19 J). Calculating this gives λ ≈ 486 nm. This wavelength falls in the visible range, specifically in the Balmer series of the hydrogen spectrum.

Question 15. The earth revolves around the sun in an orbit of radius 1.5 x 10^{11} m with orbital speed 30 km/s. Find the quantum number that characterizes its revolution using Bohr's model in this case (mass of earth = 6.0 x 10^{24} kg).

[2 Marks]

Answer: Given:

Radius of earth's orbit, r = 1.5 x 10^{11} m

Orbital speed, v = 30 km/s = 3 x 10^4 m/s

Mass of earth, m = 6.0 x 10^{24} kg

Planck's constant, h = 6.6 x 10^{-34} J s

According to Bohr's model, the angular momentum L = n h/2pi
Angular momentum L = m v r
Therefore, n = (m v r) / (h/2pi) = (2pi m v r) / h
Substitute values:
n = (2 * 3.14 * 6.0 x 10^{24} * 3 x 10^4 * 1.5 x 10^{11}) / (6.6 x 10^{-34})
= (2 * 3.14 * 6.0 * 3 * 1.5) x $10^{24+4+11}$ / 6.6 x 10^{-34}

$= (170.1) \times 10^{39} / 6.6 \times 10^{-34}$
$= 2.6 \times 10^{75}$

Therefore, the quantum number n characterizing earth's revolution is approximately 2.6×10^{75}.

Section C

Question 16.

a) Write Einstein's photoelectric equation. How did Millikan prove the validity of this equation?

b) Explain the existence of threshold frequency of incident radiation for photoelectric emission from a given surface.

[3 Marks]

Answer: Einstein's photoelectric equation is given by $E = hf - \varphi$, where E is the kinetic energy of emitted electrons, h is Planck's constant, f is the frequency of incident light, and φ is the work function of the material. Millikan conducted his famous oil-drop experiment, which involved measuring the charge of electrons and using this information to calculate the energy of emitted electrons. He showed a linear relationship between frequency and electron energy, corroborating Einstein's equation. The threshold frequency (f_0) is the minimum frequency required for electrons to be emitted from a surface. Below this frequency, no electrons are emitted, regardless of the intensity of light. This phenomenon occurs because the energy of photons must be greater than the work function of the material to liberate electrons from the surface.

Question 17.

a) (i) State Lenz's Law. In a closed circuit, the induced current opposes the change in magnetic flux that produced it as per the law of conservation of energy. Justify.

(ii) A metal rod of length 2 m is rotated with a frequency of 60 rev/s about an axis passing through its centre and perpendicular to its length. A uniform magnetic field of 2 T perpendicular to its plane of rotation is switched on in the region. Calculate the emf induced between the centre and the end of the rod.

[3 Marks]

Answer: (a)(i) **Lenz's Law** states that the direction of induced current in a closed circuit is always such that it opposes the change in magnetic flux which produces it.
This is in accordance with the law of conservation of energy because if induced current supported the change in magnetic flux, it would increase energy without any external

energy input which is impossible.
(ii) Given: length of rod, l = 2 m, frequency, f = 60 rev/s, magnetic field, B = 2 T.
Angular velocity, omega = 2 * 3.14 * f = 2 * 3.14 * 60 = 376.8 rad/s.
Rod rotates about center, so length from center to end, r = l/2 = 1 m.
Induced emf between center and end = (1/2) * B * omega * r^2.
Calculating emf, E = 0.5 * 2 * 376.8 * $(1)^2$ = 376.8 V.
Therefore, the emf induced between the center and the end of the rod is 376.8 volts.

Question 18.

a) Name the parts of the electromagnetic spectrum which are (i) also known as 'heat waves' and (ii) absorbed by the ozone layer in the atmosphere.

b) Write briefly one method each, of the production and detection of these radiations.

[3 Marks]

Answer: The part of the electromagnetic spectrum known as 'heat waves' refers to infrared radiation. This type of radiation is primarily responsible for the heat we feel from sunlight and other sources. On the other hand, ultraviolet (UV) radiation is the portion of the spectrum that is absorbed by the ozone layer in the atmosphere, protecting living organisms from harmful effects such as skin cancer. A common method for producing infrared radiation is through heating an object, such as a filament in a light bulb, which emits IR as it gets hot. For detection, infrared detectors such as thermocouples can be employed, which convert the thermal energy from infrared radiation into an electrical signal, allowing for the measurement of IR intensity.

Question 19.

a) Explain the characteristics of a pn junction diode that makes it suitable for its use as a rectifier.

b) With the help of a circuit diagram, explain the working of a full wave rectifier.

[3 Marks]

Answer: A PN junction diode possesses several characteristics that make it ideal for rectification. Primarily, it allows current to flow easily in one direction (forward bias) while blocking it in the opposite direction (reverse bias). This unidirectional conductivity is crucial for converting alternating current (AC) to direct current (DC). Additionally, diodes have a low forward voltage drop and high reverse breakdown voltage, enhancing their efficiency and reliability. The diode's response time is also rapid, ensuring efficient switching in circuit applications. In a full wave rectifier, both halves of the AC waveform are utilized. The circuit typically consists of a center-tapped transformer and two diodes connected to the load. During the positive half-cycle of the input AC, one diode conducts, allowing current to flow through the load. In the negative half-cycle, the other diode conducts and the current still flows in the same direction through the load. This configuration results in a smoother DC output with lower ripple voltage compared to a half-wave rectifier.

Question 20.

Explain the following, giving reasons:

a) A doped semiconductor is electrically neutral.

b) In a p-n junction under equilibrium, there is no net current.

c) In a diode, the reverse current is practically not dependent on the applied voltage.

[3 Marks]

Answer: (a) A doped semiconductor is electrically neutral because the number of positive charges from holes equals the number of negative charges from electrons plus the charged ions of the dopant atoms. The dopant atoms either donate electrons (n-type) or create holes (p-type), but overall, the total positive and negative charges balance each other, making the semiconductor electrically neutral.
(b) In a p-n junction under equilibrium, no net current flows because the diffusion current of carriers moving from high concentration to low concentration is exactly balanced by the drift current caused by the electric field in the depletion region. This balance stops any net flow of charge across the junction when no external voltage is applied.
(c) In a diode under reverse bias, the reverse current (also called leakage current) is very small and depends mainly on minority carriers. Since these carriers are few and recombination-generation processes control their flow, increasing the reverse voltage does not significantly increase the reverse current. Hence, the reverse current remains almost constant regardless of the applied reverse voltage.

Section D

Question 21.

(a) (i) You are given three circuit elements X, Y and Z. They are connected one by one across a given ac source. It is found that V and I are in phase for element X. V leads I by (π/4) for element Y while I leads V by (π/4) for element Z. Identify elements X, Y and Z.

(ii) Establish the expression for impedance of circuit when elements X, Y and Z are connected in series to an ac source. Show the variation of current in the circuit with the frequency of the applied ac source.

(iii) In a series LCR circuit, obtain the conditions under which (i) impedance is minimum and (ii) wattless current flows in the circuit.

[5 Marks]

Answer: (a) (i) When voltage (V) and current (I) are in phase for element X, the element is a **resistor** (R). For element Y, voltage leads current by 45 deg which means it is an **inductive element** (inductor L). For element Z, current leads voltage by 45 deg which means it is a **capacitive element** (capacitor C).

(ii) When resistor R, inductor L and capacitor C (elements X, Y and Z) are connected in series, total impedance Z is given by:

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

where $X_L = 2 * \text{pi} * f * L$ (inductive reactance), and $X_C = 1 / (2 * \text{pi} * f * C)$ (capacitive reactance).

The current I in the circuit is I = V / Z, so it varies inversely with impedance Z which depends on frequency f. As frequency increases, X_L increases and X_C decreases, affecting Z and thus current.

(iii) In the series LCR circuit:

(i) **Impedance is minimum** when inductive reactance equals capacitive reactance, i.e. $X_L = X_C$. At this frequency called **resonance frequency** f_0, Z = R.

(ii) **Wattless current** flows when the phase difference between voltage and current is 90 deg, meaning current is either leading or lagging voltage purely due to reactance. This happens if the circuit has only inductive reactance (I lags V by 90 deg) or only capacitive reactance (I leads V by 90 deg) without resistance.