2025

(NEP—2020)

(4th Semester)

PHYSICS (MAJOR/MINOR)

(Modern Physics)

Full Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

(SECTION : A—OBJECTIVE)

(*Marks* : 10)

Tick (✓) the correct answer in the brackets provided : 1×10=10

1. According to Bohr's postulate, an electron of mass m moving in a circular path of radius r with velocity v will satisfy the relation

   (a) $\frac{mv}{r} = \frac{nh}{2\pi}$ ( )

   (b) $\frac{mv}{r} = \frac{2\pi}{nh}$ ( )

   (c) $mvr = \frac{2\pi}{nh}$ ( )

   (d) $mvr = \frac{nh}{2\pi}$ ( )

   where $n = 1, 2, 3, \ldots$ is called the principal quantum number.

2. Which of the following sets of quantum numbers is not possible?

(a) $n = 4,\ l = 1,\ m_l = 0,\ m_s = +\frac{1}{2}$ ( )

(b) $n = 4,\ l = 3,\ m_l = -3,\ m_s = -\frac{1}{2}$ ( )

(c) $n = 4,\ l = 1,\ m_l = 2,\ m_s = -\frac{1}{2}$ ( )

(d) $n = 4,\ l = 0,\ m_l = 0,\ m_s = -\frac{1}{2}$ ( )

3. In continuous X-ray spectra, the Duane-Hunt law specifically describes which of the following relationships?

(a) Generation of low-energy (soft) X-rays ( )

(b) The minimum wavelength of X-rays produced as a function of the accelerating voltage ( )

(c) Electron transitions between atomic orbitals ( )

(d) Ionization of gases by positive rays ( )

4. As the temperature of a blackbody is increased, the peak in the blackbody spectrum

(a) remains the same for all temperatures ( )

(b) shifts to higher frequency ( )

(c) shifts to lower frequency ( )

(d) does not depend on temperature, but depends on the material of the body only ( )

5. Which law states that the total energy radiated per unit surface area of a blackbody is directly proportional to the fourth power of its absolute temperature?

(a) Wien's displacement law ( )

(b) Kirchhoff's law ( )

(c) Stefan-Boltzmann law ( )

(d) Planck's law ( )

6. The de Broglie wavelength of a body of mass m and kinetic energy E is

(a) $\frac{2mh}{\sqrt{E}}$ ( )

(b) $\frac{h}{\sqrt{2mE}}$ ( )

(c) $\frac{\hbar}{\sqrt{2mE}}$ ( )

(d) $\frac{2m\hbar}{\sqrt{E}}$ ( )

7. Which experiment provides the first experimental evidence for the wave nature of electrons?

(a) Millikan's oil-drop experiment ( )

(b) Davisson-Germer experiment ( )

(c) Rutherford's alpha scattering experiment ( )

(d) Young's double-slit experiment ( )

8. According to Einstein's special theory of relativity, which of the following is true about time dilation?

(a) A moving clock ticks faster than a stationary clock ( )

(b) Time dilation occurs solely in non-inertial frames ( )

(c) A stationary observer measures a moving clock as ticking more slowly ( )

(d) Time dilation is influenced by the gravitational field ( )

9. According to Dulong and Petit's law, the molar-specific heat capacity of a solid at high temperature is approximately

(a) $3R$ ( )

(b) $5R$ ( )

(c) R ( )

(d) $2R$ ( )

10. The Fermi velocity (v_F) of electrons in a metal is related to the Fermi energy (E_F) by the equation

(a) $E_F = \frac{1}{2} m_e v_F^2$ ( )

(b) $E_F = m_e v_F^2$ ( )

(c) $E_F = \frac{2}{3} m_e v_F^3$ ( )

(d) $E_F = \frac{1}{2} m_e v_F^3$ ( )

(SECTION : B—SHORT ANSWERS)

(*Marks* : 15)

Answer *five* questions, taking at least *one* from each Unit : 3×5=15

UNIT—I

1. Differentiate between hard and soft X-rays in terms of energy, wavelength and penetration power.

2. State Hund's rule and provide an example of its application in electronic configuration.

UNIT—II

3. State and explain Kirchhoff's law of thermal radiation.

4. State and explain the Stefan-Boltzmann law in relation to thermal radiation.

UNIT—III

5. Derive the relationship between Group velocity (v_g) and Phase velocity (v_p).

6. An electron travels at a velocity of $6 \cdot 6 \times 10^4$ m/s with a measurement precision of 0·02%. Calculate the minimum uncertainty in the electron's position using the electron's mass ($m = 9 \cdot 1 \times 10^{-31}$ kg) and Planck's constant ($h = 6 \cdot 6 \times 10^{-34}$ J-s).

UNIT—IV

7. What is the Wiedemann-Franz law?

8. Write a short note on Dulong and Petit's law for the specific heat of solids.

(SECTION : C—DESCRIPTIVE)

(*Marks* : 50)

Answer *five* questions, taking at least *one* from each Unit : 10×5=50

UNIT—I

1. Describe the experimental setup and methodology of Millikan's oil-drop experiment. Using Stokes' law, derive the expression for the elementary charge (e).

2. Outline the fundamental postulates of Bohr's atomic model. Using these postulates, mathematically derive the expressions for the radius (r_n), orbital velocity (v_n) and energy (E_n) of an electron in the nth orbit of a hydrogen-like atom.

UNIT—II

3. What is Planck's law of radiation? Derive Planck's formula for energy distribution in the black-body spectrum.

4. Explain Wien's displacement law and derive it from Planck's law. The peak wavelength of the star Sirius is approximately 290 nm. Calculate its surface temperature.

UNIT—III

5. Derive the Lorentz transformations from Einstein's postulates. Use these transformations to explain time dilation.

6. Discuss the Davisson-Germer experiment. Determine the anticipated wavelength of an electron by applying de Broglie's formula.

UNIT—IV

7. Show how Debye's approximation for phonons leads to the T^3 scaling of specific heat in solids in the low-temperature limit.

8. Calculate the density of states (DoS) for electrons in one-dimensional and three-dimensional systems.

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