Mid-semester Examination 2024-25

PH100: Mechanics and Thermodynamics

Time: 180 Minutes **Marks: 45**

- **All questions are compulsory and their marks are indicated in square brackets.**
- **All questions need to be answered sequentially without fail. Non-compliance with instructions will invite a deduction in marks.**
- **In case you feel any question/s is/are incorrect or have insufficient instruction then write in the answer book with your justification without wasting any time.**

1. Answer the following questions briefly.

(a) Discuss the postulates of quantum mechanics.

(b) An electron and a proton with the same energy *E* approach a potential barrier whose height *U* is greater than *E*. Do they have the same probability of getting through? If not, which has the greater probability?

(c) Differentiate between phase and group velocities. The phase velocity of ripples on a liquid surface is $\sqrt{2\, pi\, S/\lambda\rho}$, where *S* is the surface tension and ρ the density of the liquid. Find the group velocity of the ripples.

(d) Write down Rayleigh-Jeans and Planck's radiation laws. Explain ultraviolet catastrophe.

(e) A metal surface illuminated by 8.5×10^{14} Hz light emits electrons whose maximum energy is 0.52 eV. The same surface illuminated by 12.0×10^{14} Hz light emits electrons whose maximum energy is 1.97 eV. From these data find Planck's constant and the work function of the surface.

(f) Plot the displacement-time graph for undamped, damped (with damping factor $-b\, v$) – (i) lightly damped, (ii) critically damped, and (iii) heavily damped harmonic oscillation. Write down their displacement form also.

[6 × 2.5=15 Marks]

2. (a) In order to give physically meaningful results in calculations, a wave function and its partial derivatives must be finite, continuous, and single-valued, and in addition must be normalizable. The wave function of a particle moving freely (that is, with no forces acting on it) in the +x-direction as

$$\Psi = Ae^{-(i/\hbar)(Et-px)}$$

where *E* is the particle's total energy and *p* is its momentum. Does this wave function meet all the above requirements? If not, could a linear superposition of such wave functions meet these requirements? What is the significance of such a superposition of wave functions?

(b) A particle is in a cubic box with infinitely hard walls whose edges are *L* long and inside the box *U* = *0*. The wave functions of the particle are given by

$$\psi = A \sin\frac{n_x \pi x}{L} \sin\frac{n_y \pi y}{L} \sin\frac{n_z \pi z}{L} \qquad \begin{aligned} n_x &= 1, 2, 3, \ldots \\ n_y &= 1, 2, 3, \ldots \\ n_z &= 1, 2, 3, \ldots \end{aligned}$$

(i) Find the value of the normalization constant A. (ii) Find the possible energies of the particle in the cubic box by substituting its wave function in Schrödinger's equation and solving for *E*. (iii) Compare the ground-