Assignment # 13+14

Modern Physics II & III

Chapter 39: Light Waves Behaving as Particles

Chapter 40: Quantum Mechanics

Important Formulas and Concepts:

Symmetry, Wave Particle Duality,

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV_{ba}}}$

$L_n = mv_n r_n = n\frac{h}{2\pi}$

$r_n = \epsilon_o \frac{n^2 h^2}{\pi m e^2}$

$I = \sigma T^4$ (Stefan-Boltzmann law for blackbody)

$\lambda_m T = 2.90 \times 10^{-3}$ = constant

$I = \int_0^\infty I(\lambda)\, d\lambda$ (Total Intensity)

$I(\lambda) = \frac{2\pi hc^2}{\lambda^5(\exp^{\frac{hc}{\lambda kT}} - 1)}$

Question 1:

For crystal diffraction experiments, wavelengths on the order of 0.20 nm are often appropriate. Find the energy in electron volts for a particle with this wavelength if the particle is;

(a) a photon
(b) an electron
(c) an alpha particle ($m = 6.64 \times 10^{-27}$ kg)

Question 2:

Determine λ_m the wavelength at the peak of the Planck distribution, and the corresponding frequency ƒ, at these temperatures:

(a) 3.00 K
(b) 300
(c) 3000 K
(d) Analyse the wavelengths at these three temperatures and arrange them in ascending order.

Question 3:

A 20.0-kg satellite circles the earth once every 2.00 h in an orbit having a radius of 8060 km. Assuming that Bohr's angular-momentum result $L = n\frac{h}{2\pi}$ applies to satellites just as it does to an electron in the hydrogen atom.

(a) Find the quantum number n of the orbit of the satellite.

(b) Show from Bohr's angular momentum result and Newton's law of gravitation that the radius of an earth-satellite orbit is directly proportional to the square of the quantum number, $r = kn^2$,where k is the constant of proportionality.
(c) Using the result from part (b), find the distance between the orbit of the satellite in this problem and its next "allowed" orbit. (Calculate a numerical value.)
(d) Comment on the possibility of observing the separation of the two adjacent orbits.
(e) Do quantized and classical orbits correspond for this satellite? Which is the "correct" method for calculating the orbits?

Question 4:

Write the Planck distribution law in terms of frequency f, rather than the wavelength λ, to obtain I(f).

(a) Show that

$$\int_0^\infty I(\lambda)\, d\lambda = \frac{2\pi^5 k^4}{15\, c^2\, 4^3}\, T^4$$

Where I(λ) is the Planck distribution formula. For the solution, you will be i need of following tabulated integral;

$$\int_0^\infty \frac{x^3}{exp^{\alpha x}-1}\, dx = \frac{1}{240}\left(\frac{2\pi}{\alpha}\right)^4$$

(b) The result of part (b) is I and has the form of Stefan-Boltzmann law, $I = \sigma T^4$. Evaluate the constants in part (b).

Question 5:

The wave function $\psi(x,t) = A\exp^{i(k1x - \omega 1t)} + A\exp^{i(k2x - \omega 2t)}$ is a superposition of two free-particle wave functions. Both k_1 and k_2 are positive.

(a) Show that this wave function satisfies the Schrodinger equation for a free particle of mass m.
(b) Find the probability distribution function for ψ(x,t).

Question 6:

Compute $|\psi|^2$ for $\psi = \psi \mathrm{Sin}\omega t$, where ψ is time independent and ω is real constant. Is this a wave function for a stationary state? Why or why not