BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE

DEPARTMENT OF MATHEMATICS AND PHYSICS

DIPSCED PHYSICS PART 3.2

PH 009: QUANTUM THEORY



**DURATION: 3 HOURS**

Answer **ALL** parts of Section A and any **THREE** questions from Section B. Section A carries 40 marks and each question of Section B carries 20 marks.

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|---|---|
| Electron charge, | $e = 1.60 \times 10^{-19}\, C$ |
| Planck's constant, | $h = 6.63 \times 10^{-34}\, Js$ |
| Mass of an electron, | $m_e = 9.11\, x\, 10^{-31}\, kg$ |
| Acceleration due to gravity, | $g = 9.81\, ms^{-2}$ |
| Permittivity of free space, | $\varepsilon_0 = 8.85 \times 10^{-12}\, Fm^{-1}$ |
| Speed of light, | $c = 3 \times 10^{8}\, ms^{-1}$ |

## SECTION A

1.a)How does quantum mechanics differ from classical mechanics? [3]

b)(i) State the main proparties of a photon [3]

(ii) Photons in a pale blue light have a wavelength of $500\, nm$. What is the energy of this photon? [3]

(iii) Calculate the cycle time and frequency of this light. [4]

c) State Wien's displacement law [2]

d) A radiometer used to observe radiation from an object that is heated to maintain a temperature of 1278 K. The radiometer records radiation in a wavelenth interval of 12.6nm. If the radiometer is varied and set to record the most intense radiation emisssion from the object,

(i)Determine the wavelenght setting for the most intense radiation emission [3]

(ii) What is the intensity of the emitted radiation in this interval. [5]

(e) ( i) What is a black body ? [2]

(ii) Show that the energy in a black body cavity is proportional to $T^4$ in accordance with the Stefan-Boltzmann law. [4]

(f) . Discuss the statement "***x-ray emission*** is the inverse *of* ***photoelectric effect.***" [3]

(g) Calculate the fraction of an incident beam of alpha particles of kinetic energy 5Mev that Geiger and Marsden expected to see for $\theta \geq 90°$ from a gold foil (Z=79)$10^{-6}m$ thick. [3]

(h) Describe what happens when a particle is incident on the wall of a potential well. [3]

(i)The time-independent Schrödinger equation for a particle of mass *m* moving in one direction with energy *E* is

$$-\frac{\hbar}{2m}\frac{d^2\psi(x)}{dx^2}+V(x)\psi(x)=E\psi(x).$$

What is represented by the symbols . $\psi(x)$ and V(x) in the equation [2]

**SECTION B**

2 (a) Distinguish between Compton scattering and compton effect [4]

(b) In a Compton scattering experiment it is found that the incident wavelength $\lambda_1$ is shifted by1.5 percent when the scattering angle $\theta = 120°$.

(i ) What is the value of $\lambda_1$ ? [5]

(ii)What will be the wavelength $\lambda_2$ of the shifted photon when the scattering angle is 75°? [5]

(c) Light of wavelength 400nm and intensity $10^{-2}W/m^2$ is incident on potasium. Estmate the time lag for the emission of photoelectrons expected classically. The workfunction of potasium is is 2.22eV ( assume $r = 10^{-10}m$ to be the typical radius of an atom) [6]

3(a) state Bohr postulates [5]

(b). Compute the wavelength of $H_\beta$ spectral lines (i.e. the second line of the Balmer

Series predicted by Bohr's model of atomic structure). The $H_\beta$ line is emitted in the transition from $n_i$ = 4 to $n_f$ =2. [5]

(c) In a particular experiment, alpha particles from $^{226}$Ra are scattered at $\theta = 45°$ From a silver foil and 450 particles are counted each minute at the scintilation detector.If every thing is kept the same except that the detector is moved to observe particles scattered at 90°, How many particles will be counted per minute ? [10]

4(a)What is meant by Wave -particle duality ? [5]

(b)Calculate the de Brogglie wavelength of a Ping-Pong ball of mass 2.0g after it is slammed across the table with speed 5m/s ? [5]

(c) An electron is trapped in a one-dimensuional region of length 1.00 x $10^{-10}$m (a typical atomic diameter).

i) Find the energies of the ground state and first two excite states. [4]
ii) How much energy must be supplied to excite the electron from the ground state to the second excited state? [3]
iii) From the second excited state, the electron drops down to the first excited state. How much energy is released in this process? [3]

5(a) State the correspondence principle [4]

(b) An electron is moving in a thin wire 1.0cm long.The potential in the wire is constant on avarage but rises sharply at each end.

i. Compute the ground- state energy for the electron. [6]
ii. If the electron's energy is equivalent to the avarege kinetic energy of the molecules in a gas at T=300K , about 0.03eV
What is the electron's quantum number n? [10]

6 (a) State the Heisenberg uncertainty principle [3]

(b) An electron is moving along an x axis with a speed of $2.052 \times .05 \times 10^6$m/s which can be known with precision of 0.50%. What is the minimum uncertainty with which you can simultaneously measure the position of the electron along the x axis? [7]

(c). Verify explicitly that the function $\psi''(x) = A \sin kx + B \cos kx$ is a solution of the Schrödinger equation $\psi''(x) = -k^2\, \psi(x)$ for any values of the constants $A$ and $B$. [10]

END OF EXAMINATION