BINDURA UNIVERSITY OF SCIENCE EDUCATION

PHYSICS AND MATHEMATICS DEPARTMENT

MPH505: ATOMIC AND OPTICAL PHYSICS

DURATION: THREE HOURS

AUG 2024

Answer **ALL** parts of Section A and any **THREE** questions from Section B. Section A carries 40 marks and Section B carries 60 marks.

SECTION A

Question 1

a) Estimate the electric field needed to pull an electron out of an atom in a time comparable to that for the electron to go around the nucleus. **[5]**

b) Briefly describe each of the of the following effects or, in the case of rules, state the rule:

i. Auger effect **[3]**

ii. Anomalous Zeeman effect [3]

iii. Lamb shift [3]

iv. Land'e internal rule [3]

v. Hund's rules for atomic levels. [3]

c) Light is commonly described in terms of brightness and colour. Copy and complete the following table by filling in the quantities in the wave and particle models of light which relate to colour and brightness. [8]

	Wave Model	Particle Model
Brightness		
Colour		

d) Consider a ruby laser which emits light at a wavelength of 94.4 nm. This laser emits pulses which last for 1.20×10^{-11} s and the energy released per pulse is 0.150 J.

i. What is the length (distance in m) of the pulse? [4]

ii. How many photons are in each pulse? [4]

iii. What is the power delivered in each pulse? [4]

SECTION B

Answer any **THREE** questions from this section.

Question 2

In 1923 Compton measured the scattering of X-rays by electrons. Classical wave theory predicts that if an electromagnetic wave of frequency f is incident on a material containing charges, the charges will oscillate at the same frequency and reradiate electromagnetic waves of the same frequency. Compton observed a change in frequency and that the electrons absorbed some energy from the X-rays. He explained this by modelling the interaction between the electron and the photon as a collision. Before colliding with a stationary electron, an X-ray has a wavelength of 6.0 pm. The photon collides with an electron head-on so that it is scattered at 180^{o}.

a) What is the wavelength of the scattered photon? [10]

b) What is the difference in energy between the incident and the scattered photons? [5]

c) What is the energy of the scattered electron? [5]

Question 3

One of the puzzles of early models of atomic structure was why the electrons didn't simply go into the nucleus, to which they are attracted by electrostatic (Coulomb) force.

a) Calculate the smallest allowed energy of an electron trapped inside an atomic nucleus (diameter about 1.4×10^{-14}m). **[10]**

b) Calculate the smallest allowed energy of a proton trapped inside an atomic nucleus. **[5]**

c) Comparing these energies, should we expect to find electrons inside an atomic nucleus? Justify your suggestion. **[5]**

Question 4

The currently accepted model of the atom is the quantum model, which overcomes some of the limitations of the Bohr model. While this model is bound to change a bit, it works extremely well. All modern electronics is based on it. Everything that has a transistor in it, from a digital watch to a computer, is based on quantum mechanics and the quantum model of the atom. This model uses the wave function, ψ, which obeys the Schrödinger equation, to describe the electron.

a) Compare the Bohr model to the quantum model of the atom, what parallels can you draw? **[12]**

b) What is normalisation and what is its physical significance? **[4]**

c) The requirements that the wave function be normalisable and continuous introduce three quantum numbers, n, l and m. What do these quantum numbers represent? **[3]**

d) There is a fourth quantum number is m_s. What property of an electron does this fourth quantum number represent? **[1]**

Question 5

LASER stands for Light Amplification by Stimulated Emission of Radiation.

a) Explain the steps involved in producing laser light. Use diagrams to illustrate your explanation. **[16]**

b) Why does a helium-neon (HeNe) laser use helium instead of just neon when the neon emits the coherent photons that make up the laser beam? **[4]**

Question 6

Discuss the principles of laser operation and the different types of lasers used in various applications. How have lasers revolutionized communication, manufacturing, and scientific research, and what are the key characteristics that make lasers indispensable in these fields? [20]

END OF EXAM