Homework exercise 1 – Introduction to Quantum Theory

Total =26 marks

Question 1:

(a) Explain qualitatively how the Bohr Model of the atom can account for line emission spectra. 2

(b) It is possible to calculate a de Broglie wavelength for a moving object.

A ball of mass 45 g has a speed of 68 m s^{-1}.

(i) Calculate the de Broglie wavelength for the ball. 2

(ii) Explain why wave-like properties are not observed for the ball. 1

(5)

Question 2:

(a) State what is meant by the Uncertainty Principle in relation to the position and momentum of a subatomic particle. 1

(b) An athlete has a mass of 70 kg. At the finish line the position of the athlete has an uncertainty of $1{\cdot}0 \times 10^{-3}$ m.

Calculate the minimum uncertainty in the momentum of the athlete at the finish line. 2

(c) It takes about $1{\cdot}6 \times 10^{-13}$ J of energy to create an electron-positron pair.

For what approximate period of time can this amount of energy be borrowed before it has to be paid back by electron-positron annihilation? 2

(5)

Question 3:

(*a*) Bohr's model of the hydrogen atom includes assumptions about the orbiting electron. One of these is that the electron moves in a circular orbit centred on the nucleus.

(i) State briefly one of the other assumptions.

(ii) By considering the electron as a point mass m travelling around the nucleus, show that the radii of the allowed orbits r_n are given by

$$r_n = \frac{nh}{2\pi mv}$$

where the remaining symbols have their usual meanings.

(iii) Calculate the speed of an electron in the first allowed orbit of radius $5{\cdot}3 \times 10^{-11}$ m. 5

(*b*) Planck and Einstein suggested that electromagnetic radiation exhibits a wave-particle duality. De Broglie extended this idea to matter.

(i) Write down an expression for the wavelength λ associated with a particle that has a momentum of magnitude p.

(ii) (A) A woman of mass 50 kg walks through a doorway at a speed of $1{\cdot}5\,\text{m s}^{-1}$. Calculate her de Broglie wavelength.

(B) Explain why the effect of diffraction is negligible when the woman passes through the doorway. 4

(9)

Question 4:

(*a*) Electrons can exhibit wave-like behaviour. Give **one** example of evidence which supports this statement. **1**

(*b*) The Bohr model of the hydrogen atom suggests a nucleus with an electron occupying one of a series of stable orbits.

A nucleus and the first two stable orbits are shown in Figure 6.

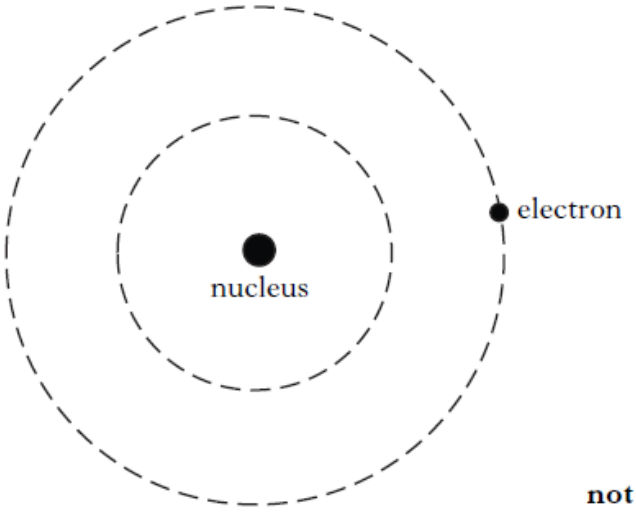

Figure 6

(i) Calculate the angular momentum of the electron in the second stable orbit. **2**

(ii) Starting with the relationship

$$mrv = \frac{nh}{2\pi}$$

show that the circumference of the second stable orbit is equal to two electron wavelengths. **2**

(iii) The circumference of the second stable orbit is $1{\cdot}3 \times 10^{-9}$ m.

Calculate the speed of the electron in this orbit. **2**

(7)