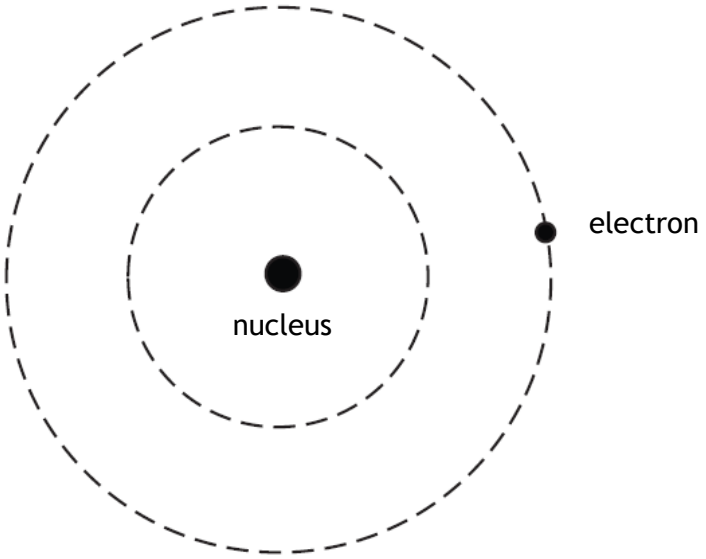
**Homework - Quantum Mechanics**

1. Electrons can exhibit wave-like behaviour.

   (a) State one example of evidence which supports this statement.

   (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 orbit are shown in the diagram below.




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

   (ii) Starting with the relationship

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

   Show that the circumference of the second stable orbit is equal to two electron wavelengths.

   (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.

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2. The Bohr model of the hydrogen atom states that the angular momentum of an electron is quantised.

   (a) For the hydrogen atom:

   (i) Calculate the minimum angular momentum of the electron.

   (ii) Calculate the linear momentum of the electron in an orbit with a radius of $5{\cdot}3 \times 10^{-11}$ m.

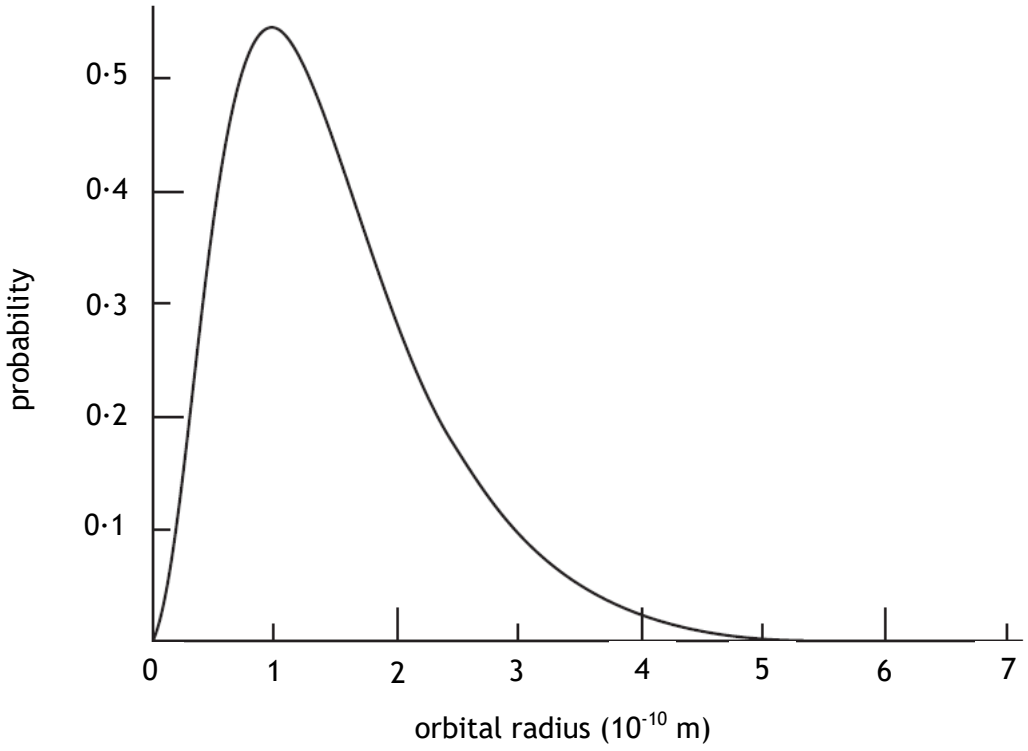
   (iii) Calculate the de Broglie wavelength of the electron in this orbit.

   (b) One of the limitations of the Bohr model is that an orbiting electron is constantly accelerating and therefore should continuously emit electromagnetic radiations.

   (i) State what would happen to the orbit of the electron if electromagnetic radiation were to be continuously emitted.

   (ii) State the name of the branch of physics that provides methods of determining the electron's position in terms of probability.

   (iii) A diagram of electron probability distribution for the hydrogen atom is shown in the graph below.




   Comment on the position of the electron in this orbital.

**Homework - Quantum Mechanics**

3. Heisenberg uncertainty principle states that the momentum and the position of a particle cannot both be measured precisely, at the same time.

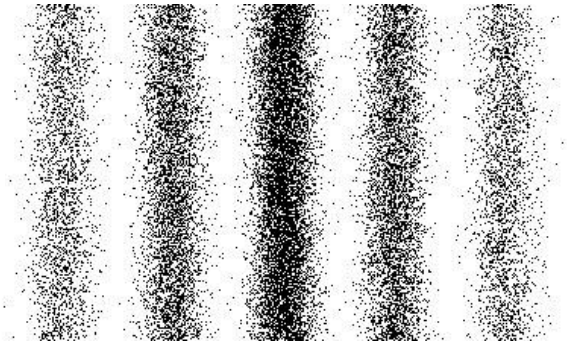
   This gives the equation

$$\Delta x \Delta p_x \geq \frac{h}{4\pi}$$

   An electron is found to be in a position within $\pm$ 3·4 x $10^{-12}$ m.

   (a) Calculate the associated uncertainty in the momentum along the same directional axis.

   Electrons can be fired at a double slit, one at a time. The pattern they create on a screen over a set time period is observed below.

   interference pattern 

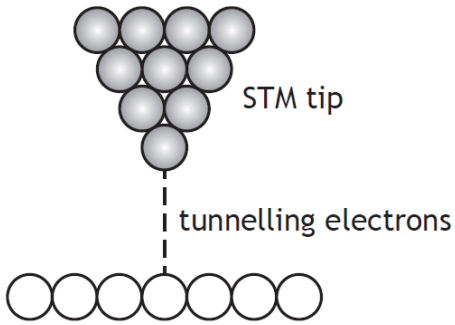
   (b) State what this indicates about electrons.

   A sensor is set up to detect which of the two slits the electron passes through.

   (c) Describe the pattern observed on the screen, over the same time period.

**Homework - Quantum Mechanics**

4. In a scanning tunnelling microscope (STM) a sharp metallic tip is brought very close to the surface of a conductor. As the tip is moved back and forth, an electric current can be detected due to the movement ("tunnelling") of electrons across the air gap between the tip and the conductor, as shown in Figure 6B.




According to classical physics, electrons should not be able to cross the gap as the kinetic energy of each electron is insufficient to overcome the repulsion between electrons in the STM tip and the surface.

Explain why an electron is able to cross the gap.