4. Define the *commutator* of two operators $\hat{A}$ and $\hat{B}$. [3]

Explain the physical significance of the operators $\hat{L}^2$ and $\hat{L}_z$ in quantum mechanics. [2]

These two operators are *compatible*; what does this mean, and what can you deduce about their commutator? (Detailed mathematical working is *not* required.) [3]

5. The *true* potential energy of an electron in a hydrogen atom depends only on its distance from the nucleus. What are the consequences of this fact for the solution of the Schrödinger equation in this system? [3]

The *effective* potential for an electron in a state of orbital angular momentum l in a hydrogen atom can be written as

$$V_{\text{eff}}(r) = \frac{-e^2}{4\pi\epsilon_0 r} + \frac{l(l+1)\hbar^2}{2m_e r^2},$$

where m_e is the electron mass. What is the physical significance of the two terms in this effective potential? [4]

6. In a Stern-Gerlach experiment, a beam of sodium atoms is passed through an inhomogeneous magnetic field. Explain why atoms are attracted into the strong-field or weak-field regions, according to the directions of their magnetic moments. [2]

The experiment divides the atoms into groups according to the value of the z component of the angular momentum of the outermost electron. How many such groups are there? [2]

According to the theory of spin in quantum mechanics, these groups correspond to different values of the quantum number m_s. What are the possible values of m_s for an electron? [2]