11. The solution to the time-dependent Schrödinger equation for the hydrogen atom may be written in the form

$$\psi_{nlm} = R_{nl}(r)\Theta_{lm}(\theta)\Phi_m(\phi).$$

Outline how the boundary conditions on the wavefunction restrict the possible values of the quantum numbers n, l and m. For a given value of n, state the allowed values of l and m. [4]

Which three physical quantities do n, l and m provide a measure of? [3]

A hydrogen atom is prepared in one of its energy eigenstates, with given n, l and m, and a magnetic field $\mathrm{B} = (0, 0, B_z)$ is then applied along the z-axis. Explain qualitatively why the energy changes by an amount

$$\Delta E = \mu_B B_z(m + gm_s)$$

where $\mu_B = e\hbar/2m_e$, $g \approx 2$ and m_s is the magnetic spin quantum number. [4]

Briefly describe the Stern-Gerlach experiment. What feature of its results indicated that the spin term must be included in the above expression. What are the possible values of m_s for an electron? [4]

If a hydrogen atom is prepared in a state with $n = 3$ and the measured change in energy is $\Delta E \approx 3\mu_B B_z$, deduce the values of l and m. Also determine the squared magnitude, J^2, of the total angular momentum of the electron. [5]

END OF PAPER