4. Write down the equation that defines an *eigenfunction* and an *eigenvalue* of a Hermitian operator $\hat{O}$, explaining carefully which quantity in your equation is which. [3]

What mathematical condition are the eigenvalues required to satisfy as a result of the fact that $\hat{O}$ is Hermitian? What is the physical intepretation of the eigenvalues of a Hermitian operator that represents an observable quantity? [3]

When such a physical quantity is measured, explain how the wavefunction of the system immediately after the measurement is related to the measurement result. [2]

5. The angular momentum operators in the x, y and z directions, ($\hat{L}_x$, $\hat{L}_y$ and $\hat{L}_z$), obey the commutation relation

$$[\hat{L}_x, \hat{L}_y] = i\hbar\hat{L}_z.$$

Give the mathematical definition of the commutator appearing on the left-hand side. Explain the physical significance of the fact that the commutator is not zero. [4]

How are the *spherical harmonics* $Y_l^m(\theta, \phi)$ related to the angular momentum operators? [3]

6. An electron is in the 3d state of a hydrogen atom. What is the value of the angular momentum quantum number l? [1]

State the possible corresponding values of the magnetic quantum number m. [2]

If the spin of the electron is also accounted for, its total angular momentum quantum number j can take one of two possible values. What are they, and what are the corresponding spectroscopic term symbols? [3]

7) i) i) $a+b$

　　　ii) $a+b-ab$

b)

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