MODULE PH201 : Atoms and Nuclei
Example Sheet 2

All questions should be submitted by Friday 2nd March

This is a **ASSESSED** sheet

A) An eigenstate for the electron of the hydrogen atom is

$$\psi(\underline{x}) = \frac{C}{a_0^{3/2}} \left(2 - \frac{r}{a_0}\right) e^{-\frac{r}{2a_0}}$$

For this state calculate

i) the value of C to correctly normalise this state

ii) the expectation value of r of the electron

iii) the expectation value of r^2 of the electron

iv) Using $(\Delta r)^2 = < r^2 > - < r >^2$ what is Δr for this state.

Hint: you will probably need

$$\int d^3x f(r) = 2\pi \int_0^\infty dr r^2 \int_0^\pi \sin\theta d\theta f(r,\theta) = 4\pi \int_0^\infty dr r^2 f(r)$$

and

$$\int_0^\infty dr r^n e^{-\alpha r} = n! \alpha^{-n-1}, n > -1$$

[12 marks]

B) The values of the energy levels of Hydrogen are given by

$$E_n = -\frac{A}{n^2}$$

where

$$A = \frac{2m_e e^4}{4(4\pi\epsilon_0)^2\hbar^2} = 13.6eV$$

Calculate the wavelength of the photon emmited when an electron makes a transition from level $n = 2$ to $n = 1$.

[3 marks]

[You may use $hc = 1.24 \times 10^{-6} eVm$]

How is this formulae altered to take into account the fact that the proton has finite mass?

A mixture of normal hydrogen and deuterium emits light when an electron transitions from level $n = 2$ to level $n = 1$. Calculate the *ratio* of the two wavelengths of light emmitted. You may use the approximation that the mass of the dueterium nucleus is twice that of the proton.

[5 marks]