Ph 135b: Solution Set 1

January 21, 2004

1

We have the conversion factor

$$1.78 \times 10^{-36}\text{kg} = 1/c^2\text{eV}$$

and in natural units

$$6.58 \times 10^{-25}\text{GeV s} = 1$$
$$0.197 \text{ GeV fm} = 1$$
$$3 \times 10^{8}\text{m s}^{-1} = 1$$

so,

$$G_N = 6.67 \times 10^{-11} \left(\frac{10^{15}}{0.197\text{GeV}}\right)^3 \left(1.783 \times 10^{-27}\text{GeV}^{-1}\right) \left(6.58 \times 10^{-25}\text{GeV}\right)^2 \quad (1)$$
$$= 6.71 \times 10^{-39}\text{GeV}^{-2} \quad (2)$$

2

Nuclear radius is 10^{-15}m = 1fm and $\hbar = c = 1$.From the uncertainty relation,

$$\Delta x \Delta p \sim \hbar$$

we get that $\Delta p \sim 1\text{fm}^{-1} = 197\text{MeV}$. This is much greater than the rest mass of an electron so the electrons energy is $E_e \sim 197\text{MeV}$. Now Tritium decay gives electrons with energy of the order of 5KeV which is much smaller and so is not compatible.

3

The 10 baryons with charm zero are

$$uuu, ddd, sss,$$
$$uud, udd, uss, uus, dds, dss$$
$$uds$$

the six with charm 1 are

$$uuc, ddc, ssc$$
$$udc, usc, dsc$$

the three with charm 2 are

$$ucc, dcc, scc$$

and the one with charm 3 is

$$ccc$$

4

The time-dependent Schrodinger equation in cgs-esu units is

$$i\hbar\frac{\partial}{\partial t}\psi(\mathbf{x},t) = -\frac{\hbar^2}{2m_e}\nabla^2_{\mathbf{x}}\psi(\mathbf{x},t) - \frac{e^2}{|\mathbf{x}|}\psi(\mathbf{x},t)$$

Now we choose our units of mass so that $m_e = 1$. To make the above equation parameter free we also choose

$$\frac{2m_e e^2}{\hbar} = 1$$

which has dimensions of length. Hence this sets our length unit. Similarly, by looking at the above equation we can see that $2m_e/\hbar$ has dimensions of time and by setting it to 1 we fix our time unit. In our new units the time-dependent Schrodinger equation looks like

$$i\frac{\partial}{\partial t}\psi(\mathbf{x},t) = -\nabla^2_{\mathbf{x}}\psi(\mathbf{x},t) - \frac{1}{|\mathbf{x}|}\psi(\mathbf{x},t)$$

If we consider a more complicated atom with more electrons and a larger nucleus no new parameters are introduced. Additional electron-electron interaction terms are introduced and a dimensionless integer valued number Z which counts the nuclear charge are needed but that is all. However if we wish to consider more than one nucleus or molecules we need to introduce a parameter which gives the nuclei separation.

If we include the effects of spin and magnetism we also need to introduce new parameters for example the spin-orbit coupling is a relativistic effect and so we can no longer treat c as infinite. Similarly if we wish to include hyperfine interactions we must introduce g factors and treat the mass of the nucleons as finite.

5

In QED we do not have elastic photon-photon scattering at lowest order but at higher order we have diagrams such as the one below.

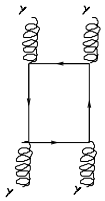

Figure 1: Photon-Photon Scattering

This is quantum effect and is not seen in the classical theory. Maxwells equations are linear and the electro-magnetic waves do not scatter each other.