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,

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

(1)

\[
= 6.71 \times 10^{-39} \text{GeV}^{-2}
\]

(2)

2

Nuclear radius is \(10^{-15}\text{m} = 1\text{fm} \) 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

\[
ccc
\]
The time-dependent Schrödinger equation in cgs-esu units is
\[ i\hbar \frac{\partial}{\partial t} \psi(x, t) = -\frac{\hbar^2}{2m_e} \nabla_x^2 \psi(x, t) - \frac{e^2}{|x|} \psi(x, t) \]

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 Schrödinger equation looks like
\[ i\frac{\partial}{\partial t} \psi(x, t) = -\nabla_x^2 \psi(x, t) - \frac{1}{|x|} \psi(x, t) \]

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.

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](image_url)