Department of Physics
University of California San Diego

Modern Physics (2D)
Prof. V. Sharma
Quiz # 4 (Oct 7 2003)

Some Relevant Formulae, Constants and Identities

Edge of Observable Universe $\approx 10^{26}\,m$ away

Centripetal Acc.= $\dfrac{u^2}{r}$

Bohr's Angular Momentum Quantization: $mvr = n\hbar$

Bohr Radius $a_0 = \dfrac{\hbar^2}{mke^2} = 0.529\ \text{Å}$

Quantized Orbit in Hydrogenlike atom $r_n = \dfrac{n^2 a_0}{Z}$

Energy in Hydrogen atom $E_n = \dfrac{-ke^2}{2a_0}\left(\dfrac{1}{n^2}\right) = \left(\dfrac{-13.6\text{ eV}}{n^2}\right)$

Gravitational Constant $G = 6.67\times10^{-11}\,\text{N.m}^2/\text{Kg}^2$

Coulomb's Constant $k = 8.988\times10^{9}\,\text{N.m}^2/\text{C}^2$

Planck's Constant $h = 6.626\times10^{-34}\,\text{J.s} = 4.136\times10^{-15}\,\text{eV.s}$

$1\text{ eV} = 1.60\times10^{-19}\text{ J}$

Electron Mass $= 9.1\times10^{-31}\text{ Kg} = 0.511\text{ MeV/c}^2$

Proton Mass $= 938.3\text{ MeV/c}^2$

Speed of Light in Vaccum $c = 2.998\times10^{8}\text{m/s}$

Electron Charge $= 1.602\times10^{-19}\text{ C}$

Pl. write you answer in the Blue Book in indelible ink. Make sure <u>your code number is prominently displayed on each page</u>.

Department of Physics
University of California San Diego
Modern Physics (2D)
Prof. V. Sharma
Quiz # 4 (Feb 7)

Problem 1 : Probing The Nucleus [6 pts]

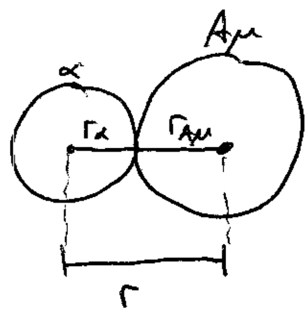
Assume that Gold (Z=79) nucleus has a radius of 6.4 fm and the α–particle has radius of 1.8 fm. What minimum energy E must an incident α–particle have to experience non-Coulombic Nuclear forces, that is to say, penetrate the nucleus?

Problem 2: Basketball Team From Hell ! [14 pts]

Suppose an electron was bound to a proton, as in the hydrogen atom, by the gravitational force rather than by electric force. Write the equations for (a) the total energy of the system and (b) Newton's second law (equality of forces) . Now calculate (c) the radius and (d) the energy of the ground state. (e) Compare the size of the atom with that of our universe. Should humans made of such altered atoms be allowed in the basketball tournaments?

Phys 2D Quiz 4 Sol'ns

1] When far away, $E = KE$ (since $PE = 0$ for large r).
This E gets entirely converted to PE (for the min. energy case) when the nuclei touch.



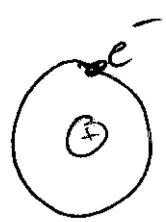
charge on α

$$\text{So } E = k\frac{(2e)(79e)}{r}$$

$$= k\frac{158e^2}{(r_\alpha + r_{Au})}$$

$$= \boxed{4.43 \times 10^{-12}\,\text{J} = 27.7\,\text{MeV}}$$

2]



a] $$\boxed{E = \frac{1}{2}m_e v^2 - G\frac{m_e m_p}{r}}$$

since grav $PE = -G\frac{m_e m_p}{r}$

b] $F = ma \Rightarrow$ $$\boxed{G\frac{m_e m_p}{r^2} = \frac{mv^2}{r}}$$

c] Assume $m_e v r = n\hbar$. So $v = \frac{n\hbar}{m_e r}$

Using part (b), we get

$$G\frac{m_e m_p}{r^2} = \frac{m_e}{r}\frac{n^2\hbar^2}{m_e^2 r^2} \Rightarrow \boxed{r = \frac{n^2\hbar^2}{G m_e^2 m_p}}$$

for $n=1$ (the ground state), $\boxed{r = 1.2\times10^{29}\,m}$

d] Since by part (b) $G\frac{m_e m_p}{r} = mv^2$,

$$\boxed{E = -\frac{1}{2}G\frac{m_e m_p}{r}}$$

Using our answer from part (c) for r,

$$\boxed{E = -4.2\times10^{-97}\,J = -2.6\times10^{-78}\,eV}$$ DAMN.

e] r is larger than the size of the universe ($10^{26}\,m$)!

∴ It would be totally sweet if people made of these atoms played basketball.