Department of Physics
University of California San Diego

Modern Physics (2D)
Prof. V. Sharma
Quiz # 5 (Friday the 13th !)

Some Relevant Formulae, Constants and Identities

$p = \gamma m u$; $E = KE + mc^2 = \gamma mc^2$

$E^2 = (pc)^2 + (mc^2)^2$

Bragg's Law: $n\lambda = 2d\sin\theta$

$\lambda = \frac{h}{p}$; $\Delta x.\Delta p \geq \frac{h}{4\pi}$; $\Delta E.\Delta t \geq \frac{h}{4\pi}$

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

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

$1\ eV = 1.60 \times 10^{-19}\ J$

Electron mass $= 9.1\times 10^{-31}$ Kg $= 0.511\ MeV/c^2$

Proton mass $= 938.3\ MeV/c^2$

Speed of light in vaccum $c = 2.998\times10^{8}$ m/s

Electron charge $= 1.602 \times 10^{-19}$ C

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

Pl. write you answer in the Blue Book in indelible ink. Make sure your code number is prominently displayed on each page. Ask the proctor if you do not understand the question.

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Problem 1: Tiger Hunting in a Quantum Jungle ! [10 pts]

Somewhere in the Himalayan mountain range there are rumors of a mysterious Quantum jungle where the value of the Planck's constant h is much larger than our usual world. Imagine that you are in this quantum jungle where h=50 J.s !! **Sher Khan**, the tiger, runs past you in the bushes a few meters away. The tiger, weighing 100kg, is known to be in a region about 4m long. (a) What is the minimum uncertainty in his speed? (b) Assuming this uncertainty in his speed to prevail for 10 seconds, determine the uncertainty in his position after this time.

Problem 2: Guessing Electron's Location [10 pts]

An electron is confined in an "opaque" box the size of an atom so that one side of the box has the length L=0.1nm. (a) Calculate the uncertainty in momentum Δp of the electron. (b) Assuming that the electron is "bouncing" around inside the box with momentum $p \approx \Delta p$, calculate the kinetic energy of the electron. Express your answers in units of eV. (c) repeat steps (a) and (b) for the case where the electron is confined inside a box with sides the size of a nucleus, $L = 10^{-14}$m. (d) Compare the kinetic energy of the electron in the two situations with the ground state energy of a Hydrogen atom. Can the electron be found inside a nucleus?

2D Quiz 5 Solns

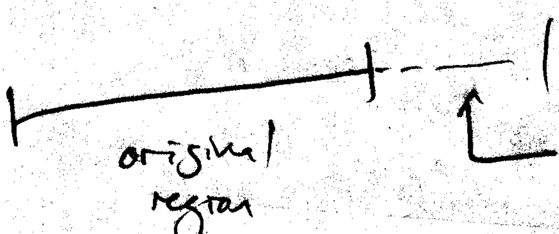
1]

a] Since he's in a region 4m long, $\Delta x = 2m$

$$\Rightarrow \Delta x\, m(\Delta v) = \frac{\hbar}{2} \Rightarrow \Delta v = \frac{\hbar}{2m\Delta x} = \frac{h}{4\pi m \Delta x}$$

$$\Rightarrow \Delta v = \frac{50}{4\pi(100)(2)} = \frac{1}{16\pi} = \boxed{0.02\ \tfrac{m}{s}}$$

b] Worst-case scenario: Tiger starts out @ one end of the region and moves with $v = 0.02\ \tfrac{m}{s}$ for 10s



$(0.02\ \tfrac{m}{s})(10s) = 0.2m$

Since he could do this at either end, the new region is $4 + .2 + .2 = 4.4m$ long $\Rightarrow \boxed{\Delta x = 2.2m}$

2a

$$\Delta p = \frac{\hbar}{2\Delta x} = \frac{\hbar}{2(.1\text{nm})} = \boxed{990\,\frac{eV}{c}}$$

(Could have used $\Delta x = 0.05$nm too, whichever).

b $$KE = E - mc^2 = \sqrt{p^2c^2 + m_e^2c^4} - m_ec^2$$

$$= \boxed{0.96\,eV}$$

(non-rel. would have been OK too).

c $$\Delta p = \frac{\hbar}{2(10^{-14}m)} = \boxed{9.9\,\frac{MeV}{c}}$$

$$KE = \sqrt{p^2c^2 + m_e^2c^4} - m_ec^2$$

$$= \boxed{9.4\,MeV}$$

d Inside 0.1nm, $KE \ll 13.6\,eV$

Inside 10^{-14}m, $KE \gg 13.6\,eV$.

Can't find the electron inside a nucleus – it has too much energy & would escape!