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Quantum Universe (4E)
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Quiz # 1 (April 11 2005)

Some Useful Numbers, Equations and Identities

$$\text{Speed of Light, } c = 2.998 \times 10^{8}\,\text{m/s}$$

$$\text{Planck's Constant, } h = 6.626 \times 10^{-34}\,\text{J} \times \text{S} = 4.136 \times 10^{-15}\,\text{eV} \times \text{S}$$

$$1\text{ eV} = 1.60 \times 10^{-19}\,\text{J}; \quad 1\text{ MeV/c} = 5.344 \times 10^{-22}\,\text{Kg.m/s}$$

$$\text{Coulomb's Constant, } k = 8.99 \times 10^{9}\,\text{N} \times \text{m}^2/\text{C}^2$$

$$\text{Electron Mass} = 9.11 \times 10^{-31}\,\text{Kg}; \quad \text{Electron Charge} = 1.602 \times 10^{-19}\,\text{C}$$

$$\text{Atomic Mass Unit } u = 1.6606 \times 10^{-27}\,\text{Kg or } 931.5\text{ MeV/c}^2$$

$$\text{Proton Mass} = 1.673 \times 10^{-27}\,\text{Kg}; \quad \text{Neutron Mass} = 1.675 \times 10^{-27}\,\text{Kg}$$

$$\text{Electron Rest Energy} = 0.511\text{ MeV/c}^2; \quad \text{Proton Rest Energy} = 938\text{ MeV/c}^2$$

$$\text{Force on a charged particle in B field : } \vec{F} = q\vec{v} \times \vec{B}$$

$$\text{Centripetal Acc.} = v^2/R \text{ where v and R are velocity and radius of orbit}$$

$$\text{Bohr Radius } a_0 = 0.529 \times 10^{-10}\,\text{m}$$

$$\Delta x \cdot \Delta p_x \geq \frac{\hbar}{2} \quad ; \quad \Delta E \cdot \Delta t \geq \frac{\hbar}{2}$$

$$\text{Construct. interfer. when path diff between two adjacent rays is } d\sin\phi = n\lambda$$

$$\int u \cdot dv = uv - \int v \cdot du$$

Please consult the proctor if you don't understand any part of the questions

Problem 1 : Seeing Is Believing [8 pts]

Suppose one undertook a study of the orbits in Hydrogen. According to the Bohr theory, the circular orbits have radii $r_n = n^2 a_0$, where $a_0 \cong 0.05$nm is the Bohr radius. To map the orbits with some precision, it is necessary to localize the electrons with a precision of say $0.1a_0$. (a) What amount of kinetic energy (in eV) is likely to be transferred to the electron that is under observation with a probe that can localize the electrons with this precision? (b)Will the Hydrogen atom remain relatively undisturbed by the observation? (c) What do you think of the idea of atomic orbits ?

Problem 2: Planck's Oscillators [12 pts]

A subatomic particle is connected to a spring and undergoes one-dimensional motion. (a) Write an expression for the total energy in terms of its position **x**, its mass **m**, its momentum **p** and the angular frequency of oscillation $\omega=\sqrt{\frac{k}{m}}$. What is the smallest energy E_c this oscillator can have according to classical physics? (b) Now treat the particle as a wave. Assume that the product of the uncertainties in position and momentum is governed by the Uncertainly Principle. Also assume that since **x** and **p** are on average zero, the uncertainty Δx and Δp are typical value of the particle's position and momentum respectively. Calculate the minimum energy E_q of this oscillator. (c) How does it compare with E_c ? (d) How does E_q compare with minimum energy of Planck's oscillator ?