Final - Modern Physics for Engineers

December 7, 1998

Test Number:____________________

Name:________________________

S.S. No.:______________________

Do all work in this exam booklet. Use the backs of the sheets if necessary. An equation sheet is provided as the second page of this exam. You may use your calculators to evaluate answers if necessary.

Good luck.

Enjoy the Holidays!!!

EQUATION SHEET

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \qquad \beta = \frac{v}{c} \qquad f\lambda = c$$

$$x' = \gamma(x + \beta ct) \qquad p' = \gamma(p + \beta E/c)$$

$$t' = \gamma(t + \beta x/c) \qquad E' = \gamma(E + \beta cp)$$

$$E^2 = p^2c^2 + m^2c^4 \qquad KE = E - mc^2$$

$$\vec{p}_i = \vec{p}_f \qquad f' = f\sqrt{\frac{1-\beta}{1+\beta}}$$

$$E_i = E_f \qquad v' = \frac{v+u}{1+uv/c^2}$$

$$\int_{-\infty}^{\infty} e^{-\frac{x^2}{2\sigma^2}}\, dx = \sqrt{2\pi}\sigma \qquad \int_{-\infty}^{\infty} x^2 e^{-\frac{x^2}{2\sigma^2}}\, dx = \sqrt{2\pi}\sigma^3$$

$$\int_0^{\pi} \sin^2 x\, dx = \frac{\pi}{2} \qquad \int_0^{\pi} x^2 \sin^2 x\, dx = \frac{4\pi^3}{3} - \frac{\pi}{2} \qquad \int_0^{\pi} \sin x \cos x\, dx = 0$$

$$E = (n + \frac{1}{2})\hbar\omega \qquad E = \frac{\hbar^2\pi^2n^2}{2mL^2} \qquad E = \frac{\hbar^2 l(l+1)}{2I_{cm}} \qquad E = -\frac{\hbar^2}{2a_0n^2}$$

$$V = \frac{1}{2}m\omega^2x^2 \qquad V = -\frac{kq^2}{r}$$

$$\hbar = 1.055 \times 10^{-34}\ \mathrm{J \cdot s} = 4.136 \times 10^{-15}\ \mathrm{eVsec}$$

Problem 1 - (**50 points**)

Two engineering students, Martha and Tim, who had been going together broke up and never wanted to see each other again. Martha hopped the first space ship heading to a star 5 light years away and Tim hopped a space ship going in exactly the opposite direction to another star 5 light years away. Both ships were going .99c relative to the earth.

Part A: How much older are Tim and Martha, when they reach their respective planets than they were on earth?

Part B: To Martha, how fast is Tim moving?

Part C: To Martha, how far did Tim go?

Problem 1 (Continued)

Part D: If Tim were to send an ultraviolet signal at a wave length of 400 nm to Martha, at what wave length would Martha receive it?

Part E: If Tim has a mass of 60 kilos (kg), what is his energy as he is moving as observed by his professor back on earth?

Problem 2 - (**50 points**)

A wave function that solves the Schrödinger equation for a particle m in a simple harmonic oscillator potential $V = \frac{1}{2}m\omega^2 x^2$ has the form:

$$\psi(x) = Axe^{-\alpha x^2}$$

Part A: Sketch this wave function and state whether this is the ground state or not. If it is not, which excited state is it?

Part B: How is the constant A determined? (Write down the equation, but do not solve it!)

Part C: Write down an integral that you could evaluate to determine the average of the potential energy of the particle $\langle V \rangle$. (Do not evaluate the integral.)

Problem 2 (continued)

Part D and E: How is the constant α determined? Determine α.

Short Answer Problems - (**100 points**) - 10 points each.

Problem 1) Draw the quark lines for the strong interaction $K^- p \to D_s^- \Lambda_c$ where the quark content of the particles is the following:

$$K^- = (s\bar{u})$$

$$p = (uud)$$

$$D_s^- = (s\bar{c})$$

$$\Lambda_c = (udc)$$

Problem 2) What is the energy of a 140 MeV/c^2 particle that is travelling at .9998c?

Problem 3) What are the quantum numbers of the six electrons around a carbon atom?

Problem 4) What is the total binding energy of the carbon nucleus (6 protons and 6 neutrons) if its atomic mass is 12 u and the mass of hydrogen is 1.007825 and of the neutron is 1.008665? (1 u = 931.49 MeV/c^2 = 1.66 $\times$ 10^{-27} kg)

Problem 5) Name three pieces of evidence that support for the "Big Bang" theory of the universe.

Problem 6) Given an example of an experiment that illustrates the wave nature of light.

Problem 7) When impurities are present in a metal, the conductivity decreases because the impurities scatter the conduction electrons. If a semiconductor is doped with donor impurities, the conductivity increases. Why?

Problem 8) If molecular carbon monoxide (CO) has a moment of inertia of I, what is the energy of the angular momentum $\ell = 2$ state?

Problem 9) If an hadron has a half-life of 10^{-24} seconds, how well can you measure it's mass?

Problem 10) Sketch wave function for the third excited state of a particle confined to a one dimensional box of width a.