MidTerm - Modern Physics for Engineers

October 28, 1994

Name:______________________________

S.S. No.:______________________________

Do all work in this exam booklet. Use the backs of the sheets if necessary. One 8.5" x 11" sheet of notes is permissible. Please use your calculator. If integrals are needed that are not given below, there is a CRC handbook available at the front of the classroom for your use. If you cannot find the integral in that, just leave it. On some questions, there are multiple parts. If you need the answer from some previous part to do a calculation, but were unable to obtain it, assume some reasonable value (informing me what you are doing) and use it.

Useful Constants: $c = 3 \times 10^8$ m/sec

$h = 4.14 \times 10^{-15}$ eV sec

Useful integrals:

$$\int \cos^2\theta \, d\theta = \frac{1}{2}\sin\theta\cos\theta + \frac{1}{2}\theta$$

$$\int \theta\cos^2\theta \, d\theta = \frac{\theta^2}{4} + \frac{\theta\sin 2\theta}{4} + \frac{\cos 2\theta}{8}$$

$$\int \theta^2\cos^2\theta \, d\theta = \frac{\theta^3}{6} + \left(\frac{\theta^2}{4} - \frac{1}{8}\right)\sin 2\theta + \frac{\theta\cos 2\theta}{4}$$

$$\int f(\theta)\sin^2\theta \, d\theta = \int f(\theta)\, d\theta - \int f(\theta)\cos^2\theta \, d\theta$$

Problem 1: A pion ($m_\pi c^2 = 139.6$ MeV) can decay into an electron ($m_e c^2 = .5$ MeV) and a neutrino ($m_\nu c^2 = 0$).

a. [**Points 13**] In the pion's rest frame, what is the total (rest plus kinetic) energy of the electron?

b. [**Points 12**] If the pion is traveling at .99 c in the lab, and the electron from the decay comes out in the same directions as the pion was originally moving, what is the energy of the electron in the lab?

Problem 2: Frank, a UC engineering student, graduates and climbs on the next rocket ship heading for a star 10 light years away. His rocket ship travels at .9c relative to earth. Mary graduates with Frank, but waits on earth for 1.01 years to get her Master's Degree, and then climbs on the next space ship heading for the same star. Improvements in the space ship industry now allow her ship to travel at .99c relative to earth which it does. Their professor stays on earth but watches their progress. He observes that they both arrive at the star at the same time.

a. [**Points 5**] Do Frank and Mary agree with their professor that they arrive at the star simultaneously? (Circle one.)

Yes	No
Mary does but Frank does not	Frank does but Mary does not

b. [**Points 10**] Who is younger when they reach the star, Frank or Mary? By how much?

c. [**Points 10**] What would Frank measure the velocity of Mary's space ship to be during the trip?

Problem 3

a. [**Points 5**] Describe an experiment or phenomenon which illustrates the wave nature of light.

b. [**Points 10**] Describe an experiment or phenomenon which illustrates the particle nature of light.

c. [**Points 10**] Describe an experiment or phenomenon which illustrates the wave nature of electrons.

Problem 4 A particle is bound in a finite depth square well:

$$V(x) = \begin{cases} 0 & \text{if } -L \leq x \leq L; \text{ and} \\ V_0 & \text{otherwise.} \end{cases}$$

a. [**Points 10**] Sketch approximately the potential, the ground state and the first two excited states wave functions for the particle.

Problem 4 - Continued

Specifically, for a potential value of $V_0 = \frac{\sqrt{2}\hbar^2}{2mL^2}$, the ground state wave function is given by:

$$\Psi(x) = \begin{cases} A\cos\left[\frac{\pi x}{4L}\right] & \text{if } -L \leq x \leq L; \\ A\cos\left[\frac{\pi}{4}\right] e^{-\frac{\pi}{4}(x-L)} & \text{if } x > L; \text{ and} \\ A\cos\left[\frac{\pi}{4}\right] e^{+\frac{\pi}{4}(x+L)} & \text{if } x < -L. \end{cases}$$

b. [**Points 5**] Calculate the energy of a particle of mass m in this ground state.

c. [**Points 5**] Set up *but do <u>not</u> evaluate* the integral(s) necessary to determine the normalization constant A.

d. [**Points 5**] Set up *but do <u>not</u> evaluate* the integral(s) necessary to determine the $< x^2 >_{average}$ for the particle.