TRENT UNIVERSITY
DEPARTMENT OF PHYSICS
PHYSICS 202H FINAL EXAMINATION

December 12, 2001 Time: 3 hours

PART A

Answer two (2) questions.

1. In its own rest frame, a π^0 (neutral pion) decays into two photons of equal energy, and equal but opposite momenta. If a π^0 has a velocity v_0 in the laboratory, what are the longest and shortest photon wavelengths (Å) that can arise from the decay?

2. A photon of energy $m_e c^2$ (where m_e is the electron rest mass) undergoes Compton scattering from an electron. Find the energy of a photon scattered through 60° , the recoil momentum of the electron (keV/c), and the recoil angle of the electron.

3. The π^+ has a rest mass of 139.57 MeV/c^2, and a proper *mean* lifetime of 2.603×10^{-8}s. How far will a beam of pions travel before *half* of them decay, if their kinetic energy is 139.57 MeV? (Note: the mean lifetime is the time within which a fraction $1/e$ of the beam decays.)

4. A 50 kT fission bomb is used as a source of X-rays to implode a thermonuclear "secondary". Assume that the entire 50 kT yield is deposited instantaneously in the form of X-rays within a sphere of radius 5 cm, and further, that the radiation has a blackbody spectrum. What is the energy density, *i.e.*, the pressure in the radiation field? Express your answer in atmospheres. (1 kT = 4.2×10^{12} J: 1 atm = 1.01325×10^5 N m^{-2}.)

PART B

Answer two (2) questions.

5. Light of wavelength 2000 Å falls on an aluminum surface. The work function of aluminum is 4.2 eV. What is the kinetic energy of (a) the fastest, and (b) the slowest photoelectrons? (c) What is the stopping potential? (d) What is the cutoff wavelength for aluminum? (e) If the intensity of the incident light is 2.0 W m^{-2}, what is the average number of photons per second per square metre that strike the surface?

6. Quantization in circular orbits is achieved by combining the equation of motion

$$\frac{mv^2}{r} = \left| \frac{dU(r)}{dr} \right| ,$$

(where U is the potential energy) with the angular momentum quantization condition $mvr = n\hbar$. Use this procedure to calculate the spectrum for circular motion in the potential $U(r) = F_0 r$.

(7.) A 50 eV electron beam is incident on a metal surface at an angle of 30° with the surface. As they are refracted into the metal, the electrons *gain* energy because of the work function ϕ. Suppose that $\phi = 4$ eV.

(a) Find the de Broglie wavelength (Å) and speed of the incident beam.
(b) Find the de Broglie wavelength and speed of the refracted beam.
(c) Find the angle of refraction of the electron beam within the metal.

8. The ground state energy of the electron in hydrogen is -13.6 eV. From this datum, calculate the wavelength of the photon emitted in the $n = 3$ to $n = 2$ transition in singly-ionized helium ($Z = 2$).

PART C

Answer the following question.

9. (a) Verify that the wave function

$$\Psi(x,t) = \begin{cases} A\sin(2\pi x/a)\, e^{-iEt/\hbar}, & -a/2 < x < a/2 \\ 0, & \text{elsewhere,} \end{cases}$$

is a solution to the Schrödinger Equation in the region $-a/2 < x < a/2$ for a particle that moves freely through that region but is strictly confined to it. (b) Normalize $\Psi(x,t)$. (c) Determine the total energy E of the particle described by Ψ. (d) Evaluate $\langle p \rangle$, $\langle p^2 \rangle$. (d) Is Ψ an eigenfunction of the momentum operator? Explain.