1. In an inertial frame S, a particle has a momentum $(P_x, P_y, P_z) = (5, 3, \sqrt{2})$ MeV/c and a total energy= 10 MeV.
   (a) Find the speed u of the particle as measured in the frame S. (Please answer in terms of speed of light c). (10%)
   (b) Which of the following combinations of momentum P' and energy E' could represent the motion of the particle described above as observed in another inertial frame S' moving with an unspecified velocity v relative to S? Please give your reasons. (10%)
       (A) $P' = (50, -30, \sqrt{200})$ MeV/c, $E' = 100$ MeV,
       (B) $P' = (8, 0, \sqrt{2})$ MeV/c, $E' = 10$ MeV,
       (C) $P' = (0, 0, 8)$ MeV/c, $E' = \sqrt{128}$ MeV,
       (D) $P' = (31, 4, 6)$ MeV/c, $E' = \sqrt{949}$ MeV

2. A photon of energy 0.511 MeV strikes a free electron on a metal. What is possible process for this collision (photoelectric effect, Rayleigh scattering, Compton effect, or pair production)? Please give your reasons. (20%)

3. A particle moves in the infinite square well potential which is

$$V(x) = \begin{cases} \infty & |x| \geq a/2 \\ 0 & -a/2 < x < a/2 \end{cases}$$

   (a) Show that the eigenfunction ψ of the time-independent Schrödinger's equation is either $\psi(-x) = \psi(x)$ or $\psi(-x) = -\psi(x)$. (10%)
   (b) Please determine the total wave function and the total energy of the particle. (10%)

4. (a) Using classical expressions for the kinetic and potential energy of the electron-proton system and the Bohr quantum condition, drive an expression for the energy levels of the hydrogen atom. (15%)
   (b) Find the energy difference between the second and fourth energy levels. (5%)

5. The atomic number of carbon is 6.
   (a) What is the electron configuration of the ground state of carbon? (5%)
   (b) How many energy states are permitted by the Pauli exclusion principle for the p orbital of electrons in this configuration? (5%)
   (c) Under the assumption of L-S coupling, give the set of values of J, L, S allowed for this configuration of two p-state electrons. (10%)