1. Give the reasons for the magnetic force between parallel currents in wires on the basis of Coulomb's law by using the theory of relativity. (10%)

2. An observer on Earth sends light with frequency $2. \times 10^{15} Hz$ to a spacecraft traveling with speed 0.8c around the Earth. What will be the frequency of the light observed on the spacecraft? (10%)

3. A photon of frequency v collides with an electron at rest. What is the maximum energy loss of the photon? What is the maximum velocity of the electron? (10%)

4. For what energy will a particle's de Broglie wavelength equal its Compton wavelength? (10%)

5. (a) What is the wave function for a free particle with a definite precise momentum?
   (b) What is the wave function for a localized free particle? (10%)

6. A classical oscillator with mass m on a spring with spring-constant κ. The energy of the oscillator is given by

$$E = \frac{p^2}{2m} + \frac{\kappa x^2}{2}$$

   where p is the momentum and x is the displacement distance.
   (a) Determine the energy for a quantum oscillator, in term of the momentum and the displacement distance. (5%)
   (b) Determine the uncertainty of position Δx at which the energy is minimum. (10%)
   (c) Determine the minimum energy, in terms of the angular frequency of a classical oscillator $\omega = \sqrt{\kappa / m}$. (5%)

7. Is it possible to specify all three components of the angular momentum simultaneously? From the quantum theory of the hydrogen atom, what are the angles between its orbital angular momentum vector $\vec{L}$ and the z-axis for orbital quantum number (a) $l = 1$? (b) $l = 2$? (10%)

8. How to learn the sun's magnetic field from the knowledge of quantum theory of the hydrogen atom? (10%)

9. Consider a gas of atoms, each atom has only three possible energies: $-\varepsilon$, 0, $+\varepsilon$.
   (a) Obtain an expression for the probability that, when the system is in thermal equilibrium at temperature T, the lowest level is occupied. (5%)
   (b) Find the average energy of the system. (5%)