1. A particle of rest mass m_0 is acted upon by a force F such that its velocity changes from 0 to u. By work-energy theorem, work done by the force ($= \int F dx$) is equal to the change in Kinetic energy.

   (a) If $F = dP/dt$, where P is momentum, show that the KE of the particle is given by

   $$K = mc^2 - m_0c^2.$$

   (b) Show that the total energy $E(= mc^2)$ can be written as

   $$E = \sqrt{P^2c^2 + m_0^2c^4}$$

   (c) Show that the result of first part reduces to classical result when $u << c$.

   (d) From the second part show that the energy of the photon is given by Pc.

2. A photon (light particle) of wavelength λ collides with an electron which is at rest initially. After scattering by an angle θ, the wavelength of the photon is found to be λ'. Treating photon as a particle with momentum $P = h/\lambda$ and energy $E = Pc$, show that

   $$\lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

   assuming that the collision is elastic. [Relativistic Treatment]

3. X-ray photons of wavelength 0.02480 nm are incident on a target and the Compton-scattered photons are observed at 90 degrees. (a) What is the wavelength of scattered photons? (b) What is the momentum of incident and scattered photons? (c) What is the KE of the scattered electrons? (d) What is the magnitude and direction of the momentum of scattered electrons?

4. Find the de Broglie wavelength of (a) a nitrogen molecule in air at room temperature. (b) A 5-MeV proton. (c) A 50-GeV electron. (d) An electron moving with speed $10^6 m/s$.

5. In the double slit experiment for helium atoms, the beam of atoms had a kinetic energy of 0.020 eV. The separation of the slits is 8 μm. The observed fringe pattern is shown in the figure. Estimate the de Broglie wavelength of these atoms from this data. Also estimate the same from the KE and compare.

6. The atoms in a gas can be treated as classical particles if their de Broglie wavelength is much smaller compared to the average separation between the particles. Compare the average de Broglie wavelength and average separation between the atoms in a container of (monatomic) helium gas at 1.00 atm pressure and at room temperature (20 C). At what temperature would you expect the quantum effects to be important?