1. (20%) Describe the experimental setup of Rutherford scattering. What is the angular distribution of outgoing α particles in the Rutherford scattering? How did the results of Rutherford scattering disapprove Thomson’s model of atoms? Describe Rutherford’s model of atoms due to results of the above experiment.

2. (15%) In the usual case of Compton scattering, one has the photon beam colliding with the target electron initially at rest. The wavelength of the final-state photon is related to that of the initial-state photon according to
\[
\lambda_f - \lambda_i = \frac{h}{m \cdot c} (1 - \cos \theta),
\]
where \( \lambda_f \) and \( \lambda_i \) are wavelengths of final-state and initial-state photons respectively while \( \theta \) is deflection of photon momentum direction by the scattering. Let us now consider the Compton scattering where the target electron is no longer at rest initially, but rather moves in a direction opposite to that of the incident photon. Assuming the speed of the target electron is \( 0.9c \), derive the relation among \( \lambda_f, \lambda_i \) and \( \theta \) in such a case.

3. (15%) To confirm the parity non-conservation of weak interactions, C.-S. Wu and her collaborators studied the β decay
\[
^{27}\text{Co}^{60} \rightarrow ^{28}\text{Ni}^{60} + e + \bar{\nu}, \text{ where the magnetic dipole moment of } ^{27}\text{Co}^{60}
\]
was aligned by a strong external magnetic field. Let us denote this direction of magnetic dipole moment as \( +z \) direction. Please describe qualitatively the angular distribution of outgoing electrons in this experiment. Explain also how one can conclude that the parity is not conserved by the above angular distribution of electrons.

4. (10%) Suppose we live in a world without spins. But Pauli Exclusion Principle is still valid and atoms have the same energy sub-shells s, p, d, f ...as usual. What are the atomic numbers of the first four noble elements in the corresponding new periodic table?

5. (10%) An electron is accelerated from the rest by a potential difference of 1 V. What is its de Broglie wavelength after the acceleration?
6. (8%) Planck’s radiation law is described by the formula \( y = A x^{-y} \left[ \exp(B/xT) - 1 \right] \), with \( A = 8 \pi h c, B = hc / k \), where \( h \) is Planck’s constant, \( c \) is the light speed, and \( T \) is the temperature. Which physical quantities do \( x \) and \( y \) represent in this formula?

(12%) Please derive Wien’s radiation law and Rayleigh-Jeans law from Planck’s formula.

7. (10%) A particle of mass \( M \) is confined to a two-dimensional rectangular area of side lengths \( A \) and \( B \) bounded by hard walls. Write down the Schrödinger equation and determine the energy eigenvalues of the system.

Useful constants: Planck’s constant \( h = 6.63 \times 10^{-34} \) joule-sec, electron mass \( m_e = 9.11 \times 10^{-31} \) kg.