Problems:

1. (20 pts) Consider a beam of 7.7 MeV $\alpha$ particles which Rutherford scatter off a thin gold ($Z = 79$) target of 0.1 $\mu$m thickness. Gold’s density is 19.3 $g/cm^3$, and its atomic weight is 197 u.
   (a) (5 pts) What is the impact parameter for scattering at an angle of 90°?
   (b) (5 pts) What is the fraction of $\alpha$ particles which are deflected at an angle 90° or greater?
   (c) (5 pts) What fraction is scattered between 70° and 80°? What fraction is scattered between 1° and 2°?
   (d) (5 pts) If the target is exchanged for an aluminum target ($Z = 13$) with the same number density, by what factor are more (or less) $\alpha$ particles scattered at any angle per unit area?

2. (5 pts) Thornton and Rex, problem 4.22

3. (10 pts) Thornton and Rex, problem 4.28

4. (15 pts) Positronium is the bound system of a positron (of mass $m_e$ and charge $+e$) and an electron.
   (a) (5 pts) Calculate the distance between the positron and the electron.
   (b) (5 pts) What is the energy of the ground state and the first excited state?
   (c) (5 pts) What are the wavelength of the $K_\alpha$ and $K_\beta$ transitions?

5. (5 pts) Thornton and Rex, problem 5.3

6. (5 pts) Thornton and Rex, problem 5.11

7. (10 pts) Thornton and Rex, problem 5.28

8. (5 pts) Thornton and Rex, problem 5.48

9. (10 pts) Thornton and Rex, problem 5.69

10. (15 pts) Re-derive the particle of mass $m$ in a one-dimensional box of length $L$ relativistically.
    (a) (5 pts) What is the kinetic energy corresponding to each standing wave?
    (b) (5 pts) Based on the uncertainty principle, estimate the minimum possible energy that the particle can have?
    (c) (5 pts) Can a particle confined to a finite space have zero energy?
Grading rubric:

- You are encouraged to show work and explain it in your own words. Partial credit will be assigned in proportion to the correct principle applications.

- Your work must be legible. Illegible (parts of) solutions will not be read, and points may be deducted.

- One point will be deducted for missing or incorrect units on (numerical) solutions.

- For plots one point will be deducted for missing axis and tick labels. Another point will be deducted for missing or incorrect units if applicable.

- “An Aggie does not lie, cheat or steal, or tolerate those who do.” If academic dishonesty is discovered, all associated individuals will receive a zero for this assignment.