33-331 Physical Mechanics I. Fall Semester, 2009
Assignment No. 13
Due Friday, Dec. 4

READING

Thornton and Marion Ch. 9, Secs. 9.6, 9.7, 9.9, 9.10. Omit Sec. 9.8 on inelastic collisions.
Handout: Scattering Kinematics (Omit Sec. 6 on inelastic processes)

EXERCISES

1. Turn in at most one page, and not less than a third of a page, indicating what you have read, examples or exercises (apart from those assigned below) that you worked out, difficulties you encountered, questions that came to mind, etc.

2. Although the total cross section for Rutherford scattering, assuming a fixed target, is infinite, the cross section $\sigma_T(\theta_0)$ for scattering to an angle greater than or equal to θ_0 is finite for $\theta_0 > 0$.

a) Find a formula for $\sigma_T(\theta_0)$ (the integral can be done in closed form).

b) Geiger and Marsden (Proc. Roy. Soc. London **83** (1910) 492) found in an experiment that when they let a beam of alpha particles impinge on a thin platinum foil, a fraction of 1 in 8000 was scattered in the backwards direction, i.e., through an angle of more than 90°. Platinum has an atomic number of $Z = 78$, an atomic mass of $A = 195$, and the metal has a density of 21450 kg/m^3. Find the length κ (Thornton and Marion), the same as a in the notes on hyprbolic orbits handed out in class, for alpha particles, charge $2e$, of energy 6.0 MeV, assuming the platinum nucleus is sufficiently massive that you can treat it as a fixed target (its recoil can be neglected). Then estimate the thickness of the foil used by Geiger and Marsden, assuming alpha particles of this energy and no multiple scattering. (The original paper does not specify the thickness of the foil, and the associated discussion suggests that there was probably quite a bit of multiple scattering.)

3. Thornton and Marion 9-22. Do this problem starting from first principles (conservation laws), and use dimensionless quantities in which velocities (speeds) are expressed in units of u_1, and $\lambda := m_1/m_2$ is the ratio of masses, where particle 1 is the deuteron. Also work out the magnitude V of the velocity of the center of mass $\mathbf{V}$, and the value(s) of θ in the center of mass that correspond to ψ. (One can easily determine ζ from θ, or vice versa.)

4. For an elastic collision in which the mass ratio is $\lambda = m_1/m_2 = 1/3$ there is a theoretical model with a prediction for the CM cross section $\sigma_C(\theta)$. Due to difficulties in arranging the equipment the experiment has only been able to determine the integrated cross section for scattering between the laboratory angles of $\psi = 30°$ and $45°$. What should the theorists do with $\sigma_C(\theta)$ in order to compute something to compare with experiment? [Hint. The answer, in the form of an integral, is not particularly difficult.]