

**Write the following text on the front cover of your homework assignment and sign it. If the text is missing, 20 points will be subtracted from your homework grade.**

**Honor Pledge for Graded Assignments**

"I affirm that I have not given or received any unauthorized help on this assignment, and that this work is my own."

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Signature \_\_\_\_\_

**Problem 1 (20 points)**

The center of gravity of a system of particles is the point about which the external gravitational forces exert no net torque. For a uniform gravitational force, show that the center of gravity is identical to the center of mass for the system of particles.

**Problem 2 (20 points)**

A projectile is fired at an angle of  $45^\circ$  with an initial kinetic energy  $E_0$ . At the top of its trajectory, the projectile explodes into two fragments (an additional energy  $E_0$  is released during the explosion). One fragment of mass  $m_1$  travels straight down. What is the velocity (specify both magnitude and direction) of the second fragment of mass  $m_2$ . What is the velocity of the first fragment?

**Problem 3 (20 points)**

A fixed force center scatters a particle of mass  $m$  according to the force law

$$F(r) = \frac{k}{r^3} \quad (1)$$

If the initial velocity of the particle is  $u_0$ , show that the differential scattering cross section is

$$\sigma(\theta) = \frac{k\pi^2(\pi - \theta)}{mu_0^2\theta^2(2\pi - \theta)^2\sin\theta} \quad (2)$$

**Problem 4 (20 points)**

The most energetic  $\alpha$ -particles available to Ernest Rutherford and his colleagues for the famous Rutherford scattering experiment were 7.7 MeV. For the scattering of 7.7-MeV  $\alpha$  particles from  $^{238}\text{U}$  (initially at rest) at a laboratory scattering angle of  $90^\circ$ , find the following:

1. The recoil scattering angle of  $^{238}\text{U}$  in the laboratory frame.
2. The scattering angles of the  $\alpha$  particle and  $^{238}\text{U}$  in the center-of-mass frame.
3. The laboratory kinetic energy of the scattered  $\alpha$  particle and  $^{238}\text{U}$ .
4. The impact parameter  $b$ .
5. The distance of closest approach  $r_{min}$ .
6. The differential cross section at a laboratory scattering angle of  $90^\circ$ .
7. The ratio of the probabilities of scattering at  $90^\circ$  to that of  $5^\circ$  in the laboratory frame.

**Problem 5 (20 points)**

A rocket in outer space, in a negligible gravitational field, starts from rest and accelerates uniformly with an acceleration  $a$  until it reaches its final speed  $v$ . The initial mass of the rocket is  $m_0$ . How much work does the rocket's engine do?