Physics 110
Spring 2006
Momentum Problems

1. A karate expert strikes downward with his fist of mass m_{fist} = 0.7kg breaking a 0.14kg board. He then does the same to a 3.2kg concrete block. The spring constant for the board and block are 4.1×10^4 N/m and 2.6×10^6 N/m respectively. The board breaks at a deflection d = 16mm and while for the block the deflection is d = 1.1mm.
    a. Just before each object breaks, what is the energy stored in the object?
    b. What is the lowest fist speed required to break the objects? (Hint: The collision is completely inelastic and bending begins just after the collision. Mechanical energy is conserved from the beginning of the bending until just before the object breaks. The speed of the fist and the object are negligible at the breaking point.)

2. The National Transportation Safety Board is testing the crash worthiness of new cars. A 2300kg car, moving at 15m/s is allowed to collide with a stationary concrete pier which brings the car to rest in 0.56s. What is the magnitude of the force that acts on the car during the impact?

3. A paratrooper jumps from an airplane and tries to open her parachute. It fails to open and she falls 370m and happens to land in some snow, where she suffers only minor injuries. If her velocity at impact was 56m/s (due to air resistance, she reaches a terminal velocity and her speed, due to gravity, doesn't continue to increase.) Suppose further that her mass (including gear) is 85kg and that the force on her from the snow was 1.2×10^5N.
    a. What is the minimum depth of snow that would have stopped her safely?
    b. What is the impulse on her from the snow?

4. A meteor impact crater is formed by the impact of a meteor with the earth. If the mass of a meteor is 5×10^{10}kg and has a speed of 7200m/s, what speed would this meteor give the earth in a direct head on collision?

5. Two cars A and B slide on an icy road as they attempt to stop at a traffic light. The mass of car A is 1100kg and that of B is 1400kg. The coefficient of kinetic friction between the locked wheels of either car and the road is 0.13. Car A succeeds in stopping but car B does not and subsequently collides with car A. After the collision, car A stops 8.2m ahead of its position at impact and car B 6.1m ahead. Both drivers had their brakes locked throughout the incident.
    a. What are the speeds of car A and car B immediately after the impact?
    b. What was the speed of car B when it struck car A?

6. A railroad freight car of mass 3.2x104kg collides with a stationary caboose. After the collision the cars are coupled together and 27% of the initial kinetic energy has been lost during the collision. What is the mass of the caboose?

7. In the basement of Science and Engineering we routinely accelerate alpha particles into targets of various elements. A famous experiment called Rutherford's experiment fires alpha particles at a target of gold. An alpha particle (a helium nucleus) is accelerated to a certain speed and makes an elastic head-on collision with a stationary gold nucleus. What percentage of its original kinetic energy is transferred to the gold nucleus?

8. Suppose that a block of mass m_1 traveling to the right with speed v_{1i} collides with another block of mass m_2 traveling to the left (at block 1) with speed v_{2i}. If the blocks collide, what are the final velocities of the two blocks? (Hint: make sure that you explore all cases for the masses of the blocks to see if your solutions make sense.)

9. Suppose that we again accelerate an alpha particle at an oxygen nucleus this time. Suppose that the alpha particle is incident along the x-axis and makes a grazing collision with a stationary oxygen atom. Suppose further that the alpha particle is scattered through an angle of 64^o with respect to its initial direction and that the oxygen nucleus recoils at an angle of 51^o below the +x-axis.
    a. What are the initial and final speeds of the alpha particle?
    b. What is the final speed of the oxygen nucleus?

10. A shell is shot with an initial velocity of 20m/s at an angle of 60^o with respect to the horizontal. At the top of the trajectory the shell explodes into two fragments of equal mass. Immediately after the explosion, one fragment whose speed is zero falls vertically to the ground. How far from the launcher does the other fragment land, assuming that the ground is level and that air drag is negligible?

12. Three particles are located in an x-y coordinate system. Particle 1 is located at the origin (x,y) = (0m,0m) and has mass 3kg. Particle 2 is located at the position (2m,1m) and has mass 4kg while particle 3 is located at position (1m,2m) and has mass 8kg.
    a. What are the x- and y- coordinates of the center of mass of the three particle system?
    b. What happens to the center of mass as the mass of the top most particle gradually increases?