Physics 2210 (Schroeder) Name ____________________
spring 2006

Problem Set 6

(due Wednesday, February 15)

1. Paddy the bricklayer (whose mass is 75 kg) has 100 kg of leftover bricks that he needs to bring down from the top of a 14-story building. To avoid hauling them down by hand, he hangs a rope from a pulley and hoists a barrel to the top, tying off the rope at ground level. After loading the bricks into the barrel, he goes back down to untie the rope, clinging tightly to it. Much to his surprise (as he has not studied physics), he begins to accelerate upwards. (a) What is his acceleration? (Please neglect the mass of the barrel, rope, and pulley, as well as any friction in the pulley.) (b) How fast is Paddy going when he collides into the descending barrel, 7 floors (25 meters) above the ground?

2. You need to drive your car (mass 1000 kg) and tow a trailer (mass 500 kg) up an icy 10% incline, at constant speed. The coefficient of friction between your tires and the road surface is 0.18. Can you make it? (A 10% incline is one that rises 10 meters for every 100 meters of horizontal distance.)

3. A frictionless puck of mass m moving in a circle of radius R on a horizontal tabletop, attached to a string which runs through a hole in the center of the circle. Hanging motionless from the other end of the string (below the table) is a weight of mass M. Assuming that m, M, and R are all known, find a formula for the speed of the puck.

4. (a) How far is the center of mass of the earth-moon system from the center of the earth? (Look up the data you need in the back of your textbook.) (b) Express the answer to part (a) as a fraction of the earth's radius.

5. The distance between the centers of the carbon and oxygen atoms in a carbon monoxide molecule is 1.131×10^{-10} m. Where is the center of mass of this molecule, relative to either atom? (You can look up the atomic masses in your textbook or on any periodic table.)

6. While out taking a stroll by moonlight, you stumble upon a man with a long nose who claims he has just fallen from the moon. Putting aside the matter of how he could have survived the fall, you ask him how he got to the moon in the first place. He then describes a most ingenious method: Stand on a large iron plate with a large magnet in your hands. Throw the magnet upwards; the iron plate will then be pulled up to it. Catch the magnet, and repeat the procedure, working your way up as high as you please! Having studied physics, you are skeptical. Explain why, using the concept of the center of mass.

7. Carmelita, mass 58 kg, and Ricardo, who is heavier, are enjoying Lake Merced at dusk in a 30 kg canoe. When the canoe is at rest in still water, they exchange seats, which are 3.0 m apart and symmetrically located with respect to the canoe's center. Carmelita notices that the canoe moved 40 cm relative to a submerged log during the exchange, and calculates Ricardo's mass, which he has not told her. What is it?

8. A car with mass 1000 kg is moving at 55 mph in a direction 25° south of east. Taking the x axis to point east and the y axis to point north, find the x and y components of its momentum vector. Express your answers in SI units.

9. Suppose your mass is 80 kg. How fast would you have to run, in order to have the same momentum as a 1600-kg car moving at 1.2 km/hr?

10. Describe an example of a collision in which the total momentum of the two colliding objects is *not* conserved.
11. A child (mass 38 kg) is standing on a frictionless skateboard (mass 2 kg), initially at rest. The child then throws a 2 kg rock directly forward (to the east) with a speed of 8 m/s. What is the velocity of the child (and skateboard) just after the rock is thrown? (You may wish to use the conservation laws worksheet.)
12. A railroad freight car weighing 32 tons and traveling at 5.0 ft/s overtakes one weighing 24 tons and traveling at 3.0 ft/s in the same direction. If the cars couple together, find the speed of the cars after the collision.
13. You are to knock over a giant bowling pin at a fair by throwing a ball at it. You have a choice between two balls of equal mass: a hard rubber ball that will bounce back when it hits the pin, and a soft beanbag that will hit with a thud and not bounce back. Which should you choose? Explain your reasoning carefully.
14. Car A, with a weight of 2700 lb, is initially moving west at 40 mph. Car B, with a weight of 3600 lb, is initially moving south at at 60 mph. The two cars then collide at an intersection and lock together. What is the velocity (magnitude and direction) of the tangled wreck just after the collision? (Hint: There's no need to convert the weights of the cars to other units. You may wish to use the worksheet.)

Study Guide

You should be able to solve constrained-motion problems involving more than one object, using Newton's third law to relate the partner forces.

The position of the center of mass of a system of objects is the "weighted" average of their individual positions:

$$\vec{r}_{CM} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + m_2\vec{r}_3 + \cdots}{m_1 + m_2 + m_3 + \cdots} = \frac{\sum m_i\vec{r}_i}{\sum m_i}.$$

The motion of the center of mass is determined only by the *external* forces acting on the system from outside. More precisely,

$$\sum \vec{F}_{\text{external}} = M_{\text{total}}\,\vec{a}_{CM}.$$

Definition of momentum: $\vec{p} \equiv m\vec{v}$.

For any isolated system of objects (possibly exerting forces on each other but not subject to any outside forces), the total momentum is conserved:

$$\sum p_{f,x} = \sum p_{i,x} \qquad \sum p_{f,y} = \sum p_{i,y} \qquad \sum p_{f,z} = \sum p_{i,z}$$

You should be able to solve collision and recoil problems, using the principle of conservation of momentum.