Physics 2010 (Schroeder) Name ________________________________
spring 2004

Problem Set 7

(due Monday, March 1)

1. 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.

2. 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.

3. 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. (Hint: In which case does the projectile's momentum change more during the collision?)

4. Describe an example of a collision in which the total momentum of the two colliding objects is *not* conserved.

5. 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.)

6. Suppose you jump into the air with an upward speed of 3 m/s. Calculate the recoil speed of the earth, assuming that both you and the earth were initially at rest. Also calculate the earth's kinetic energy, and compare to your kinetic energy.

7. 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 (a) the speed of the cars after the collision and (b) the amount of kinetic energy lost during the collision. (Hint: There is no need to convert the numbers to metric units.)

8. 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? (You may wish to use the worksheet.)

9. An astronaut in training is rotated in a horizontal centrifuge at a radius of 5.0 m. (a) What is the astronaut's speed if the magnitude of her acceleration vector is $7.0g$? (b) How many revolutions per minute are required for this speed and acceleration? (c) What is the period of revolution, that is, the time to go around once?

10. Calculate the magnitude of the acceleration vector for each of the following objects undergoing circular motion at constant speed: (a) a centrifuge with a radius of 10 cm that spins at a rate of 100 revolutions per second; (b) the earth in its orbit around the sun.

11. In a popular amusement park ride, you stand with your back against the wall inside a cylinder of radius 2.5 meters. The cylinder then begins to turn, eventually reaching a speed at which it turns once every 1.5 seconds. At this point the floor drops away, but you feel pressed against the wall by an unseen (and nonexistent!) force. Draw a diagram of all the *actual* forces acting on your body, then apply Newton's second law to determine whether you will fall. Assume that the coefficient of gripping friction between your clothing and the wall is 0.4. (You may wish to use the constrained motion problem worksheet.)

12. A stuntman drives a car over the top of a hill, the cross section of which can be approximated by a circular arc of radius 250 m. What is the greatest speed at which he can drive without the car leaving the road at the top of the hill?

Study Guide

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

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

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. (If kinetic energy is also conserved, the collision is called "elastic".)

When an object moves in a circle at constant speed, its acceleration vector points toward the center of the circle and has magnitude

$$|\vec{a}| = \frac{|\vec{v}|^2}{r},$$

where $|vecv|$ is the object's speed and r is the radius of the circle. Using this formula, you should be able to solve constrained motion problems involving circular motion at constant speed. (Often in these problems, you also need to relate the speed to the time required for one trip around the circle, or to the number of circular trips per unit time. It's better to figure out these relations than to memorize formulas for them.)