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Problems set # 6 **Physics 168**

1. A water molecule consists of an oxygen atom and two hydrogen atoms. An oxygen atom has a mass of 16 u (unified mass units) and each hydrogen atom has a mass of 1 u. The hydrogen atoms are each at an average distance of 96 pm from the oxygen atom and are separated from one another by an angle of 104.5 degrees. Find the center of mass of a water molecule.(See Fig. 1.)

2. Determine the center of mass of a uniform semicircular hoop of radius R.

3. Pete (mass 80 kg) and Dave (mass 120 kg) are in a rowboat (mass 60 kg) on a calm lake. Dave is near the bow of the boat, rowing, and Pete is at the stern, 2 m from Dave. Dave gets tired and stops rowing. Pete offers to row, so after the boat comes to rest they change places. How far does the boat moves as Pete and Dave change places. (Neglect any horizontal force exerted by the water).

4. Two pucks, each of mass m, are initially at rest in the configuration shown in Fig. 1. A constant force of magnitude F accelerates the system towards the right. After the point of application P of the force has moved a distance d, the pucks collide and stick together. What is the speed of the pucks immediately after the collision?

5. (a) If a volcano spews a 500-kg rock vertically upward a distance of 500 m, what is its velocity when it left the volcano. (b) If the volcano spews the equivalent of 1000 rocks of this size every minute, what is the power output?

6. A runaway 14,000 kg railroad car is rolling horizontally at 4 m/s toward a switchyard. As it passes by a grain elevator, 2000 kg of grain suddenly drops into the car. How long does it takes the car to cover the 500 m distance from the elevator to the switchyard? Assume that the grains falls straight down and that slowing due to rolling friction or air drag is negligible.

7. A 40 kg skateboarder on a 3 kg board is trainning with two 5 kg weights. Beginning from rest, she throws the weights horizontally, one at a time, from her board. The speed of each weight is 7 m/s relative to her after it is thrown. Assume the board rolls without friction. (a) How fast is she moving in the opposite direction after throwing the first weight? (b) After throwing the second weight?

8. A thorium-227 nucleus (mass 227 u) at rest decays into radium-223 nucleus (mass 223 u) by emitting an alpha particle (mass 4 u). The kinetic energy of the alpha particle is measured to be 6 MeV. What is the kinetic energy of the recolling radium nucleus?

9. A measure of inelsticity in a head-on collision of two objects is the coefficient of restitution defined as

$$e = \frac{v'_A - v'_B}{v_B - v_A} \ ,$$

where $v'_A - v'_B$ is the relative velocity of the two objects after the collision and $v_B - v_A$ is their relative velocity before it. (a) Show that $e = 1$ for a perfectly elastic collision and $e = 0$ for a complete inelastic collision. (b) A simple method for measuring the coefficient of restitution for an object colliding with a very hard surface like steel is to drop the object onto a heavy steel plate, as shown in Fig. 2. Determine a formula for e in terms of the original height h and the maximum height h' reached after one collision.

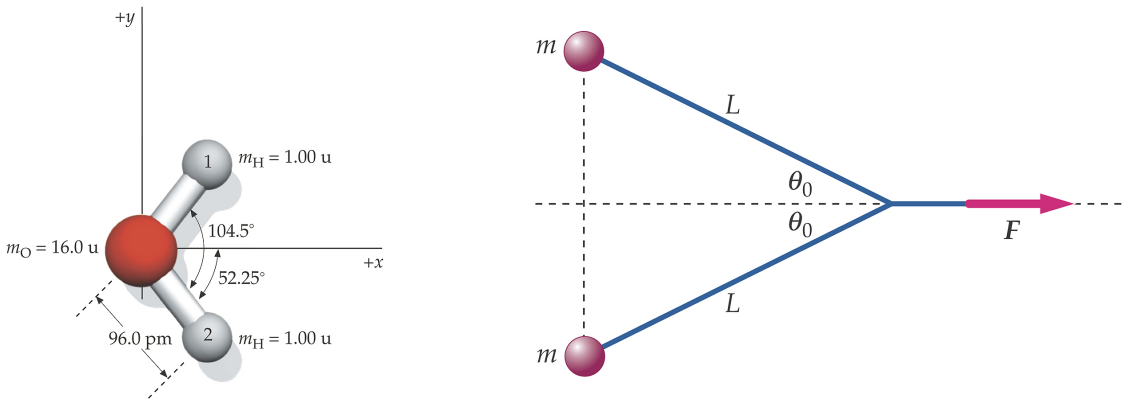

Figure 1: The situations in problems 1 (left) and 4 (right).

10. You strike a golf ball with a driving iron. What a reasonable estimates for the magnitude of the (a) impulse (b) collision time (c) average force? A typical golf ball has a mass $m = 45$ g and a radius $r = 2$ cm. For a typical drive, the range is roughly 190 m. Assume the ball leaves the ground at an angle $\theta_0 = 13°$ above the horizontal.

11. An astronaut of mass 60 kg is on a space walk to repair a communications satellite when he realizes he needs to consult the repair manual. You happen to have it with you, so you throw it to him with a speed 4 m/s relative to the spacecraft. He is at rest relative to the spacecraft before catching the 3 kg book. Find (a) his velocity after catching the book (b) the initial and final kinetic energies of the book-astronaut system and (c) the impulse exerted by the book on the astronaut.

12. In a feat of public marksmanship, you fire a bullet into a hanging wood block, which is a device known as a ballistic pendulum. The block, with bullet embedded, swings upward. Noting the height reached the top of the swing, you immediately inform the crowd of the bullet speed. How fast was the bullet traveling?

13. A neutron of mass m_n and speed $v_{n,\mathrm{i}}$ undergoes a head-on elastic collision with a carbon nucleus of mass m_C initially at rest. (a) What are the final velocities of both particles? (b) What fraction f of its initial kinetic energy does the neutron lose?

14. A neon atom ($m = 20u$) makes a perfectly elastic collision with another atom at rest. After the impact, the neon atom travels away at 55.6° angle from its original direction and the unknown atom travels away at a $-50°$ angle. What is the mass (in u) of the unknown atom?

15. A novice pool player is faced with the corner pocket shot shown in Fig. 2. Relative dimensions are also given. Should the player be worried about this being a "scratch shot" in which the cue ball will also fall into a pocket? Give details.

16. Two billard balls of equal mass move at right angles and meet at the origin of an xy coordinate system. Ball A is moving upward along the y axis at 2 m/s, and ball B is moving to the right along the x-axis with speed 3.7 m/s. After the collision, assumed elastic, the ball B is moving along the positive y axis. What is the final direction of ball A and what are their two speeds?(See Fig. 3.)

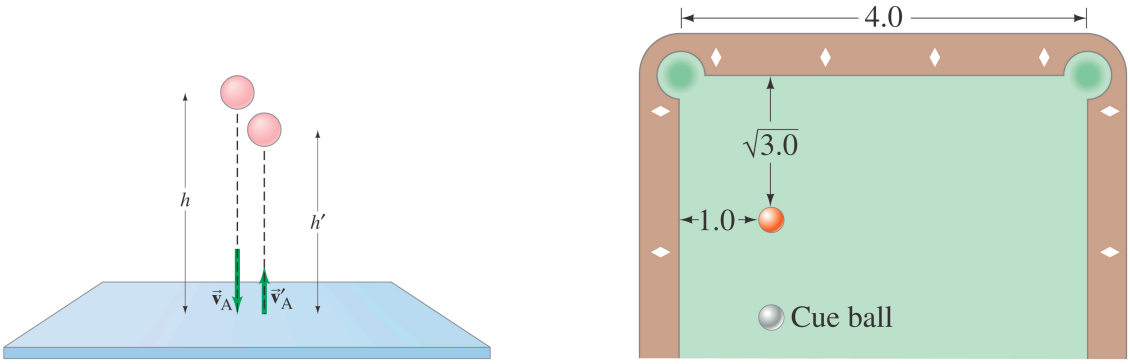

Figure 2: The situation in problems 9 (left) and 15 right.

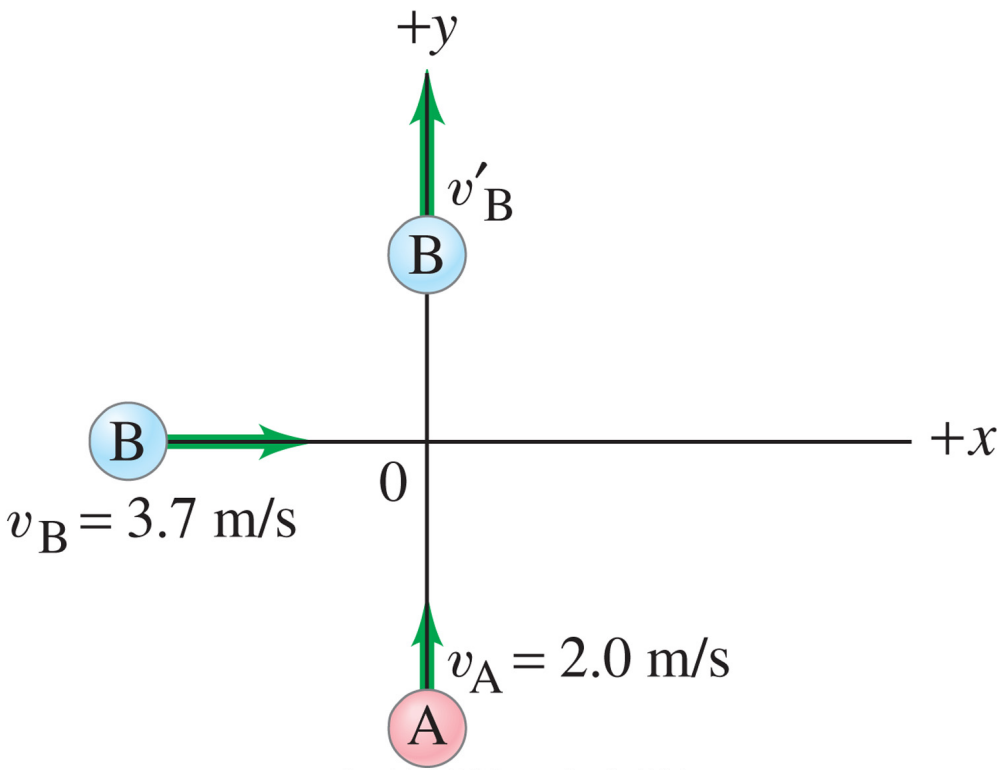

Figure 3: The situation in problem 16.