Holt Physics

Problem 6G

ELASTIC COLLISIONS

PROBLEM

In the game of marbles, a shooter is a large marble about 2 cm in diameter that is used to knock smaller marbles out of the ring. Suppose a shooter with a speed of 0.80 m/s hits a 4.8 g marble that is at rest in the ring. The shooter continues forward with a speed of 0.51 m/s while the smaller marble moves forward with a speed of 1.33 m/s. What is the mass of the shooter?

SOLUTION

1. DEFINE

Given:

$\mathbf{v_{1,i}}$ = initial velocity of shooter = 0.80 m/s forward

$\mathbf{v_{2,i}}$ = initial velocity of marble = 0 m/s

$\mathbf{v_{1,f}}$ = final velocity of shooter = 0.51 m/s forward

$\mathbf{v_{2,f}}$ = final velocity of marble = 1.33 m/s forward

m_2 = mass of marble = 4.8 g

Unknown: m_1 = mass of shooter = ?

2. PLAN

Choose the equation(s) or situation: Use the equation for the conservation of momentum to determine the mass of the shooter.

$$m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$$

Rearrange the equation(s) to isolate the unknown(s):

$$m_1(\mathbf{v_{1,i}} - \mathbf{v_{1,f}}) = m_2\mathbf{v_{2,f}} - m_2\mathbf{v_{2,i}}$$

$$m_1 = \frac{m_2\mathbf{v_{2,f}} - m_2\mathbf{v_{2,i}}}{\mathbf{v_{1,i}} - \mathbf{v_{1,f}}}$$

3. CALCULATE

Substitute the values into the equation(s) and solve:

$$m_1 = \frac{(4.8 \text{ g})(1.33 \text{ m/s}) - (4.8 \text{ g})(0 \text{ m/s})}{0.80 \text{ m/s} - 0.51 \text{ m/s}}$$

$$m_1 = \frac{6.4 \text{ g}\bullet\text{m/s}}{0.29 \text{ m/s}}$$

$$m_1 = \boxed{22 \text{ g}}$$

3. EVALUATE

Confirm your answer by making sure that kinetic energy is also conserved.

$$\tfrac{1}{2}m_1v_{,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2 = \tfrac{1}{2}m_1v_{1,f}^2 + \tfrac{1}{2}m_2v_{2,f}^2$$

$$\tfrac{1}{2}(22 \times 10^{-3} \text{ kg})(0.80 \text{ m/s})^2 + \tfrac{1}{2}(4.8 \times 10^{-3} \text{ kg})(0 \text{ m/s})^2$$

$$= \tfrac{1}{2}(22 \times 10^{-3} \text{ kg})(0.51 \text{ m/s})^2 + \tfrac{1}{2}(4.8 \times 10^{-3} \text{ kg})(1.33 \text{ m/s})^2$$

$$7.0 \times 10^{-3} \text{ J} + 0 \text{ J} = 2.9 \times 10^{-3} \text{ J} + 4.2 \times 10^{-3} \text{ J}$$

$$7.0 \text{ mJ} = \boxed{7.1 \text{ mJ}}$$

The slight difference arises from rounding.

ADDITIONAL PRACTICE

1. A highly elastic rubber ball is tossed at a moveable wooden wall panel that is initially at rest. The ball's initial velocity is 6.00 m/s to the right. After the elastic collision, the ball returns with a velocity of 4.90 m/s to the left, while the panel moves 1.09 m/s to the right. If the panel's mass is 1.25 kg, what is the mass of the ball?

2. A 2.0 kg block of ice with a speed of 8.0 m/s makes an elastic collision with another block of ice that is at rest. The first block of ice proceeds in the same direction as it did initially, but with a speed of 2.0 m/s. What is the mass of the second block? (Hint: Use the conservation of kinetic energy to solve for the second unknown variable.)

3. A golf ball slides down a pipe from the upper level of a miniature golf course and heads directly for the hole on the green. Unfortunately, another player's ball is directly in the way. The second ball, which is initially at rest, moves forward with a speed of 3.0 m/s, causing it to land in the cup. The first ball comes to a complete stop after the collision. Both balls have a mass of 45 g. What is the first ball's speed before the collision.

4. Suppose two ships, one with a mass of 3.0×10^7 kg and the second with a mass of 2.5×10^7 kg, are equipped with bumpers, so that they undergo a completely elastic collision. Before the collision, the second ship moves north with a speed of 4.0 km/h. After the collision, the first ship moves 3.1 km/h to the north while the second ship moves 6.9 km/h to the south. Assume that the ships move over the ocean without friction. Given this information, calculate the initial velocity of the first ship.

5. A basketball player throws a ball at the same time a ball from a nearby court is thrown. The two balls collide elastically, so that the final velocity of the first ball is 4.0 m/s to the west and the final velocity of the second ball is 3.0 m/s to the north. If the first ball's initial velocity is 3.0 m/s to the north, what is the initial velocity of the second ball. Assume both balls have identical masses.

6. A red ball with a mass of 0.75 kg strikes two croquet balls, a 0.50 kg green ball and a 0.50 kg blue ball, that are at rest next to each other on a smooth wood floor. After the collision, the red ball has a velocity of 0.80 m/s to the east, the green ball moves 45° north of east with a speed of 3.4 m/s, and the blue ball moves 45° south of east with a speed of 3.4 m/s. What is the red ball's initial velocity?

7. An elevator is moving upward at a speed of 2.000 m/s. At the instant the elevator is 20.4 m from the top of the shaft, a ball is dropped down the shaft. The ball collides elastically with the elevator, so that it rises up the shaft again. The elevator's velocity immediately after the collision is 1.980 m/s upward. If the ball has a mass of 0.150 kg and the elevator's mass is 325.0 kg, what is the velocity of the ball after the collision with the elevator? How high above the elevator shaft does the returning ball bounce?

8. Suppose the initial conditions are the same as for problem 7, except that the elevator's initial velocity is 2.000 m/s downward and its final velocity is 2.017 m/s downward. What is the velocity of the ball after the collision with the elevator? How far below the top of the elevator shaft does the returning ball bounce?

9. A steel ball with a mass of 0.50 kg is fastened to a cord that is 40.0 cm long and is released from a height of 40.0 cm. At the bottom of its path the ball strikes a 2.5 kg block that is initially at rest on a frictionless surface. The collision is elastic. What are the final velocities of the ball and block? (Hint: Use the conservation of kinetic energy to solve for the second unknown variable.)

10. A bowling ball of mass 7.00 kg moves east with a speed of 2.00 m/s. The ball collides with an identical ball at rest, which causes the first ball to move 30.0° north of east at a speed of 1.73 m/s. What is the velocity of the second ball after the collision?