Unit 4C
Collisions
Practice Problems TEACHER

Work each of the following problems. SHOW ALL WORK.

1. **A 1 kg blob of clay moving at 8 m/s collides inelastically with a 3 kg wooden block that is initially at rest.**

   a. What is the initial momentum of the system?

$$p_i = p_{blob_i} + p_{block_i}$$
$$p_i = m_{blob} v_{blob_i} + m_{block} v_{block_i}$$
$$p_i = (1\,kg)(8\,^m\!/_s) + (3\,kg)(0)$$
$$p_i = 8\,kg\,^m\!/_s$$

   b. What must be the final momentum of the system?

   Because momentum is conserved, the final momentum of the system must also be 8 kg m/s.

   c. Calculate the velocity of the blob and block immediately after the collision.

$$p_f = p_{blob\,f} + p_{block\,f}$$
$$8\,kg\,^m\!/_s = m_{blob} v_{blob\,f} + m_{block} v_{block\,f}$$
$$v_{blob\,f} = v_{block\,f} = v_f$$
$$8\,kg\,^m\!/_s = m_{blob} v_f + m_{block} v_f$$
$$8\,kg\,^m\!/_s = (1\,kg) v_f + (3\,kg) v_f$$
$$8\,kg\,^m\!/_s = (4\,kg) v_f$$
$$v_f = 2\,^m\!/_s$$

2. **A 1,250 kg car is stopped at a traffic light. A 3,550 kg truck moving at 8.33 m/s hits the car from behind.**

   a. What is the initial momentum of the system?

$$p_i = p_{car_i} + p_{truck_i}$$
$$p_i = m_{car} v_{car_i} + m_{truck} v_{truck_i}$$
$$p_i = (1250\,kg)(0) + (3550\,kg)(8.33\,^m\!/_s)$$
$$p_i = 29571.5\,kg\,^m\!/_s$$

   b. What must be the final momentum of the system?

   Because momentum is conserved, the final momentum of the system must also be 29,571.5 kg m/s.

questions continued on next page

Unit 4C
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c. If the bumpers of the car and truck lock, how fast will the two vehicles move together?

$$p_f = p_{car\,f} + p_{truck\,f}$$
$$29571.5\ kg\,{}^{m}\!/\!{}_{s} = m_{car} v_{car\,f} + m_{truck} v_{truck\,f}$$
$$v_{car\,f} = v_{truck\,f} = v_f$$
$$29571.5\ kg\,{}^{m}\!/\!{}_{s} = m_{car} v_f + m_{truck} v_f$$
$$29571.5\ kg\,{}^{m}\!/\!{}_{s} = (1250\ kg)v_f + (3550\ kg)v_f$$
$$29571.5\ kg\,{}^{m}\!/\!{}_{s} = (4800\ kg)v_f$$
$$v_f = 6.16\,{}^{m}\!/\!{}_{s}$$

3. **Twins Bo and Joe have a combined mass of 200 kg and are zooming along at 10 m/s in a 100 kg amusement park bumper car. They bump into Melinda's car, which is sitting still. Melinda has a mass of 25 kg and is also in a 100 kg car. After the collision, the twins continue moving with a speed of 4.12 m/s.**

a. What is the initial momentum of the system?

$$p_i = p_{BoJoe_i} + p_{Melinda_i}$$
$$p_i = m_{BoJoe} v_{BoJoe_i} + m_{Melinda} v_{Melinda_i}$$
$$p_i = (300\ kg)(10\,{}^{m}\!/\!{}_{s}) + (125\ kg)(0)$$
$$p_i = 3000\ kg\,{}^{m}\!/\!{}_{s}$$

b. What must be the final momentum of the system?

Because momentum is conserved, the final momentum of the system must also be 3,000 kg m/s.

c. How fast is Melinda's car bumped across the floor?

$$p_f = p_{BoJoe\,f} + p_{Melinda\,f}$$
$$3000\ kg\,{}^{m}\!/\!{}_{s} = m_{BoJoe} v_{BoJoe\,f} + m_{Melinda} v_{Melinda\,f}$$
$$3000\ kg\,{}^{m}\!/\!{}_{s} = (300\ kg)(4.12\,{}^{m}\!/\!{}_{s}) + (125\ kg)v_{Melinda\,f}$$
$$3000\ kg\,{}^{m}\!/\!{}_{s} = 1236\ kg\,{}^{m}\!/\!{}_{s} + (125\ kg)v_{Melinda\,f}$$
$$1764\ kg\,{}^{m}\!/\!{}_{s} = (125\ kg)v_{Melinda\,f}$$
$$v_{Melinda\,f} = 14.11\,{}^{m}\!/\!{}_{s}$$

questions continued on next page

Unit 4C
Collisions
Practice Problems TEACHER

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4. Jamal is playing in the arcade at Six Flags. At one booth, he throws a 0.5 kg ball with a velocity of 21 m/s and hits a 0.2 kg bottle sitting on a shelf. The bottle goes flying forward at 30 m/s.

a. What is the velocity of the ball after it hits the bottle?

First Step: Determine the initial momentum of the system.

$$p_i = p_{ball_i} + p_{bottle_i}$$
$$p_i = m_{ball}v_{ball_i} + m_{bottle}v_{bottle_i}$$
$$p_i = (0.5\ kg)(21\ m/s) + (0.2\ kg)(0)$$
$$p_i = 10.5\ kg\ m/s$$

In all collisions, momentum is conserved, so the final momentum of the system must also be 10.5 kg m/s.

$$p_f = p_{ball_f} + p_{bottle_f}$$
$$10.5\ kg\ m/s = m_{ball}v_{ball_f} + m_{bottle}v_{bottle_f}$$
$$10.5\ kg\ m/s = (0.5\ kg)v_{ball_f} + (0.2\ kg)(30\ m/s)$$
$$10.5\ kg\ m/s = (0.5\ kg)v_{ball_f} + 6\ kg\ m/s$$
$$4.5\ kg\ m/s = (0.5\ kg)v_{ball_f}$$
$$v_{ball_f} = 9\ m/s$$

b. If the bottle was more massive but flew forward with the same final velocity, how would this affect the final velocity of the ball?

Depending on the mass of the bottle, the final velocity of the ball could be zero, it could be smaller but in the same (positive) direction, or it could bounce backwards with a speed in the opposite (negative) direction.

questions continued on next page

Unit 4C
Collisions
Practice Problems TEACHER

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5. **Valentina, a Russian cosmonaut, exits her ship for a space walk. When she is 15 m from the ship and floating motionless, her tether catches on a sharp piece of metal and is severed. Valentina quickly reacts by tossing her 2 kg camera away from the spaceship with a speed of 12 m/s.**

   a. How fast will Valentina, whose mass is 68 kg, float toward the spaceship?

First Step: Determine the initial momentum of the system.

$$p_i = p_{Valentina_i} + p_{camera_i}$$
$$p_i = m_{Valentina} v_{Valentina_i} + m_{camera} v_{camera_i}$$
$$p_i = (68\ kg)(0\ m/s) + (2\ kg)(0\ m/s)$$
$$p_i = 0\ kg\ m/s$$

Because momentum is always conserved, the momentum of the system must also be zero after the camera is thrown.

$$p_f = p_{Valentina_f} + p_{camera_f}$$
$$0 = m_{Valentina} v_{Valentina_f} + m_{camera} v_{camera_f}$$
$$-m_{Valentina} v_{Valentina_f} = m_{camera} v_{camera_f}$$
$$-(68\ kg) v_{Valentina_f} = (2\ kg)(12\ m/s)$$
$$-(68\ kg) v_{Valentina_f} = 24\ kg\ m/s$$
$$v_{Valentina_f} = -0.35\ m/s$$

   b. Assuming the spaceship remains at rest with respect to Valentina, how long will it take her to reach the ship?

$$d = 15\ m$$
$$v = 0.35\ m/s$$
$$t = ?$$

$$v = \frac{d}{t}$$
$$0.35\ m/s = \frac{15\ m}{t}$$
$$t = \frac{15\ m}{0.35\ m/s} = 42.86\ s$$

questions continued on next page

Unit 4C
Collisions
Practice Problems TEACHER

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Work each of the following problems. SHOW ALL WORK.

6. **A 4 kg bowling ball rolls at 8 m/s to the right and strikes a 6 kg bowling ball that is rolling at 2 m/s to the left. If the 4 kg ball bounces back with a velocity of 4 m/s to the left, what is the velocity of the 6 kg ball after the collision?**

First Step: Determine the initial momentum of the system.

$$p_i = p_{left_i} + p_{right_i}$$
$$p_i = m_{left} v_{left_i} + m_{right} v_{right_i}$$
$$p_i = (6\ kg)(-2\ m/s) + (4\ kg)(8\ m/s)$$
$$p_i = -12\ kg\,m/s + 32\ kg\,m/s$$
$$p_i = 20\ kg\,m/s$$

Because momentum is always conserved, the momentum of the system must also be 20 kg m/s after the balls collide.

$$p_f = p_{left_f} + p_{right_f}$$
$$p_f = m_{left} v_{left_f} + m_{right} v_{right_f}$$
$$20\ kg\,m/s = (6\ kg) v_{left_f} + (4\ kg)(-4\ m/s)$$
$$20\ kg\,m/s = (6\ kg) v_{left_f} - 16\ kg\,m/s$$
$$36\ kg\,m/s = (6\ kg) v_{left_f}$$
$$v_{left_f} = 6\ m/s$$

The ball that was originally moving to the left is now moving at a final velocity of 6 m/s to the right. The direction is indicated by the positive sign.