Physics **Name:**

Unit 5: Momentum Practice Problems 2 **Date:** ____________

According to the **law of conservation of momentum**, the total momentum in a system remains the same if no external forces act on the system. Consider the two types of collisions that can occur.

Vocabulary **Elastic collision**: A collision in which objects collide and bounce apart with no energy loss.

In an elastic collision, because momentum is conserved, the (*mv*) before a collision for each of the two objects must equal the (*mv*) after the collision for each of the two objects. This is written as:

Before ***After***

$$(m_1v_{1o}) + (m_2v_{2o}) = (m_1v_{1f}) + (m_2v_{2f})$$

The subscripts 1 and 2 refer to objects 1 and 2, while "o" is the original, and "f" is the final velocity respectively.

Vocabulary **Inelastic collision**: A collision in which objects collide and some mechanical energy is transformed into heat energy.

A common kind of inelastic collision is one in which the colliding objects stick together, or start out stuck together and then separate (aka an explosion).

Because momentum is also conserved in an inelastic collision, the *mv* before the collision for each of the two objects must equal the *mv* after the collision for each of the two objects. When objects are stuck together after the collision (assuming mass does not change), this equation becomes

Before *After*

$$(m_1v_{1o}) + (m_1v_{1o}) = (m_1 + m_2)v_f$$

TYPO

m_2v_2

where v_f is the combined final velocity of the two objects.

This course will only consider situations of perfect or completely elastic or inelastic situations. The strategy for solving such ideal situations remains the same.

- read the problem
- sketch the situation (s)
- identify the known and unknown values
- determine the type of equation
- substitute values and perform operations
- check answer for soundness (magnitude and direction)

Solved Examples

Example 1: Tubby and his twin brother Chubby have a combined mass of 200.0 kg and are zooming along in a 100.0 kg amusement park bumper car at 10.0 m/s. They bump Melinda's car, which is sitting still. Melinda has a mass of 25.0 kg. After the elastic collision, the twins continue ahead with a speed of 4.12 m/s. How fast is Melinda's car bumped across the floor?

Solution: Notice you must add the mass of the bumper car to the mass of the riders.

Given: $m_1 = 300.0$ kg
$m_2 = 125.0$ kg
$v_{1o} = 10.0$ m/s
$v_{2o} = 0$ m/s
$v_{1f} = 4.12$ m/s

Unknown: $v_{2f} = ?$
Original equation: $m_1v_{1o} + m_2v_{2o} = m_1v_{1f} + m_1v_{1f}$

Solve: $v_{2f} = m_1v_{1o} + m_2v_{2o} - m_1v_{1f} / m_2$

= (300.0 kg)(10.0 m/s) + (125.0 kg)(0 m/s) – (300 kg)(4.12 m/s) / 125.0 kg)

= 3000 kg*m/s + 0 kg*m/s – 1236 kg*m/s / 125.0 kg

= 1756 kg*m/s/125.0 kg

= 14.1 m/s

Example 2: Sometimes the curiosity factor at the scene of a car accident is so great that it actually produces secondary accidents as a result, while people watch to see what is going on. If an 800 kg sports car slows to 13.0 m/s to check out an accident scene and the 1200 kg pick-up truck behind him continues traveling at 25.0 m/s, with what velocity will the two move if they lock bumpers after a rear-end collision?

Solution: Since the two vehicles lock bumpers, both objects have the same final velocity.

Given: $m_1 = 800$ kg
$m_2 = 1200$ kg
$v_o = 13.0$ m/s
$v_{2f} = 25.0$ m/s

Unknown: $v_{1f} = ?$
Original equation: $m_1v_{1o} + m_2v_{2o} = (m_1 + m_2)\, v_f$

Solve: $v_f = m_1v_{1o} + m_2v_{2o} / (m_1 + m_2)$
= (800. kg)(13.0 m/s) + (1200. kg)(25.0 m/s)/ (800. kg + 1200. kg)
= 10,400 kg*m/s + 30,000 kg*m/s / 2000. kg
= 20.2 m/s forward

Example 3: Charlotte, a 65.0 kg diver, shoots a 2.0 kg spear with a speed of 15 m/s at a fish who darts quickly away without getting hit. How fast does Charlotte move backwards when the spear is shot?

Solution: To start, Charlotte and the spear are together and both are at rest.

Given $m_1 = 65.0$ kg
$m_2 = 2.0$ kg
$v_o = 0$ m/s
$v_{2f} = 15.0$ m/s

Unknown: $v_{1f} = ?$
Original equation: $(m_1 + m_2)v_o = m_1v_{1f} + m_2v_{2f}$

Solve: $v_{1f} = (m_1 + m_2)v_o - m_2v_{2f} / m_1$

$= (65.0 \text{ kg} + 2.0 \text{ kg})(0\text{m/s}) - (2.0 \text{ kg})(15\text{m/s}) / 65.0\text{kg}$

$= -30 \text{ kg m/s} / 65 \text{ kg}$

$= -0.46$ m/s

Remember, the minus sign here is indicating direction. Therefore, Charlotte would travel with a speed of 0.46 m/s in the direction opposite to that of the spear.

Practice Exercise

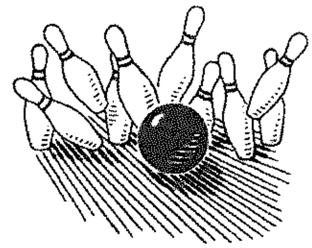
#1: Jamal is at the state fair playing some of the games. At one booth he throws a 0.50 kg ball forward with a velocity of 21.0 m/s in order to hit a 0.20 kg bottle sitting on a shelf. When he makes contact the bottle goes flying forward at 30.0 m/s.
a) What is the velocity of the ball after it hits the bottle?
b) If the bottle were more massive, how would this affect the final velocity of the ball?

Sketch: Given: Solve:

Answer: a. ____________________

Answer: b. ____________________

 # 2: Jeanne rolls a 7.0 kg bowling ball down the alley for the league championship. One pin is still standing, and Jeanne hits it head-on with a velocity of 9.0 m/s. The 2.0 kg pin acquires a forward velocity of 14.0 m/s. What is the new velocity of the bowling ball?



Sketch: Given: Solve:

Answer: ______________________

#3: Running at 2.0 m/s, Bruce, the 45.0 kg quarterback, collides with Biff, the 90.0 kg tackle, who is traveling at 7.0 m/s in the other direction. Upon collision, Biff continues to travel forward at 1.0 m/s. How fast is Bruce knocked backwards?

Sketch: Given: Solve:

Answer: ______________________

#4: Anthony and Sally are participating in the "Roll-a-Rama" roller skating dance championship. While 75.0 kg Anthony roller skates backwards at 3.0 m/s, 60.0 kg Sally jumps into his arms with a velocity of 5.0 m/s in the same direction.

a) How fast does the pair roll backwards together?

b) If Anthony is skating toward Sissy when she jumps, would their combined final velocity be larger or smaller than your answer to part A? Why?

Sketch: Given: Solve:

Answer: a. ______________________

Answer: b. ______________________

#5: To test the strength of a retainment wall designed to protect a nuclear reactor, a rocket-propelled F-4 Phantom jet aircraft was crashed head-on into a concrete barrier at high speed in Sandia, New Mexico on April 19, 1988. The F-4 Phantom had a mass of 19,100 kg, while the retainment wall's mass was 496,000 kg. The wall sat on a cushion of air that allowed it to move during impact. If the wall and F-4 moved together at 8.41 m/s during the collision, what was the initial speed of the F-4 Phantom?

Sketch: Given: Solve:

Answer: ____________________________

 # 6: Valentina, the Russian Cosmonaut, goes outside her ship for a spacewalk, but when she is floating 15 m from the ship, her tether catches on a sharp piece of metal and is severed. Valentina tosses her 2.0 kg camera away from the spaceship with a speed of 12 m/s. a) How fast will Valentina, whose mass is now 68 kg, travel toward the spaceship? b) Assuming the spaceship remains at rest with respect to Valentina, how long will it take her to reach the ship?

Sketch: Given: Solve:

Answer: a. ________________________

Answer: b. ________________________

 # 7: A 620 kg moose stands in the middle of the railroad tracks, frozen by the lights of an oncoming 10,000 kg locomotive that is traveling at 10.0 m/s. The engineer sees the moose but is unable to stop the train in time and the moose rides down the track sitting on the cowcatcher. What is the new combined velocity of the locomotive and the moose?

Sketch: Given: Solve:

Answer: ____________________________

 # 8: Lee is rolling along on her 4.0 kg skateboard with a constant speed of 3.0 m/s when she jumps off the back and continues forward with a velocity of 2.0 m/s relative to the ground. This causes the skateboard to go flying forward with a speed of 15.5 m/s relative to the ground. What is Lee's mass?

Sketch: Given: Solve:

Answer: ____________________________

Additional

A-1 Astronaut Pam Melroy, history's third woman space shuttle pilot, flew the space shuttle *Discovery* to the International Space Station to complete construction in October of 2000. To undock from the space station Pilot Melroy released hooks holding the two spacecrafts together and the 68,000 kg shuttle pushed away from the space station with the aid of four large springs. a) If the 73,000 kg space station moved back at a speed of 0.50 m/s, how fast and in what direction did the space shuttle move? b) What was the relative speed of the two spacecraft as they separated?

A-2 Tyrrell throws his 0.20 kg football in the living room and knocks over his mother's 0.80 kg antique vase. After the collision, the football bounces straight back with a speed of 3.9 m/s, while the vase is moving at 2.6 m/s in the opposite direction. a) How fast did Tyrrell throw the football? b) If the football continued to travel at 3.9 m/s in the same direction it was thrown, would the vase have to be more or less massive than 0.80 kg?

A-3 A 300 kg motorboat is turned off as it approaches a dock and it coasts in toward the dock at 0.50 m/s. Isaac, whose mass is 62.0 kg, jumps off the front of the boat with a speed of 3.0 m/s relative to the boat. What is the velocity of the boat after Isaac jumps?

A-14 Miguel, the 72.0 kg bullfighter, runs toward an angry bull at a speed of 4.00 m/s. The 550 kg bull charges toward Miguel at 12.0 m/s and Miguel must jump on the bull's back at the last minute to avoid being run over. What is the new velocity of Miguel and the bull as they move across the arena?

A-5 A space shuttle astronaut is spent to repair a defective relay in a 600.00 kg satellite that is traveling in space at 17,000 m/s. Suppose the astronaut and his Manned Maneuvering Unit (MMU) have a mass of 400.00 kg and travel at 17,010.0 m/s toward the satellite. What is the combine velocity when the astronaut grabs hold of the satellite?

A-6 The U.S.S. *Constitution*, the oldest fully commissioned war ship in the world, is docked in Boston, Massachusetts. Also known as "Old Ironsides" for her seemingly impenetrable hull, the frigate houses 56 pieces of heavy artillery. Mounted on bearings that allow them to recoil at a speed of 1.30 m/s are 20 carronades, each with a mass of 1000 kg. If a carronade fires a 145. kg cannonball straight ahead, with what muzzle velocity does the cannonball leave the cannon?

ANSWERS:

1. a. +.9 m/s b. greater
2. + 5 m/s
3. 10 m/s
   1.4
4. a. - 3.9 m/s b. -0.6 m/s
5. + 215 m/s (226)
6. a. +0.4 m/s b. 38 sec
7. +9.4 m/s
8. 50 kg