PHY I - MOMENTUM
Unit Practice Pack - 1

Name:
Date:

Vocabulary Momentum: Physical property of an object in motion or a measure of how difficult it is to stop a moving object.

Momentum = (mass)(velocity) or $p = mv$

If the momentum of an object is changing, as it is when a force is exerted to start it or stop it, the change in momentum can be found by looking at the change in mass and velocity during the interval.

Change in momentum = change in [(mass)(velocity)] or $\Delta p = \Delta(mv)$

Ideal conditions - For all the exercises in this section, assume that the mass of the object remains constant, and consider only the change in velocity, Δv, which is equal to $(v_f - v_o)$.

Momentum is a vector quantity. Its direction is in the direction of the object's velocity.

The SI unit for momentum is the **kilogram · meter/second (kg · m/s).**

Vocabulary Impulse: The product of the force exerted on an object and the time interval during which it acts.

Impulse = (force)(elapsed time) or $J = F\Delta t$

The SI unit for impulse is the **newton · second** (N·s).

The impulse given to an object is equal to the change in momentum of the object.

$$F\Delta t = m\Delta v$$

The same change in momentum may be the result of a large force exerted for a short time, or a small force exerted for a long time. In other words, impulse is the thing that you *do*, while change in momentum is the thing that you *see*.

The units for impulse and momentum are equivalent.

Remember, $1\ N = 1\ kg \cdot m/s^2$. Therefore, $1\ N \cdot s = 1\ kg \cdot m/s$.

As always measurements must be converted if they are not given in kg, m, or s.

Other: Some one might ask why the letter p is used to represent momentum. A few explanations exist but one might be of use. It says "p is used because the word "impetus" formally in place of "momentum" comes from the Latin, "petere," to go towards or rush upon...so therefore we get "p". This is plausible as m is already used for mass.

Solved Examples

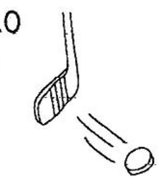
Example 1: Winfield hits a 0.050 kg golf ball, giving it a speed of 75 m/s. What impulse does he impart to the ball?

Solution: Because the impulse equals the change in momentum, you can reword this exercise to read, "What was the ball's change in momentum?" It is understood that the ball was initially at rest, so its initial speed was 0 m/s.

Given: $m = 0.050$ kg
$\Delta v = 75$ m/s
$\Delta p = ?$

Original equation = $\Delta p = m\Delta v$
$\Delta p = (0.050 \text{ kg})(75 \text{ m/s})$
$= \underline{3.8 \text{ kg} \cdot \text{m/s}}$

Example 2: Wayne hits a stationary 0.12 kg hockey puck with a force that lasts for 1.0×10^{-2}s and makes the puck shoot across the ice with a speed of 20.0 m/s, scoring a goal for the team. With what force did Wayne hit the puck?



Given: $m = 0.12$ kg
$\Delta v = 20.0$ m/s
$\Delta t = 1.0 \times 10^{-2}$s
$F = ?$

Original equation: $F\Delta t = m\Delta v$
Solve: $F = m\Delta v/\Delta t$
$= (0.12 \text{ kg})(20.0 \text{ m/s})/1.0 \times 10^{-2}\text{s}$
$= 240 \text{ kg} \cdot \text{m/s}^2$
$= \underline{240 \text{ N}}$

Example 3: A tennis ball traveling at 10.0 m/s is returned by Venus. It leaves her racket with a speed of 36.0 m/s in the opposite direct from which it came. a) What is the change in momentum of the tennis ball? b) If the 0.060 kg ball is in contact with the racket for 0.020 s, with what average force has Venus hit the ball?

Solution: In this exercise, the tennis ball is coming toward Venus with a speed of 10.0 m/s in one direction, but she hits it back with a speed of 36.0 m/s in the opposite direction. Therefore, you must think about velocity vectors and call one direction positive and the opposite direction negative.

a. Given: $v_o = -10.0$ m/s
$v_f = 36.0$ m/s
$m = 0.060$ kg
$\Delta p = ?$

Original equation: $\Delta p = m\Delta v = m(v_f - v_o)$
$= (0.060 \text{ kg})[36.0 \text{ m/s} - (-10.0 \text{ m/s})]$
$= \underline{2.8 \text{ kg} \cdot \text{m/s}}$

b. Given: $m = 0.060$ kg
$\Delta v = 46.0$ m/s
$\Delta t = 0.020$ s
$F = ?$

Original Equation: $F\Delta t = m\Delta v$
$= (0.060 \text{ kg})(46.0 \text{ m/s})/0.0.20 \text{ s})$
$= \underline{140 \text{ N}}$

Example 4: To demonstrate his new high-speed camera, Flash performs an experiment in the physics lab in which he shoots a pellet gun at a pumpkin to record the moment of impact on film. The 1.0 g pellet travels at 100. m/s until it embeds itself 2.0 cm into the pumpkin. What average force does the pumpkin exert to stop the pellet?

Solution: First, convert g to kg and cm to m.

1.0 g = 0.0010 kg   2.0 cm = 0.020 m

Before you can solve for the force in the exercise, you must first know how long the force is being exerted. Remember, in order to find the time, you must use the average velocity, v_{av}.

$V_{av} = v_f + v_o/2$
$= 0$ m/s + 100 m/s/2
$= 50.0$ m/s

Given: v = 50.0 m/s
$\Delta d = 0.020$ m   Original equation: $\Delta d = v\Delta t$
$\Delta t = ?$ $\Delta t = \Delta d/v = 0.020$ m/50.0 m/s = 0.00040 s

Now we can solve for the force the pumpkin exerts to stop the pellet.

Given: m = 0.0010 kg   Original equation: $F\Delta t = m\Delta v$
$\Delta v = 100$ m/s $F = m\Delta v/\Delta t$
$\Delta t = 0.0040$ s   = (0.0010 kg)(100 m/s)/ (0.00040 s)
F = ?   = 250 N

Practice Exercises

1. **Ship vs. Ice** - On April 15, 1912, the luxury cruise liner *Titanic* sank after running into an iceberg. What momentum would the 4.23×10^8 kg ship have it had hit the iceberg head-on with a speed of 11.6 m/s? (Actually, the impact was a glancing blow).

Sketch: Given: Solve:

Answer: ______________________

2. **Car vs. Wall** - Auto companies frequently test the safety of automobiles by putting them through crash tests to observe the integrity of the passenger compartment. If a 1000 kg care is sent toward a cement wall with a speed of 14 m/s and the impact brings it to a stop in 8.00×10^{-2} s, with what average force is it brought to rest?

Sketch: Given: Solve:

Answer: ______________________

3: **Body vs. Belt or Window** - Rhonda, who has a mass of 60.0 kg, is riding at 25.0 m/s in her sports car when she must suddenly slam on the brakes to avoid hitting a dog crossing the road. She is wearing her seatbelt, which brings her body to a stop in 0.400 s. a) What average force did the seatbelt exert on her? b) If she had not been wearing her seatbelt, and the windshield had stopped her head in 1.0×10^{-3}s, what average force would the windshield have exerted on her? c) How many time greater is the stopping force of the windshield than the seatbelt?

Sketch: Given: Solve:

Answer: ______________________

4: Humans vs. Earth - If all 350 million people in the United States jumped in the air simultaneously, pushing off Earth with an average force of 800 N each for a time of 0.10 s, what would happen to the 5.98×10^{24} kg Earth? (In other words – what is the change in Earth's velocity – and show a calculation that justifies your answer)

Sketch: Given: Solve:

Answer: ____________________

5: Cue vs. Eight - In Sharkey's Billiard Academy, Maurice is waiting to make his last shot. He notices that the cue ball is lined up for a perfect head-on collision, as shown. Each of the balls has a mass of 0.0800 kg and the cue ball comes to a complete stop upon making contact with the 8 ball. Suppose Maurice hits the cue ball by exerting a force of 180 N for 5.00×10^{-3} s, and it knocks head-on into the 8 ball. Calculate the resulting velocity of the 8 ball.

Sketch: Given: Solve:

Answer: ____________________

6: Hail vs. Car - During an autumn storm, a 0.012 kg hail stone traveling at 20.0 m/s made a 0.20 cm deep dent in the hood of Christopher's new car. What average force did the car exert to stop the damaging hail stone?

Sketch: Given: Solve:

Answer: ____________________

Additional Exercises

A-1 BernDog, whose mass is 70.0 kg, leaves a ski jump with a velocity of 21.0 m/s. What is BD's momentum as he leaves the ski jump?

A-2 Steph is sitting on a park bench feeding the pigeons when a child's ball rolls toward her across the grass. Steph returns the ball to the child by hitting it with her 2.0 kg purse with a speed of 20 m/s. If the impact lasts for 0.4 s, with what force does Steph hit the ball?

A-3 When John stepped up to the plate and hit a 0.150 kg fast ball traveling at 36.0 m/s, the impact caused the ball to leave his bat with a velocity of 45.0 m/s in the opposite direct. If the impact lasted for 0.0002 s, what force did John exert on the baseball?

A-4 The U.S. Army's parachuting team, the Golden Knights, are on a routine jumping mission over a deserted beach. On a jump, a 65 kg Knight lands on the beach with a speed of 4.0 m/s, making a 0.20 m deep indentation in the sand. With what average force did the parachutist hit the sand?

A-5 The late news reports the story of a shooting in the city. Investigators think that they have recovered the weapon and they run ballistics test on the pistol at the firing range. If a 0.005 kg bullet were fired from the handgun with a speed of 400 m/s and it traveled 0.080 m into the target before coming to rest, what force did the bullet exert on the target?

A-6 About 50,000 years ago, in an area located outside Flagstaff, Arizona, a giant 4.5×10^7 kg meteor fell and struck the earth, leaving a 180 m deep hole now known as Barringer crater. If the meteor was traveling at 20,000 m/s upon impact, with what average force did the meteor hit the earth?

Answers:
1. 4.9×10^9 kg * m/s
2. 1.7×10^5 N
3. 3750 N and 1.5×10^6 N so 400 times greater
4. 4.37×10^{-15} m/s – no observable change is velocity
5. 11.3 m/s – both the initial speed of the cue and final of the eight
6. 1200 N

A-1. 1.5×10^3 kg * m/s
A-2. 100 N
A-3. 6.8×10^3 N
A-4. 2.6×10^3 N
A-5. 5.0×10^3 N
A-6. 1.3×10^{13} N