Unit 3 Momentum
1- Momentum

Any moving object has momentum which depends on:

1.

2.

Where:

p=

m=

v=

- Momentum is a _____ quantity, meaning is has both _____ and _____

- The units are _____ but can also be written as _____

Ex 1: Calculate the momentum of a 6.2 kg pumpkin traveling at a velocity of 5.0 m/s west.

Ex 2: A baseball of mass 0.14 kg is moving at 35.0 m/s. a.

Find the momentum of the baseball.

b. Find the velocity at which a bowling ball, mass 7.6 kg, would have the same momentum as the baseball

Remember that: Change =

Ex 3:

a) A 0.50 kg water balloon is thrown against a wall at 32 m/s coming to a stop. What was its change in momentum?

b) A 0.50 kg bouncy ball is thrown at 32 m/s, bouncing back with the same speed. How does its change in momentum compare to that of the water balloon?

Momentum: Worksheet 1

1. Calculate the momentum of a 4.0 kg object traveling at a velocity of 12.0 m/s east.

2. A 5.0 kg object has a momentum of 25.0 kgm/s west. What is its velocity?

3. An object has a velocity of 8.0 m/s south and a momentum of 36.0 kgm/s south. What is its mass?

4. An object has a velocity of 2.0 m/s east and a momentum of 29 kgm/s. What is the weight of the object?

5. A 6.6 N object is traveling at a velocity of 3.0 m/s north. What is the object's momentum?

6. A 7.0 kg object travels 2.6 m west in 1.1 s. Assuming uniform velocity, what is the momentum of the object?

7. A 5.0 kg object is dropped from a height of 2.5 m above the floor. What is the object's momentum after 0.25 s?

8. A 1.0 kg ball hits the floor with a velocity of 2.0 m/s. If the ball bounces up with a velocity of 1.6 m/s, what is the ball's change in momentum?

9. A 0.144 kg baseball is pitched horizontally at + 38 m/s. The batter hits a horizontal line drive at – 38 m/s (the opposite direction!). What is the ball's change in momentum?

10. The 1205 kg physics dragster is traveling at 35 km/h east when it hits the gas and accelerates at 12.5 m/s^2 for 3.25 s. What is its change in momentum during this time?

1) 48 kgm/s E 2) 5.0 m/s W 3) 4.5 kg 4) 140 N 5) 2.0 kgm/s 6) 17 kgm/s 7) -12 kgm/s 8) 3.6 kgm/s 9) -11 kg m/s 10) 49 000 kgm/s

Impulse:

We can derive the change in momentum from newton's 2nd Law:

Ex: Luigi is sick of taking orders. He swings a 9.0 kg hammer at 16 m/s when Mario's mustache brings it to a stop in 0.25 s. What is the net force exerted on Mario's mustache?

Ex. A soccer player kicks a 0.450 kg ball at 25.0 m/s east. If the goalie stops the ball by exert 215 N of force, how long does it take the ball to stop?

If the goalie stops the 6.5 kg bowling ball traveling at the same velocity in the same amount of time, how much force is required?

Example: Impulse in 2D
A 1250 kg car traveling east at 25 m/s turns due north and continues on at 15 m/s. What was the impulse of the car exerted while turning the corner?

Example: Coaches for many sports such as baseball, tennis and golf can often be heard telling their athletes to "follow through" with their swing. How does this help a weaker player hit a ball farther than a stronger player?

Example: Using the principle of impulse, explain why an airbag can help people sustain less damage during a collision.

Momentum: Worksheet 2 - Impulse

1. A rocket at rest with a mass of 9.5 x 10³ kg is acted on by an average net force of 1.5 x 10⁵ N upwards for 15 s. What is the final velocity of the rocket?

6. An average net force caused an 11.0 kg object to accelerate uniformly from rest. If this object travels 26.3 m west in 3.20 s, what is the change in momentum of the object?

2. A 26.3 kg object is traveling at 21.0 m/s north. What average net force is required to bring this object to a stop in 2.60 s?

7. A 1.30 kg object is dropped from a height of 6.5 m. How far did the object fall when its momentum is 6.0 kgm/s?

3. An average force of 31.6 N south is used to accelerate a 15.0 kg object uniformly from rest to 10.0 m/s. What is the change in momentum?

8. An average net force of 16.0 N acts on an object for 2.00 x 10⁻¹ s causing it to accelerate from rest to 3.50 m/s. What is the mass of the object?

4. An average net force of 25.0 N acts north on an object for 7.20 x 10⁻¹ s. What is the change in momentum of the object?

9. A 0.500 kg object is thrown vertically upward with an average applied force of 8.20 N by a student. The force is applied through a displacement of 1.50 m.

a. What is the average net force acting on the object?

5. A 5.00 kg object accelerates uniformly from rest to a velocity of 15.0 m/s east. What is the change in momentum on the object?

b. What is the velocity of the object when it leaves the student's hand? (Assume initial velocity is zero)

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1) 240 m/s 2) 212 N South 3) 150 kgm/s 4) 18 Ns 5) 75 kgm/s 6) 180. kgm/s 7) 1.1 m 8) 0.914 kg 9)a. 3.30 N b. 4.45 m/s

Unit 3 Momentum
3 -The Law of Conservation of momentum

Recall Newton's 3rd Law:

For every action there is an equal and opposite reaction force

Two colliding objects experience _____ and _____ forces for the _____ amount of time, hence their impulses……...

$$\Delta p = F_{net}t$$

…… must be _____ and _____

Ex: A cue ball is traveling with a momentum of 5 kgm/s east and strikes the 8 ball. If the cue ball comes to a stop what is the change in momentum on the cue ball? How about on the 8 ball?

Ex. A clown is stuck on a sheet of frictionless ice. He hurls one of his clown shoes with momentum of 80 kgm/s east. What is his momentum before and after he throws his shoe?

Ex: A fullback is traveling to the right with a momentum of 120 kgm/s while a linebacker is traveling to the left with a momentum of 110 kgm/s. If they stick together, what is their total momentum before and after they collide?

The Law of Conservation of Momentum

An isolated system means……..

1) Collisions (separate after)

Ex: A 7.1 kg bowling ball is rolling to the right at 3.8 m/s when it collides with a stationary 0.40 kg bowling pin. After the collision, the bowling ball is traveling at 2.9 m/s to the right. How fast is the pin moving after the collision?

Ex: A 0.25 kg cue ball is traveling east at 4.5 m/s when it collides head on with a 0.25 kg eight ball traveling west at 5.0 m/s. After the collision the cue ball is traveling west at 2.0 m/s. What is the final velocity of the eight ball?

2) Collision (combined after)

Ex: A 0.105-kg hockey puck moving at 48 m/s is caught by a 75-kg goalie at rest. If the ice is frictionless, at what velocity will the goalie slide on the ice after catching the puck?

Ex: A 35.0-g bullet strikes a 5.0-kg stationary wooden block and embeds itself in the block. The block and bullet move together at 8.6 m/s. What was the original velocity of the bullet?

3) Explosions

Ex: A 0.050 kg bullet is fired from a 5.0 kg gun. If the velocity of the bullet is 275 m/s, what is the recoil velocity of the gun?

Ex: A firecracker sits in a 7.0 kg pumpkin. After it explodes, the pumpkin splits into two chunks. A 5.0 kg piece travels west at 10.0 m/s. What is the mass and velocity of the other piece? (Ignore the mass of the firecracker)

Worksheet 3 Collisions

1) A 30.0 kg object moving to the right at a velocity of 1.00 m/s collides with a 20.0 kg object moving to the left with a velocity of 5.00 m/s. If the 20.0 kg object continues to move to the left at a velocity of 1.25 m/s, what is the velocity of the 30.0 kg object?

2) A $4.50 \ x \ 10^3$ kg railway car is moving east at a velocity of 5.0 m/s on a level frictionless track when it collides with a stationary $6.50 \ x \ 10^3$ kg caboose. If the two cars lock together upon impact, how fast are they moving after collision?

3) A 925 kg car moving at a velocity of 18.0 m/s right collides with a stationary truck of unknown mass. The two vehicles lock together and move off at a velocity of 6.50 m/s. What is the mass of the truck?

4) A 50.0 g bullet strikes a 7.00 kg wooden block. If the bullet becomes imbedded in the block and they both move off at a velocity of 5.00 m/s, what was the initial speed of the bullet?

5. A 40.0 g hot dog moving with a velocity of 9.00 m/s to the right collides with a 55.0 g hot dog bun with a velocity of 6.00 m/s to the left. If the two objects stick together upon collision, what is the velocity of the combined masses?

6. A 76 kg student, standing at rest on a frictionless surface throws a 0.20 kg cream pie horizontally at 22 m/s at Mr. Trask who is standing to the student's left. What was the velocity of the student after they throw the pie?

7. A 25 kg turkey is fired from a 1.1×10^3 kg turkey launcher. If the horizontal velocity of the turkey is 325 m/s east, what is the recoil of the launcher?

8. A rail vehicle with a rocket engine is being tested on a smooth track. Starting from rest the engine is fired for a short period of time, releasing 4.5×10^2 kg of gases. It is estimated that the average velocity of the gases is 1.4×10^3 m/s to the right, and that the maximum velocity of the vehicle is 45 m/s left. What is the mass of the vehicle?

1) 1.50 m/s left or -1.50 m/s 2) 2.0 m/s east 3) 1640 kg 4) 705 m/s 5) 0.316 m/s right 6) 0.058 m/s right 7) 7.4 m/s west 8) 14000 kg

When dealing with collisions in 2-dimensions it is important to remember that momentum is a vector with magnitude and direction. When finding the **total momentum** we have to do:

<u>**Collisions at 90°:**</u>
A 750 kg Peugeot travelling at 21 m/s West collides with a 680 kg Fiat travelling at 18 m/s South. If the two cars become entwined what is their total final velocity?

Remember that it is momentum that is conserved, so we need to add the _____ **NOT** _____

Collisions not at 90° (because life is never that easy…):

Example 1) A 4.0 kg bowling ball is moving east at an unknown velocity when it collides with a 6.1 kg frozen cantaloupe at rest. After the collision, the bowling ball is traveling at a velocity of 2.8 m/s 32° [N of E] and the cantaloupe is traveling at a velocity of 1.5 m/s 41° [S of E]. What was the initial velocity of the bowling ball?

Before   **After**

Component Method
1. We need to break the final momenta of the two objects into x and y components:
2. We then add the **individual x** and the **individual y** components to find our total momentum.
3. Don't forget to solve for the initial velocity (magnitude and direction):

Notice that the total momentum is all in the ___ _____! This should be no surprise since the bowling ball was initially only moving in the x direction.

Example 2) A 2.0 kg ball is moving at a velocity of 5.0 m/s to the East. It collides with a stationary 3.0 kg ball. After the collision, the 2.0 kg ball moves at a velocity of 4.0 m/s 30° North of East. What is the velocity of the 3.0 kg ball?

Before   **After**

Vector Addition Method:
Simply add the vectors and solve with the sine or cosine law. Notice that the _____ _____ is either the initial or the final because momentum is _____.

Collisions can be grouped into two categories,

1. _____ _____ are those in which
   Kinetic Energy is Conserved

2. _____ _____ are those in which
   Kinetic Energy is Not Conserved.

- **Totally Inelastic Collisions** are those in which the colliding objects **stick together** resulting in the *greatest loss in Kinetic Energy*

In reality collisions are generally somewhere in between perfectly elastic and perfectly inelastic. As a matter of fact, it is impossible for a **macroscopic** collision to ever be perfectly elastic. Perfectly elastic collisions can only occur at the **atomic** or **subatomic level**.

Why can't macroscopic collision ever be truly elastic?

	Total Momentum $\sum P_i = \sum P_f$	Kinetic Energy $\sum E_{ki} = \sum E_{kf}$	Total Energy (including Energy loss) $\sum E_T = \sum E_T$
Elastic Collision			
Inelastic Collision			

Example 3) A 2.0 kg ball moving to the right at 4.0 m/s collides with a 4.0 kg ball moving to the left at 3.0 m/s. After the collision, the 2.0 kg ball has a velocity of 4.0 m/s to the left.

   a) Determine the velocity of the 4.0 kg ball.
   b) Is the collision *elastic or inelastic*? If inelastic how much Kinetic energy is lost?

Worksheet 4

1. A 1.4×10^3 kg car is westbound at a velocity of 37.0 km/h when it collides with a 2.0×10^3 kg truck northbound at a velocity of 35 km/h. If these two vehicles lock together upon collision, what is the initial velocity of the vehicles after collision?

    (7.2 m/s 37° W of N)

2. A 6.2 kg object heading north at 3.0 m/s collides with an 8.0 kg object heading west at 3.5 m/s. If these two masses stick together upon collision, what is their velocity after collision?

    (2.4 m/s 56° W of N)

3. A 4.0×10^4 N Truck moving west at a velocity of 8.0 m/s collides with a 3.0×10^4 N truck heading south at a velocity of 5.0 m/s. If these two vehicles lock together upon impact, what is their velocity?

    (5.0 m/s 25° S of W)

4. A 50.0 kg object is moving east at an unknown velocity when it collides with a 60.0 kg stationary object. After collision, the 50.0 kg object is traveling at a velocity of 6.0 m/s 50.0° N of E and the 60.0 kg object is traveling at a velocity of 6.3 m/s 38° S of E.
    a. What was the velocity of the 50.0 kg object before collision?

    (9.86 m/s due east)

    b. Determine whether this collision was elastic or inelastic.

    (Ek loss of 340 J, so inelastic)

5. A 15.0 kg penguin waddling east at a velocity of 7.0 m/s collides with a stationary 10.0 kg penguin. After the collision the 15.0 kg penguin is traveling at a velocity of 4.2 m/s 20.0° S of E.
    a. What is the velocity of the 10.0 kg penguin after collision?

    (5.1 m/s 25° N of E)

    b. is this collision elastic or inelastic?

    (Inelastic, E_k loss of 110J)

6. A watermelon explodes into three equal masses. One mass moves east at 15.0 m/s. If a second mass moves at a velocity of 10.0 m/s 45.0° S of E, what is the velocity of the third mass? (Hint: the total momentum is zero, so how will your vector arrows add up?)