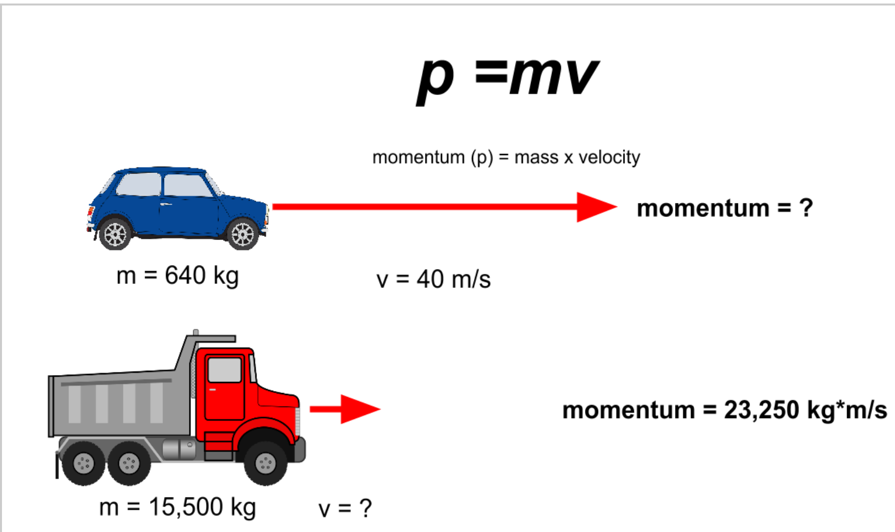
Name: ___________________________

Momentum and Impulse Guided Inquiry

Through this guided inquiry you will gain experience with the physical quantity of momentum, how it is calculated and how it is changed. You will also experience how change in momentum is related to a property known as impulse.

READ THIS! Momentum can be defined as "mass in motion." All objects have mass; so if an object is moving, then it has momentum - it has its mass in motion. The amount of momentum that an object has is dependent upon two variables: how much stuff is moving and how fast the stuff is moving. Momentum depends upon the variables mass and velocity.

Model 1



Based on Model 1, what is the mass of the dump truck?

Based on the model, what two quantities are required to calculate the momentum of an object?

How many times greater is the mass of the dump truck than the mass of the mini cooper?

Calculate the missing variables in the table below.

Object	Mass	Velocity	Momentum
Mini Cooper	640 kg	40 m/s	
Dump Truck	15,500 kg		23,250 kg*m/s

According to your calculations, which object has more momentum? Explain your answer.

How fast would the object with less momentum have to go so that the Mini Cooper and Dump Truck had equal momentum? Show your work.

Calculations practice. Determine the momentum of …

a. an electron (m= 9.1 x10^{-31} kg) moving at 2.18 x 10^{6} m/s (as if it were in a Bohr orbit in the H atom).
b. a 0.45 Caliber bullet (m = 0.162 kg) leaving the muzzle of a gun at 860 m/s.
c. a 110-kg professional fullback running across the line at 9.2 m/s.
d. a 360,000-kg passenger plane taxiing down a runway at 1.5 m/s

Show your work.

a. *(example work is shown below)* m = 9.1 x 10^{-31} kg v = 2.18 x 10^{6} m/s p = mv p = (9.1 x 10^{-31} kg)(2.18 x 10^{6} m/s) p = (	b.

Show your work.

c.	d.

READ THIS! The more momentum that an object has, the harder it is to stop.

- It would require a greater amount of ***force***
- or a longer amount of ***time***
- or ***both*** to bring such an object to rest.

As the force acts upon the object for a given amount of time, the object's velocity is changed; and hence, the object's momentum is changed. This relationship connects two quantities; impulse and change in momentum.

Model 2

Impulse = change in momentum

Units: N * s $$F * t = m * \Delta v$$ Units: kg * m / s

The equation is known as the **impulse-momentum change equation**. The law can be expressed this way:

"In a collision, an object experiences a force for a specific amount of time which results in a change in momentum."

The result of the force acting for the given amount of time is that the object's mass either: speeds up or slows down (or changes direction).

The ***impulse*** experienced by the object ***equals*** the ***change in momentum*** of the object.
In equation form, F • t = m • Δ v.

According to **Model 2**...

What are the units of impulse?	What are the units of momentum?

What two factors are required to change the momentum of an object? Use complete sentences.

According to Model 2, what is the result or effect of “impulse?” Use complete sentences.

READ THIS! In a collision, objects experience an impulse; the impulse causes and is equal to the change in momentum. Consider a football halfback running down the football field and encountering a collision with a defensive back. In the halfback-defensive back collision, the halfback experiences a force that lasts for a certain amount of time to change his momentum. Since the collision causes the moving halfback to slow down, the force on the halfback must have been directed OPPOSITE of his motion. If the halfback experienced a force of 800 N for 0.9 seconds, then we could say that the impulse was 720 N•s. This impulse would cause a momentum change of 720 kg•m/s. In a collision, the impulse experienced by an object is always equal to the momentum change.

Complete the following table using the Impulse-Momentum Change equation:

$$impulse = change\ in\ momentum$$
$$F * t = m * \Delta v$$

Force (N)	Time (s)	Impulse (N*s)	Mom. Change (kg*m/s)	Mass (kg)	Vel. Change (m/s)
	0.010			10	-4
	0.100	-40		10	
	0.010		-200	50	
-200,000			-200		-8
-200	1.0			50	

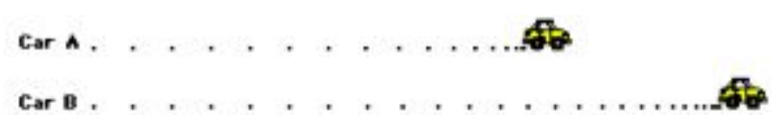
Application

A 0.50-kg cart (#1) is pulled with a 1.0-N force for 1 second; another 0.50 kg cart (#2) is pulled with a 2.0 N-force for 0.50 seconds. Which cart (#1 or #2) has the greatest acceleration? Explain.

Which cart (#1 or #2) has the greatest impulse? Explain.

Which cart (#1 or #2) has the greatest change in momentum? Explain.

Two cars of equal mass are traveling down Broadway with equal velocities. They also both happen to have oil leaks that drop one dot of oil onto the ground every second. They both come to a stop over different lengths of time. The motion for each car is shown in the diagram below.



At what approximate location on the diagram (in terms of the number dots) does each car begin to experience the impulse?

Which car (A or B) experiences the greatest acceleration? Explain.

Which car (A or B) experiences the greatest change in momentum? Explain.

Which car (A or B) experiences the greatest impulse? Explain.

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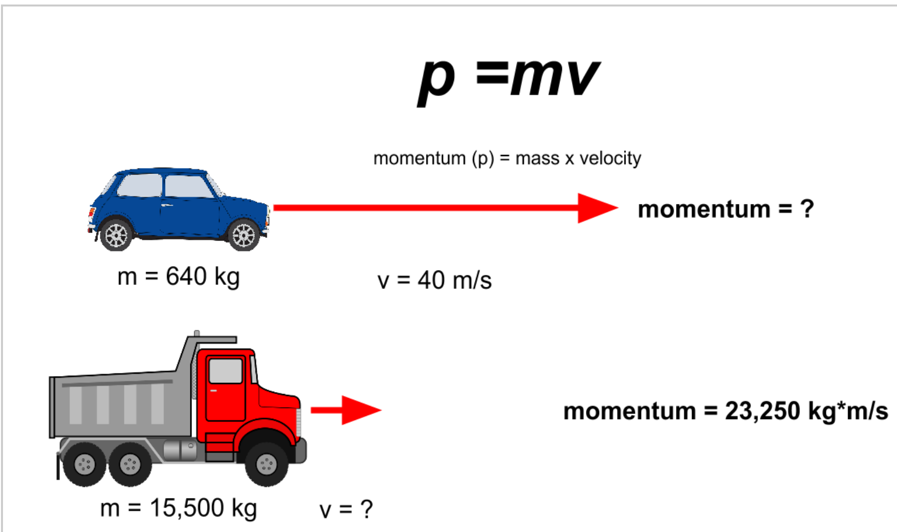
Model 1



Based on Model 1, what is the mass of the dump truck?

15,500 kg

Based on the model, what two quantities are required to calculate the momentum of an object?

mass and volume

How many times greater is the mass of the dump truck than the mass of the mini cooper?

15,500 kg/640 kg = 24.2 x greater

Calculate the missing variables in the table below.

Object	Mass	Velocity	Momentum
Mini Cooper	640 kg	40 m/s	25,600 kg*m/s
Dump Truck	15,500 kg	1.5 m/s	23,250 kg*m/s

According to your calculations, which object has more momentum? Explain your answer.

The Mini Cooper has more momentum than the dump truck. The Mini Cooper's greater velocity makes up for its lower mass.

How fast would the object with less momentum have to go so that the Mini Cooper and Dump Truck had equal momentum? Show your work.

$$\frac{25{,}600\ kg*m/s}{15{,}500\ kg} = 1.651\ m/s$$

If the dump were able to go 1.651 m/s then the Mini Cooper and the Dump Truck would have equal momentum.

Calculations practice. Determine the momentum of …

a. an electron (m= 9.1 x10^{-31} kg) moving at 2.18 x 10^6 m/s (as if it were in a Bohr orbit in the H atom).
b. a 0.45 Caliber bullet (m = 0.162 kg) leaving the muzzle of a gun at 860 m/s.
c. a 110-kg professional fullback running across the line at 9.2 m/s.
d. a 360,000-kg passenger plane taxiing down a runway at 1.5 m/s

Show your work.

a. *(example work is shown below)* m = 9.1 x 10^{-31} kg v = 2.18 x 10^6 m/s p=mv p=(9.1 x 10^{-31} kg)(2.18 x 10^6 m/s) p = (1.98 x 10^{-24} kg*m/s)	b. m = 0.162 kg v = 860 m/s p=mv p=(0.162 kg)(860 m/s) p = (139.3 kg*m/s)

Show your work.

c. m= 110 kg v = 9.2 m/s p=mv p=(110 kg)(9.2 m/s) p = (1012 kg*m/s)	d. m= 360,000 kg v = 1.5 m/s p = mv p = (360,000 kg)(1.5 m/s) p = (540,000 kg*m/s)

READ THIS! The more momentum that an object has, the harder it is to stop.

- It would require a greater amount of ***force***
- or a longer amount of ***time***
- or ***both*** to bring such an object to rest.

As the force acts upon the object for a given amount of time, the object's velocity is changed; and hence, the object's momentum is changed. This relationship connects two quantities; impulse and change in momentum.

Model 2

Impulse = change in momentum

Units: N * s $$F * t = m * \Delta v$$ Units: kg * m / s

The equation is known as the **impulse-momentum change equation**. The law can be expressed this way:

"In a collision, an object experiences a force for a specific amount of time which results in a change in momentum."

The result of the force acting for the given amount of time is that the object's mass either: speeds up or slows down (or changes direction).

The ***impulse*** experienced by the object ***equals*** the ***change in momentum*** of the object.
In equation form, F • t = m • Δ v.

According to **Model 2**...

What are the units of impulse?	What are the units of momentum?
Newton seconds (N*s)	kilogram meters per second (kg*m/s)

What two factors are required to change the momentum of an object? Use complete sentences.

For the momentum of an object to change there must be a force applied for an amount of time.

According to Model 2, what is the result or effect of “impulse?” Use complete sentences.

The effect of an impulse is a change in momentum (either increased or decreased momentum).

READ THIS! In a collision, objects experience an impulse; the impulse causes and is equal to the change in momentum. Consider a football halfback running down the football field and encountering a collision with a defensive back. In the halfback-defensive back collision, the halfback experiences a force that lasts for a certain amount of time to change his momentum. Since the collision causes the moving halfback to slow down, the force on the halfback must have been directed OPPOSITE of his motion. If the halfback experienced a force of 800 N for 0.9 seconds, then we could say that the impulse was 720 N•s. This impulse would cause a momentum change of 720 kg•m/s. In a collision, the impulse experienced by an object is always equal to the momentum change.

Complete the following table using the Impulse-Momentum Change equation:

$$impulse = change\ in\ momentum$$
$$F * t = m * \Delta v$$

Force (N)	Time (s)	Impulse (N*s)	Mom. Change (kg*m/s)	Mass (kg)	Vel. Change (m/s)
-4000	0.010	-40	-40	10	-4
-4	0.100	-40	-40	10	-4
-2	0.010	-200	-200	50	-4
-200,000	1000	-200	-200	25	-8
-200	1.0	-200	-200	50	-4

**Negative values denote direction*

Application

A 0.50-kg cart (#1) is pulled with a 1.0-N force for 1 second; another 0.50 kg cart (#2) is pulled with a 2.0 N-force for 0.50 seconds. Which cart (#1 or #2) has the greatest acceleration? Explain.

Acceleration is based on the force applied and the mass of the objects (Newton's Second Law / F = m*a). Object #1 has an acceleration of 2 m/s^2 (F/m = a, 1.0N/0.50kg = 2 m/s^2). Object #2 has an acceleration of 4 m/s^2 (F/m = a, 2.0N/0.50kg = 4 m/s^2).

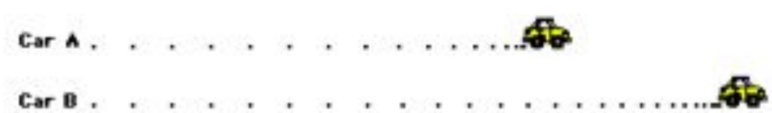
Which cart (#1 or #2) has the greatest impulse? Explain.

Object #1 has an impulse of 1 N*s (I =F * t, 1.0N*1.0 s = 1 N*s). Object #2 has an impulse of 1 N*s (I =F * t, 2.0N*0.5 s = 1 N*s). Different forces are applied over different times, but they equate to the same amount of impulse (more force over a shorter time period is equal to less force over a longer time period).

Which cart (#1 or #2) has the greatest change in momentum? Explain.

Change in momentum will be equal because the impulse is equal. There are not values to calculate the values (mass and volume) but the change in momentum is equal to impulse.

Two cars of equal mass are traveling down Broadway with equal velocities. They also both happen to have oil leaks that drop one dot of oil onto the ground every second. They both come to a stop over different lengths of time. The motion for each car is shown in the diagram below.



At what approximate location on the diagram (in terms of the number dots) does each car begin to experience the impulse?

Approximately at the 7th (or 8th) dot.

Which car (A or B) experiences the greatest acceleration? Explain.

Car A experiences the greatest acceleration (slowing down) it has a greater change in velocity in a certain amount of time. Car B takes longer to come to a stop and they started at the same velocity (judged by the equal distance between dots before the cars started slowing down).

Which car (A or B) experiences the greatest change in momentum? Explain.

Since both vehicles have the same mass and they have the same change in velocity (from the same constant velocity to not moving) they will have the same change in momentum.

Which car (A or B) experiences the greatest impulse? Explain.

They will have the same impulse (they have the same change in momentum). Car A would have a greater force applied in a shorter time. Car B would have a small force applied over a longer time period.