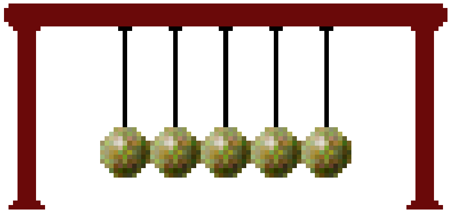
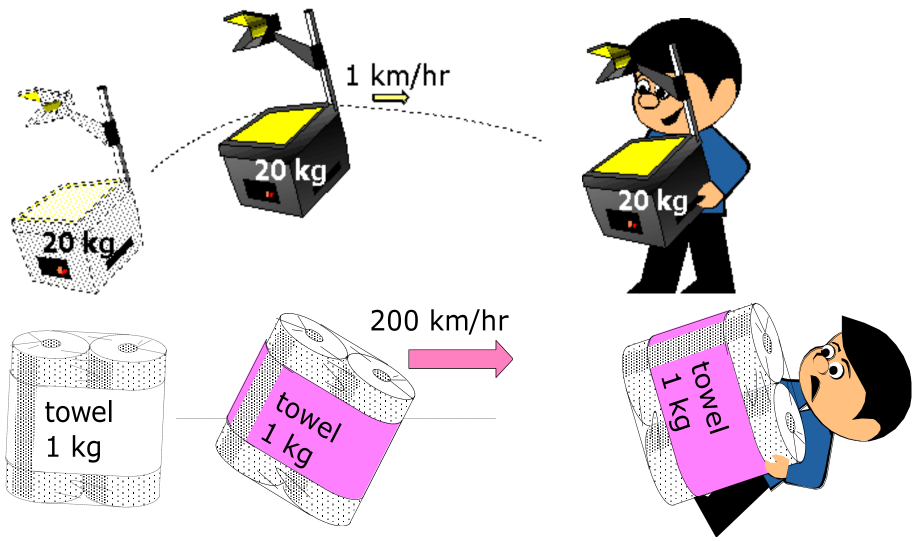
PHYSICS 2204
(Mr. J Fifield)

UNIT 3:
Impulse, Momentum and Conservation

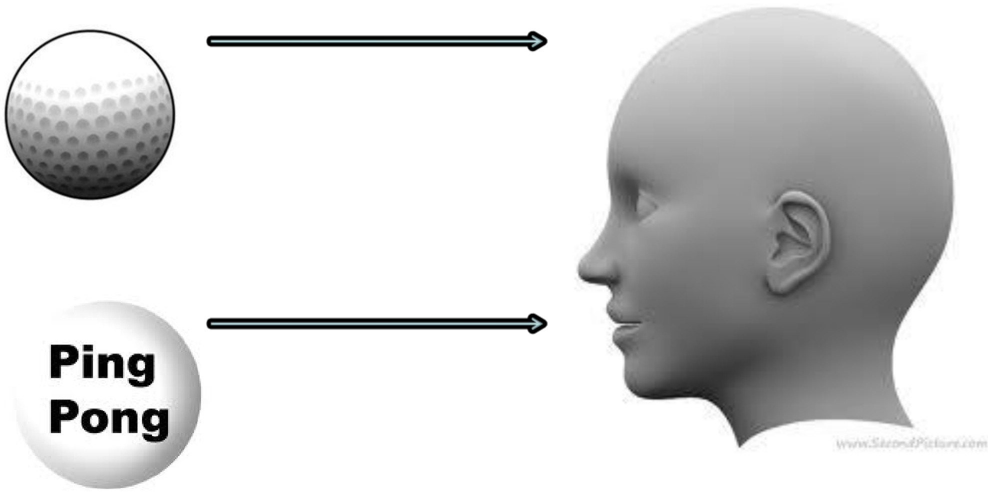


Unit 2
Topic 10: Momentum



Question?

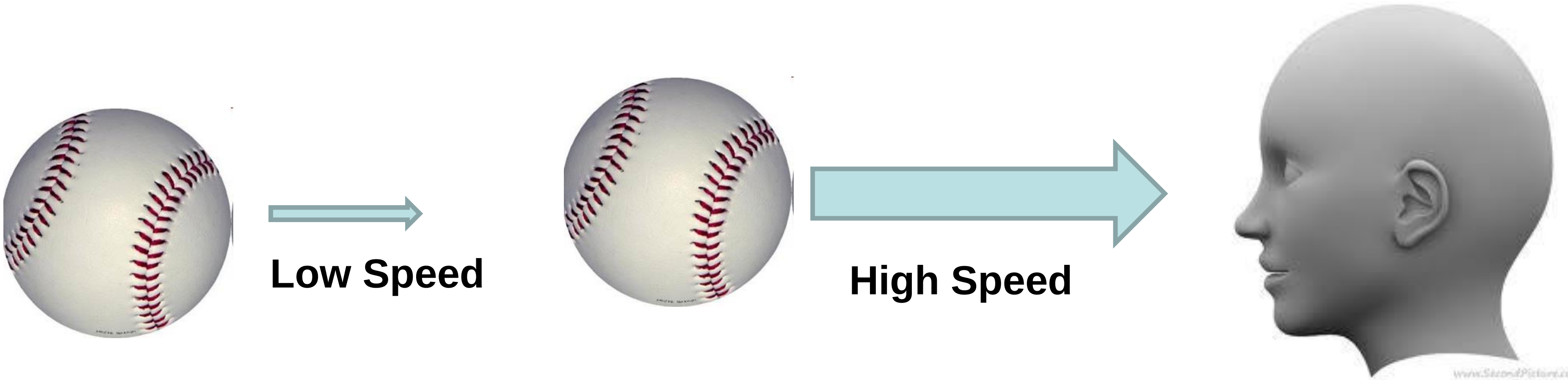
Which ball would you prefer hitting you?



Question?

Which ball would you prefer hitting you?

Two identical balls are thrown with different speed:

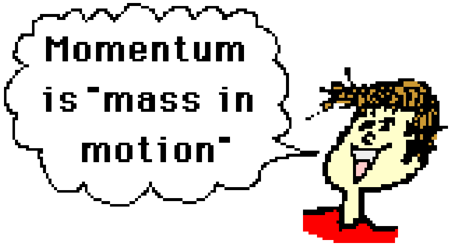


Momentum

Momentum can be defined as "mass in motion."

Momentum is dependent upon two variables:

1) Mass of the object (kg)
2) How fast the object is moving (m /s).



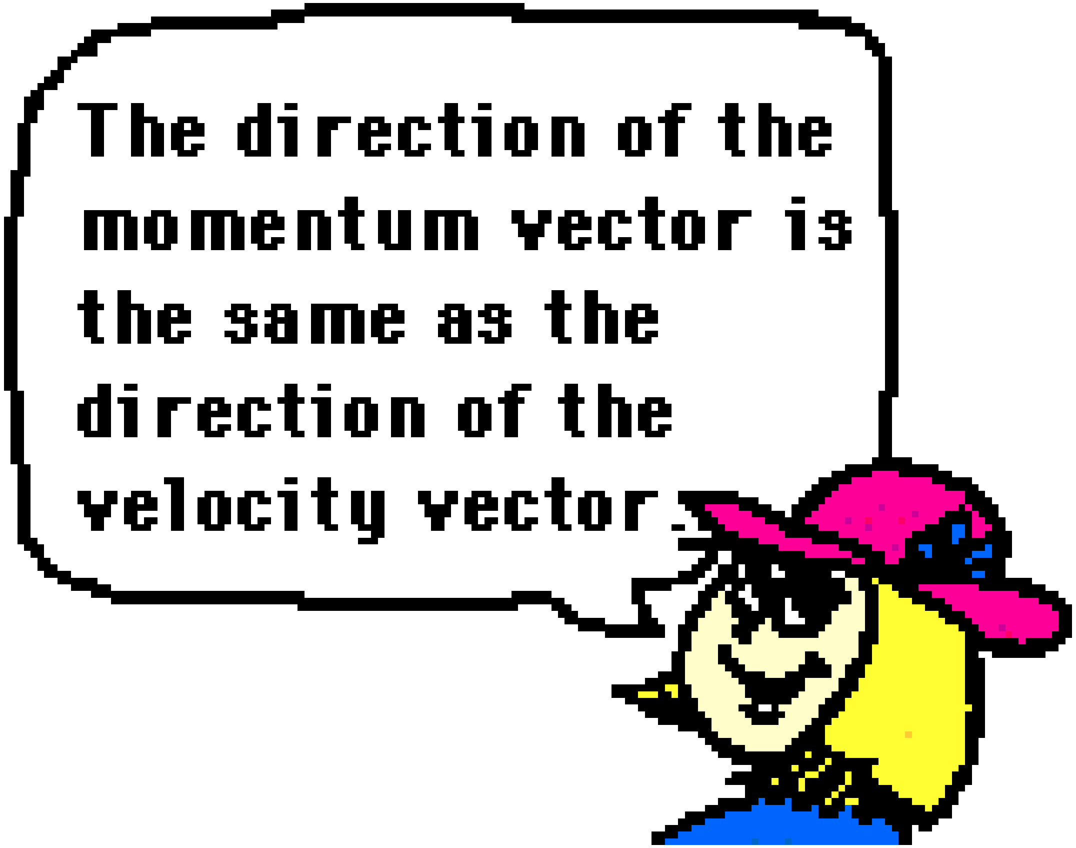
- The equation or momentum is

- **Momentum = mass × velocity**
-

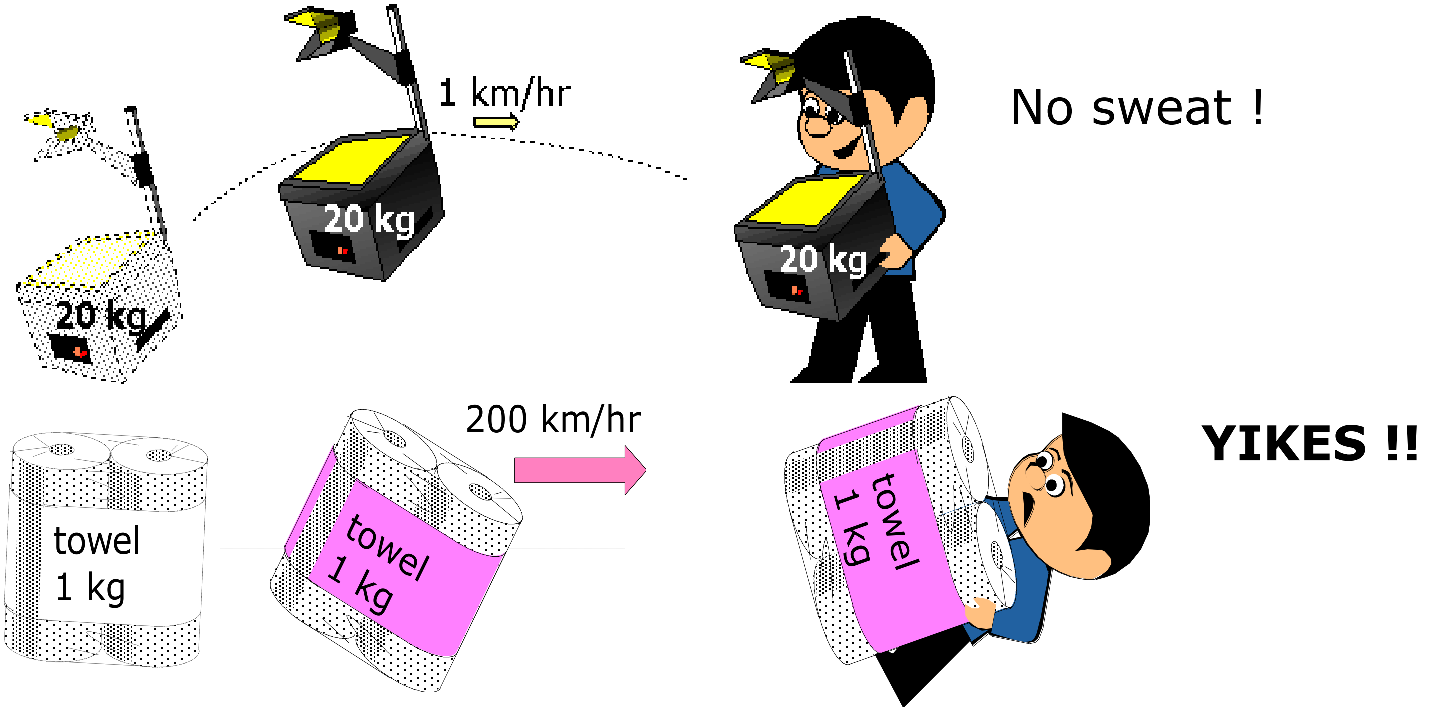
$$\vec{p} = m\vec{v}$$

The unit for momentum is kg*m/s

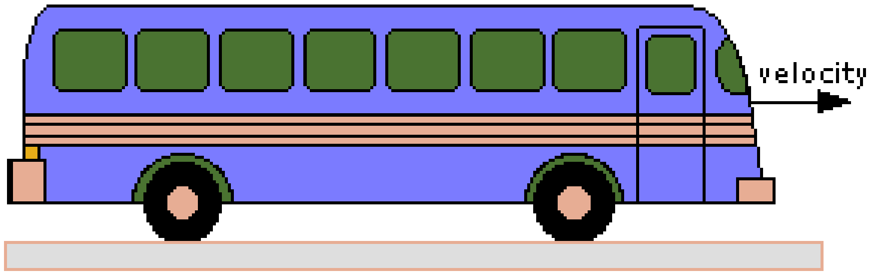
- **Momentum is a vector quantity.**



From the definition of momentum, it becomes obvious that an object has a large momentum if either its mass or its velocity is large. Both variables are of equal importance in determining the momentum of an object.



A bus can have a **large momentum** even if it is moving very slowly, because it has a **large mass.**

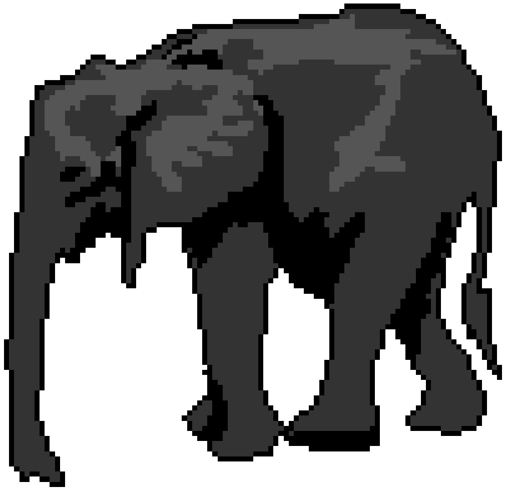


(**mass**)(velocity) = **momentum**

A bullet can have a **large momentum** even if it has a small mass, because it is moving at **high velocity**.

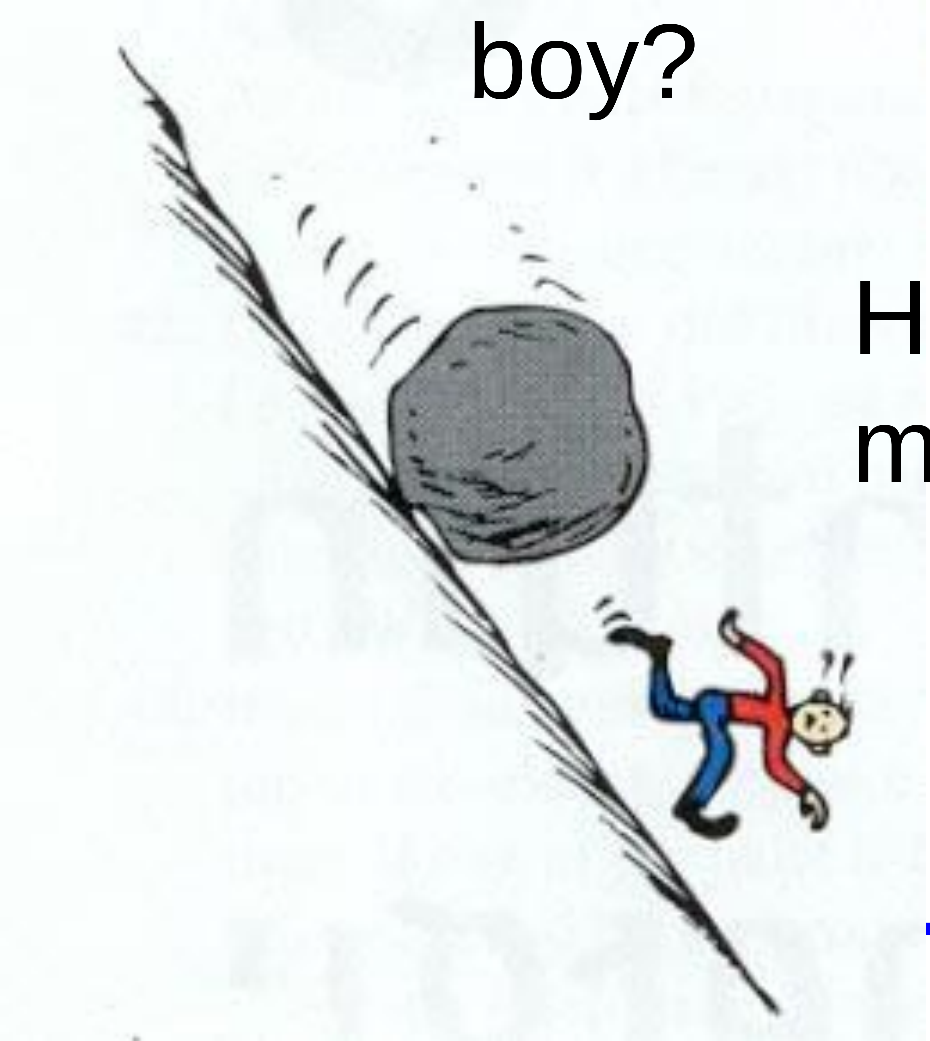
(mass)(**velocity**) = **momentum**

If an object is **at rest**, it has **no momentum** - no matter how large its mass. Momentum is not the same as inertia.



momentum = (**mass**)(0) = 0

If the boulder and the boy have the same momentum, will the boulder crush the boy?



Hint: think about the momentum formula!

$$p = mv$$

Example 1:

What is the momentum of a 2000 kg car that has a velocity of 12.8 m/s [E]

Example 2:

What is the velocity of a 50.0 g bullet that has a momentum of 24.74kg m/s [N]?

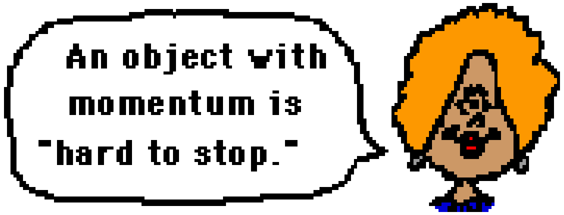
Example 3:

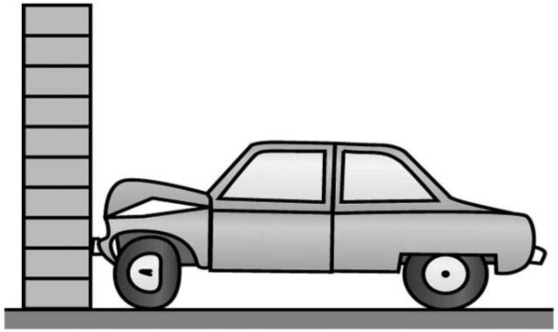
Which has the greater momentum: a 5000 kg truck traveling at 85 km/hr, or a 25 g bullet traveling at 325 m/s?

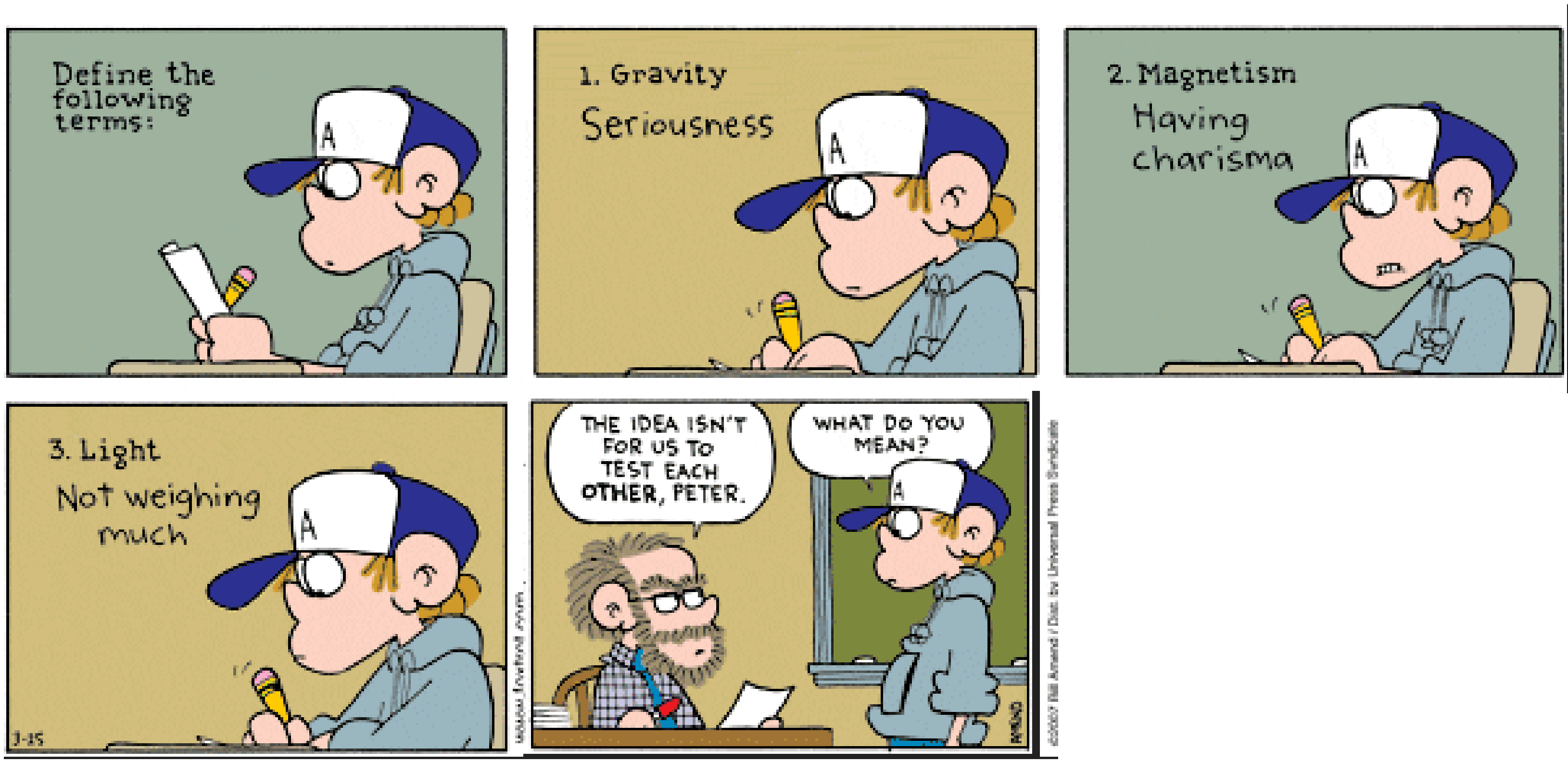
Example 4

What must be the velocity of a 1200 kg car (in km/hr) in order that it have the same momentum as a 15 kg meteor traveling at 1000 m/s? (Both motions are directed to the right).

Unit 2
Topic 11: Impulse



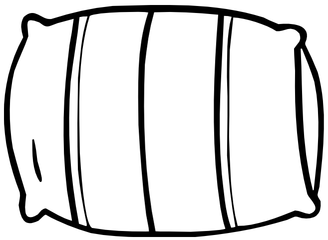



Define the following terms:
1. Gravity
Seriousness
2. Magnetism
Having charisma
3. Light
Not weighing much
THE IDEA ISN'T FOR US TO TEST EACH OTHER, PETER.
WHAT DO YOU MEAN?

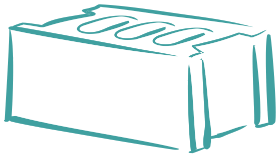
Question?

A. A 15 N Pillow, 1 m above man

B. A 15 N Brick, 1 m above man



- Same Weight
- Ignoring friction, both fall at same speed.
- Which is "better" to be hit with? Why?



Impulse

Impulse (J) **is defined as the product of the unbalanced or net force and the time that the force is acting.**

The equation for Impulse is :

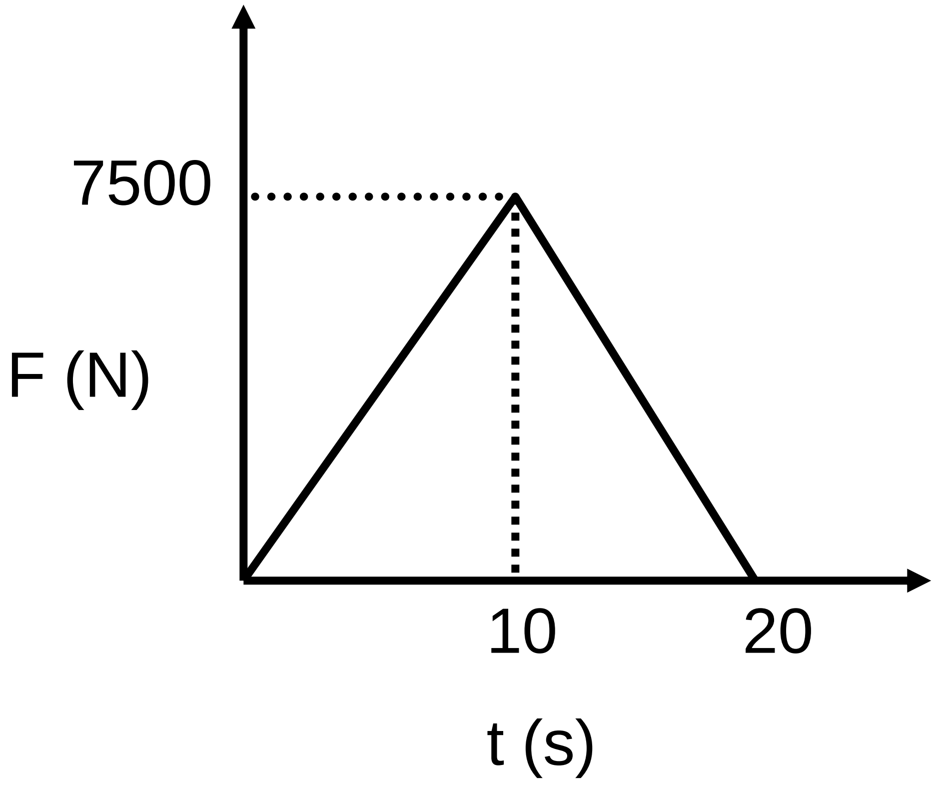
Impulse = Force x Time

$$\vec{J} = F \bullet \Delta t$$

The unit of impulse is newton-second [N s].

Impulse from an F vs t graph

- **Area under the curve**



- **Impulse = ΔF * t**
- **Find Area:**

= 2(1/2 *b*h)

= 2(1/2*10*7500)

= 75,000 N•s

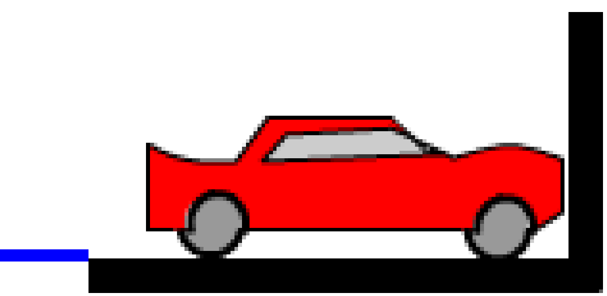
It turns out that having a net force is not enough to cause a change in the motion of an object. A net force must actually be present for some instant of time. A huge force acting for zero seconds accomplishes nothing. In fact, a small force acting for a long time can be as effective as a huge force acting for a short time.

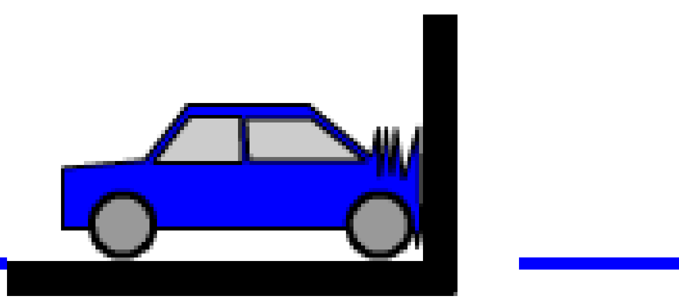
So, we see here that by **increasing the time of an impact** ("stopping time"), we **lessen the force of the impact** since the impulse is constant.

A. If a head-on impact was to occur, you will be safer in a modern car than in an older car.

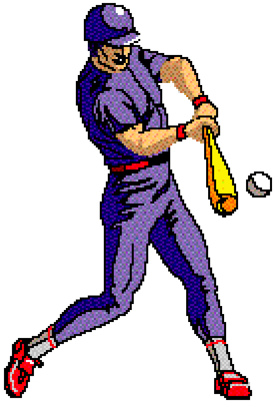
Older cars had a very stiff rigid construction. If an impact was to occur, it will **stop quickly** and a **large force** is transferred to the car and occupants.

A newer car is built with a "crumple zone" at the front of the car. On impact, the head of the car buckles and **lengthens the time for the car to stop**. This **reduces the force** on the car and occupants.





Example of Impulse



Follow through increases the time of collision and the impulse

Example 1:

- If the halfback experienced a force of 800 N for 0.9 seconds to the north, determine the impulse

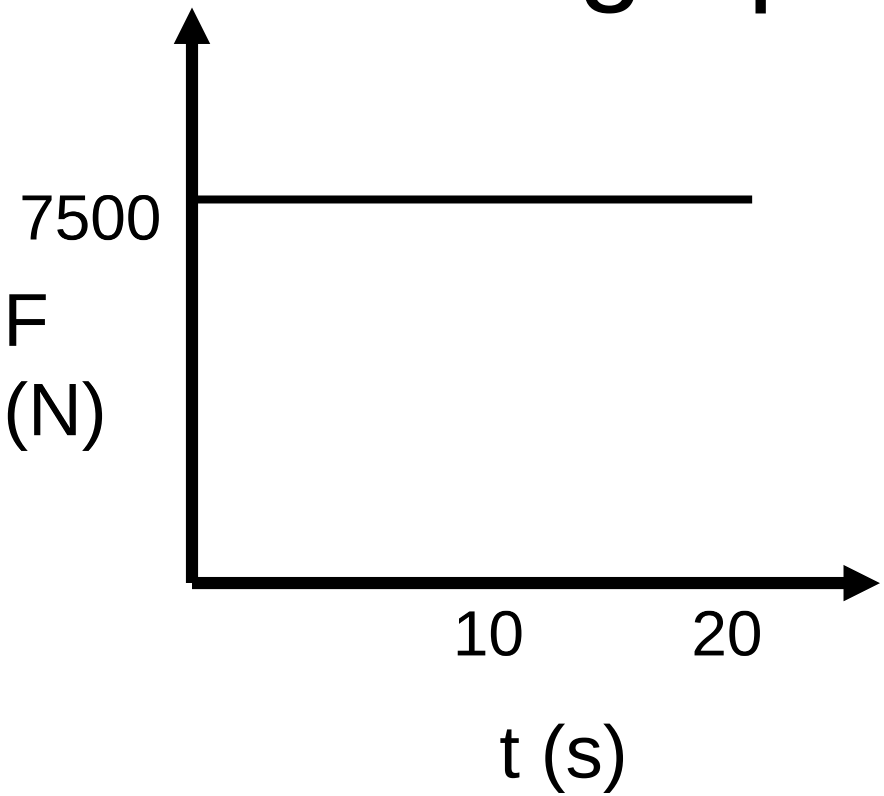
Example 2

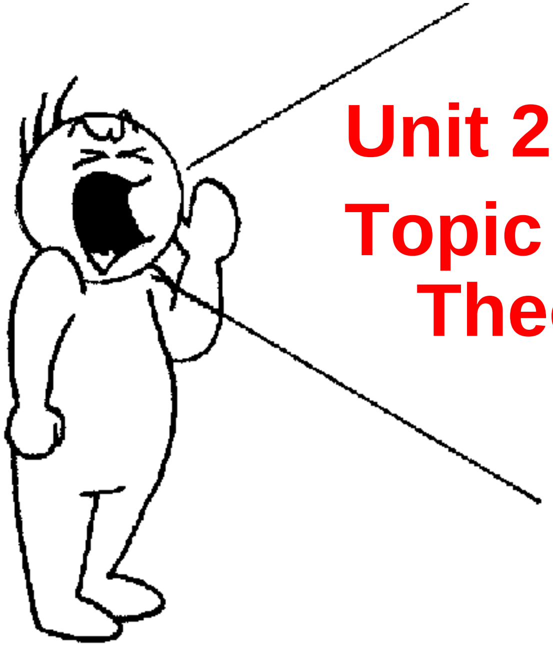
A 0.10 kg model rocket's engine is designed to deliver an impulse of 6.0 N*s. If the rocket engine burns for 0.75 s, what is the average force does the engine produce?

Example 3:

What was the impulse experienced by the object shown in the graph below?

F vs t graph



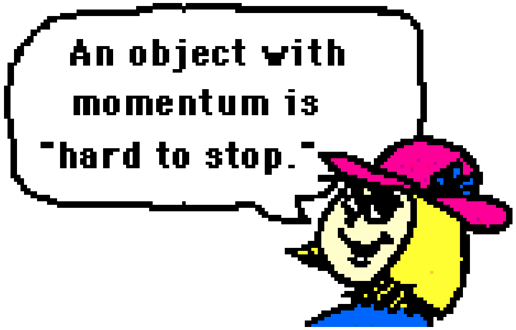


Unit 2

Topic 12: Impulse Momentum Theorem

In football, the defensive player applies a force for a given amount of time to stop the momentum of the offensive player with the ball.

In football, the defensive player applies a force for a given amount of time to stop the momentum of the offensive player with the ball.



An object with momentum is hard to stop. To stop such an object, it is necessary to apply a force against its motion for a given period of time. The more momentum which an object has, the harder that it is to stop. Thus, it would require a greater amount of force or a longer amount of time (or both) to bring an object with more momentum to a halt. 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.

The change in momentum of an object equals the impulse applied to it.

THE IMPULSE MOMENTUM THEOREM

- Newton's second Law states that

$$F=ma$$

- We know that $a = \frac{\Delta v}{\Delta t}$, substitute this into the above equation to get:

Multiple both sides by Δt

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

- mv is called momentum (p), so mΔv is the change in the momentum.
- **Therefore impulse is equal to the change in momentum.**
- **Note that a N ·s = Kg ·m/s**

The Many Forms Of The Impulse Momentum Theorem

The impulse momentum theorem can be expressed in many forms:

$$\vec{J} = \Delta \vec{p}$$

$$\vec{F} \bullet t = \vec{p}_2 - \vec{p}_1$$

$$\vec{F} \bullet t = m\vec{v}_2 - m\vec{v}_1$$

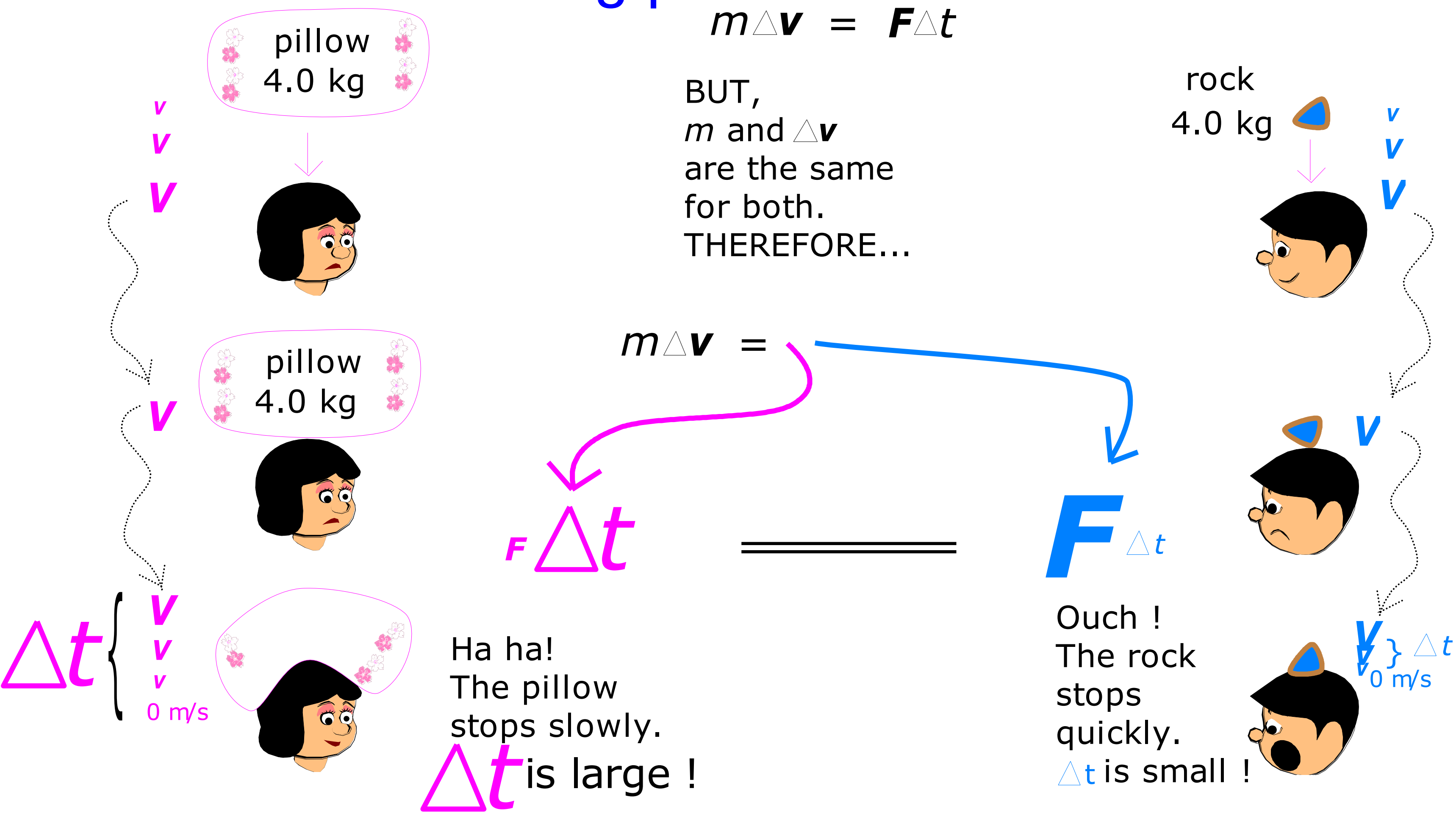
$$\vec{F} \bullet t = m\left(\vec{v}_2 - \vec{v}_1\right)$$

Understanding the Impulse –Momentum Theorem

A **short** interaction time or "time to stop"means a **large applied force**.

A **longer** interaction time or "time to stop" means a **smaller applied force**.

Question: If something was to be dropped on your head which would you choose, a 4.0kg rock or a 4.0 kg pillow?



Physics Of Jumping?

How should you jump?

Physics Of Shoes?

What Materials should be placed in shoes?

Physics Of Modern Day Cars?

Why are you safer in a modern day car for head – on collisions ?

Physics of Airbags

Why are airbags used in vehicles?

Physics of Cellphone Cases

Which cellphone cases works the best? Explain

Physics Of Goalie Pads

Why are goalie pads soft?

Physics Of Hockey Boards

Why are hockey boards design to move somewhat?

Zdeno Chara hit on Max Pacioretty

Physics Of A Helmet

Why do you use a helmet?

How Hockey Helmets Have Changed Over Time




Physics Of Wrestling

Why do guns have a recoil pad?

Physics Of Wrestling

Why does wrestling use mats?

Physics Of Guardrails

How do guardrails work?

Physics of a Runaway Truck Ramp?

The Physics Of Shocks?

Example 1

If the impulse on a 20 kg rock is 15.2 N·s, what is the change in momentum of the rock?

Example 2

A force of 500.0 N is applied to a stationary 50.0 kg toboggan for a time of 3.0 s. What is the final velocity of the toboggan? .

Example 3

If a force sensor indicates that your glove exerts a force of -52 N to stop a 190 g puck in 0.09 s, with what speed did the puck hit the glove?

$$\boldsymbol{F}\Delta t = m\Delta \boldsymbol{v}$$

$$\boldsymbol{F}\Delta t = m(\boldsymbol{v}_2 - \boldsymbol{v}_1)$$

$$\boldsymbol{F}\Delta t = m(0.0\,\text{m/s} - \boldsymbol{v}_1)$$

$$\boldsymbol{F}\Delta t = -m\boldsymbol{v}_1$$

$$\boldsymbol{v}_1 = -\frac{\boldsymbol{F}\Delta t}{m}$$

$$= -\frac{-52\,\text{N x } 0.09\,\text{s}}{0.19\,\text{kg}}$$

$$= 25\,\frac{\text{N}\,\text{s}}{\text{kg}} = 25\,\frac{\left(\text{kg}\;\frac{\text{m}}{\text{s}^2}\right)\text{s}}{kg}$$

$$= 25\,\text{m/s}$$

Example 4

If a 180 g hockey puck hits your glove at 75 km/hr and stops in 0.1 s, what average force does the puck exert on the glove?

Example 5:

- Why it is easier to drive a nail with a steel hammer than with a rubber mallet?

  Assume that both hammers have the same mass, m and are traveling with the same velocity, v. Therefore, after they both strike the nail and come to a stop, the change in momentum, $\Delta p = m\Delta v$, is the same for both.

ANSWER

The Impulse ($F\Delta t$) is the same for both hammer and mallet, where Δt is the time that the hammer and mallet are in contact with the nail as the nail is driven into the wood.

There is no doubt that Δt for the hammer is much smaller than Δt for the mallet. In other words, the soft mallet conforms to the shape of the nail and takes a longer time to stop. We can write Δt (hammer) < Δt (rubber mallet). Don't forget that the product $F\Delta t$ is the same for both hammer and mallet. This can be the case only if F(hammer) > F(mallet)

Example 6:

Would you rather be in a head on collision with an identical car, traveling at the same speed as you, or a brick wall?

Assume in both situations you come to a complete stop.

Take a guess

Everyone should vote now

Raise **one** finger if you think it is better to hit another car, **two** if it's better to hit a wall and **three** if it doesn't matter.

And the answer is…..

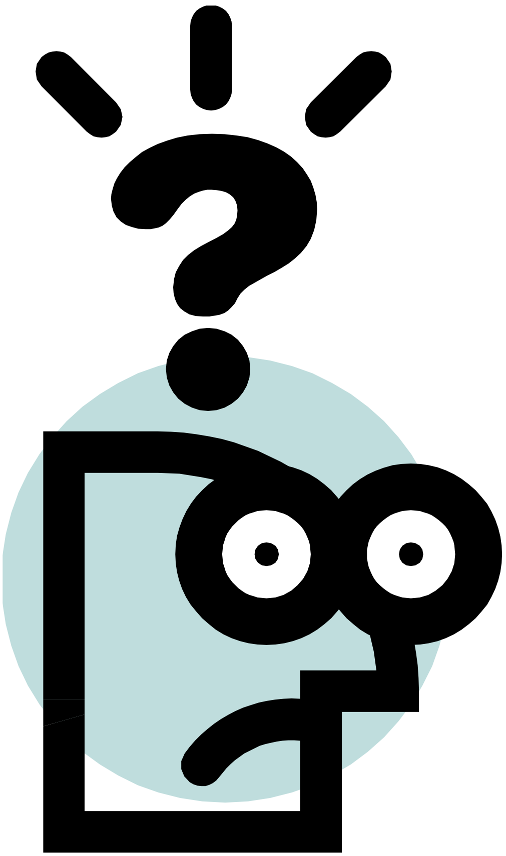
ANSWER

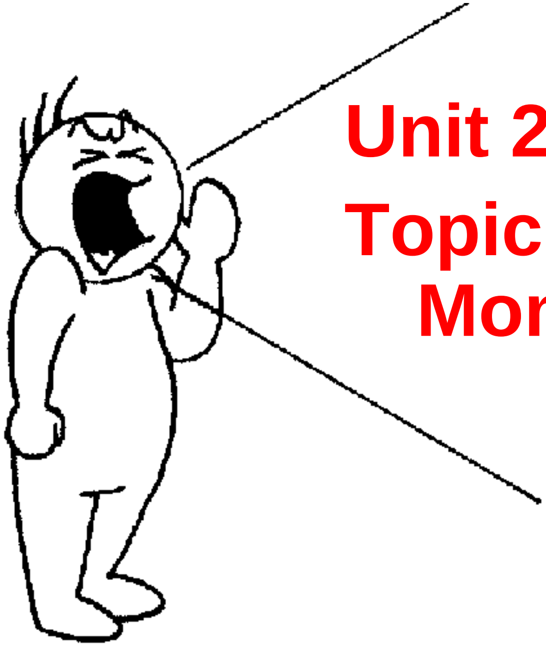
The answer is…

It Does Not Matter!

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

In both situations, Δt, m, and Δv are the same! The time it takes you to stop depends on your car, m is the mass of your car, and Δv depends on how fast you were initially traveling.





Unit 2

Topic 13: Law of Conservation of Linear Momentum

Remembering Momentum

Momentum is dependent upon two variables:

Mass of the object (kg)
How fast the object is moving (m /s).

Recall that momentum of an object is an object's *quantity of motion*. It is calculated as :

$$\vec{p} = m\vec{v}$$

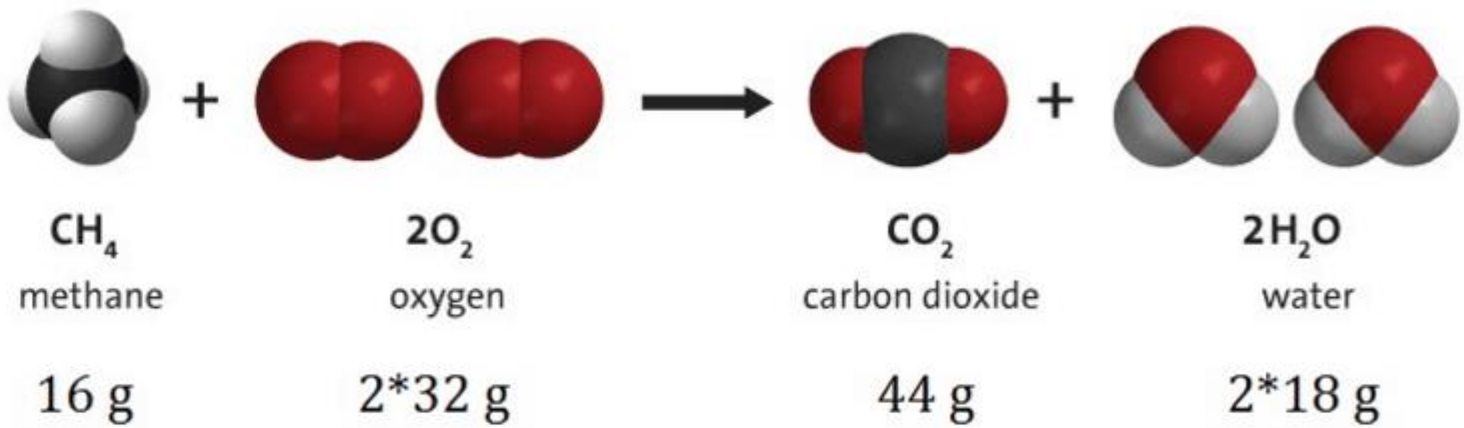
The unit for momentum is kg*m/s

What Is The Meaning Of Conservation ?

The word "conserved" means essentially the same as "constant."

In an isolated system some quantity will have same value before and after some process occurs.   It can not be lost or gained but transformed.

For example: Conservation Of Mass



CONSERVATION OF MOMENTUM

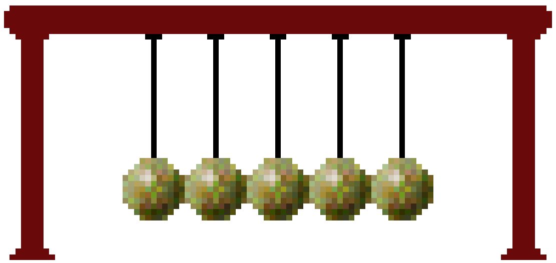
- **The Law Of Conversation states** that the total momentum of all parts of a system before an interaction equals the total momentum after, if no external unbalanced force acts on the system.

Total Momentum Before = Total Momentum After

$$p_T = p_T'$$

$$p_1 + p_2 = p_1' + p_2'$$

$$m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2'$$

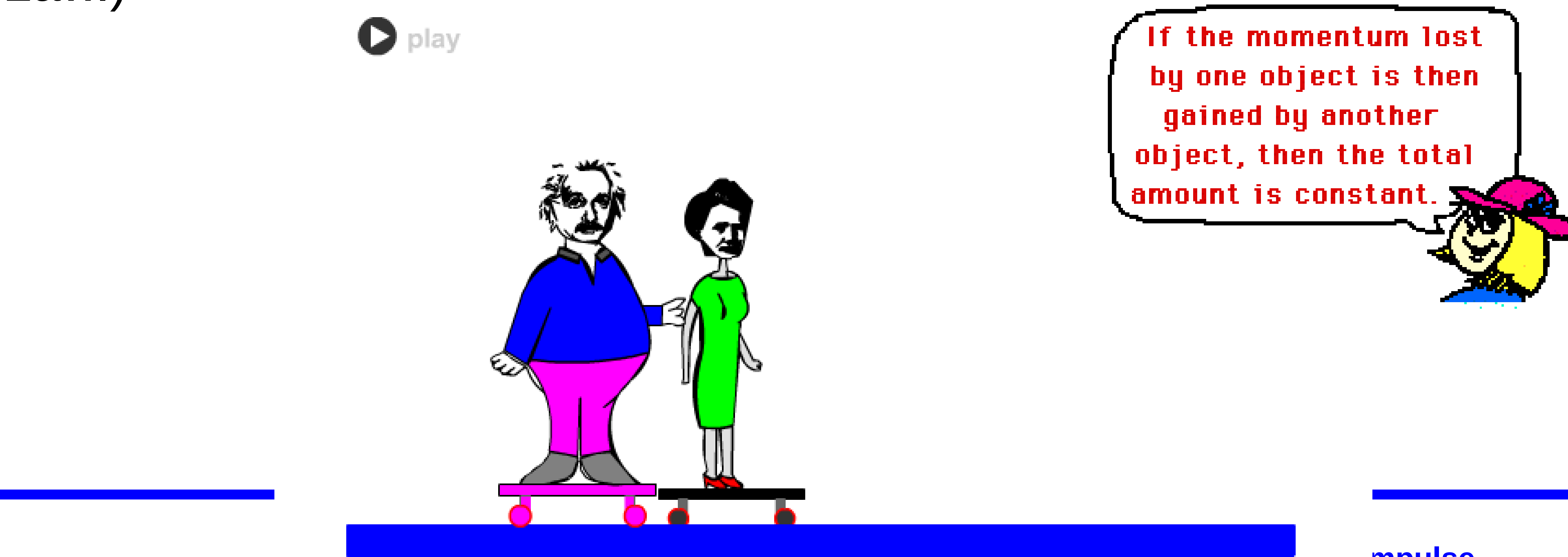


CONSERVATION OF MOMENTUM

Mr. Big (m_B = 100 kg) has a mass twice that of Ms. Small (m_S = 50 kg)

and Two people are an isolated system since there is no net external force acting on them. (No Friction)

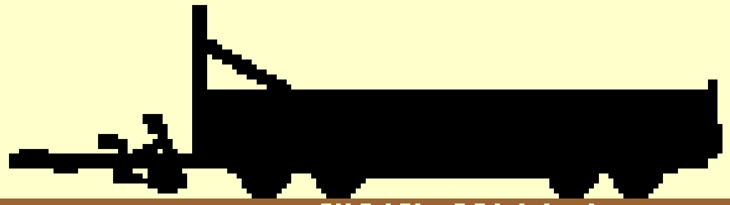
Mr. Big pushes Ms. Small, which, of course, means that Ms. Small pushes Mr. Big with the same but opposite force (Newton's Third Law.)



mpulse

Diesel	
Vel. (km/hr)	5
Mom. (kg km/hr)	40 000

Flatcar	
Vel. (km/hr)	0
Mom. (kg km/hr)	0

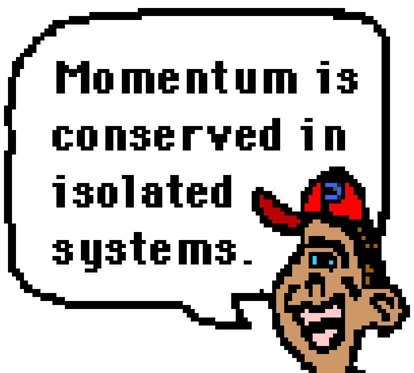


3 Types Of Momentum Conservation Situations

1. INELASTIC -“Hit and Stick” – Two objects (one or both may be moving) hit and stick together. After collision, they move as one object –

2. ELASTIC “Hit and Rebound” – Two objects (one or both may be moving) hit and bounce or rebound after impact –

3.EXPLOSION – Two objects, both initially at rest, move off in opposite directions.



Elastic Collision

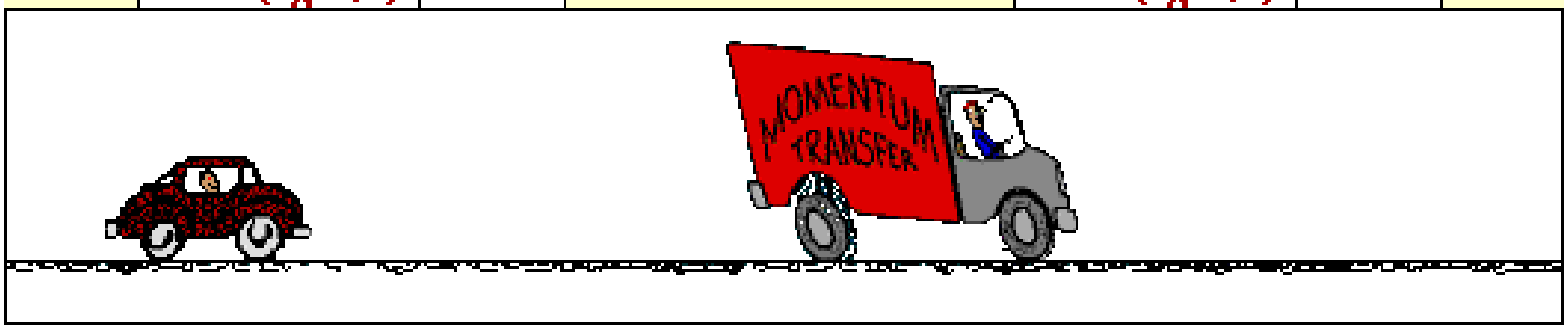
- is one in which the objects rebound after the collision

Car

mass (kg)	1000
vel. (m/s)	20.0
mom. (kg m/s)	20 000

Truck

mass (kg)	3000
vel. (m/s)	0.0
mom. (kg m/s)	0

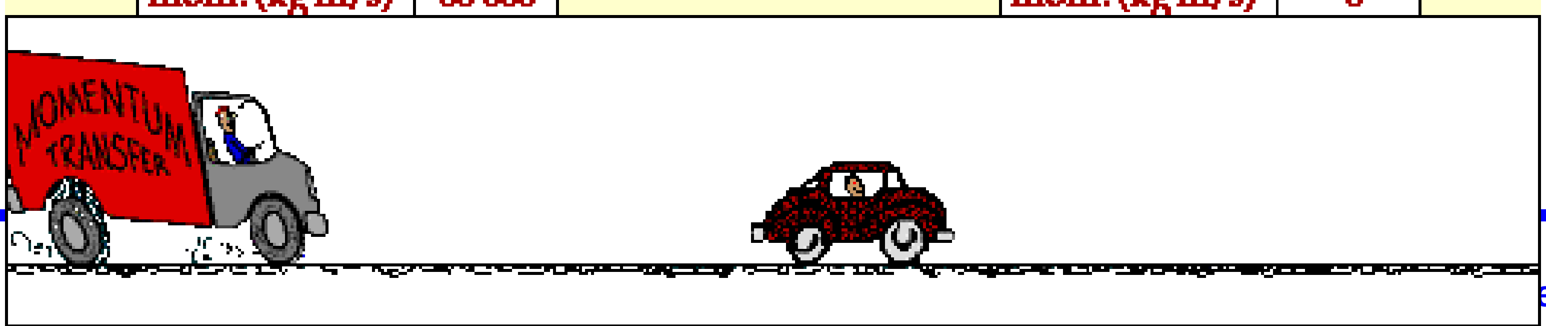


Truck

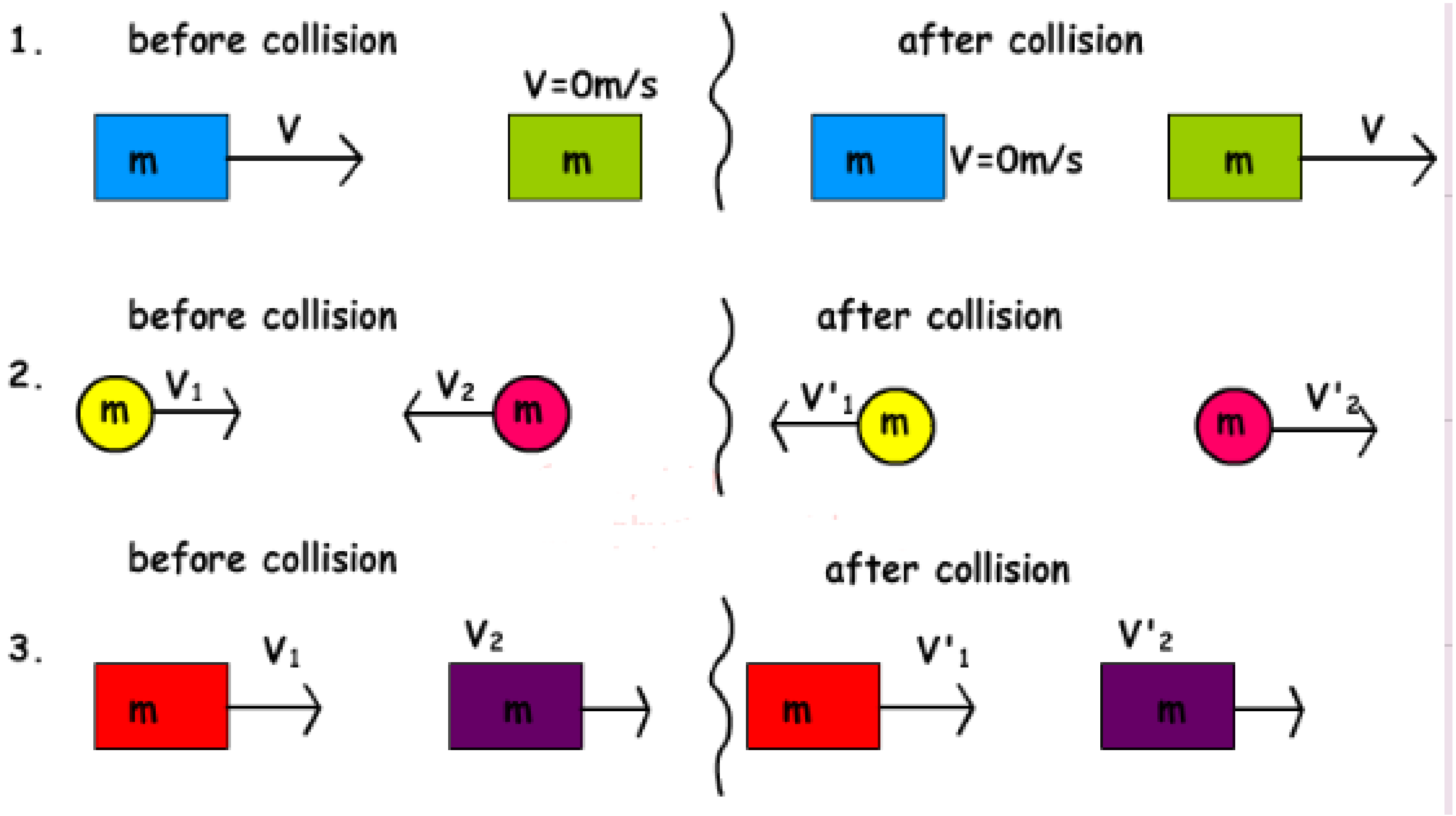
mass (kg)	3000
vel. (m/s)	20.0
mom. (kg m/s)	60 000

Car

mass (kg)	1000
vel. (m/s)	0.0
mom. (kg m/s)	0



Types Of Elastic Collisions



Example 1:

Your small bumper car (m = 100 kg) has a velocity of 6 m/s and collides head-on with a large stationary bumper car (m = 500 kg). It turns out that, after the collision, the large bumper car moves back with a velocity of v = 2 m/s.

A) What is the total momentum of the two-car-system before the collision?

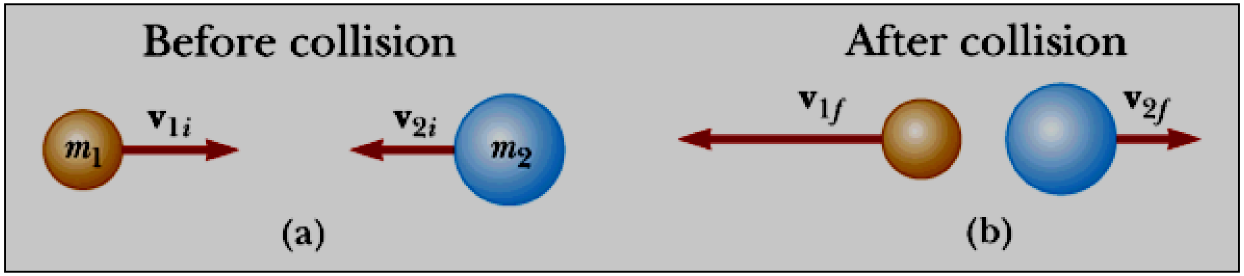
B) What is it after the collision?

C) What is the large car's momentum after the collision?

D) With what velocity do you move after the collision?

Example 2 :

A 1.0 kg ball, moving to the right at 10.0 m/s collides with a 1.5 kg ball moving to the left at 8.0 m/s. The 1.0 kg ball rebounds to the left at 11.0 m/s. What is the velocity of the 1.5 kg ball after the collision?

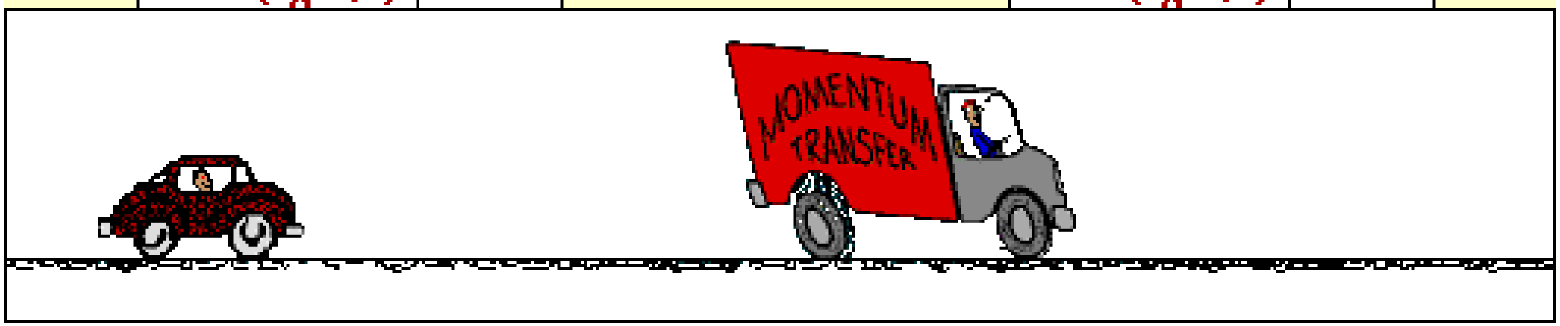


Inelastic Collision

- collision is one in which the objects stick together after the collision

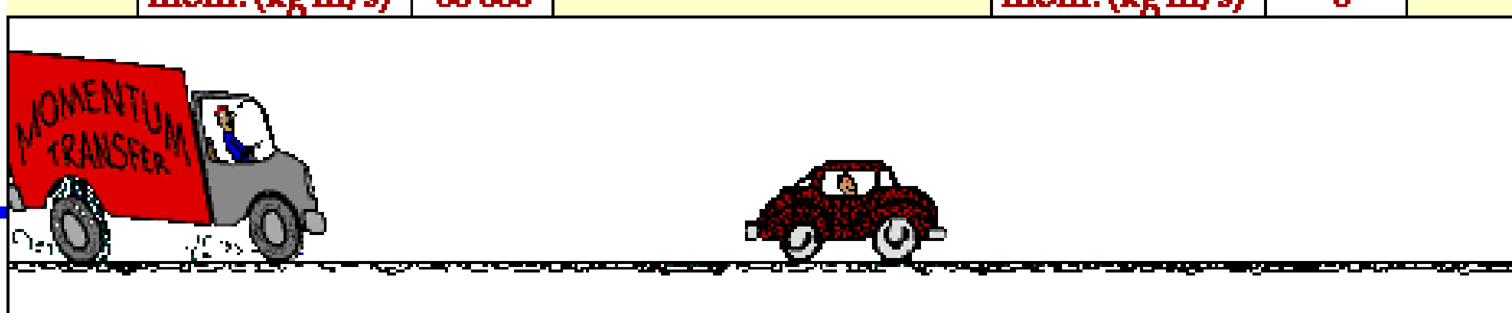
Car	
mass (kg)	1000
vel. (m/s)	20.0
mom. (kg m/s)	20 000

Truck	
mass (kg)	3000
vel. (m/s)	0.0
mom. (kg m/s)	0

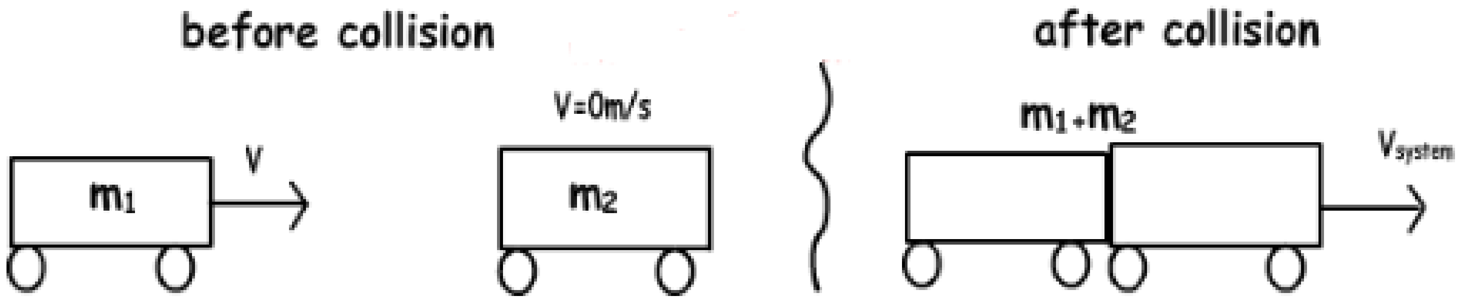


Truck	
mass (kg)	3000
vel. (m/s)	20.0
mom. (kg m/s)	60 000

Car	
mass (kg)	1000
vel. (m/s)	0.0
mom. (kg m/s)	0

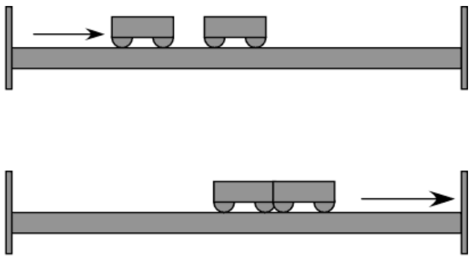


Types Of Inelastic Collisions



Example 3:

A dynamics cart A with a mass of 1.0 kg is moving to the right at 3.0 m/s. It collides with and sticks to, stationary dynamics cart B with a mass of 2.0 kg. After the collision the two carts move off to the right at 1.0 m/s.



A) What is the momentum of cart A before the collision?

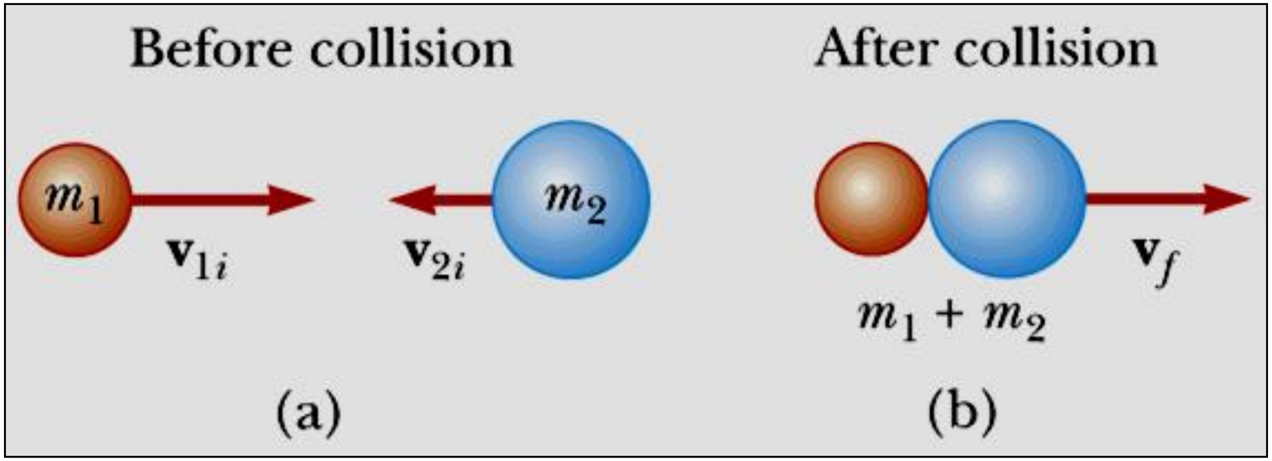
B)What is the momentum of cart B before the collision?

C)What is the total momentum before the collision?

D)After the collision the carts can be considered as ONE cart with a combined mass of 3.0 kg. What is the momentum after the collision?

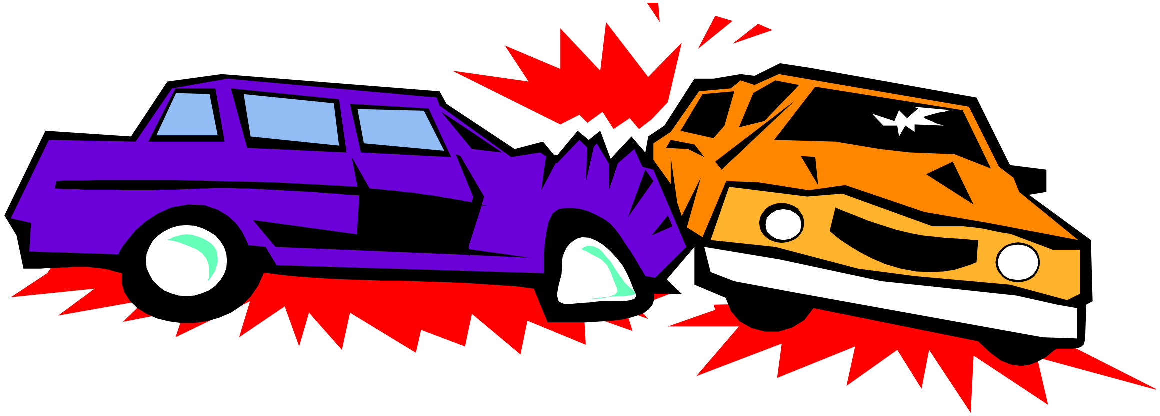
Example 4:

Ball 1, with a mass of 1.5 kg is moving right at 3.0 m/s. It collides with ball 2, which is moving left at 2.0 m/s and has a mass of 1.8 kg. If the two balls stick together after impact, what will be the velocity of the combined masses after impact?



Question

Would a head-on collision between two cars be more damaging to the occupants if the cars stick together or if the cars rebound upon impact?



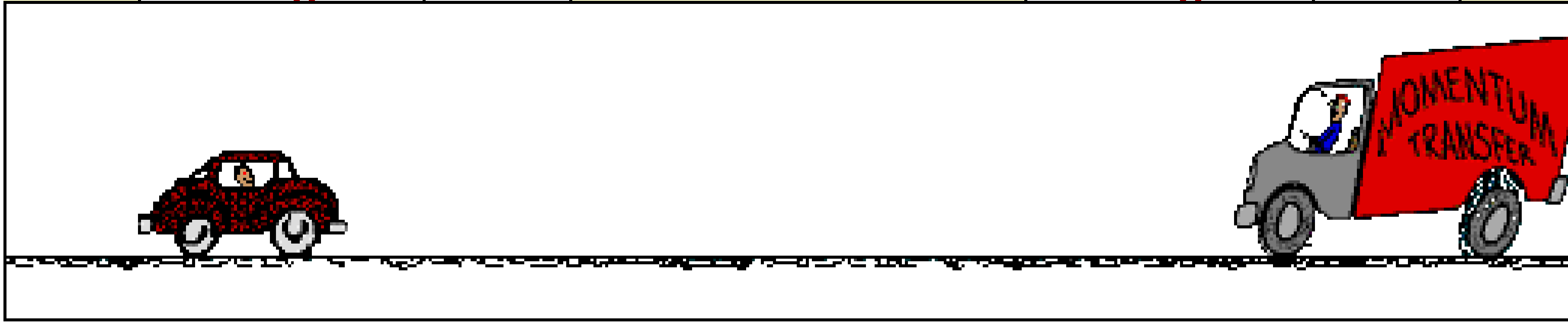
inelastic

Car

mass (kg)	1000
vel. (m/s)	20.0
mom. (kg m/s)	20 000

Truck

mass (kg)	3000
vel. (m/s)	-20.0
mom. (kg m/s)	-60 000



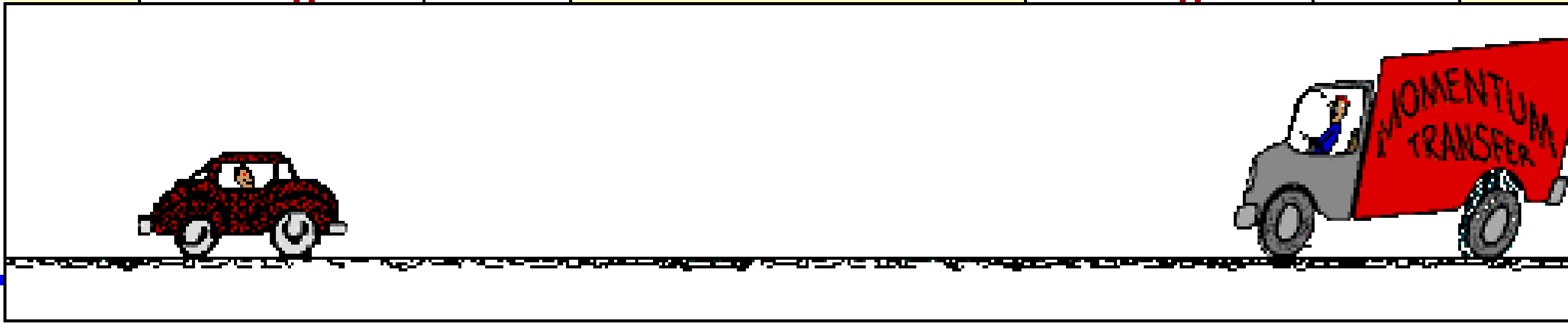
elastic

Car

mass (kg)	1000
vel. (m/s)	20.0
mom. (kg m/s)	20 000

Truck

mass (kg)	3000
vel. (m/s)	-20.0
mom. (kg m/s)	-60 000



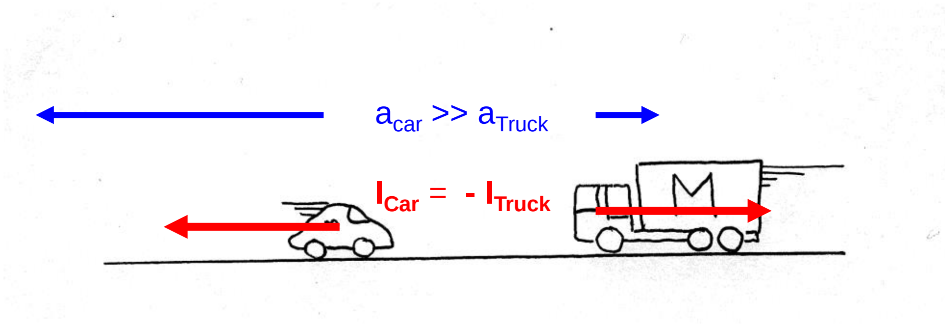
Summary of Impulse and Conservation of Momentum

According to Newton's third law when two object interact $F_A = - F_B$

Because the two objects interact for the same period of time $F_A \Delta t = - F_B \Delta t$

This can be written in terms of impulse as…. $I_A = - I_B$

Written in terms of changes in momentum…. $\Delta p_A = - \Delta p_B$



A massive truck and a small car are involved in a collision. Which object has the largest I) impulse ii) change in momentum iii) acceleration during the collision?

$I_{Car} = - I_{Truck}$

i) Both vehicles have the same impulse acting on them but in opposite directions

$m_{Car} \Delta \mathbf{v}_{Car} = M_{Truck} \Delta \mathbf{v}_{Truck}$

ii) Both vehicles have the same change in momentum but in opposite directions

iii) The change in velocity of the car is greater than the change in velocity of the truck because of its smaller inertia (mass). The car's acceleration is therefore greater than the truck's acceleration. The car's passengers would therefore feel the acceleration more than the truck driver.

PHYSICS OF KARATE

- Complete the following STSE