Momentum and Impulse

Momentum in Sports

- Momentum is a commonly used term in sports.
- A team that has a lot of momentum is really on the move and is going to be hard to stop.
- Momentum is a physics term; it refers to the quantity of motion that an object has.

Momentum Defined

Momentum is defined as the quantity of motion that an object has.

Momentum Defined

- The amount of momentum which an object has is dependent upon two variables: mass and velocity
- Momentum is a vector quantity.

Momentum Defined

$$\boxed{p = mv}$$

p = momentum

m = mass

v = velocity

The units for momentum are the kgm/s.

We will use POMS for the units- particles of momentum

Check your understanding

Determine the momentum of a ...

A. 60-kg halfback moving eastward at 9 m/s.

B. 1000-kg car moving northward at 20 m/s.

C. 40-kg student moving southward at 2 m/s.

Answers

A. 540 kgm/s East
B. 20,000 kgm/s North
C. 80 kgm/s South

Impulse

The more momentum which an object has, the harder that it is to stop.

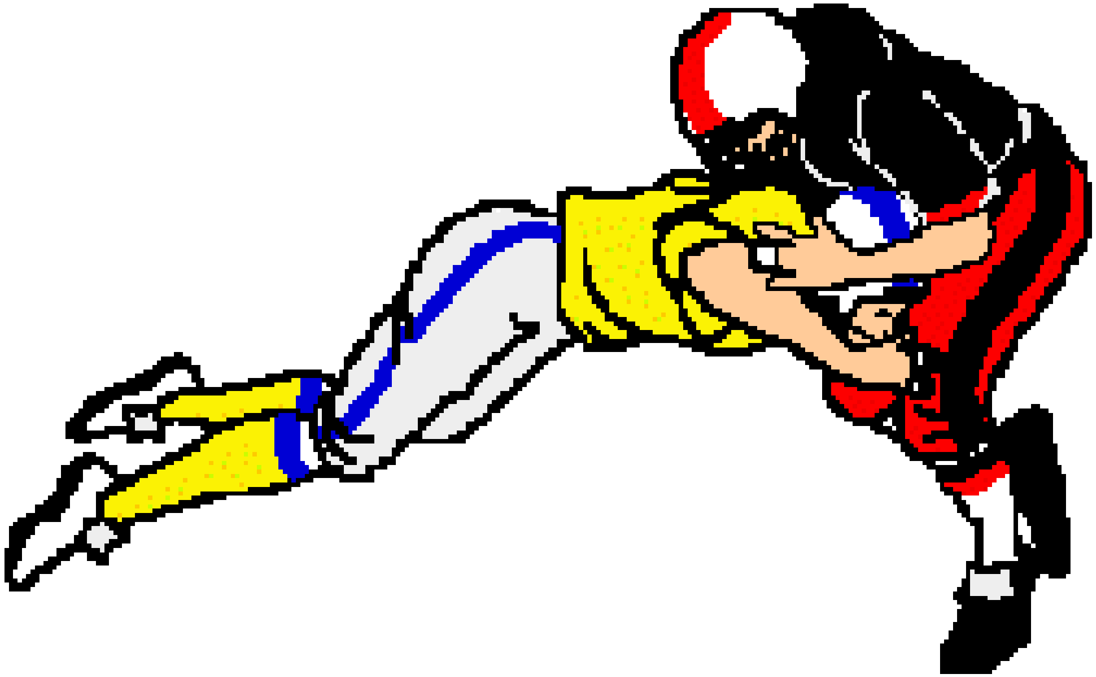
Impulse

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.

Impulse

- An object with momentum can be stopped if a force is applied against it for a given amount of time.

Impulse



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.

Impulse

In a collision, an object experiences a force for a specific amount of time which results in a change in momentum (the object's mass either speeds up or slows down).

The **impulse** experienced by the object equals the change in momentum of the object.

Impulse Equation

$$\text{Impulse} = \text{change in momentum} = \text{J}$$

$$\text{J} = \Delta p = mv_2 - mv_1$$

$$or$$

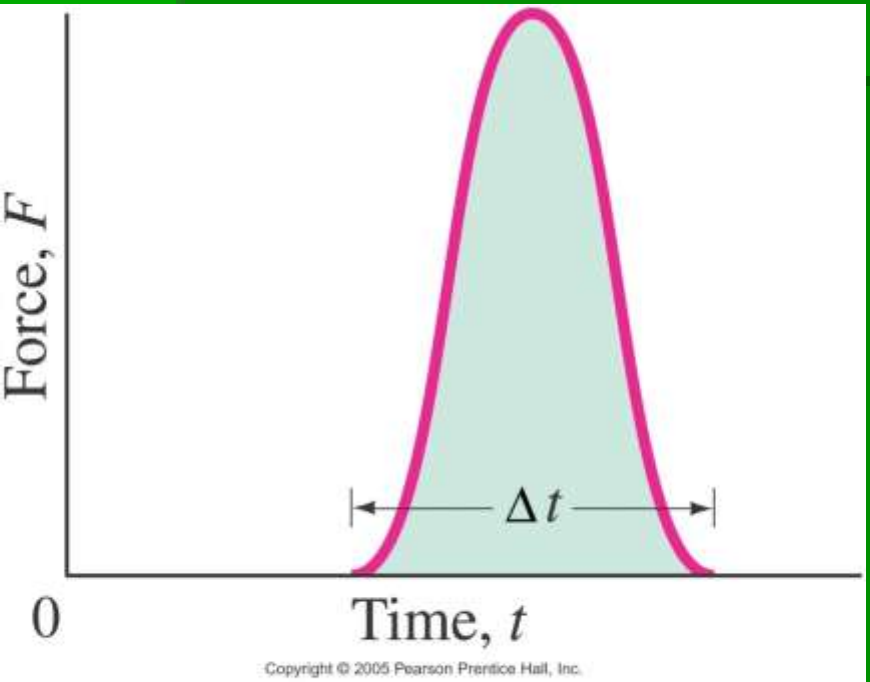
$$\text{J} = Ft$$

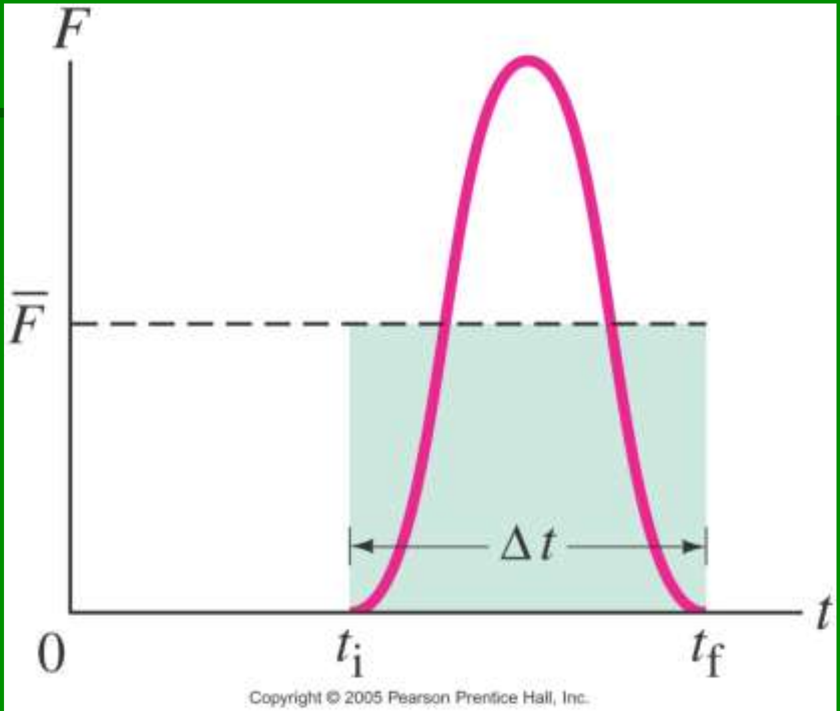
The units for impulse are the kgm/s or Ns or POMS.

We will use POMS for the units- particles of momentum

Collisions and Impulse

Since the time of the collision is very short, we need not worry about the exact time dependence of the force, and can use the average force.





Impulse

If the force acts opposite the object's motion, it slows the object down.

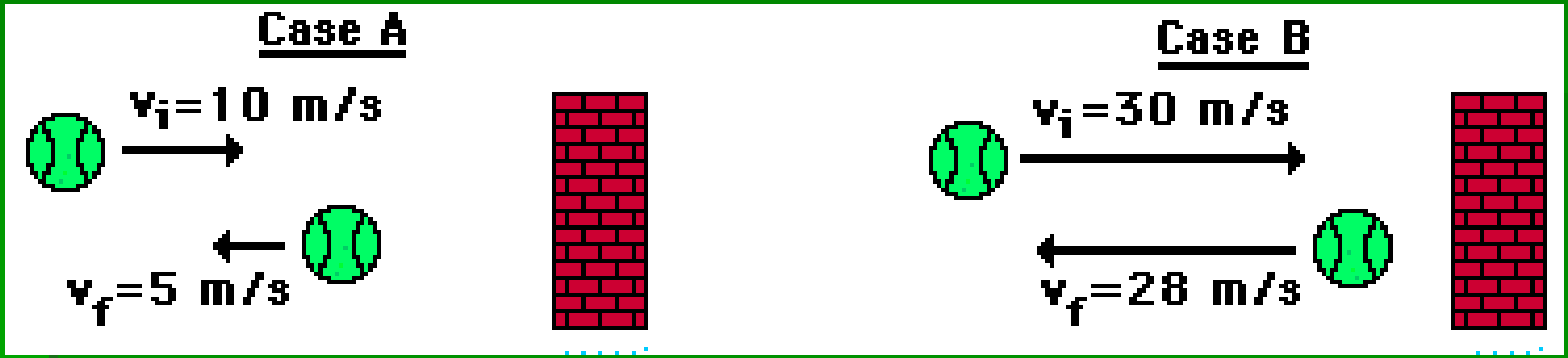
Impulse

If a force acts in the same direction as the object's motion, then the force speeds the object up.

Impulse

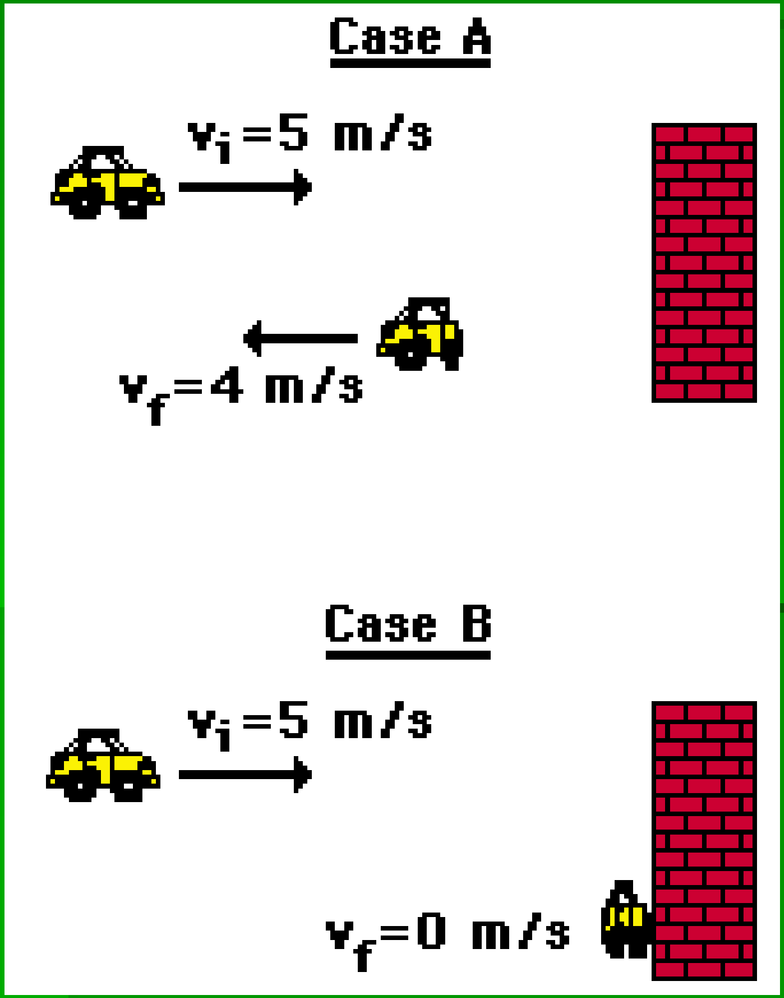
Either way, a force will change the velocity of an object. And if the velocity of the object is changed, then the momentum of the object is changed which is **impulse**.

Check your understanding



1. In which case (A or B) is the change in velocity the greatest?
2. In which case (A or B) is the change in momentum the greatest?
3. In which case (A or B) is the impulse the greatest?
4. In which case (A or B) is the force which acts upon the ball the greatest (assume contact times are the same in both cases)?

Check your understanding



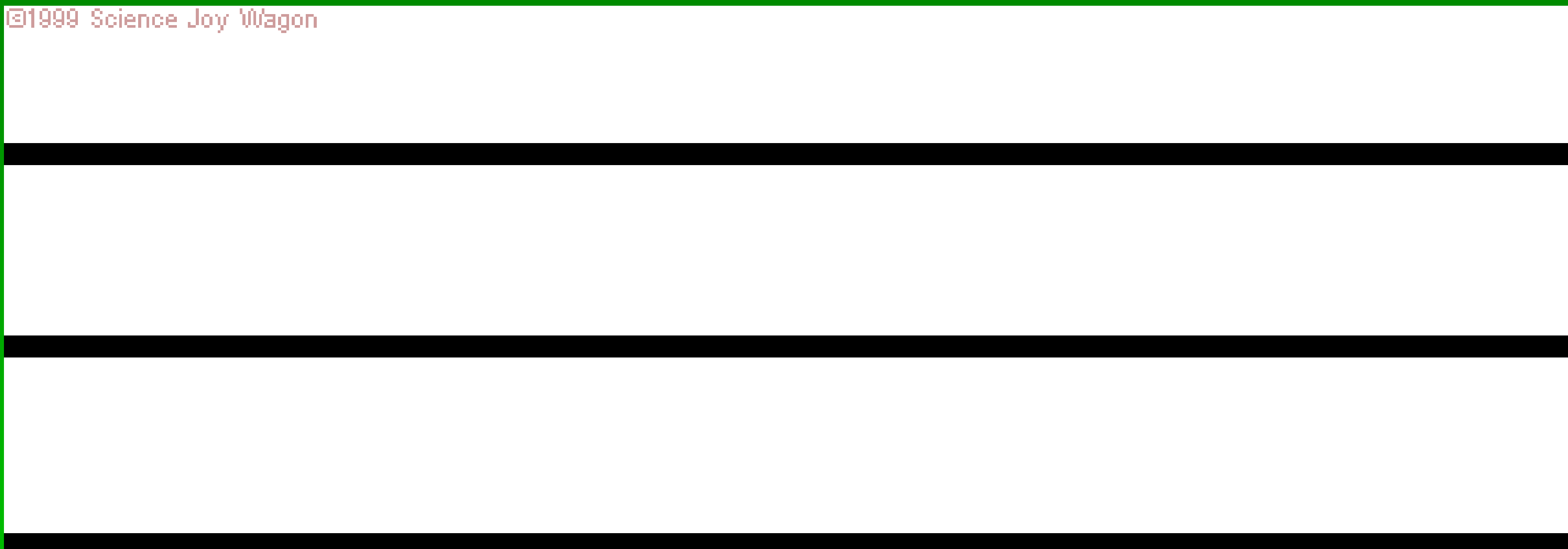
1. In which case (A or B) is the change in velocity the greatest?
2. In which case (A or B) is the change in momentum the greatest?
3. In which case (A or B) is the impulse the greatest?
4. In which case (A or B) is the force which acts upon the car the greatest (assume contact times are the same in both cases)?

Impulse

- The importance of the collision time in effecting the amount of force which an object experiences during a collision.

Force	Time	Impulse
100	1	100
50	2	100
25	4	100
10	10	100
4	25	100
2	50	100
1	100	100
0.1	1000	100

Examples



Each car experiences the same change in momentum (impulse) but over different time periods thus effecting the force being applied to them.

Examples

- To maximize the effect of the force on an object involved in a collision, the time must be decreased.
- Air bags are used in automobiles because they are able to minimize the effect of the force on an object involved in a collision.
- Air bags accomplish this by extending the time required to stop the momentum of the driver and passenger.

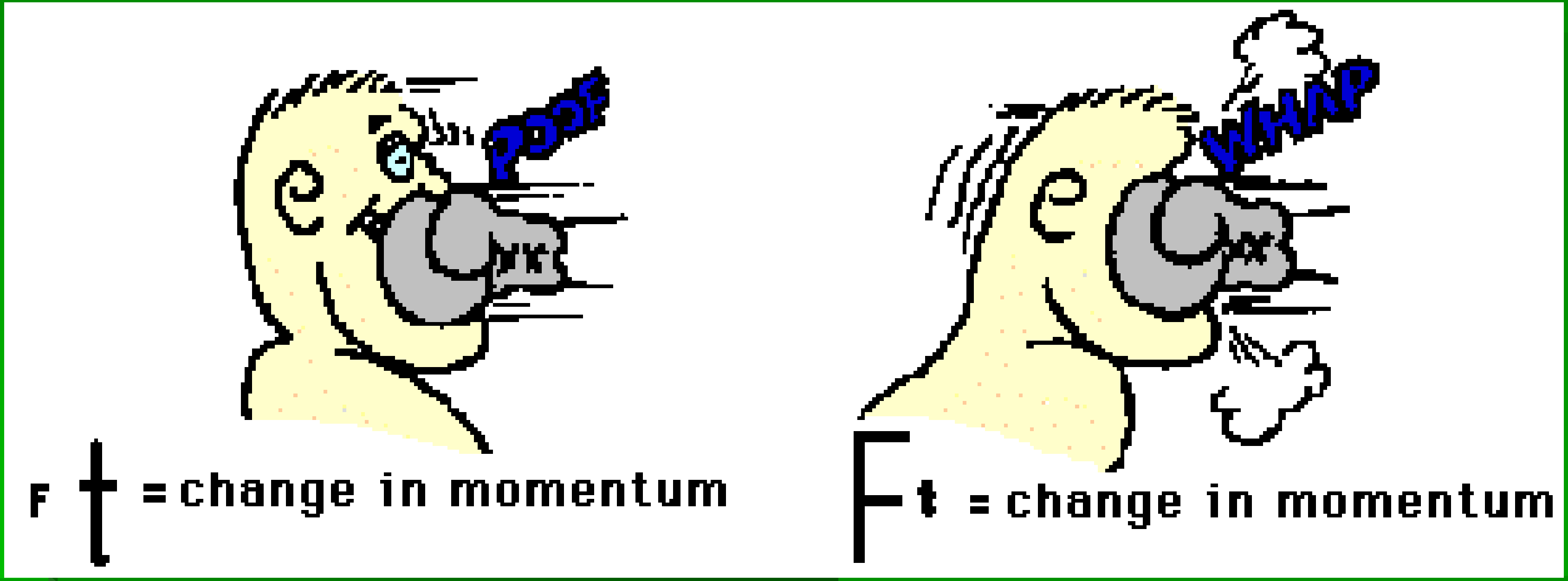
Examples

- This same principle of padding a potential impact area can be observed in gymnasiums
- Underneath the basketball hoops
- Pole-vaulting pits,
- Baseball gloves and goalie mitts
- Inside the helmet of a football player
- Gymnastic mats

Examples

- When a boxer recognizes that he will be hit in the head by his opponent, the boxer often relaxes his neck and allows his head to move backwards upon impact.
- In the boxing world, this is known as riding the punch.
- A boxer rides the punch in order to extend the time of impact of the glove with their head.
- Extending the time results in decreasing the force and thus minimizing the effect of the force in the collision.

Examples



Example

- In racket and bat sports, hitters are often encouraged to follow-through when striking a ball.
- High speed films of the collisions between bats/rackets and balls have shown that the act of following through serves to increase the time over which a collision occurs.
- The follow-through increases the time of collision and subsequently contributes to an increase in the velocity change of the ball.
- By following through, a hitter can hit the ball in such a way that it leaves the bat or racket with more velocity

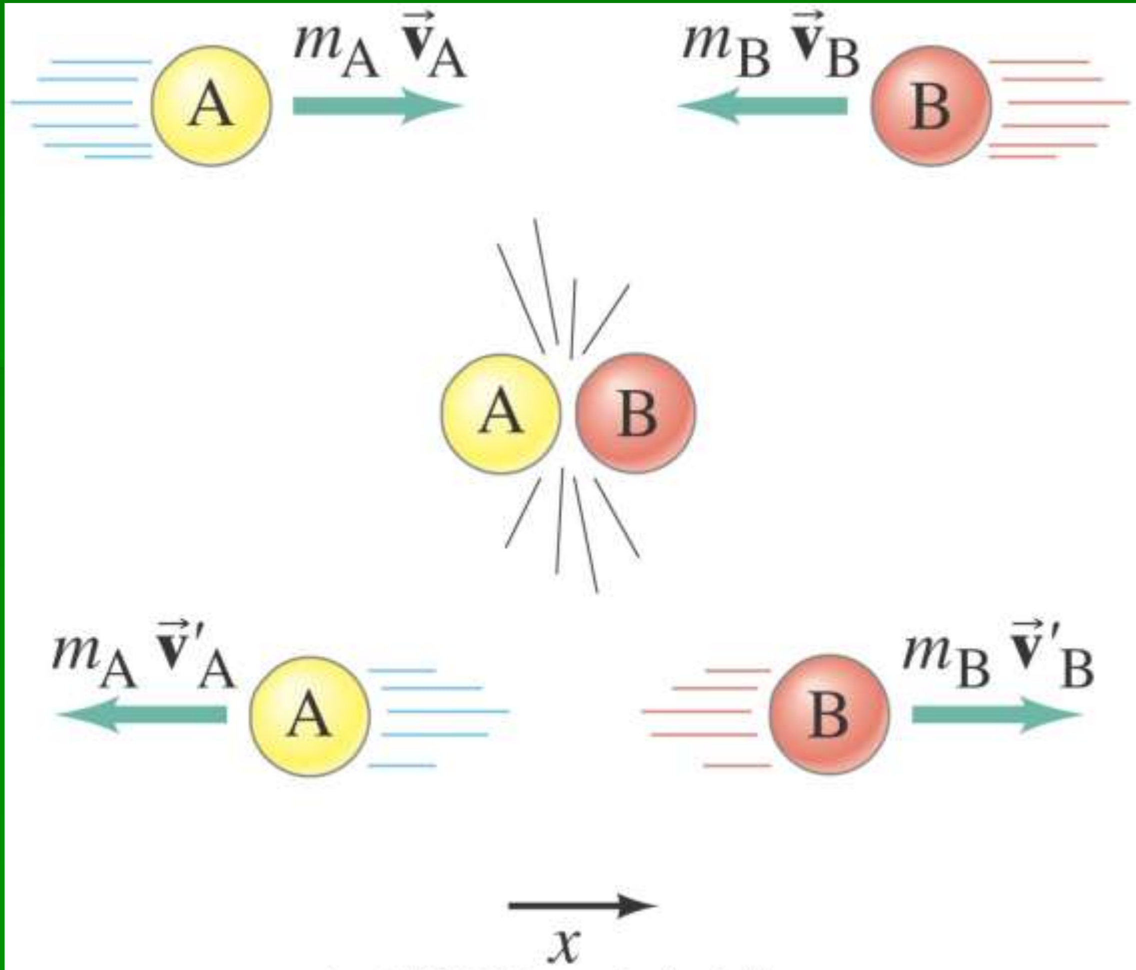
What is a “collision”

A collision is when two or more moving objects exert a force on each other.

In other words when things “collide” or crash into each other.

Conservation of Momentum

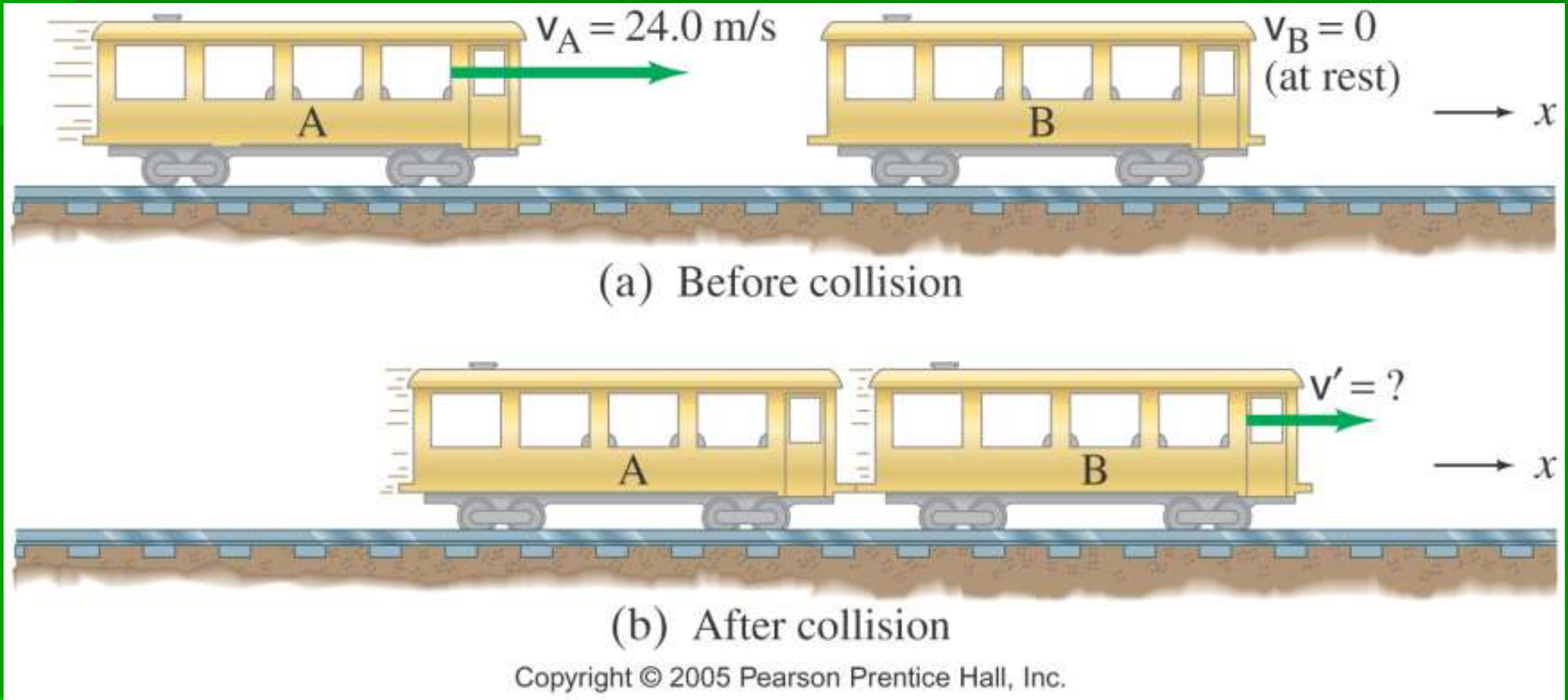
During a collision, measurements show that the total momentum does not change:



Conservation of Momentum

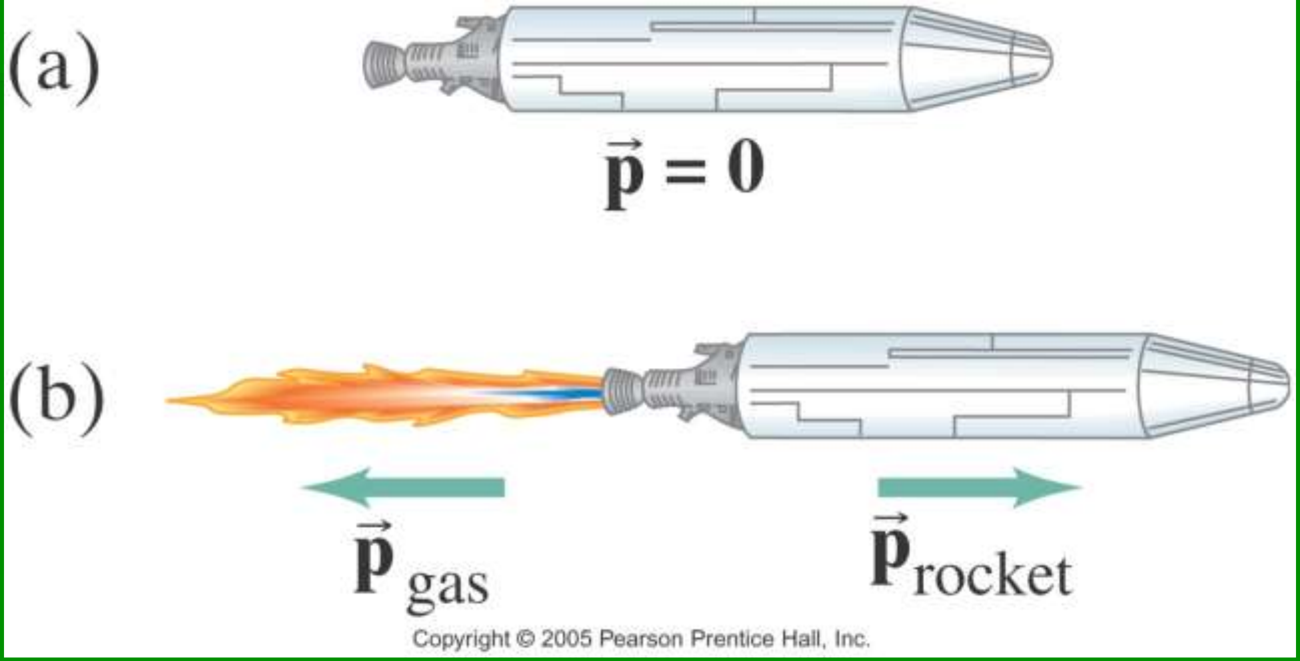
More formally, the law of conservation of momentum states:

The total momentum of an isolated system of objects remains constant.



Conservation of Momentum

Momentum conservation works for a rocket as long as we consider the rocket and its fuel to be one system, and account for the mass loss of the rocket.



Conservation of Momentum

Elastic Collisions

$$m_1 v_{i1} + m_2 v_{i2} = m_1 v_{f1} + m_2 v_{f2}$$

m_1= first mass (kg)
m_2= second mass (kg)
v_{i1}= initial velocity of first mass (m/s)
v_{i2}= initial velocity of second mass (m/s)
v_{f1}= final velocity of first mass (m/s)
v_{f2}= final velocity of second mass (m/s)

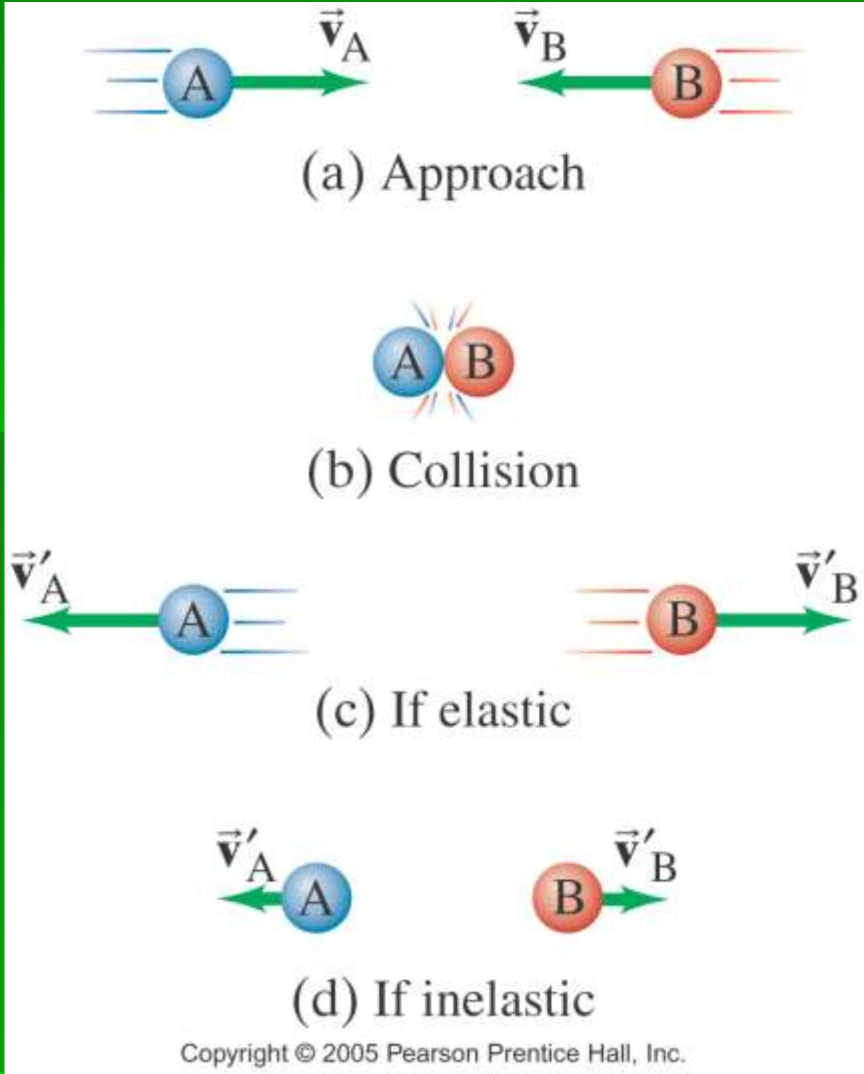
Conservation of Momentum

Inelastic Collisions

$$m_1v_{i1} + m_2v_{i2} = (m_1 + m_2)v_f$$

m_1= first mass (kg)
m_2= second mass (kg)
v_{i1}= initial velocity of first mass (m/s)
v_{i2}= initial velocity of second mass (m/s)
v_f= final velocity of both the first mass and second mass combined (m/s)

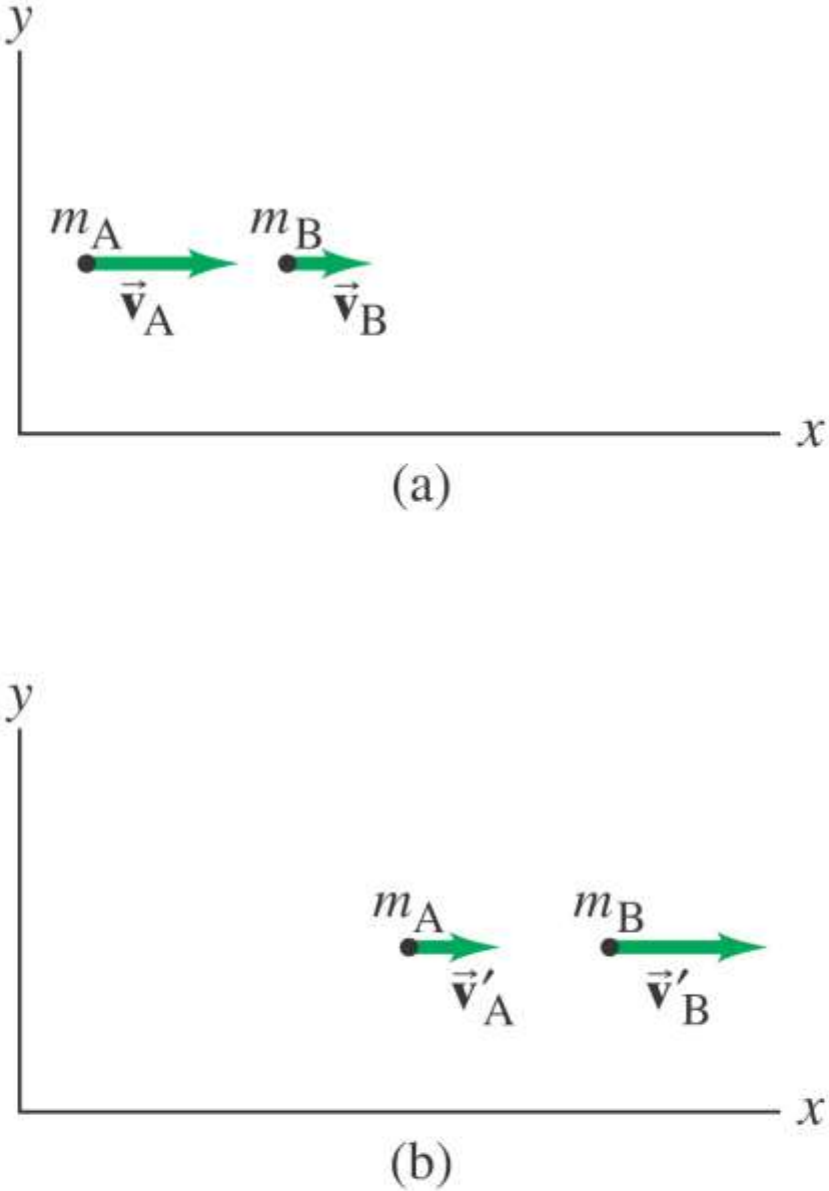
Conservation of Energy and Momentum in Collisions



- Momentum is conserved in all collisions.

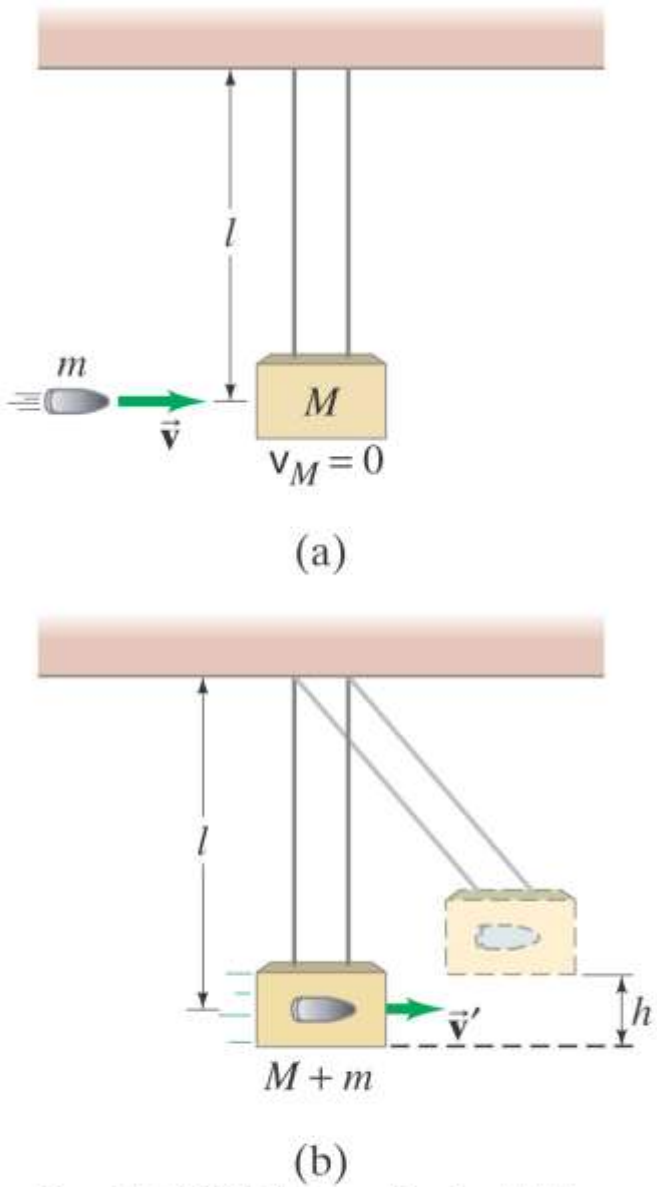
- Kinetic Energy only conserved in elastic collisions.

Elastic Collisions in One Dimension



Here we have two objects colliding elastically. We know the masses and the initial speeds.

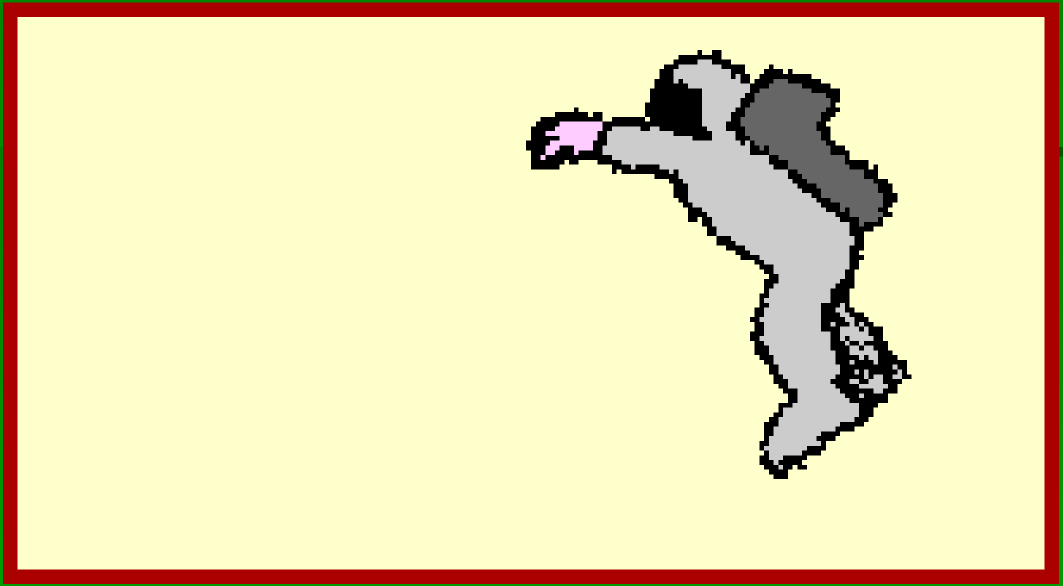
Inelastic Collisions



With inelastic collisions, some of the initial kinetic energy is lost to thermal or potential energy. It may also be gained during explosions, as there is the addition of chemical or nuclear energy.

A completely inelastic collision is one where the objects stick together afterwards, so there is only one final velocity.

Check your understanding

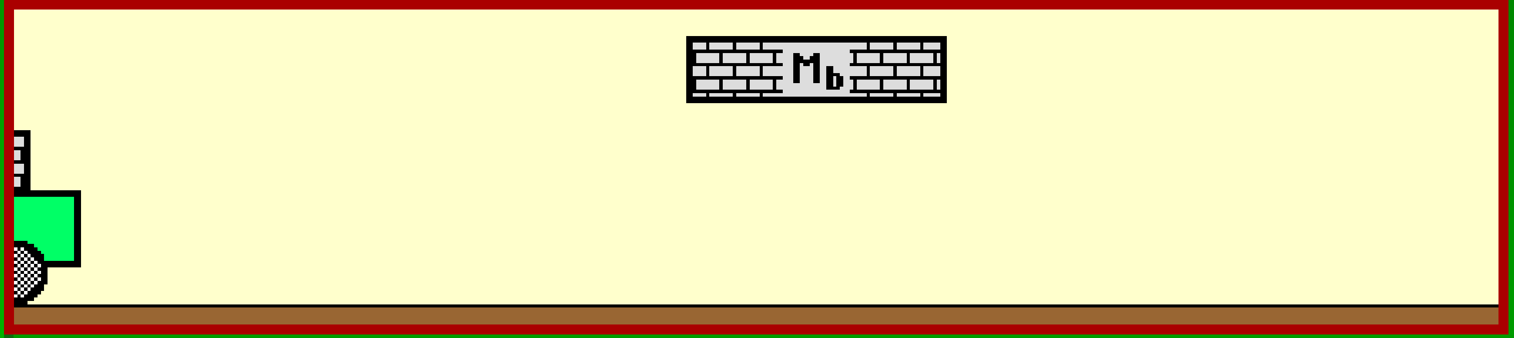


- Is the collision elastic or inelastic? **inelastic**
- Is momentum conserved? **yes**
- Is kinetic energy conserved? **no**
- If the astronaut's masses are equal, what is the final velocity of the two astronauts compared to the initial velocity of the incoming astronaut? **half**

Check your understanding

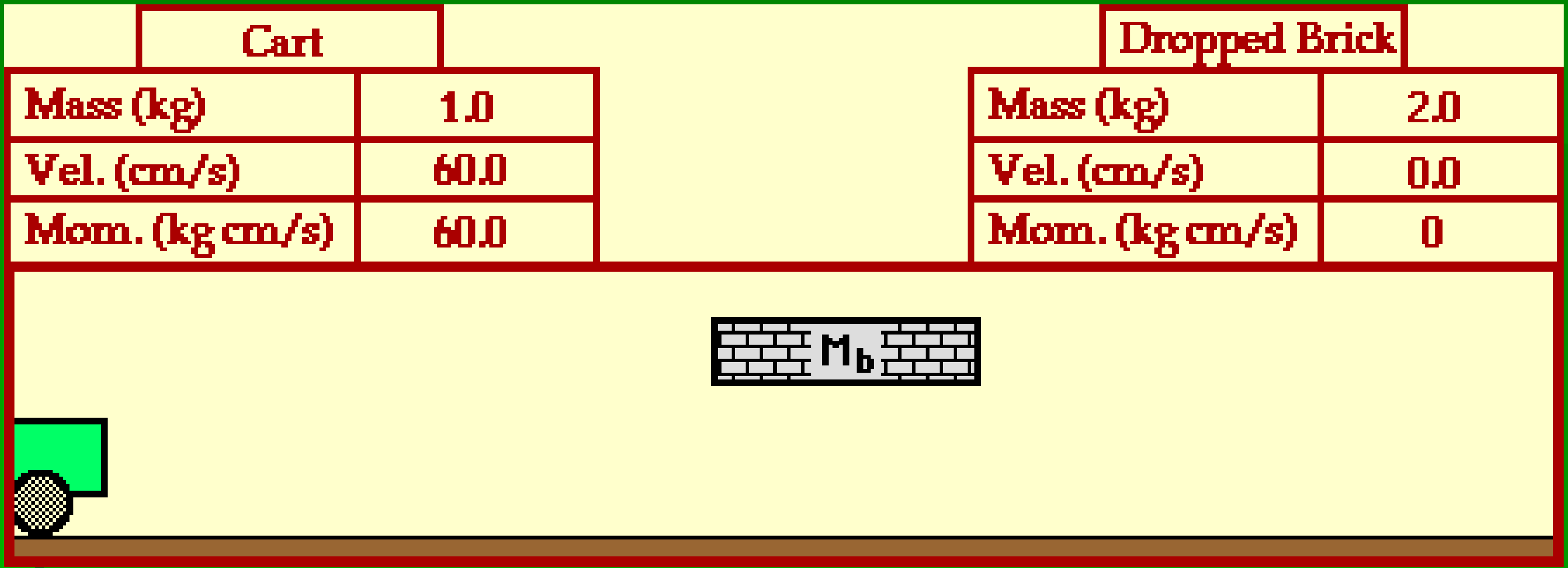
Loaded Cart	
Mass (kg)	3.0
Vel. (cm/s)	50.0
Mom. (kg cm/s)	150

Dropped Brick	
Mass (kg)	2.0
Vel. (cm/s)	0.0
Mom. (kg cm/s)	0



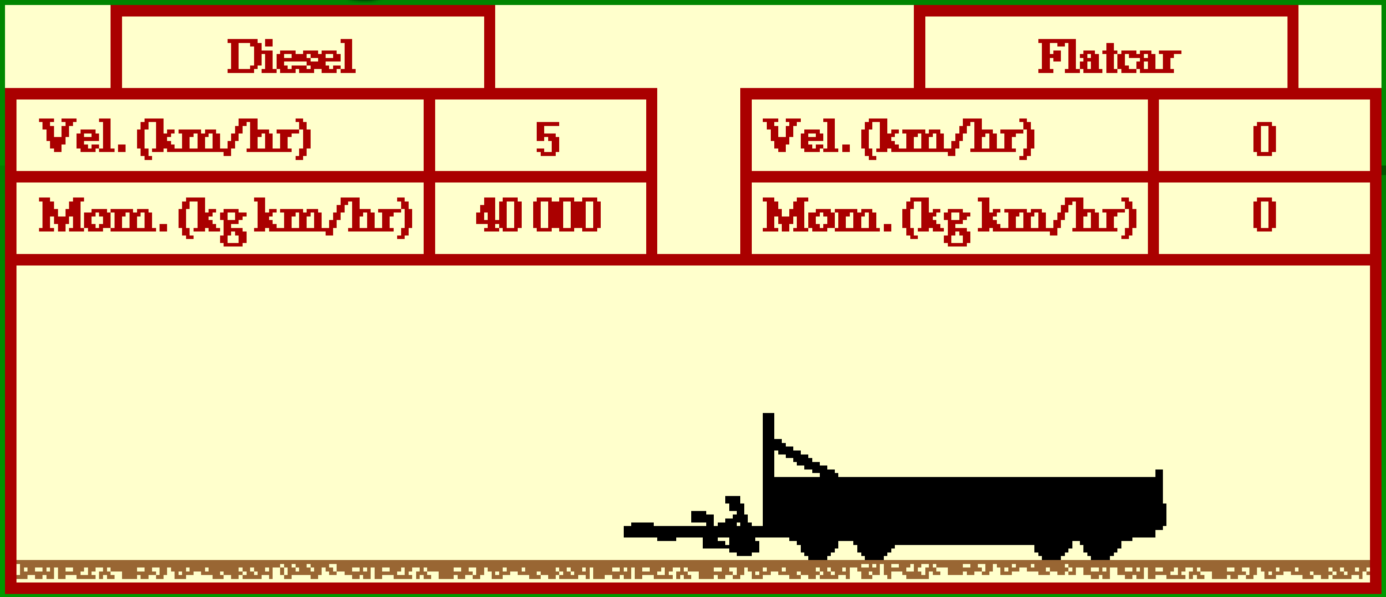
- Is the collision elastic or inelastic? **inelastic**
- What is the momentum before the collision? **150 kgm/s**
- What is the momentum after the collision? **150 kgm/s**
- Is momentum conserved? **Yes**

Check your understanding



- Is the collision elastic or inelastic? **inelastic**
- What is the momentum before the collision? **60 kgm/s**
- What is the momentum after the collision? **60 kgm/s**
- Is momentum conserved? **Yes**

Check your understanding



- What is the mass of the blue train engine? **8000 kg**
- What is the mass of the black flatbed car? **2000 kg**
- Is kinetic momentum conserved? **Yes**

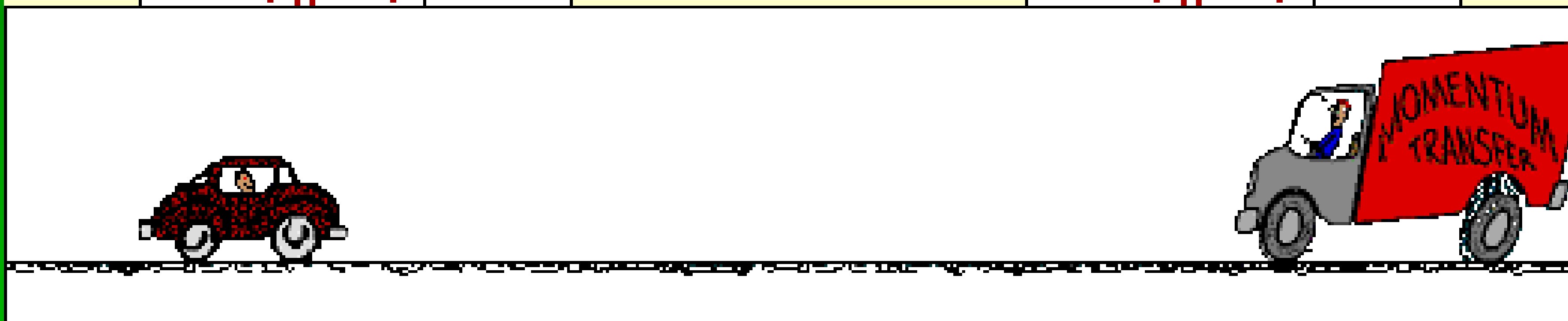
Check your understanding

Car

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

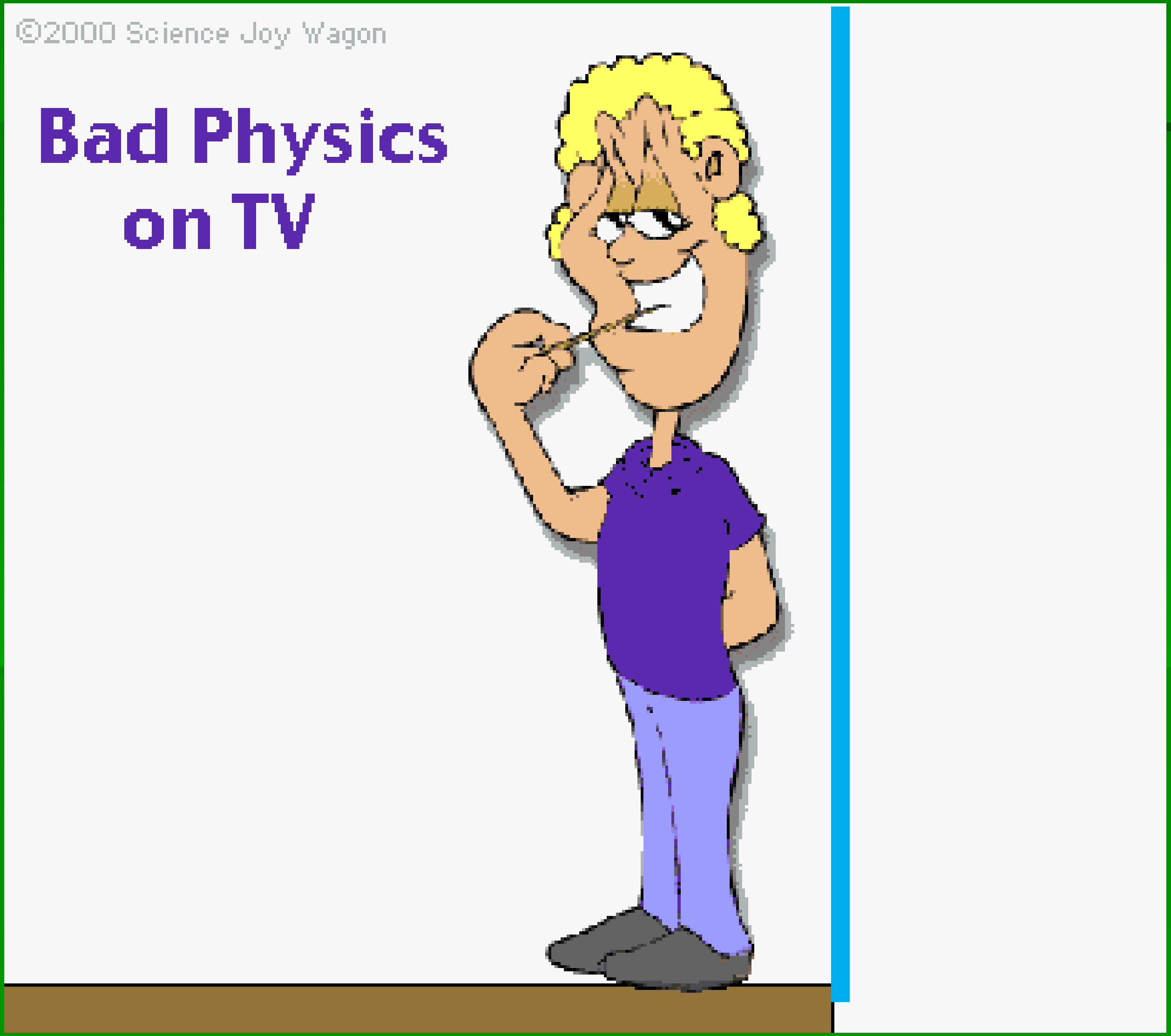
Truck

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

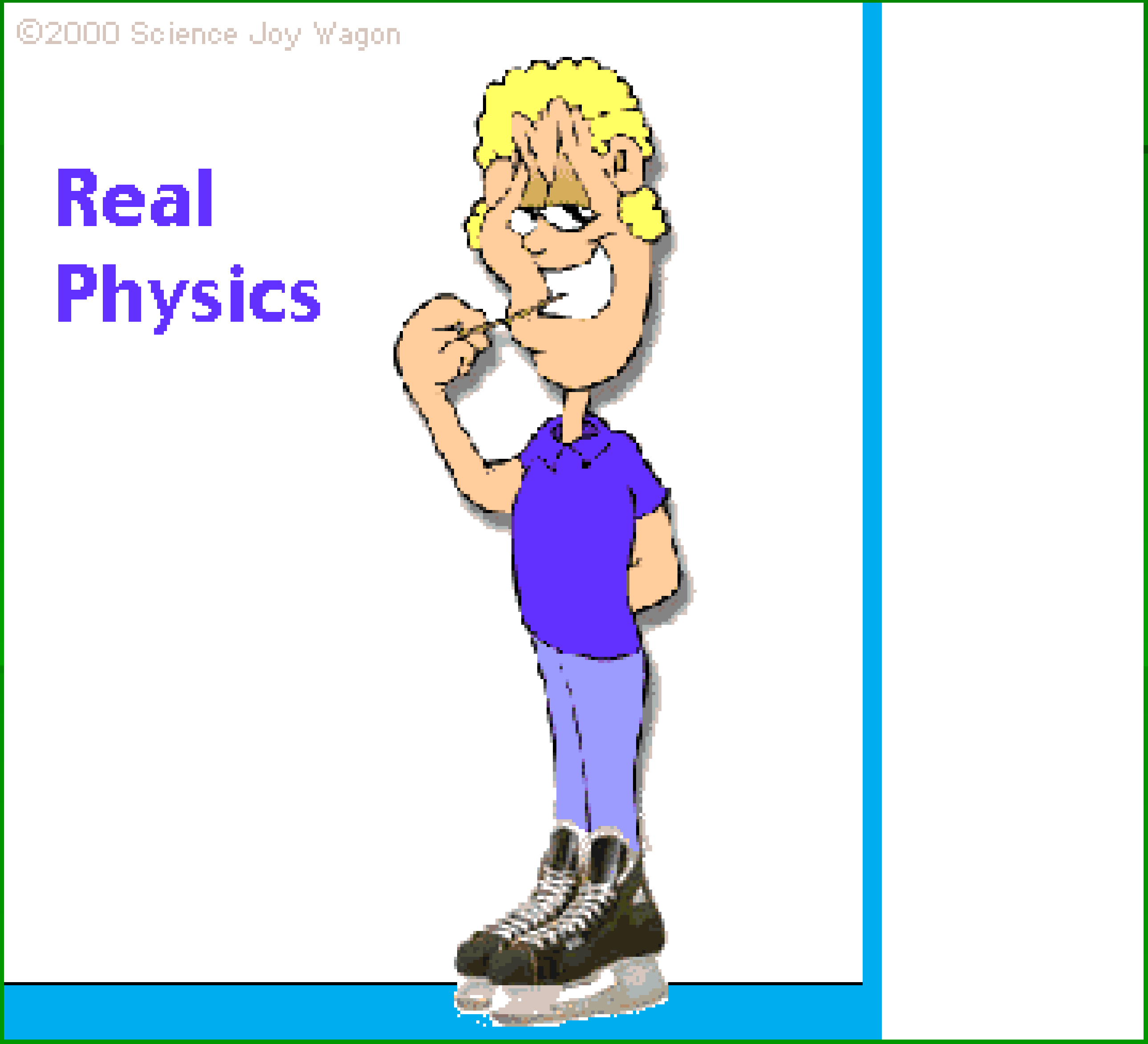


- What is the p of the car before the collision? **20000 kgm/s**
- What is the p of the truck before the collision? **-60000 kgm/s**
- What is the p of the car after the collision? **-40000 kgm/s**
- What is the p of the truck after the collision? **0 kgm/s**
- Is momentum conserved? **Yes**

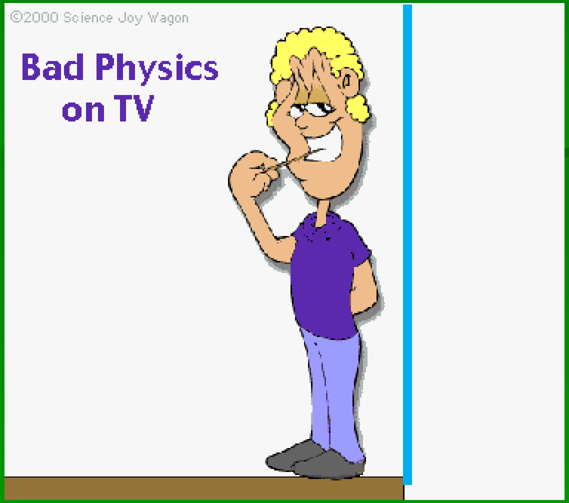
Bad Physics on TV

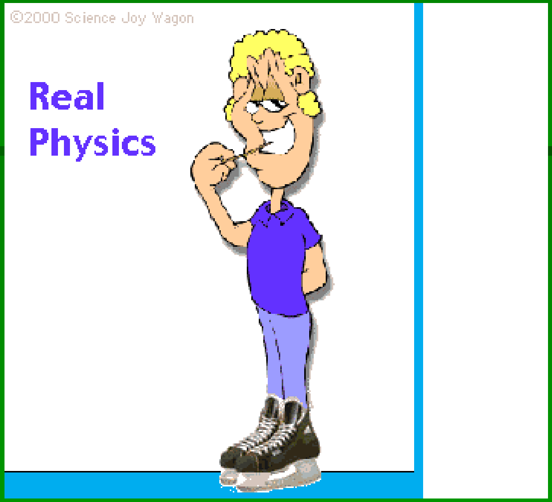


Bad Physics on TV



Bad Physics on TV





bullet mass = 0.04 kg
bullet velocity = 300 m/s
person mass= 65 kg

If the collision is perfectly inelastic then what is the velocity of the person and the bullet together?

0.1845 m/s