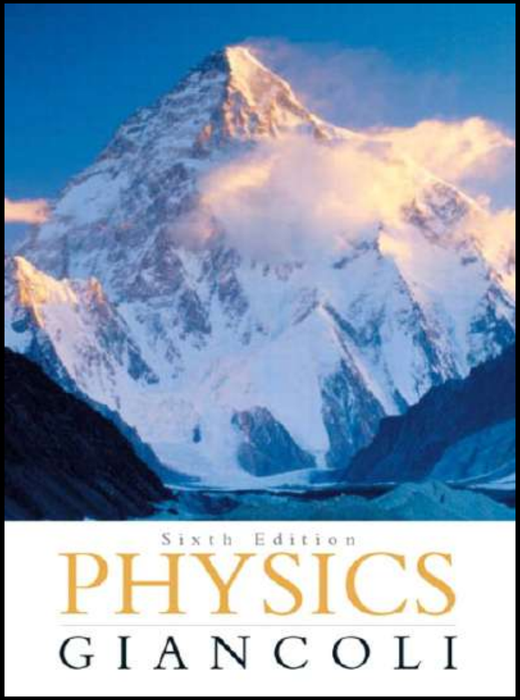


Lecture PowerPoints

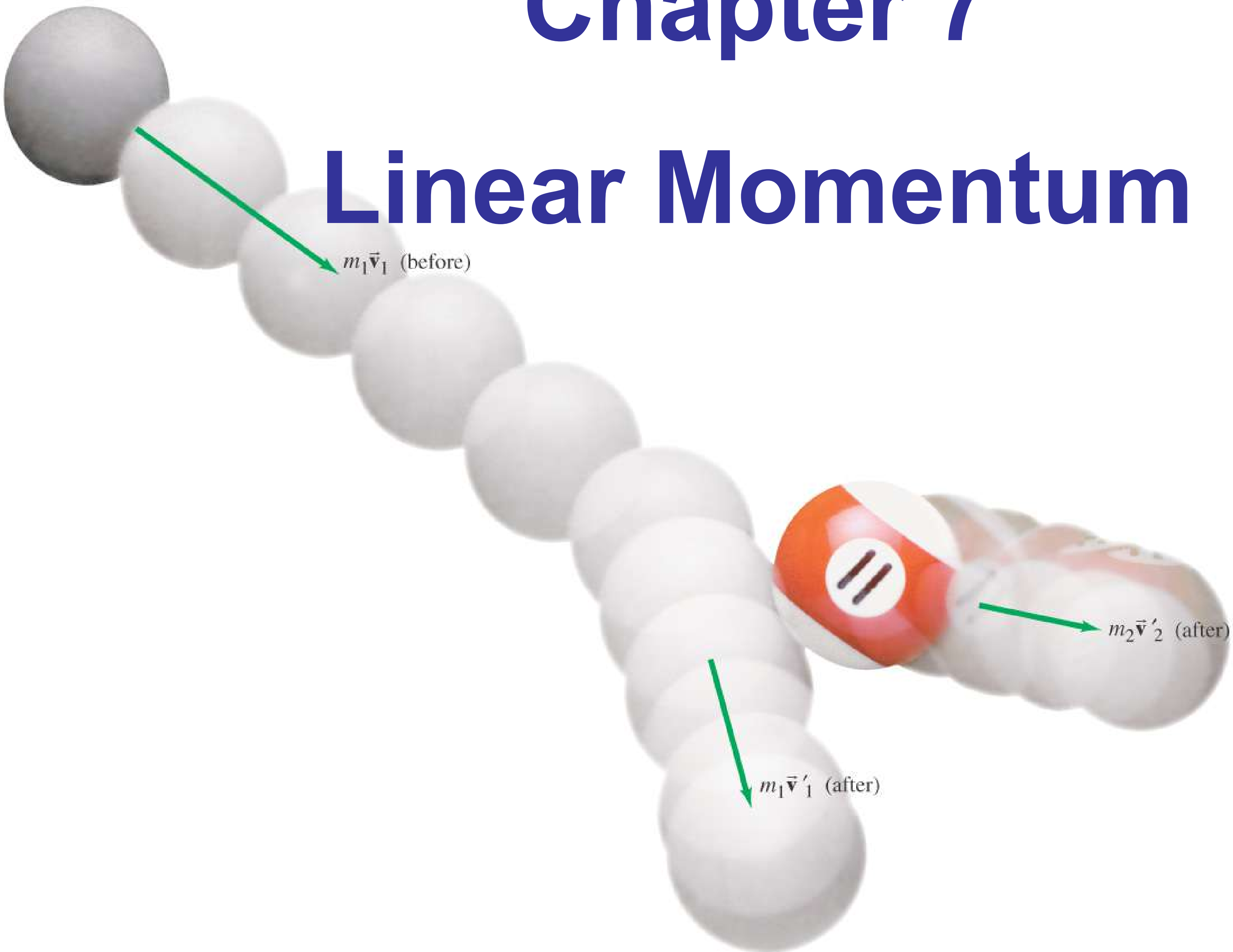
Chapter 7

Physics: Principles with Applications, 6th edition

Giancoli

Chapter 7

Linear Momentum



7-1 Momentum and Its Relation to Force

Momentum is a vector symbolized by the symbol **p**, and is defined as

$$\vec{\mathbf{p}} = m\vec{\mathbf{v}} \quad \text{(7-1)}$$

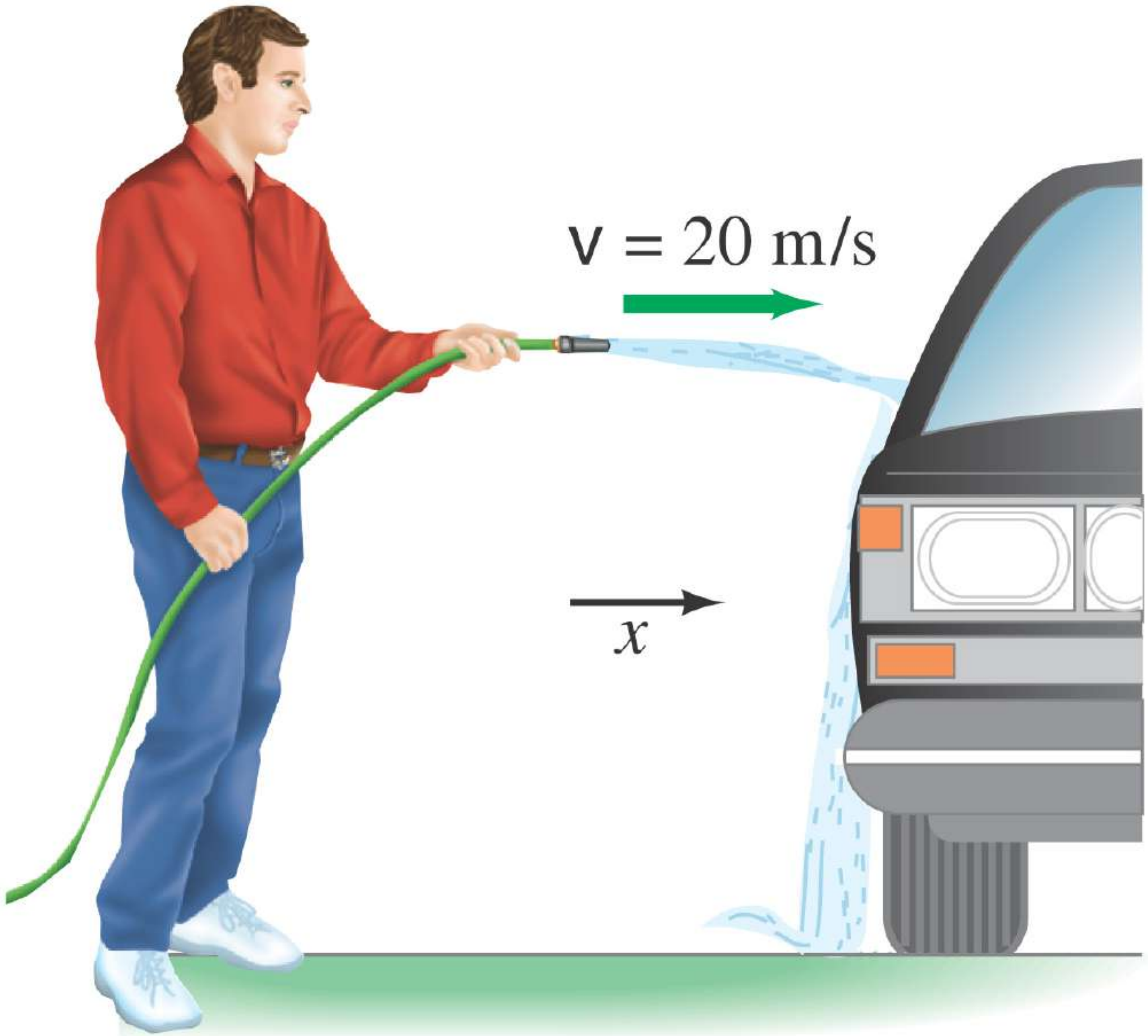
The **rate** of change of momentum is equal to the net **force**:

$$\Sigma\vec{\mathbf{F}} = \frac{\Delta\vec{\mathbf{p}}}{\Delta t} \quad \text{(7-2)}$$

This can be shown using Newton's **second** law.

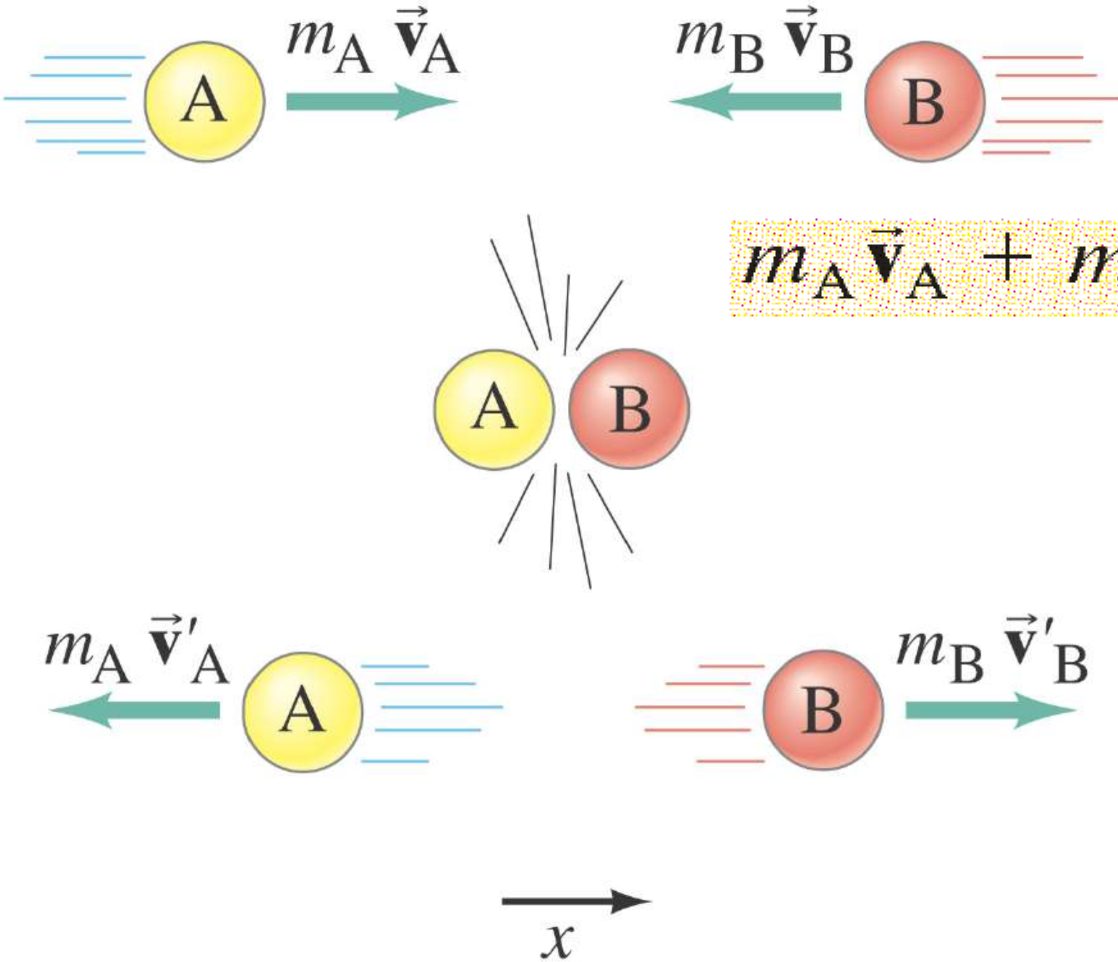
Can a small sports car ever have the same momentum as a large SUV with three times the mass of the sports car?

What if the water splashed back from the car? Would the force on the car be greater or less?



7-2 Conservation of Momentum

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

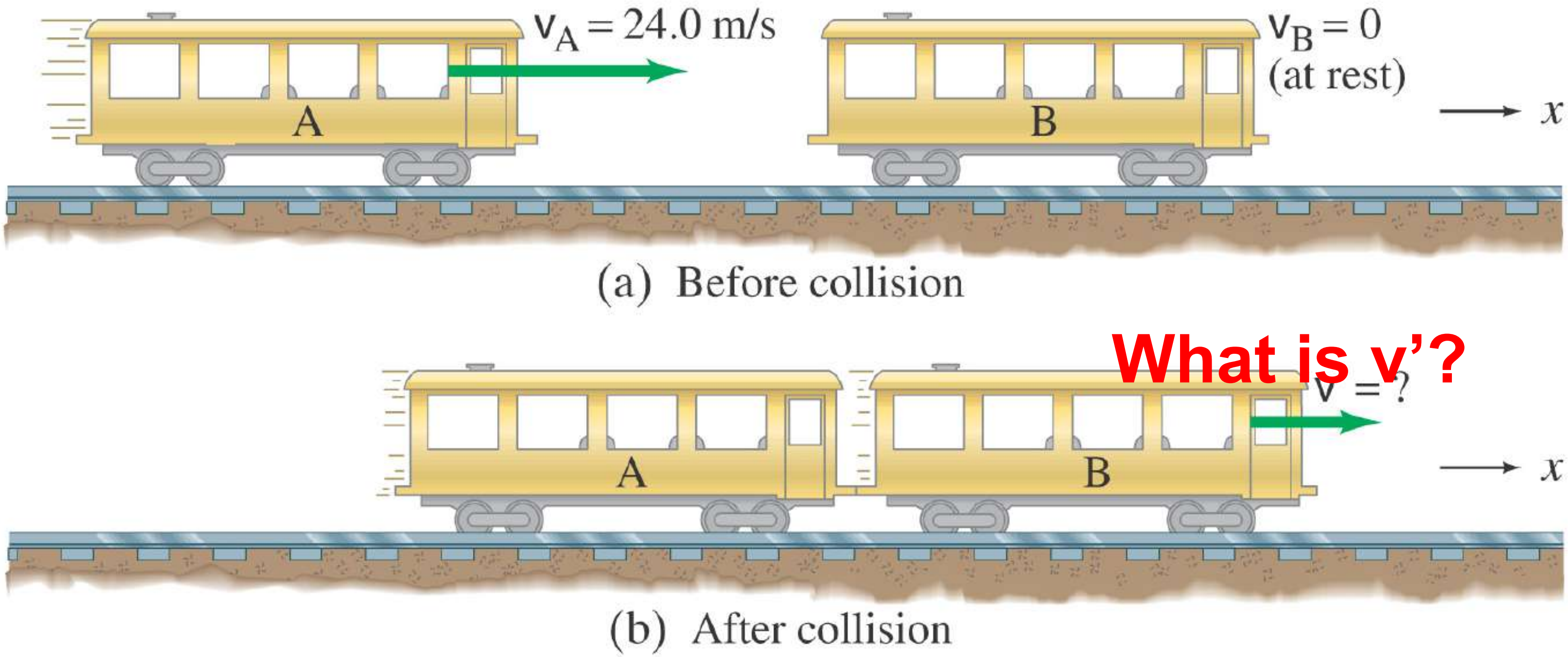


$$m_A \vec{v}_A + m_B \vec{v}_B = m_A \vec{v}'_A + m_B \vec{v}'_B \quad (7\text{-}3)$$

7-2 Conservation of Momentum

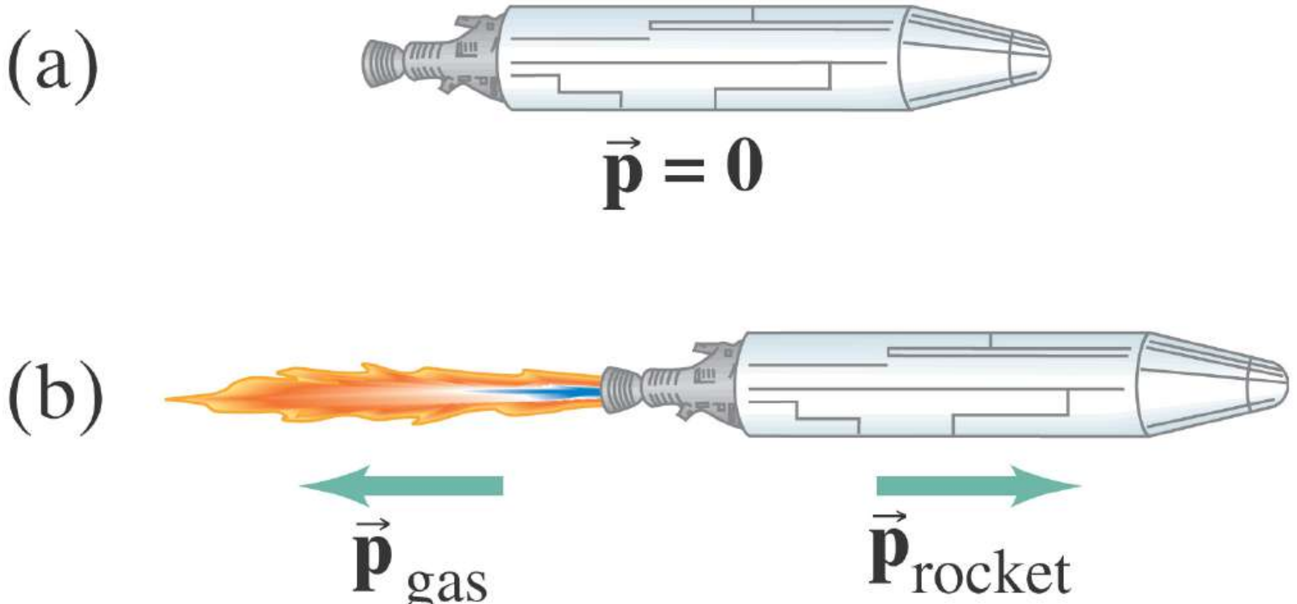
More formally, the law of **conservation** of momentum states:

The **total** momentum of an **isolated** system of objects remains constant (**isolated** means that there are no external forces).

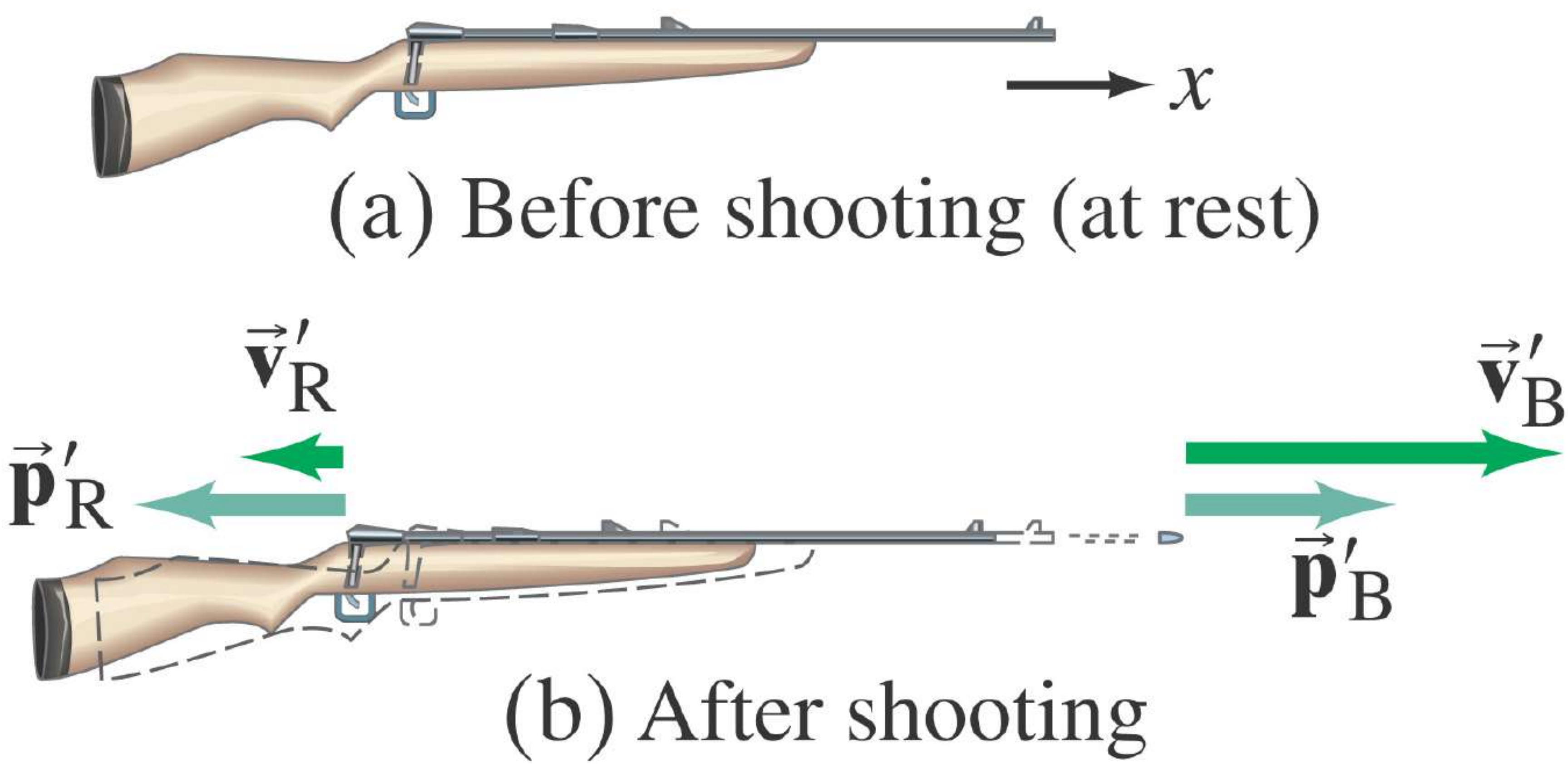


7-2 Conservation of Momentum

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.



Calculate the recoil velocity of a 5.0 kg rifle that shoots a 0.020 kg bullet at a speed of 620 m/s.



An empty sled is sliding on frictionless ice when Susan drops vertically from a tree above onto the sled. When she lands, does the sled speed up, slow down, or keep the same speed?

Later, Susan falls sideways off the sled. When she drops off, does the sled speed up, slow down, or keep the same speed?

A gun is fired vertically into a 1.40 kg block of wood at rest directly above it. If the bullet has a mass of 21.0 g and a speed of 210 m/s, how high will the block rise into the air after the bullet becomes embedded in it?

7-3 Collisions and Impulse

During a collision, objects are **deformed** due to the large forces involved.

Since , $\vec{\mathbf{F}} = \dfrac{\Delta\vec{\mathbf{p}}}{\Delta t}$

write $\vec{\mathbf{F}}\,\Delta t = \Delta\vec{\mathbf{p}}$ (7-5)

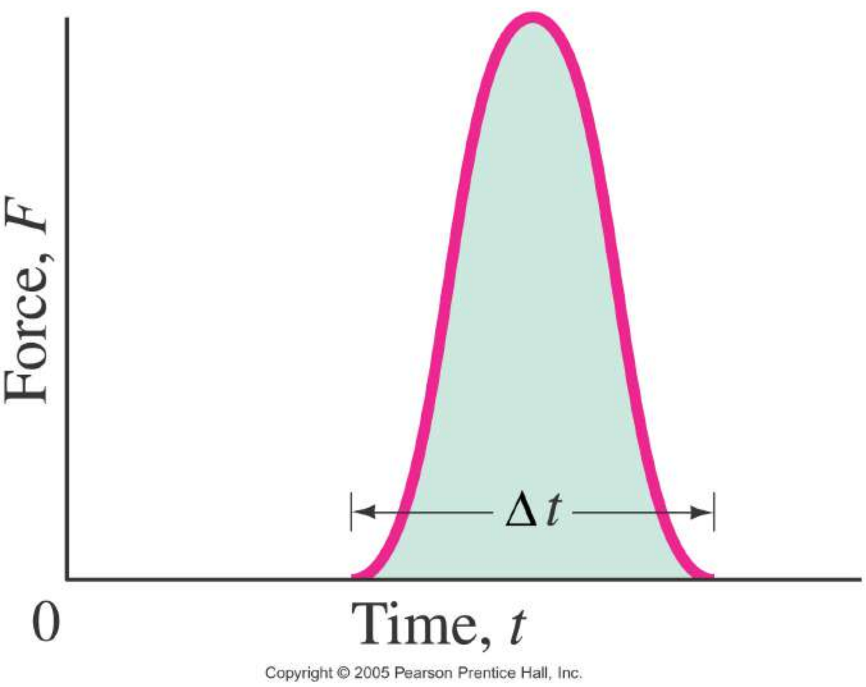
The definition of impulse:

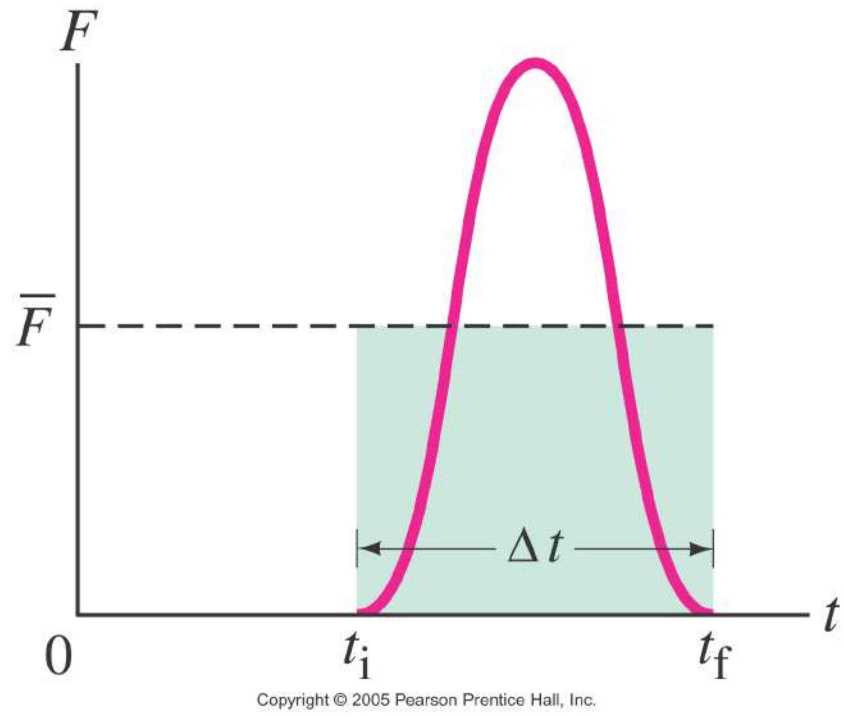
$$\text{Impulse} = \vec{\mathbf{F}}\,\Delta t$$

(F t = m Δv)

7-3 Collisions and Impulse

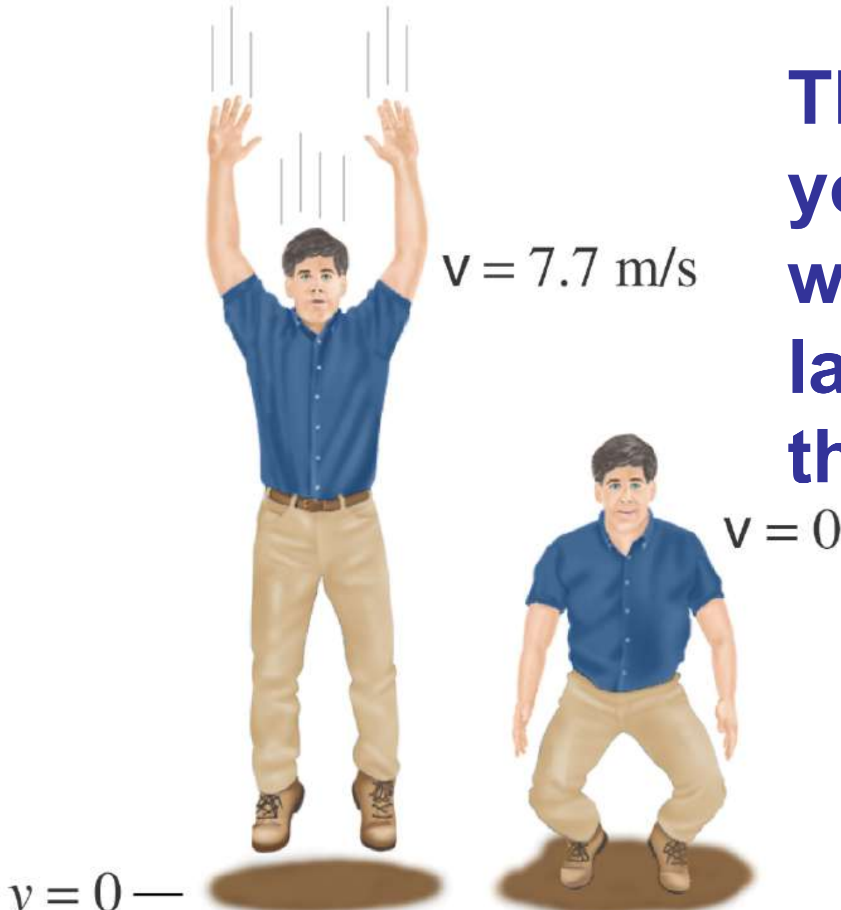
Since the **time** of the collision is very short, we need not worry about the **exact** time dependence of the force, and can use the **average force**.





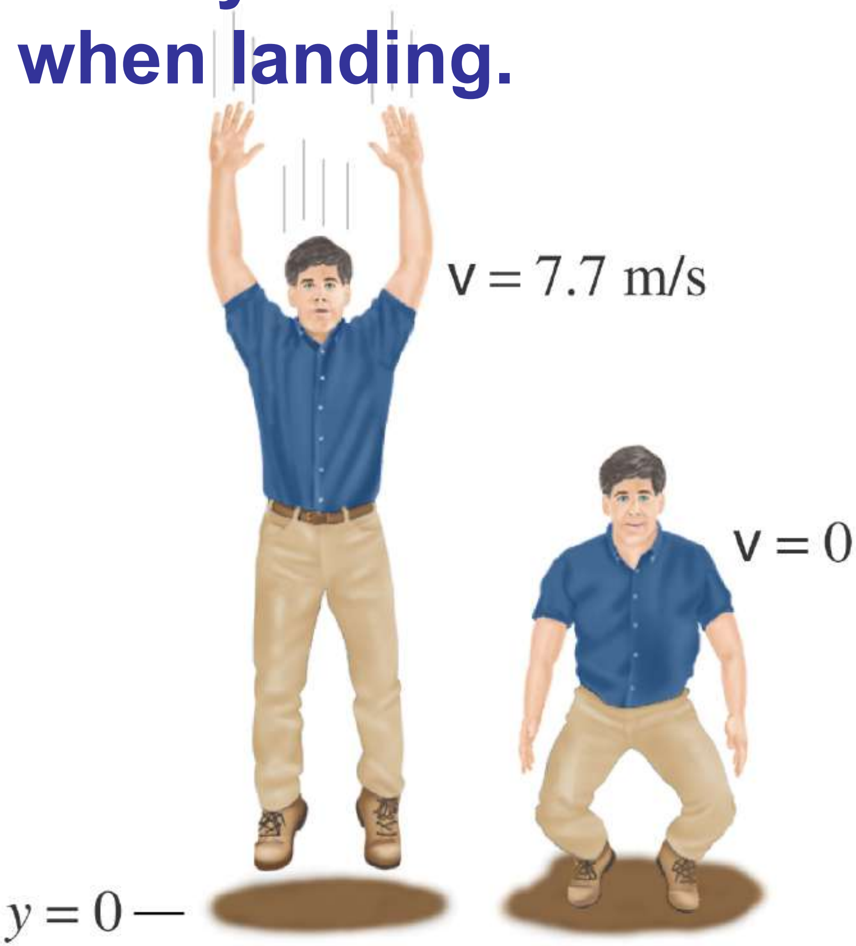
7-3 Collisions and Impulse

The **impulse** tells us that we can get the same **change** in momentum with a **large** force acting for a **short** time. or a **small** force acting for a **longer** time.



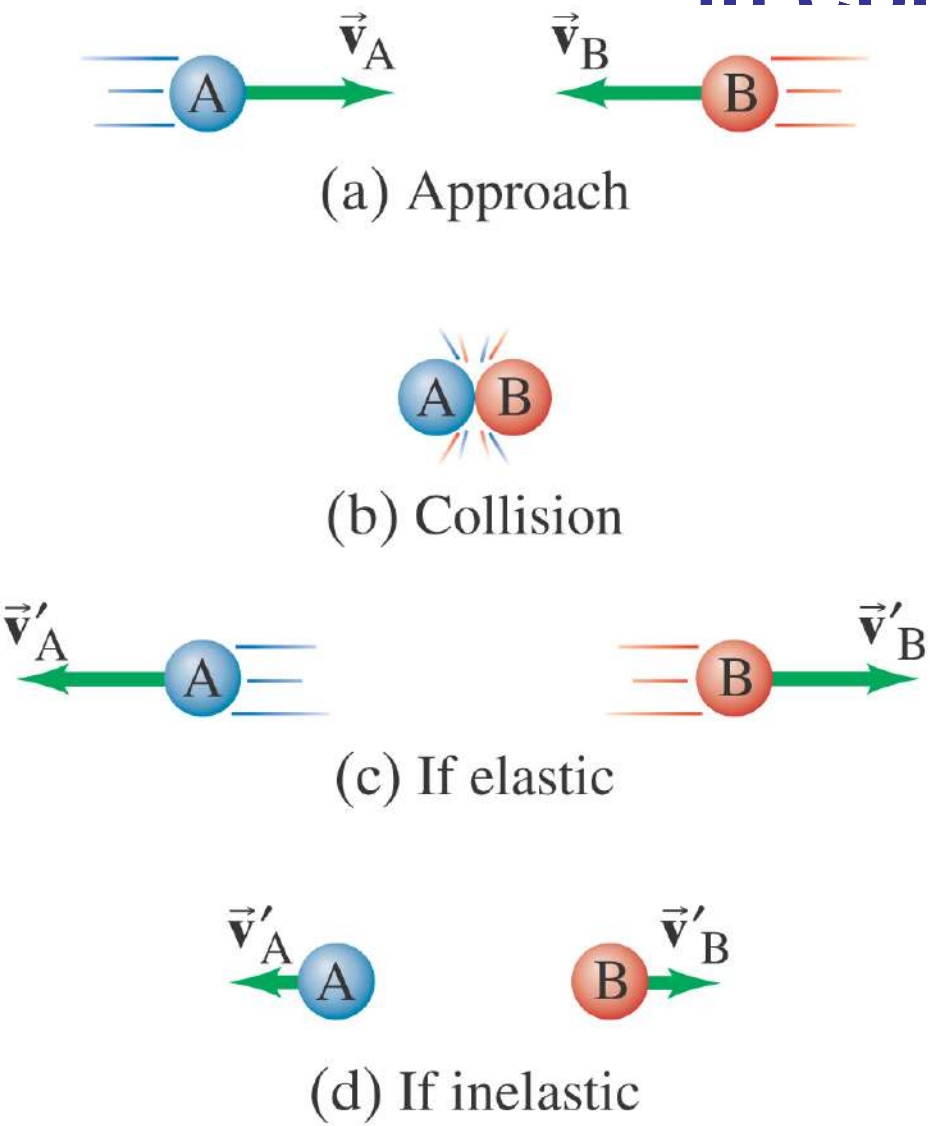
This is why you should **bend** your knees when you land; why **airbags** work; and why landing on a **pillow** hurts less than landing on **concrete**.

Why you should bend your knees when landing.



Calculate the impulse experienced when a 70. kg person lands on firm ground after jumping from a height of 3.0 m. Then estimate the average force exerted on the person's feet by the ground, if a) the landing is stiff-legged and the body only moves 1.0 cm during impact, and b) if the person bends their legs and the body moves 50. cm during impact.

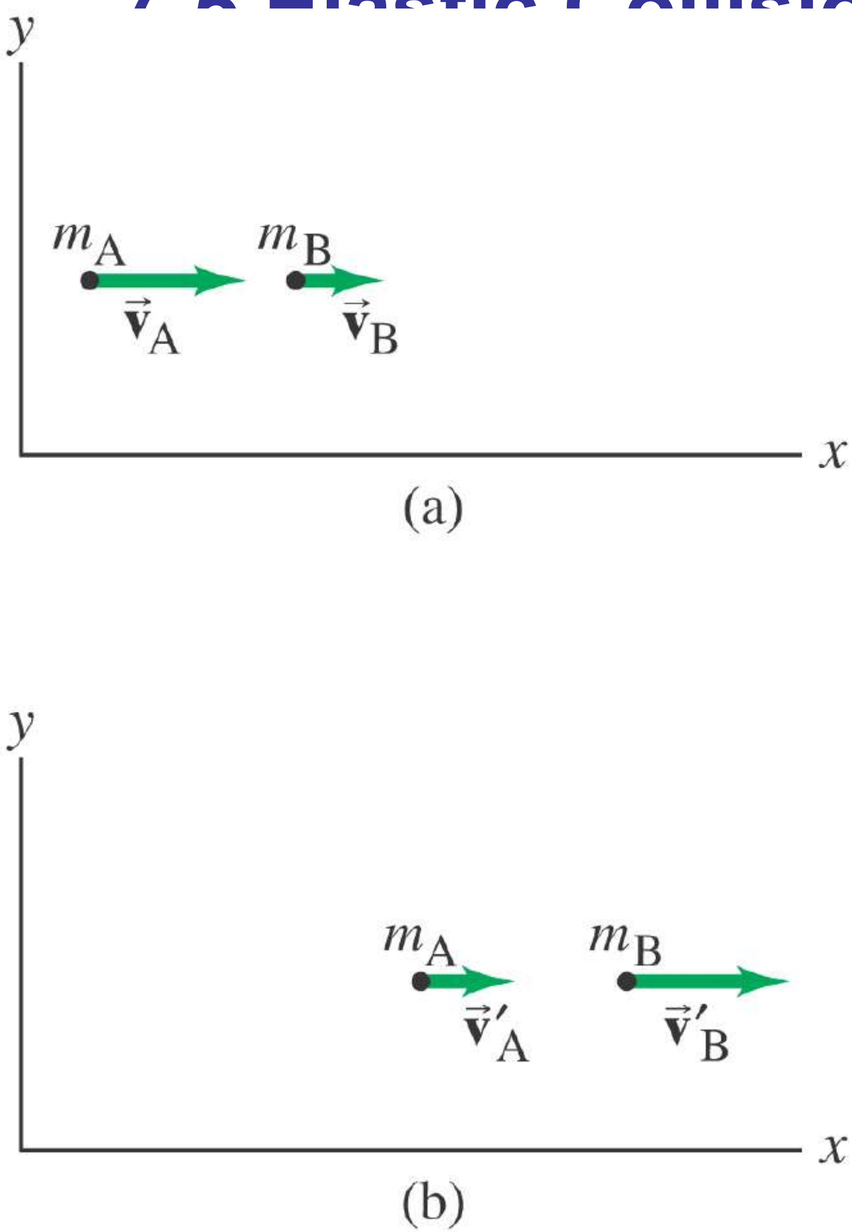
7-4 Conservation of Energy and Momentum in Collisions



Momentum is conserved in all collisions.

Collisions in which kinetic energy is conserved as well are called elastic collisions, and those in which it is not are called inelastic.

7.5 Elastic Collisions in One Dimension



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

Since both **momentum** and **kinetic energy** are conserved, we can write **two** equations. This allows us to solve for the **two** unknown final speeds.

$$v_1 - v_2 = -(v'_1 - v'_2)$$

This equation works only in 1-D not 2-D.

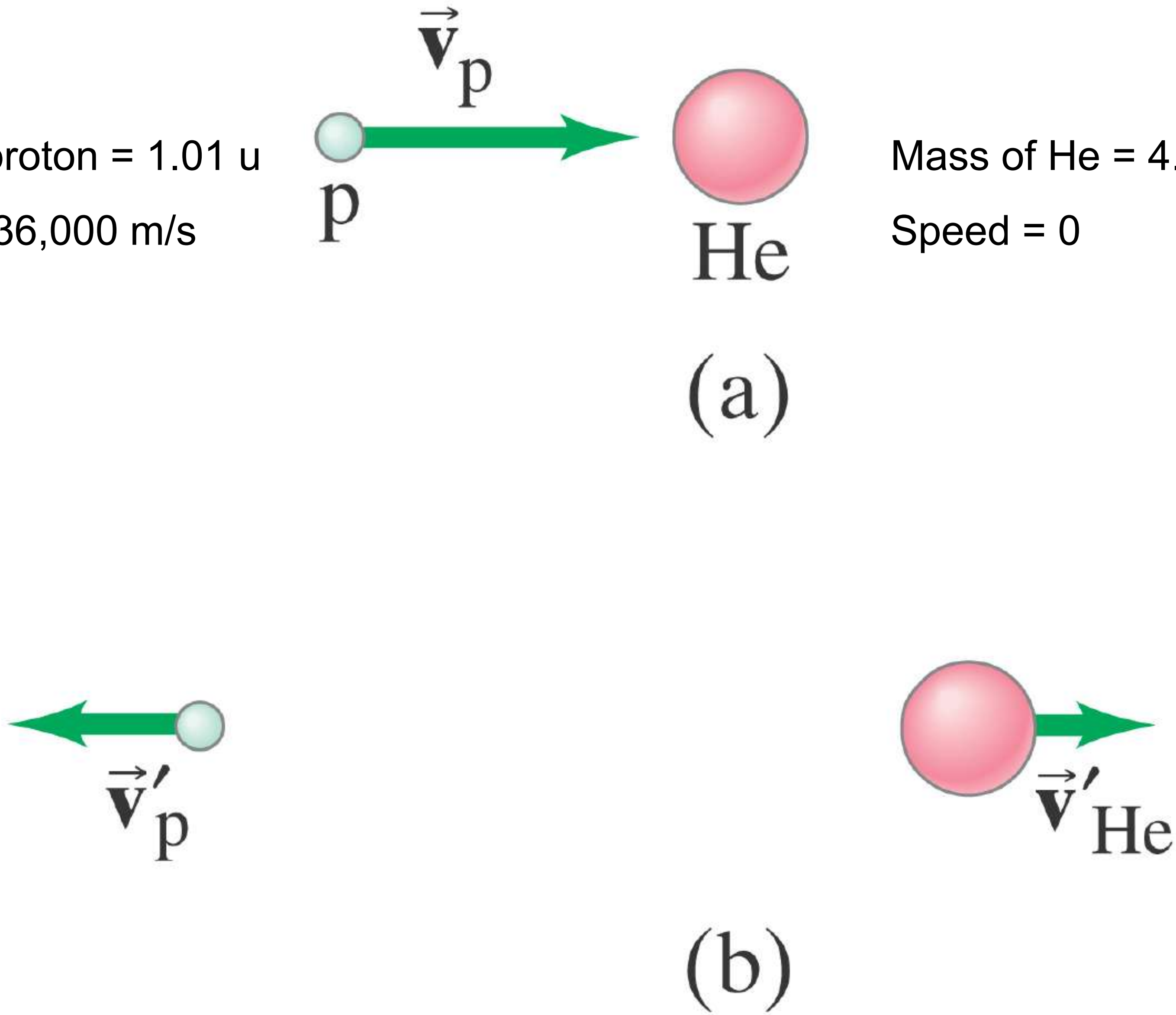
What are the velocities of the proton and Helium nucleus after this elastic collision?

Mass of proton = 1.01 u

Speed = 36,000 m/s

Mass of He = 4.00 u

Speed = 0



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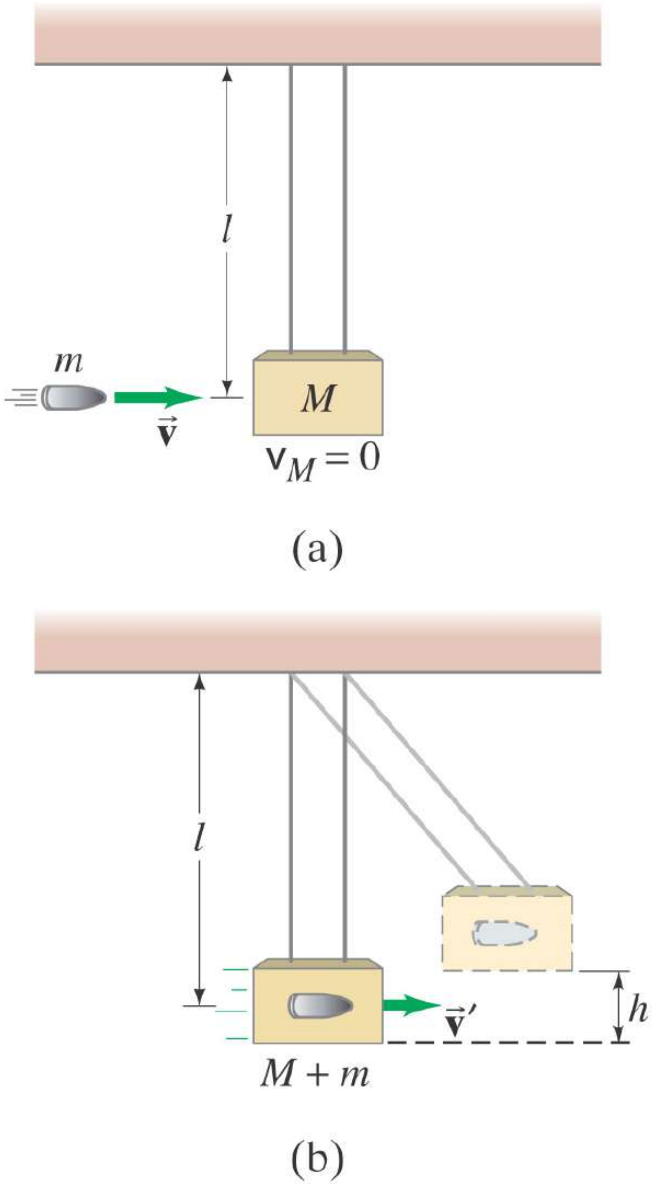
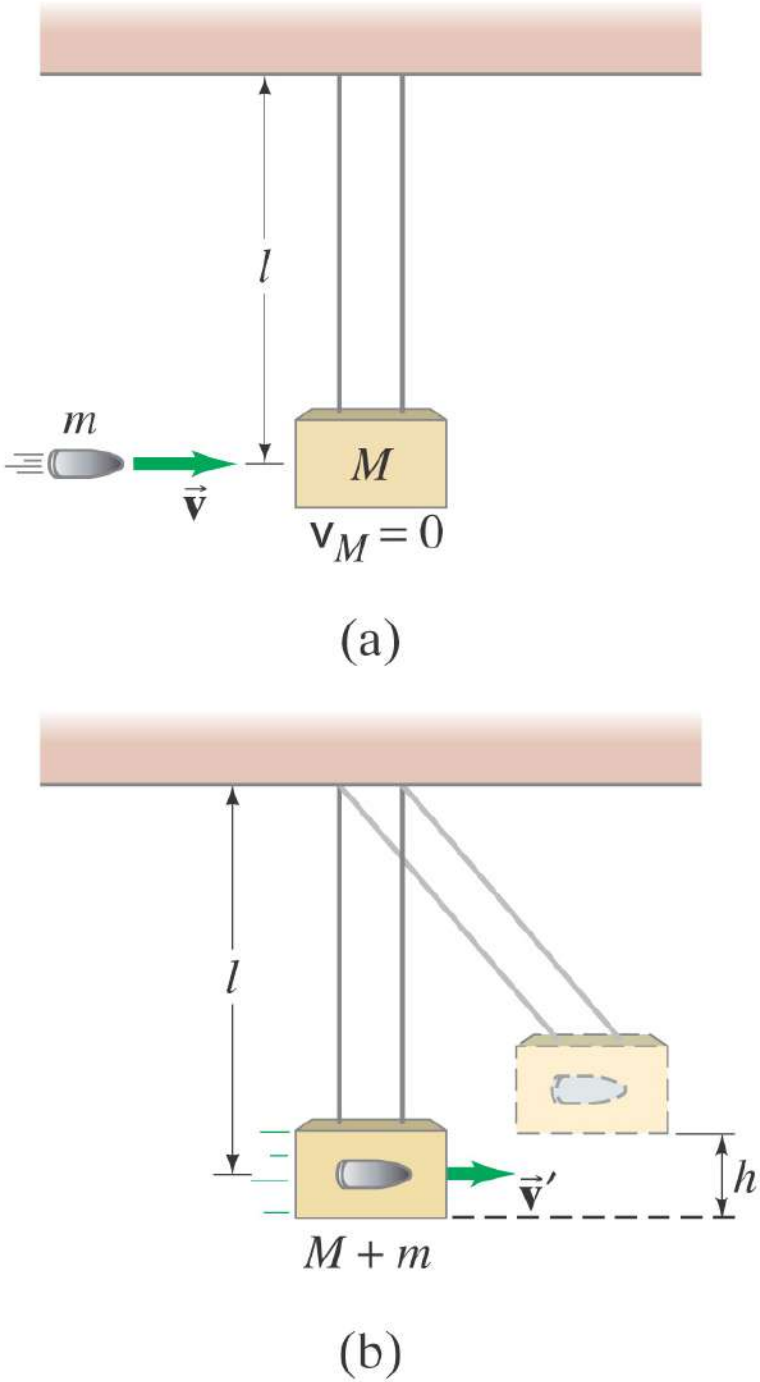
7-6 Inelastic Collisions



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.

The diagram at left is called a ballistic pendulum.



In the ballistic pendulum, a bullet of mass 10.0 g moving at 200.0 m/s is embedded in the block of wood of mass 3.00 kg. The length of the pendulum is 2.0 m. How high does the pendulum rise?

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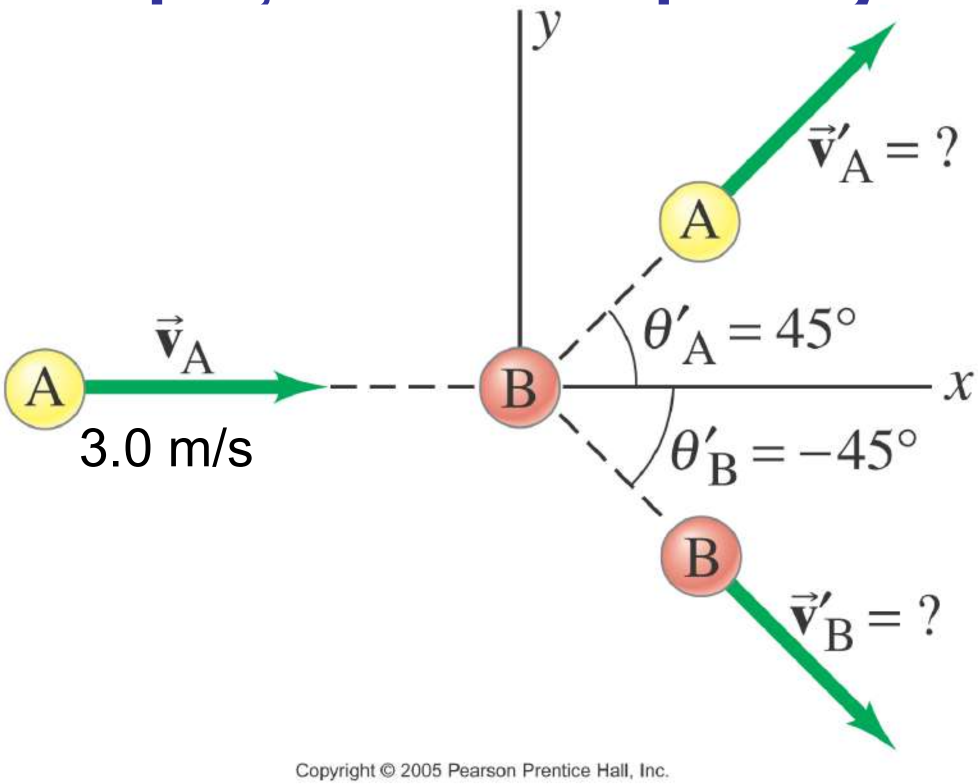
7-7 Collisions in Two or Three Dimensions

Conservation of energy and momentum can also be used to analyze collisions in **two** or **three** dimensions, but unless the situation is very simple, the math quickly becomes unwieldy.



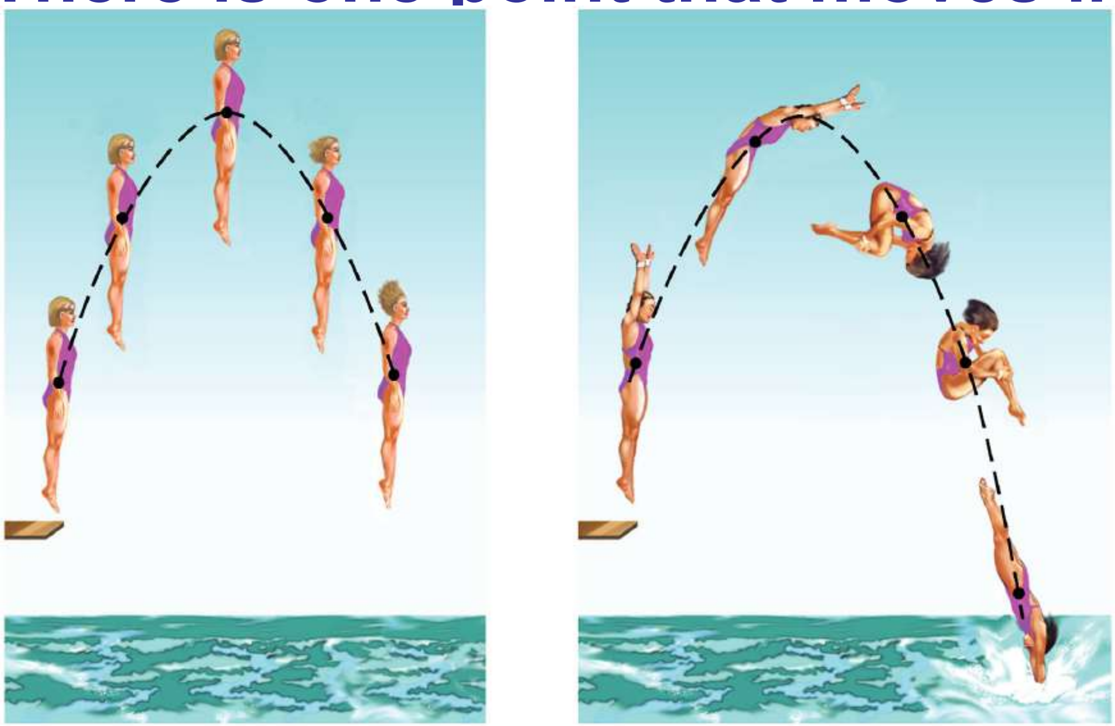
Here, a **moving** object collides with an object initially at **rest**. Knowing the masses and initial velocities is not enough; we need to know the **angles** as well in order to find the final velocities.

Calculate the velocities of both balls after the collision.

7-8 Center of Mass

In (a), the diver's motion is pure **translation**; in (b) it is **translation** plus **rotation**.

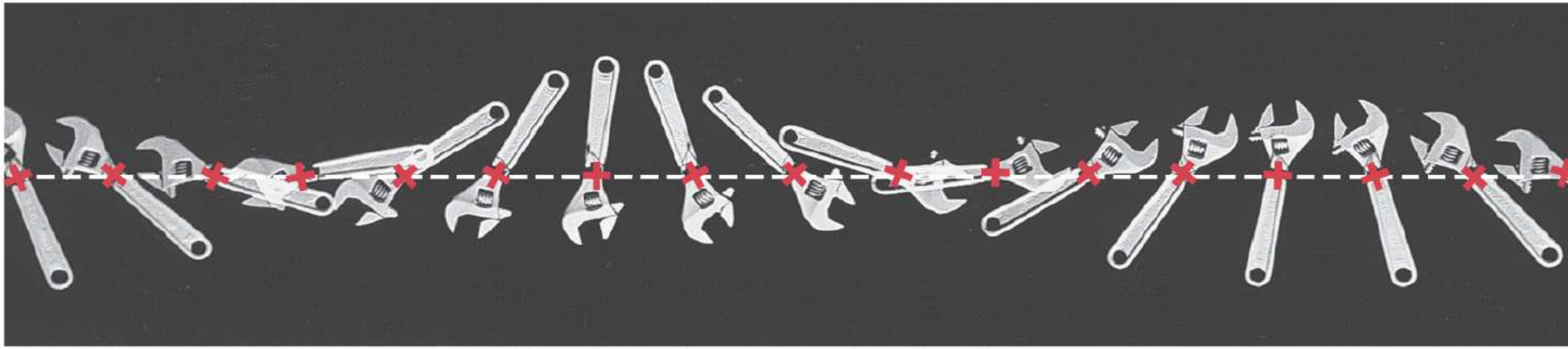
There is one point that moves in the **same** path a particle would take if subjected to the same force as the diver. This point is called the **center of mass** (**CM**).



(a) (b)

7-8 Center of Mass

The **general** motion of an object can be considered as the **sum** of the **translational** motion of the **CM**, plus **rotational**, **vibrational**, or other forms of motion about the CM.



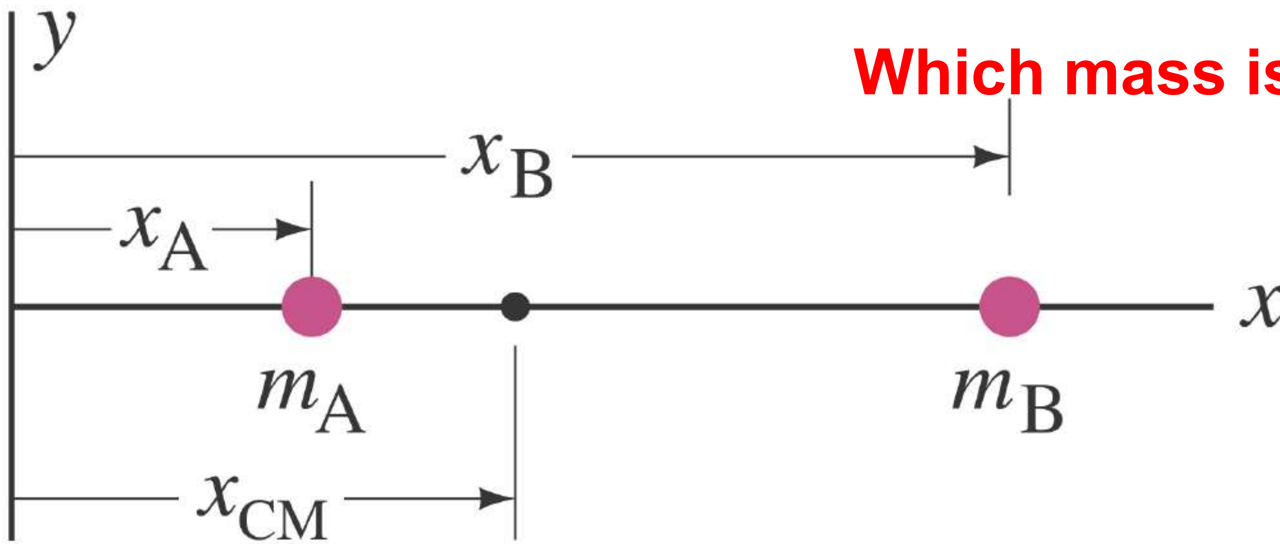
7-8 Center of Mass

For two particles, the **center of mass** lies closer to the one with the most mass:

$$x_{\mathrm{CM}} = \frac{m_{\mathrm{A}} x_{\mathrm{A}} + m_{\mathrm{B}} x_{\mathrm{B}}}{m_{\mathrm{A}} + m_{\mathrm{B}}} = \frac{m_{\mathrm{A}} x_{\mathrm{A}} + m_{\mathrm{B}} x_{\mathrm{B}}}{M}$$

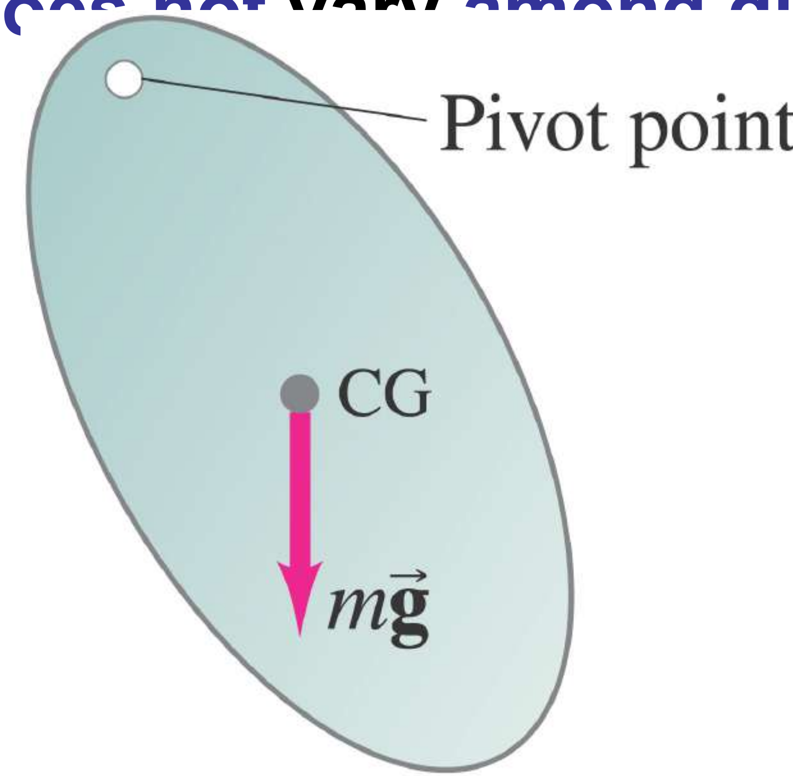
where *M* is the **total** mass.

Which mass is larger?



7-8 Center of Mass

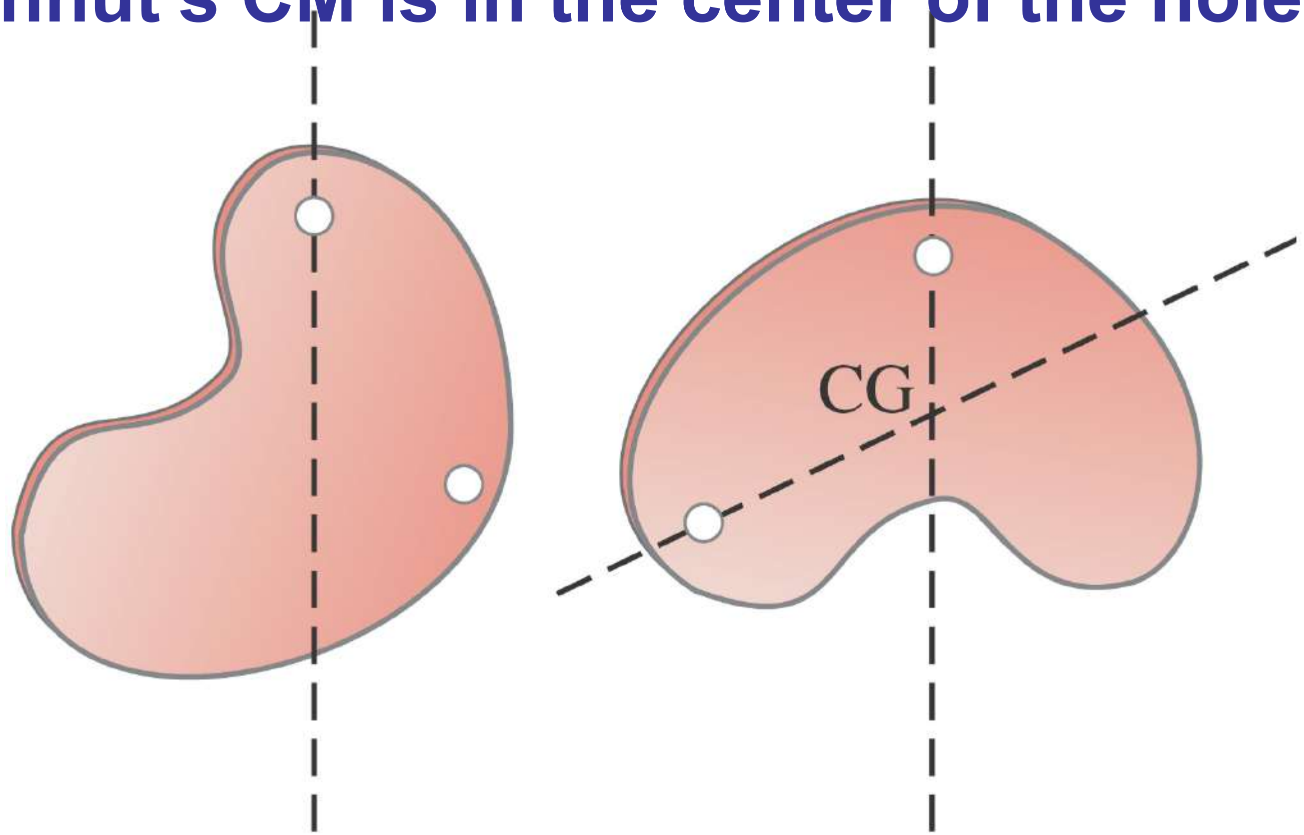
The **center of gravity** is the point where the gravitational force can be considered to act. It is the same as the **center of mass** as long as the gravitational force does not vary among different parts of the object.



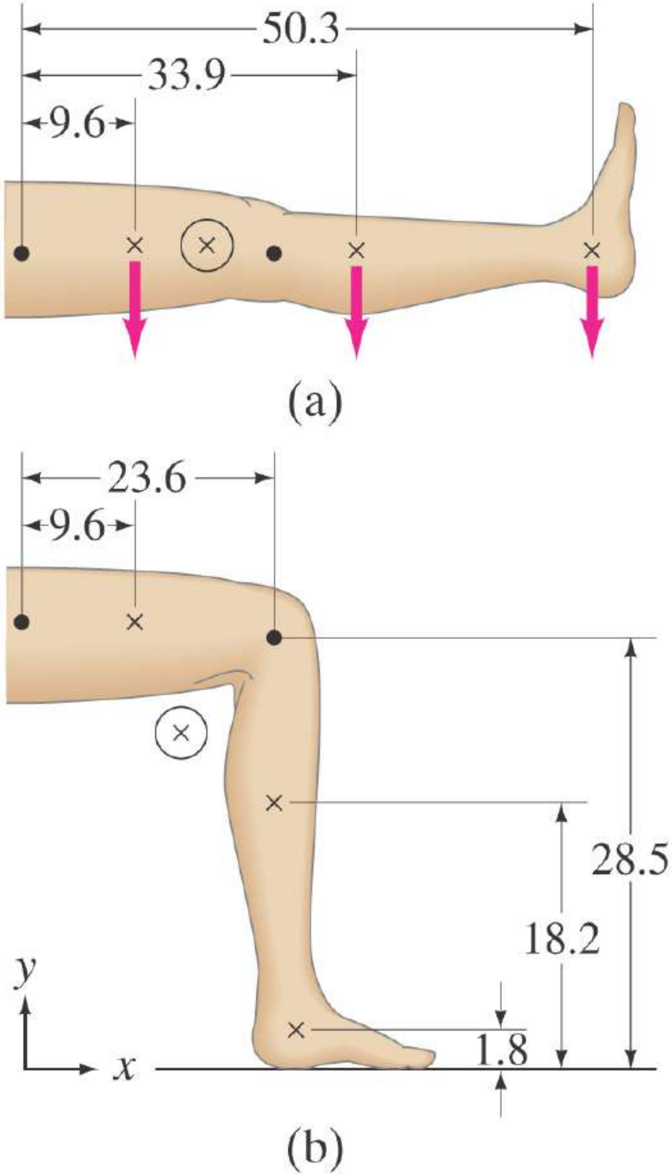
7-8 Center of Mass

The center of gravity can be found **experimentally** by **suspending** an object from different points.

The CM need not be **within** the actual object – a doughnut's CM is in the center of the hole.



Examples of CM



The location of the center of mass of the leg (circled) will depend on the position of the leg.

Examples of CM

High jumpers have developed a technique where their CM actually passes **under** the bar as they go over it. This allows them to clear **higher** bars.