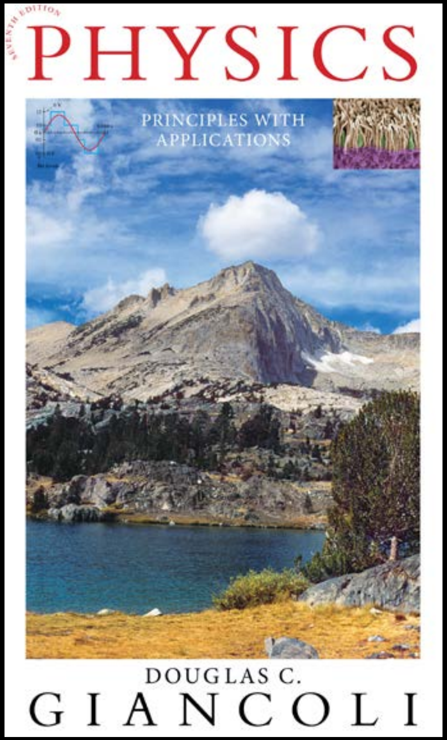
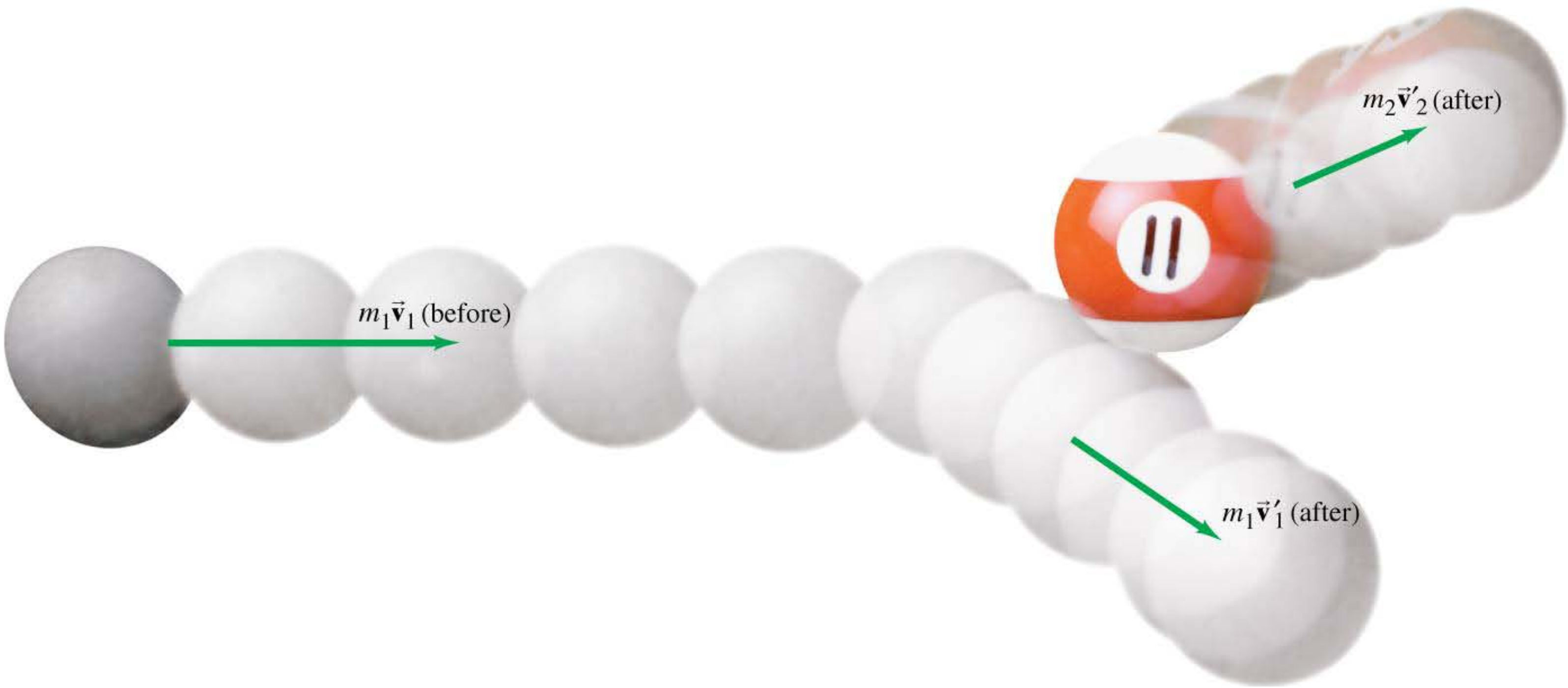


Lecture PowerPoints

Chapter 7
Physics: Principles with Applications, 7th edition
Giancoli

Chapter 7
Linear Momentum



Contents of Chapter 7

- Momentum and Its Relation to Force
- Conservation of Momentum
- Collisions and Impulse
- Conservation of Energy and Momentum in Collisions
- Elastic Collisions in One Dimension

Contents of Chapter 7

- Inelastic Collisions
- Collisions in Two or Three Dimensions
- Center of Mass (CM)
- CM for the Human Body
- Center of Mass and Translational Motion

7-1 Momentum and Its Relation to Force

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

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

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

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

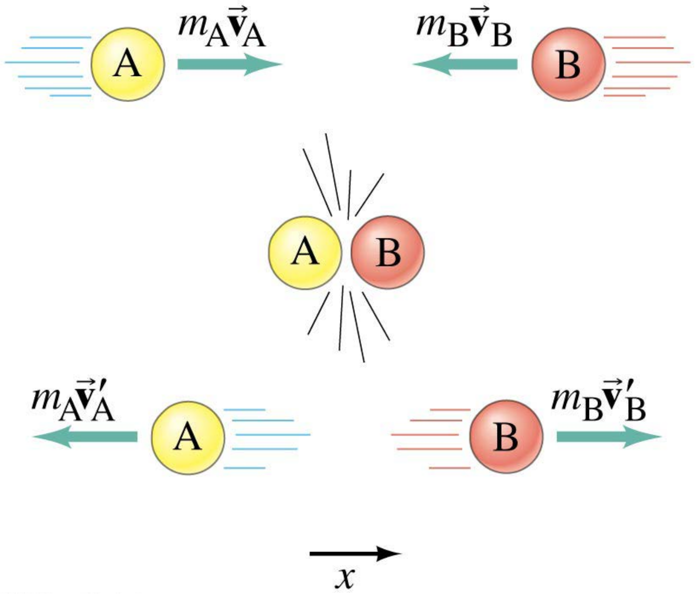
This can be shown using Newton’s second law.

7-2 Conservation of Momentum

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

$$\text{momentum before} = \text{momentum after}$$

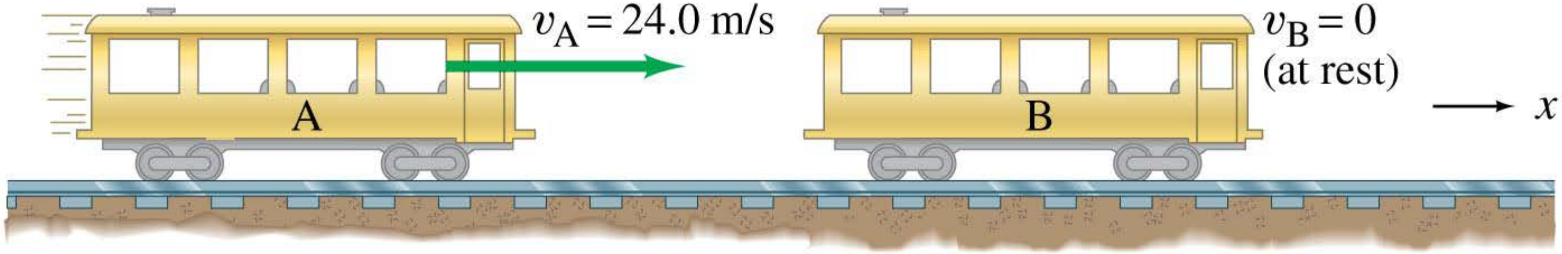
$$m_A \vec{\mathbf{v}}_A + m_B \vec{\mathbf{v}}_B = m_A \vec{\mathbf{v}}'_A + m_B \vec{\mathbf{v}}'_B . \qquad \left[\Sigma \vec{\mathbf{F}}_{\text{ext}} = 0\right] \qquad (7\text{-}3)$$



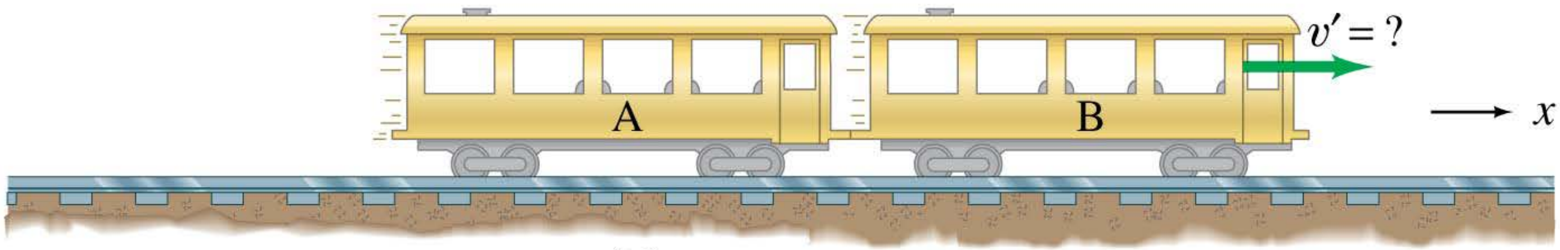
7-2 Conservation of Momentum

More formally, the law of conservation of momentum states:

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



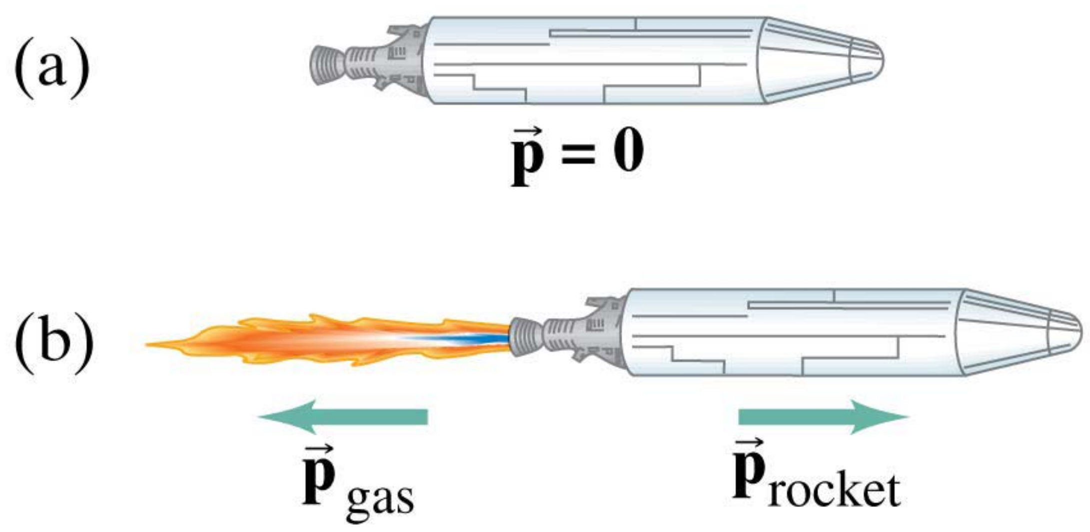
(a) Before collision



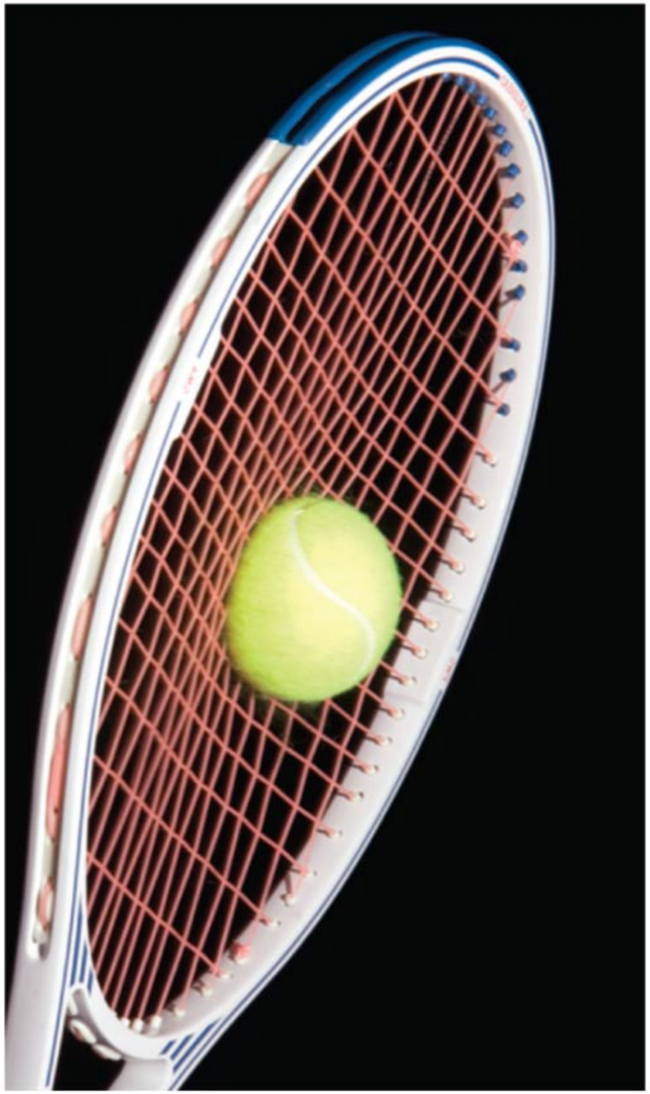
(b) After collision

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.



7-3 Collisions and Impulse



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

Since the force is equal to the change in momentum divided by time, we can write:

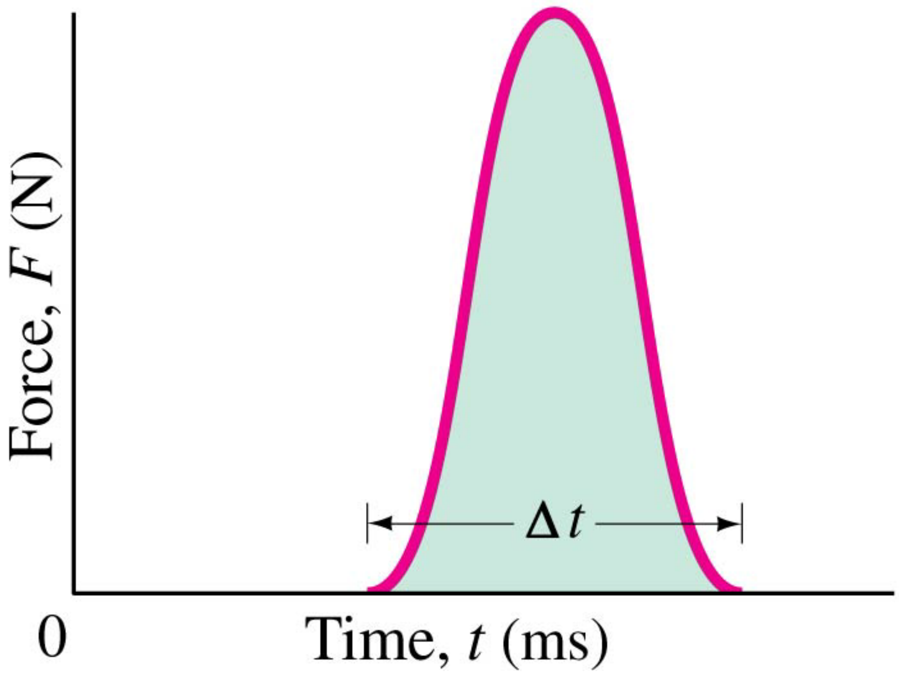
$$\vec{\mathbf{F}}\,\Delta t = \Delta\vec{\mathbf{p}}. \qquad (7\text{-}4)$$

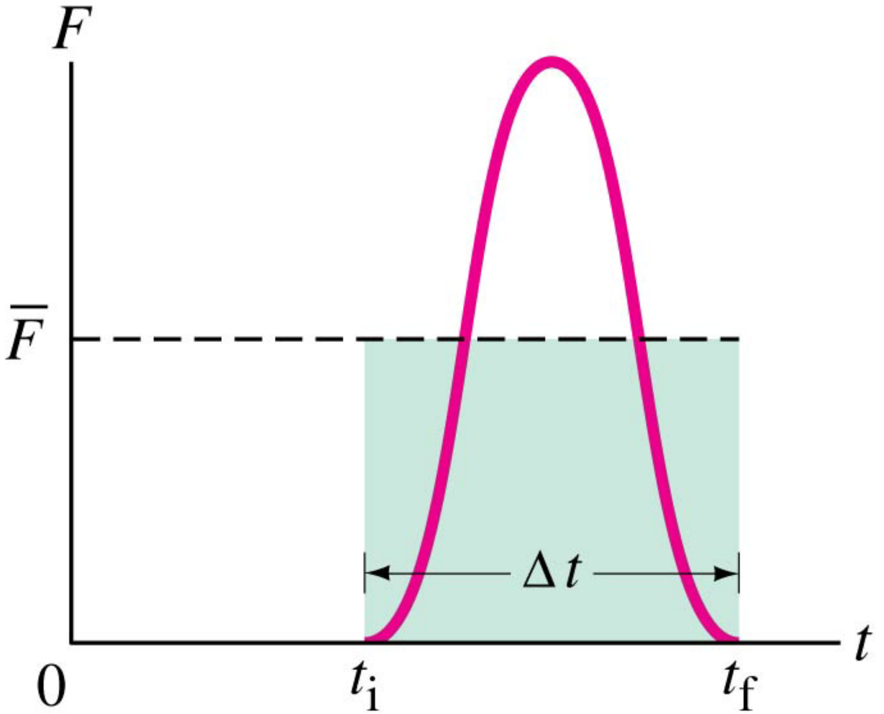
The definition of impulse:

$$\text{Impulse} = \vec{\mathbf{F}}\,\Delta t. \qquad (7\text{-}5)$$

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

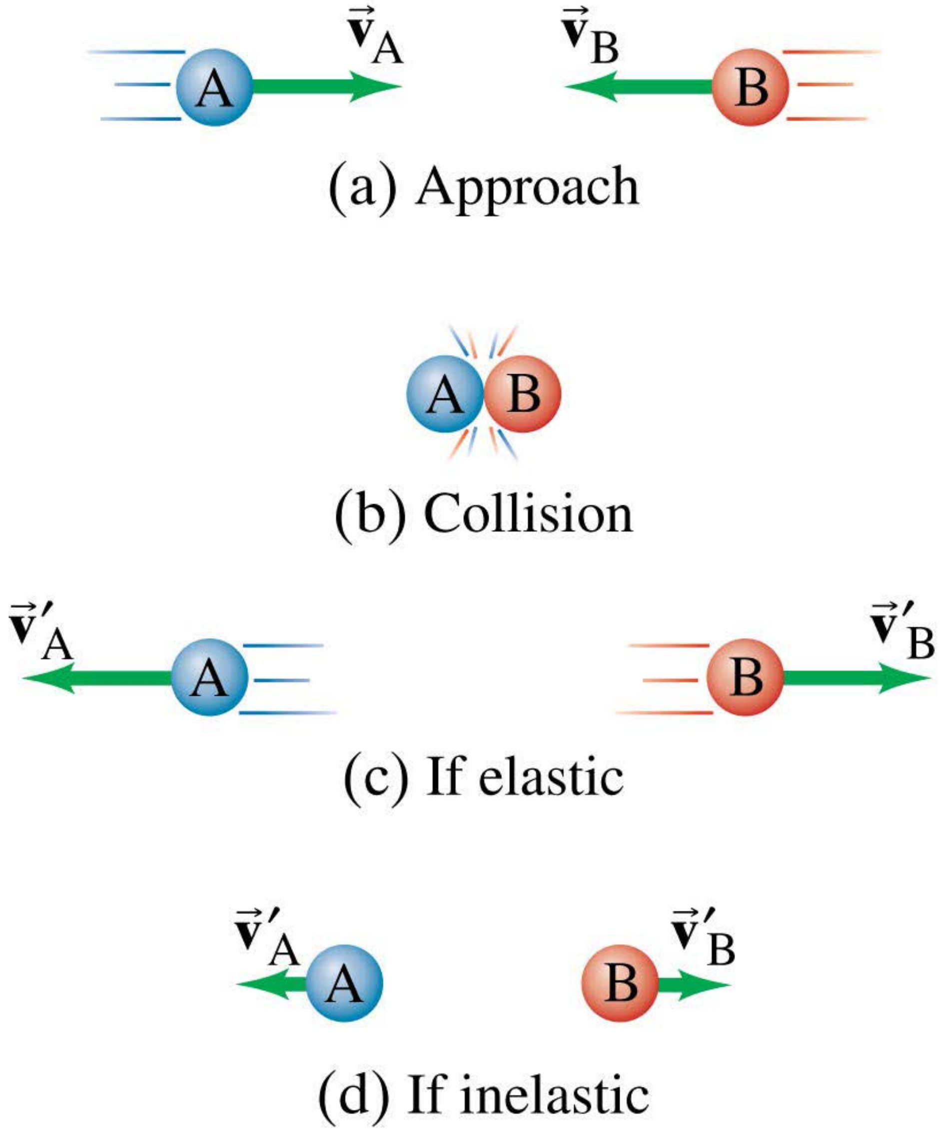
The impulse tells us that we can get the same change in momentum with a large force acting for a short time, or a small force acting for a longer time.

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.

7-4 Conservation of Energy and Momentum in Collisions

Momentum is conserved in all collisions.

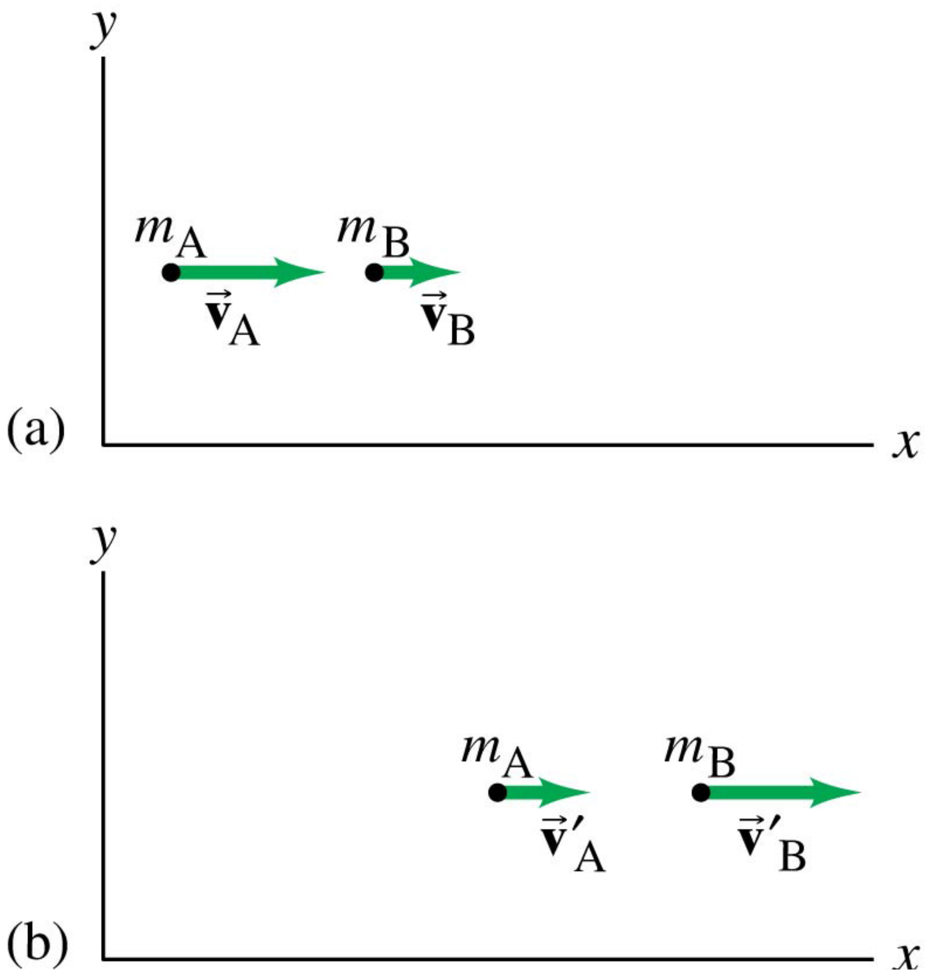
Collisions in which kinetic energy is conserved as well are called elastic collisions, and those in which it is not are called inelastic.



7-5 Elastic Collisions in One Dimension

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

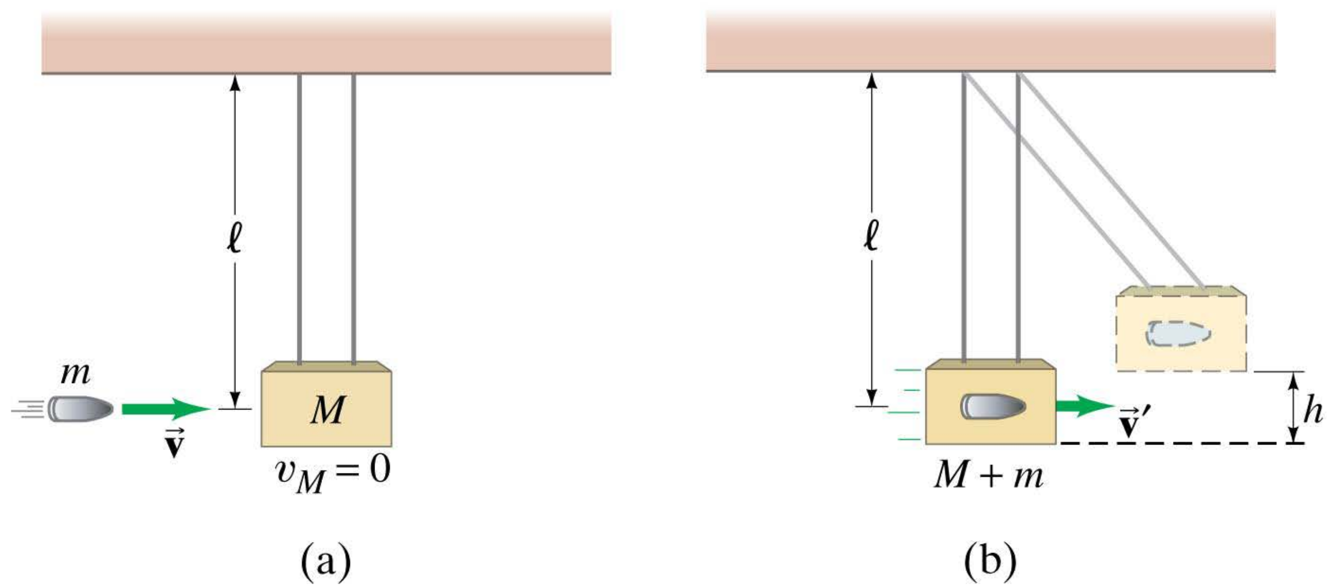
Since both momentum and kinetic energy are conserved, we can write two equations. This allows us to solve for the two unknown final speeds.



7-6 Inelastic Collisions

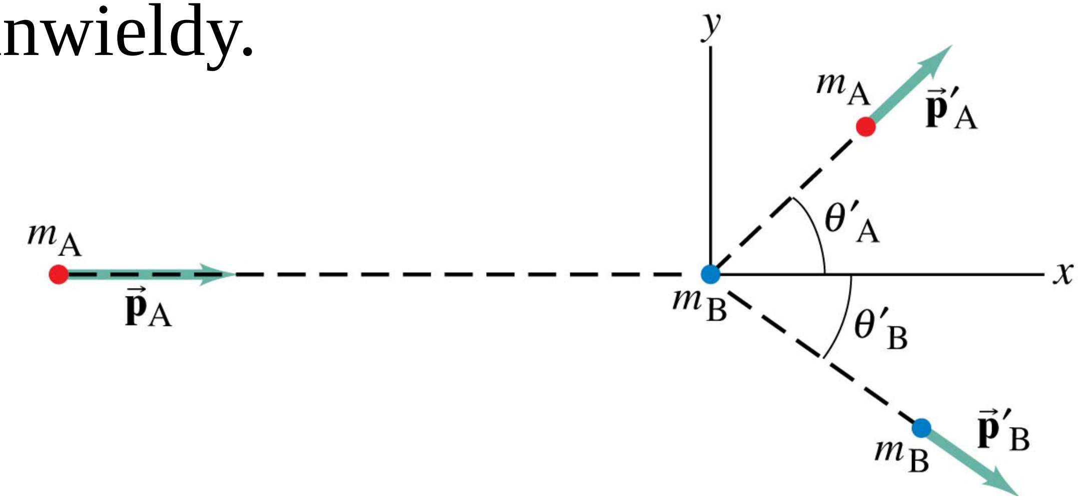
With inelastic collisions, some of the initial kinetic energy is lost to thermal or potential energy. It may also be gained during explosions, as there is the addition of chemical or nuclear energy.

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



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.

7-7 Collisions in Two or Three Dimensions

Problem solving:

1. Choose the system. If it is complex, subsystems may be chosen where one or more conservation laws apply.
2. Is there an external force? If so, is the collision time short enough that you can ignore it?
3. Draw diagrams of the initial and final situations, with momentum vectors labeled.
4. Choose a coordinate system.

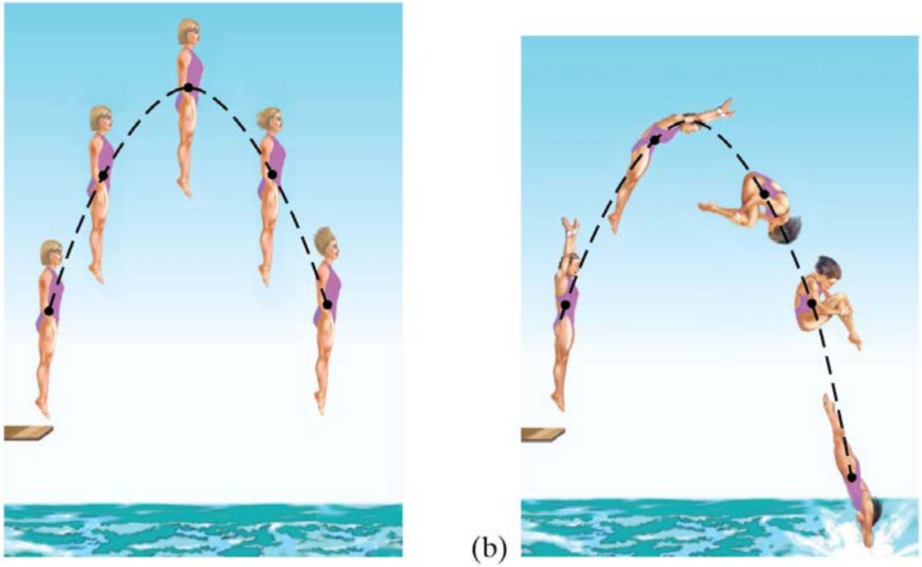
7-7 Collisions in Two or Three Dimensions

5. Apply momentum conservation; there will be one equation for each dimension.
6. If the collision is elastic, apply conservation of kinetic energy as well.
7. Solve.
8. Check units and magnitudes of result.

7-8 Center of Mass

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

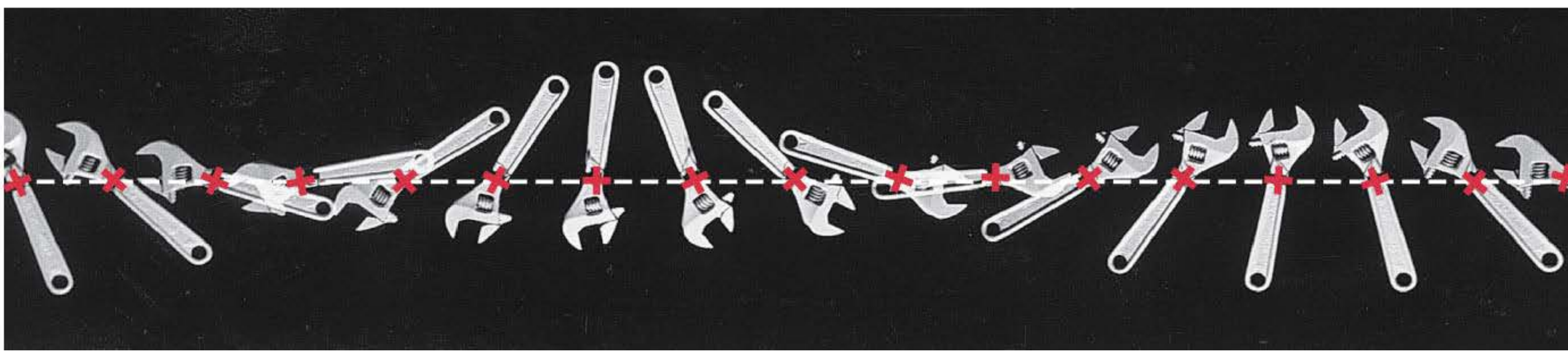
There is one point that moves in the same path a particle would take if subjected to the same force as the diver. This point is called the center of mass (CM).



(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.

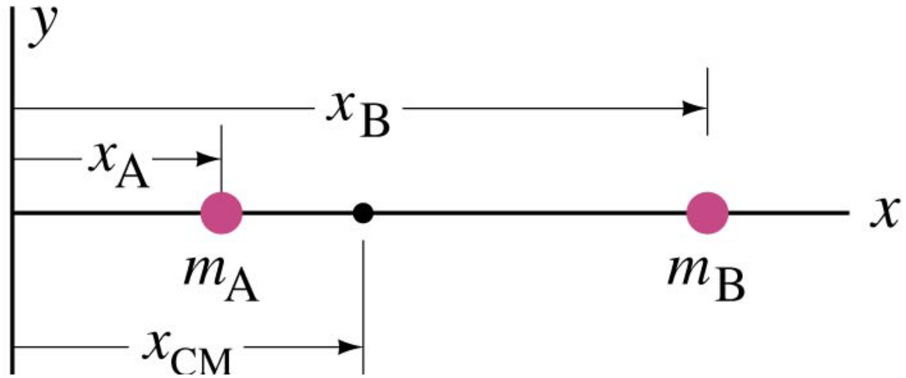


7-8 Center of Mass

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

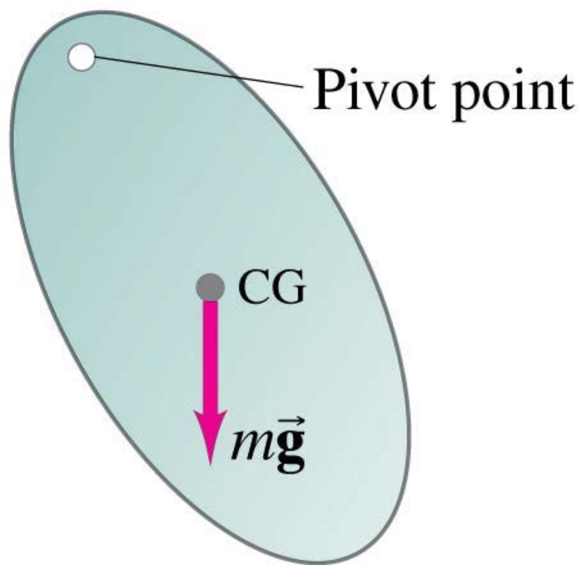
$$x_{\mathrm{CM}} = \frac{m_{\mathrm{A}} x_{\mathrm{A}} + m_{\mathrm{B}} x_{\mathrm{B}}}{m_{\mathrm{A}} + m_{\mathrm{B}}} = \frac{m_{\mathrm{A}} x_{\mathrm{A}} + m_{\mathrm{B}} x_{\mathrm{B}}}{M},$$

where M is the total mass.



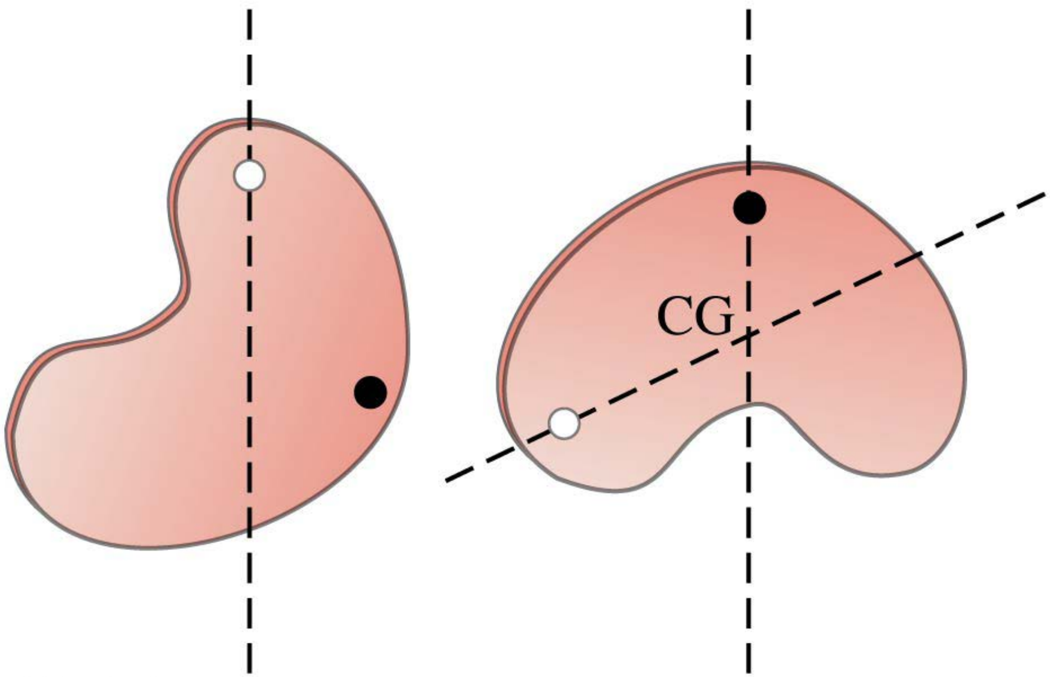
7-8 Center of Mass

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

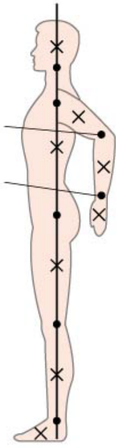
The center of gravity can be found experimentally by suspending an object from different points. The CM need not be within the actual object—a doughnut's CM is in the center of the hole.



7-9 CM for the Human Body

The x’s in the small diagram mark the CM of the listed body segments.

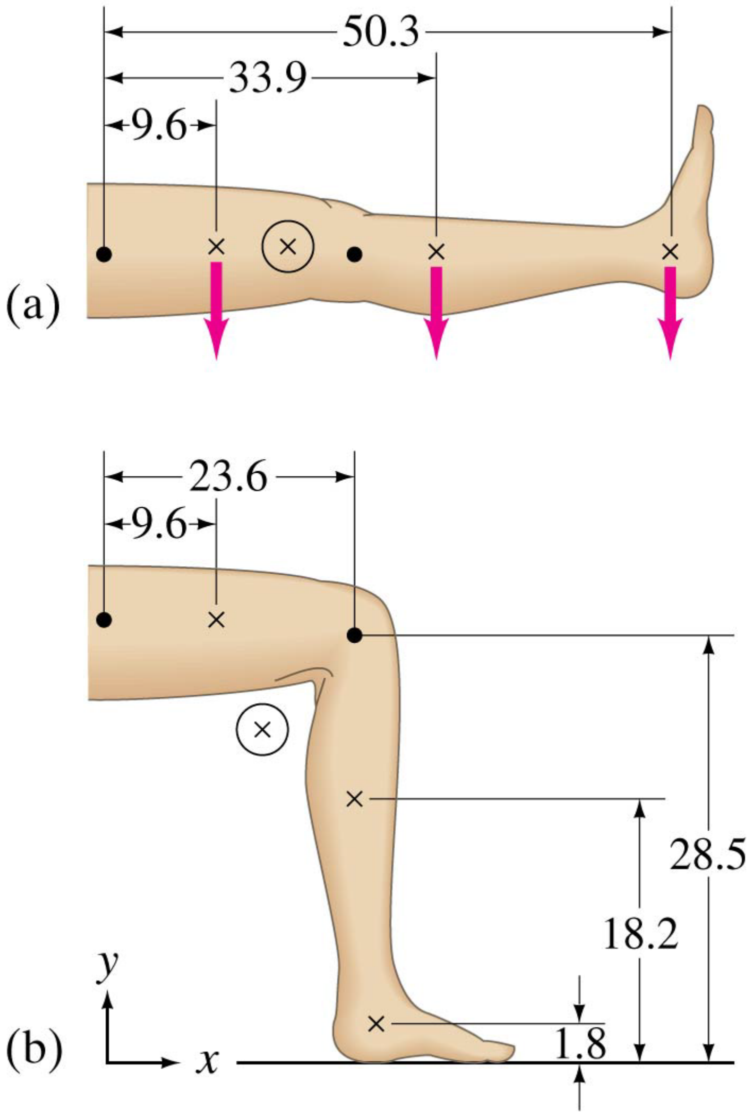
TABLE 7–1 Center of Mass of Parts of Typical Human Body, given as %
(full height and mass = 100 units)



Distance of Hinge Points from Floor (%)	Hinge Points (•) (Joints)	Center of Mass (×) (% Height Above Floor)		Percent Mass
91.2%	Base of skull on spine	Head	93.5%	6.9%
81.2%	Shoulder joint	Trunk and neck	71.1%	46.1%
	elbow 62.2%‡	Upper arms	71.7%	6.6%
	wrist 46.2%‡	Lower arms	55.3%	4.2%
52.1%	Hip joint	Hands	43.1%	1.7%
		Upper legs (thighs)	42.5%	21.5%
28.5%	Knee joint			
		Lower legs	18.2%	9.6%
4.0%	Ankle joint	Feet	1.8%	3.4%
		Body CM =	58.0%	100.0%

‡ For arm hanging vertically.

7-9 CM for the Human Body



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

7-9 CM for the Human Body

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.

7-10 Center of Mass and Translational Motion

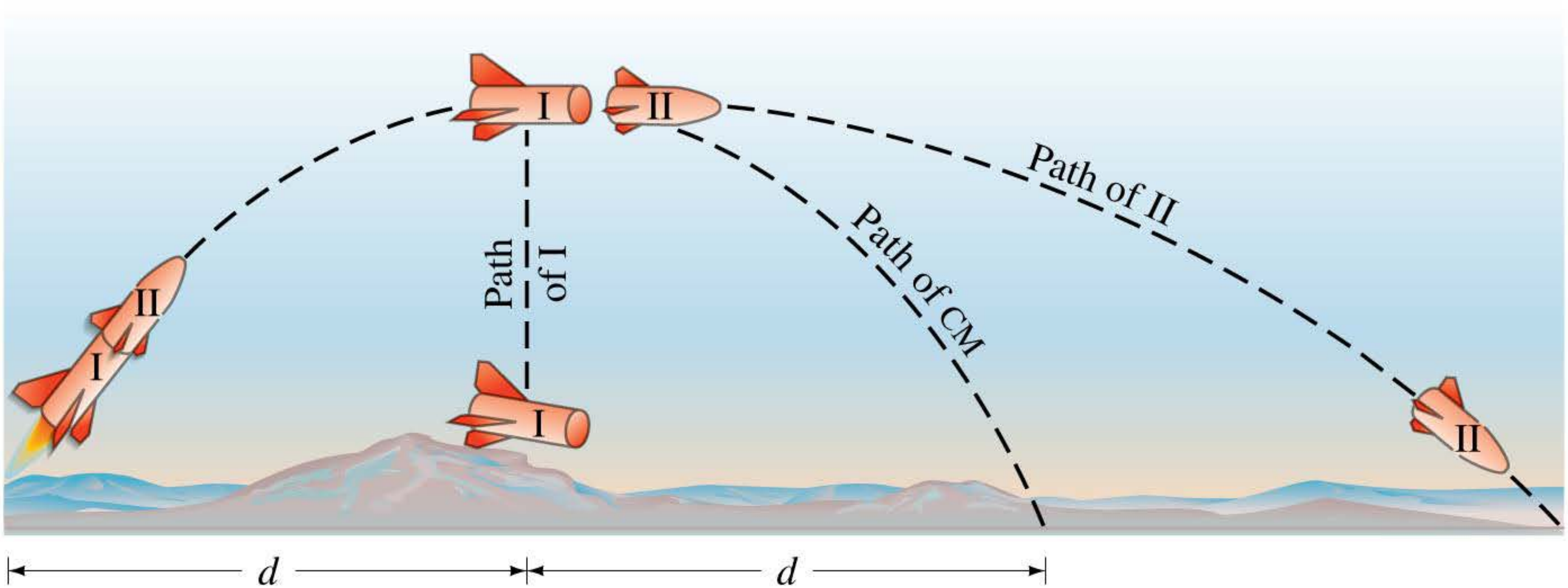
The total momentum of a system of particles is equal to the product of the total mass and the velocity of the center of mass.

The sum of all the forces acting on a system is equal to the total mass of the system multiplied by the acceleration of the center of mass:

$$Ma_{CM} = F_{net}. \qquad (7\text{-}11)$$

7-10 Center of Mass and Translational Motion

This is particularly useful in the analysis of separations and explosions; the center of mass (which may not correspond to the position of any particle) continues to move according to the net force.



Summary of Chapter 7

- Momentum of an object: $\vec{\mathbf{p}} = m\vec{\mathbf{v}}.$ (7-1)
- Newton's second law: $\Sigma\vec{\mathbf{F}} = \frac{\Delta\vec{\mathbf{p}}}{\Delta t}$ (7-2)
- Total momentum of an isolated system of objects is conserved.
- During a collision, the colliding objects can be considered to be an isolated system even if external forces exist, as long as they are not too large.
- Momentum will therefore be conserved during collisions.

Summary of Chapter 7

- $\vec{\mathbf{F}}\,\Delta t = \Delta\vec{\mathbf{p}}$ (7-4)
- In an elastic collision, total kinetic energy is also conserved.
- In an inelastic collision, some kinetic energy is lost.
- In a completely inelastic collision, the two objects stick together after the collision.
- The center of mass of a system is the point at which external forces can be considered to act.