SPH4U UNIVERSITY PHYSICS

ENERGY & MOMENTUM

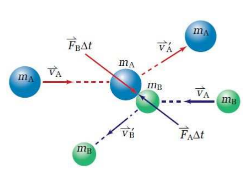
☞ Conservation of Momentum (1D) (P.228-232)

Momentum

When the cue ball hits the eight ball in billiards, the eight ball hits the cue ball. When a rock hits the ground, the ground hits the rock. In any collision, two objects exert forces on each other. You can learn more about momentum by analyzing the motion of both objects in a collision.

Newton's Third Law & Momentum

Unlike Newton's second law, which focuses on the motion of one specific object, his third law deals with the interaction between two objects. When you apply Newton's third law to collisions, you discover one of the most important laws of physics – the law of conservation of momentum.



$F_A = -F_B$ ← Newton's 3rd law (x Δt)

$F_A\Delta t = -F_B\Delta t$ ← $F\Delta t = mv_f - mv_i$

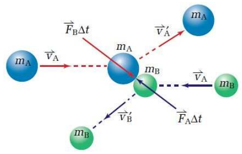
$m_A v_{Af} - m_A v_{Ai} = -(m_B v_{Bf} - m_B v_{Bi})$

$m_A v_{Af} - m_A v_{Ai} = -m_B v_{Bf} + m_B v_{Bi}$

$m_A v_{Ai} + m_B v_{Bi} = m_A v_{Af} + m_B v_{Bf}$ ← conservation of momentum

Newton's Third Law & Momentum

*This equation summarizes the **law of conservation of momentum** for two or more colliding objects:*



$$p_{i\,total} = p_{f\,total}$$

$$m_A v_{Ai} + m_B v_{Bi} = m_A v_{Af} + m_B v_{Bf}$$

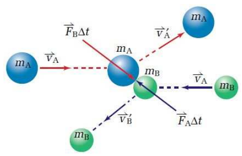
which is sometimes written as:

$$m_A v_A + m_B v_B = m_A v_A' + m_B v_B'$$

Newton's Third Law & Momentum

NOTE!

*Since momentum is a vector quantity, both the magnitude and the direction of the momentum must be conserved. Therefore, momentum is conserved in each dimension, **independently**.*



$$p_{ix\,total} = p_{fx\,total}$$

$$p_{iy\,total} = p_{fy\,total}$$

Law of Conservation of Momentum

Law of Conservation of Momentum

When two or more objects collide, the collision does not change the total momentum of the two objects. Whatever momentum is lost by one object in the collision is gained by the other. The total momentum of the system is conserved.

NOTE!

Two general categories of interactions exist: collisions and explosions (or recoil). Regardless of the category, momentum is always conserved, whether the objects bounce off one another, stick together, or break apart.

Law of Conservation of Momentum

LAW OF CONSERVATION OF MOMENTUM (Δp=0)

- when two or more objects collide, whatever momentum is lost by one object is gained by the other (momentum is conserved)

$$m_A v_{Ai} + m_B v_{Bi} = m_A v_{Af} + m_B v_{Bf}$$

where m is the mass of the object (kg)
v_i is the velocity of the object before the collision (m/s)
v_f is the velocity of the object after the collision (m/s)

NOTE!

- *The subscripts A and B refer to the two objects involved.*
- *Another form of the equation is* ☞ $m_A v_A + m_B v_B = m_A v_A' + m_B v_B'$

Law of Conservation of Momentum – DYK?

In reality, systems are rarely perfectly isolated. In nearly all real situations, immediately after a collision, frictional forces and interactions with other objects change the momentum of the objects involved in the collision. Therefore, it might appear that the law of conservation of momentum is not very useful. However, <u>the law always applies to a system from the instant before to the instant after a collision</u>.

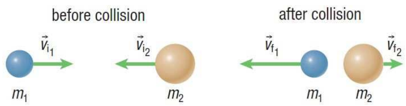
Law of Conservation of Momentum – DYK?

Therefore, if you know the conditions just before a collision, you can always use conservation of momentum to determine the momentum and, thus, velocity of an object at the instant after a collision. Often, these values are all that you need to know.

Conservation of Momentum (1D)

NOTE!

In one-dimensional collisions, each vector can point in only one of two ways. Designate directions in a way that is convenient for solving a particular problem. For example, you may choose to assign right as positive and left as negative. Then you can express the vectors using only their magnitudes, understanding that a negative value implies a left direction.

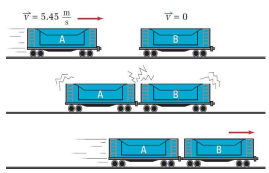


Conservation of Momentum (1D)

PRACTICE

1. A 1750 kg boxcar is rolling down a track toward a stationary 2000 kg boxcar as shown. When the boxcars collide, they lock together and continue down the track. What is the velocity of the two boxcars immediately after the collision? (Hint: they will have the same final velocity since they lock together.)

   $v_{AB}' = 2.5$ m/s[E]

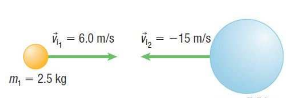


Conservation of Momentum (1D)

PRACTICE

2. The two objects shown collide head-on. If the 7.5 kg object has a velocity of -4.5 m/s after the collision, what velocity does the 2.5 kg object have after the collision?

   $v_{2.5}' = -26$ m/s

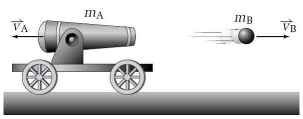


Conservation of Momentum (1D)

PRACTICE

3. A 1400 kg cannon (including the 50 kg ball) is on wheels. The cannon fires the cannon ball, giving it a velocity of 50 m/s[N]. What is the initial velocity of the cannon the instant after it fires the cannon ball?

   v_i = 1.9 m/s[S]



Conservation of Momentum (1D)

PRACTICE

4. Two objects of masses m and 3m undergo a collision in one dimension. The lighter object is moving at three times the speed of the heavier object. Describe what happens to their speeds after the collision. Explain your reasoning.

   they should rebound with the same speeds they collided with (each possess a momentum of 3mv)

✔ Check Your Learning

TEXTBOOK

P.232 Q.2-5 (Review)

WIKI (ENERGY & MOMENTUM)

✎.... 4U2 - QUIZ#1 (Work & Energy) ☞ *you can finish this now!*

✎.... 4U2 - QUIZ#2 (E&M - Part 1)