

MOMENTUM

Which is more difficult to stop: A tractor-trailer truck barreling down the highway at 35 meters per second, or a small two-seater sports car traveling the same speed? You probably guessed that it takes more force to stop a large truck than a small car. In physics terms, we say that the truck has greater momentum. We can find momentum using this equation: $p = m \cdot v$. Velocity is a term that refers to both speed and direction. For our purposes we will assume that the vehicles are traveling in a straight line. In that case, velocity and speed are the same.

The equation for momentum is abbreviated like this: $p = m \cdot v$

Momentum, symbolized with a p , is expressed in units of $\text{kg} \cdot \text{m}/\text{sec}$; m is the mass of the object, in kilograms; and v is the velocity of the object in m/sec .

MOMENTUM

1. A deer with a mass of 146 kg is running toward you with a velocity of 17 m/s North. What is the momentum of the deer?

$p = mv$
 $p = (146 \text{ kg})(17 \text{ m/s})$
 $p = 2500 \text{ kg} \cdot \text{m/s North}$

2. Which has more momentum, a 3.0 kg mass moving at 9.0 m/s or a 5.0 kg mass moving at 5.0 m/s?

$p = mv$

$(3.0 \text{ kg})(9.0 \text{ m/s})$	$(5.0 \text{ kg})(5.0 \text{ m/s})$
$27 \text{ kg} \cdot \text{m/s}$	$25 \text{ kg} \cdot \text{m/s}$

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3. A spring is compressed between two carts, one with a mass of 5 kg and one with a mass of 10 kg. Which will move away with a higher velocity? Why? 5 kg - less inertia to overcome



$P_B = P_A$
 $-10v_1 = 5v_2$
 $v_1 = \frac{1}{2}v_2$
 $v_1 \text{ is half of } v_2 \text{ in opp dir}$

IMPULSE

A change in momentum for an object is equal to impulse. Momentum changes when velocity changes. Force is what changes velocity. Therefore, when momentum changes a force must be involved for a period of time.

Impulse-Momentum Change Equation: $F \cdot t = m (v_f - v_i)$

Sample Problem: A net force of 50 newtons is applied to a 20-kilogram cart that is already moving at 1 meter per second. The final speed of the cart was 3 meters per second. For how long was the force applied?

Looking for: the time the force was applied

Given: Force applied = 50 N, Mass of the car = 20 kg, $v_i = 1 \text{ m/s}$, $v_f = 3 \text{ m/s}$

Solution: $50 \text{ N} \cdot t = 20 \text{ kg} \cdot (3 \text{ m/s} - 1 \text{ m/s})$ The force was applied to the cart for 0.8 second.

$m = .50 \text{ kg}$ $t = .20 \text{ s}$ $F(.20 \text{ s}) = (.50 \text{ kg})(0 - 15 \text{ m/s})$ $F = 38 \text{ N left}$
 $v_i = 15 \text{ m/s R}$ $F = ?$ $.20 \text{ s}$ $.20 \text{ s}$ -38
 $v_f = 0 \text{ m/s}$

4. A 0.50 kg football is thrown with a velocity of 15 m/s to the right. A stationary receiver catches the ball and brings it to a rest in 0.20 seconds. What is the force exerted on the ball by the receiver?

5. Joe the fisherman attempts to leap from his small fishing boat to the dock his boat is next to, but ends up in the water between his boat and the dock. Why is this?

Joe pushes off the boat & the boat moves in the opp. dir
 Equal F $M_a = F = m_a$
 Joe Boat

MOMENTUM CONSERVATION

Just like the third law of motion says that forces are equal and opposite, changes in momentum are equal and opposite. This is because when objects exert forces on each other, their motion is affected.

The law of momentum conservation states that if interacting objects in a system are not acted on by outside forces, the total amount of momentum in the system cannot change.

The formula below can be used to find the new velocities of objects if both keep moving after the collision.

$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

Sample Problem: You and a friend stand facing each other on ice skates. Your mass is 50 kilograms and your friend's mass is 60 kilograms. As the two of you push off each other, you move with a velocity of 4 m/s to the right. What is your friend's velocity?

Looking for: Your friend's velocity to the left.

Given: Your mass = 50 kg, Your friend's mass = 60 kg, Your velocity of 4 m/s to the right (+ direction)

Solution: $m_1 v_{1i}(\text{before}) + m_2 v_{2i}(\text{before}) = m_1 v_{1f}(\text{after}) + m_2 v_{2f}(\text{after})$

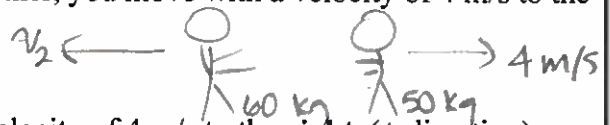
$$(50 \text{ kg} * 0 \text{ m/s}) + (60 \text{ kg} * 0 \text{ m/s}) = (50 \text{ kg} * 4 \text{ m/s}) + (60 \text{ kg} * v_{2f} \text{ m/s})$$

$$0 \text{ kg} * \text{m/s} = 200 \text{ kg} * \text{m/s} + (60 \text{ kg} * v_{2f} \text{ m/s})$$

$$-200 \text{ kg} * \text{m/s} = 60 \text{ kg} * v_{2f} \text{ m/s} \text{ (the - sign is directional and means to the left in this case)}$$

$$v_{2f} = -3.33 \text{ m/s or to the left}$$

Your friend's velocity to the left is ~~3.33~~ m/s. **1 s.f.**



MOMENTUM CONSERVATION

6. A 1500 kg car traveling at 15 m/s to the south collides with a 4500 kg truck that is initially at rest at a stoplight. The car and truck stick together and move together after the collision. What is the final velocity of the two vehicle mass?

$$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v$$

$$(1500 \text{ kg})(15 \text{ m/s}) + (4500 \text{ kg})(0) = (6000 \text{ kg})(v)$$

$$\frac{22,500}{6000} = \frac{6000 v}{6000}$$

$$v = 3.8 \text{ m/s South}$$

7. A 63 kg astronaut is on a spacewalk when the tether line to the shuttle breaks. The astronaut is able to throw a spare 10.0 kg oxygen tank in a direction away from the shuttle with a velocity of 12 m/s, propelling the astronaut back toward the shuttle. Assuming the astronaut starts from rest, find the astronaut's final speed after the tank is thrown.

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

$$(63 \text{ kg})(0) + (10.0 \text{ kg})(0) = (63 \text{ kg})(v_1) + (10.0 \text{ kg})(12 \text{ m/s})$$

$$0 = (63 \text{ kg})(v_1) + 120 \text{ kg} * \text{m/s}$$

$$-120 \text{ kg} * \text{m/s} = v_1$$

$$v_1 = -1.9 \text{ m/s}$$

1.9 m/s toward Shuttle

8. A 0.015 kg marble moves to the right at 22.5 cm/s on a frictionless surface and makes an elastic head-on collision with a 0.025 kg marble moving to the left at 18 cm/s. After the collision, the first marble is moving to the left at 18 cm/s. What is the velocity of the second ball?

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

$$(0.015)(22.5) + (0.025)(-18) = (0.015)(-18) + (0.025)(v_2)$$

$$-1.125 \text{ kg} * \text{m/s} = -0.27 \text{ kg} * \text{m/s} + (0.025)(v_2)$$

$$+0.27 \text{ kg} * \text{m/s}$$

$$\frac{.1575}{.025} = \frac{(.025)(v_2)}{.025}$$

$$v_2 = 6.3 \text{ cm/s Right}$$