# *Building Momentum*

**Linear Momentum** is a way to quantify motion. It is defined as the combination of the **mass** of the object and its **velocity**. The equation for momentum is $p = mv$ where ***p*** is the momentum, *m* is the mass and ***v*** is the velocity of the object. The quantity momentum is the motion referenced in Newton's First Law of Motion.

1. Kinetic energy is also a way to quantify motion. Identify ways that momentum and kinetic energy are different.

2. Identify the units of momentum. Show how these units can also be written as N s.

3. Calculate the momentum for the following:
    a. A 1250 kg car driving 25 m $s^{-1}$
    b. A 2500 kg truck driving 25 m $s^{-1}$
    c. A 130 kg person running 6 m $s^{-1}$

4. A 1.5 kg cart is moving at 10 m $s^{-1}$.
    a. Determine how fast a 3.0 kg cart have to travel to have the same kinetic energy.
    b. Determine how fast a 3.0 kg cart have to travel to have the same momentum.

5. The **impulse** on an object is a measure of the change in the momentum of an object. Use Newton's Second Law to show that $F_{net}\Delta t = \Delta p$. This equation shows that there are two ways to calculate impulse. The context of the problem will dictate which is more appropriate.

6. A 0.20 kg ball bounces off a wall. Initially, the ball is travelling 15 m $s^{-1}$. After bouncing off the wall, it travels 10 m $s^{-1}$ in the opposite direction.
    a. Calculate the initial momentum of the ball.
    b. Calculate the final momentum of the ball.
    c. Determine the impulse on the ball.
    d. If the change occurs over 0.30 seconds, determine the average force of the wall on the ball.

7. A major reason to choose to examine a situation through the lens of momentum is related to systems of objects. Knowing that $F_{net}\Delta t = \Delta p$, describe what must be true about the momentum of the individual parts of a system if the net *external* force on a system is zero.

8. A 75 kg person is stepping off a stationary 30 kg canoe that is not connected to the dock. He leaves the boat at 2.0 m $s^{-1}$.
    a. Describe the motion of the canoe. Include the speed of the canoe.
    b. Calculate the impulse on the person.
    c. Calculate the impulse on the canoe.

9. Rockets use momentum to change their motion.
    a. Explain to what extent this statement is true.
    b. Describe how the changing mass impacts the motion.

10. Explain the difference you would feel between firing a blank cartridge and a regular cartridge.

11. An astronaut is “floating” in space when her tether breaks. She wants to get back to the ship, but only has a wrench that will not reach the ship.
    a. Describe what she should do with the wrench.
    b. Assuming a 100 kg astronaut and a 2 kg wrench, calculate how fast must she throw the wrench in order to travel back to the ship at a speed of 0.25 m $s^{-1}$.

12. A 2.0 kg block is initially sitting at rest on a frictionless floor. When a small charge is detonated, it breaks into two pieces. One piece is 0.5 kg and is traveling 25 m $s^{-1}$ to the north.
    a. State the initial momentum of the block.
    b. Calculate the final momentum of the 0.5 kg piece.
    c. State the mass of the remaining piece.
    d. Determine the final momentum of the remaining piece.
    e. Calculate the final velocity of the remaining piece.
    f. Calculate the final kinetic energy of the system.
    g. Describe the source of this energy.

13. A rifle has a mass of 3.80 kg. The rifle can fire a 0.03 kg bullet with a speed of 900 m $s^{-1}$.
    a. Determine the recoil velocity of the gun due to the bullet.
    b. There is a secondary recoil immediately after the bullet leaves the gun. Describe the source of this recoil.