Example 2: A spring scale is used to apply 4 N of force to a toy car with a mass of 0.3 kg. What is the acceleration of the toy car to the nearest tenth m/s^2?

Known variables	Force = 4 N mass = 0.3 kg
Write the **Formula**	$F = m \bullet a$
Substitute known variables	$4 = 0.3 \bullet a$
Make a reasonable **Estimate**	0.3 is about 1/3. 4 is 1/3 of what? 4 is 1/3 of 12, so the answer should be close to 12.
Solve the equation	$4 = 0.3 \bullet a$ $\frac{4}{0.3} = \frac{0.3 \bullet a}{0.3}$ $13.3 = a$ **acceleration = 13.3 m/s^2**

Try the next problem on your own.

A bowler uses 10.5 N of force to roll a bowling ball, and the ball accelerates down the bowling lane at a rate of 2.5 m/s^2. What is the mass of the bowling ball to the nearest tenth of a kilogram?

Known variables	
Write the **Formula**	
Substitute known variables	
Make a reasonable **Estimate**	
Solve the equation	

Force, Mass, and Acceleration

Newton's Laws of Motion

Sir Isaac Newton published *Philosophiae Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy)* in 1687. In his work, he described three ideas about motion that are now known as Newton's Laws of Motion.

First Law: Law of Inertia

An object at rest will remain at rest until an unbalanced force causes it to move. An object in motion will continue moving at the same speed and in the same direction until an unbalanced force changes its motion.

Second Law: Law of Force and Acceleration

The second law describes the relationship between force, mass, and acceleration. When mass is constant, acceleration is directly related to force. The relationship can be described mathematically using the formula Force = mass • acceleration.

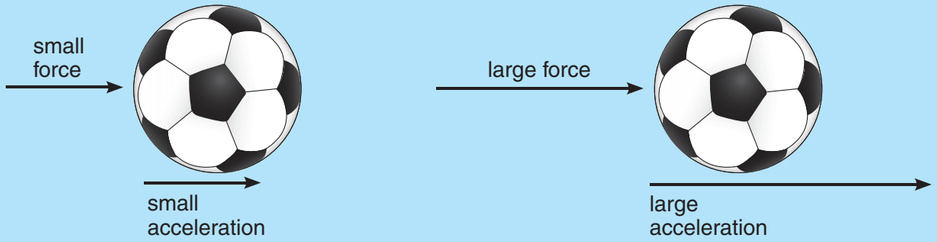
Third Law: Law of Action–Reaction

Forces occur in pairs, and every action (force) has an equal and opposite reaction (force). This means when a force is applied to an object, that object applies an equal force in the opposite direction.

Let's look more closely at the relationships between force, mass, and acceleration described in Newton's second law of motion.

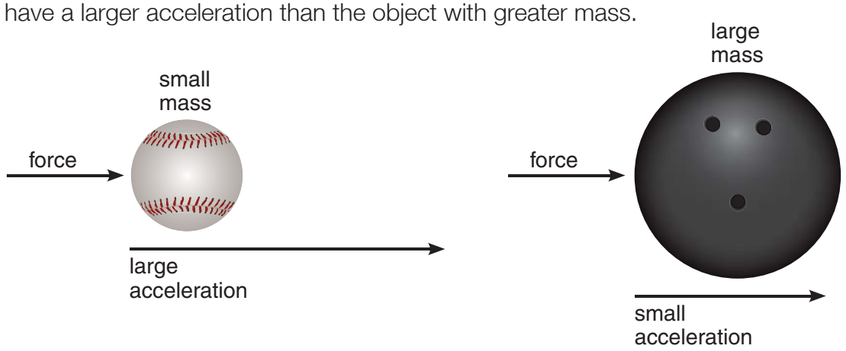
HOW ARE FORCE AND ACCELERATION RELATED?

An unbalanced force will result in a change in motion—speeding up, slowing down, or changing direction. In science, these changes in motion are called accelerations. According to the second law of motion, the acceleration of the object is directly related to the force that caused the change in motion. This means a small force will result in a small acceleration, and a large force will result in a large acceleration.



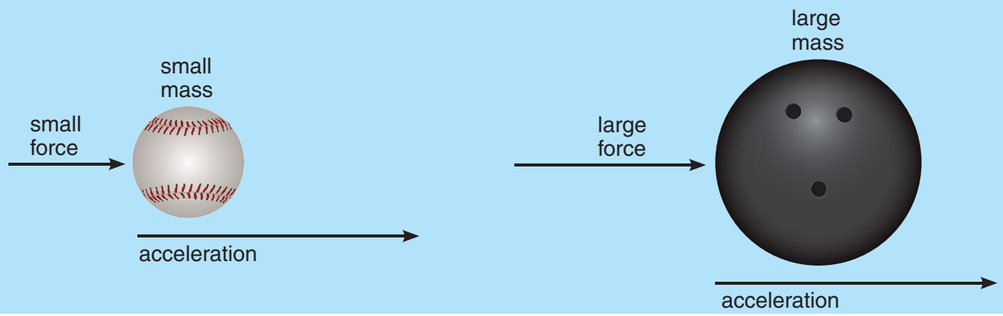
HOW ARE MASS AND ACCELERATION RELATED?

The acceleration of an object is inversely related to its mass. **Inverse** means opposite. If variables are inversely related, one variable increases as the other variable decreases. What does this tell us about mass and acceleration? If the same amount of force is applied to objects with different mass, the object with less mass will have a larger acceleration than the object with greater mass.

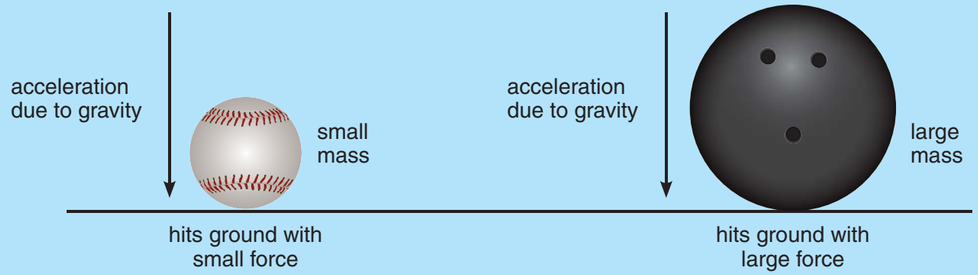


HOW ARE FORCE AND MASS RELATED?

Force and mass are directly related. If variables are directly related, one variable increases as the other variable increases. What does this tell us about force and mass? More force is needed to accelerate an object with a large mass. Less force is needed to accelerate an object with a small mass.



Let's think about force and mass another way. If two balls are falling at the same rate of acceleration and hit the ground, the ball with more mass applies a greater force to the ground than the ball with less mass.



CALCULATING FORCE, MASS, AND ACCELERATION

The second law of motion describes the relationships between force, mass, and acceleration using the formula Force = mass • acceleration.

$$F = ma$$

This formula can be used to calculate

- force in Newtons (N),
- mass in kilograms (kg), and
- acceleration in meters per second squared (m/s^2).

The following steps can be used when solving problems about force, mass, and acceleration.

1. Read the problem, and record the **Known** variables.
2. Write the **Formula**.
3. **Substitute** known variables into the formula.
4. Make a reasonable **Estimate** for the solution to the problem.
5. **Solve** the equation, and check the reasonableness of the solution.

Let's practice using a problem-solving chart to calculate force, mass, and acceleration.

Example 1: A soccer player kicks a 0.45 kg soccer ball, and the ball accelerates at a rate of 200 m/s^2. How much force did the soccer player use to kick the ball?

Known variables	mass = 0.45 kg acceleration = 200 m/s^2
Write the **Formula**	$F = m \bullet a$
Substitute known variables	F = 0.45 • 200
Make a reasonable **Estimate**	0.45 is close to 0.5, or 1/2. Half of 200 is 100. The answer should be close to 100.
Solve the equation	F = 0.45 • 200 0.45 x 200 = 90 F = 90 **Force = <u>90 N</u>**