THE BIG IDEA

An object accelerates when a net force acts on it.

Definition of acceleration:

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time interval}}$$

The *cause* of acceleration is *force*.

6.1 Force Causes Acceleration

Unbalanced forces acting on an object cause the object to accelerate.

6.1 Force Causes Acceleration

Recall that the combination of forces acting on an object is the *net force*.

- An object's acceleration is directly proportional to the net force acting on it:

acceleration ~ net force

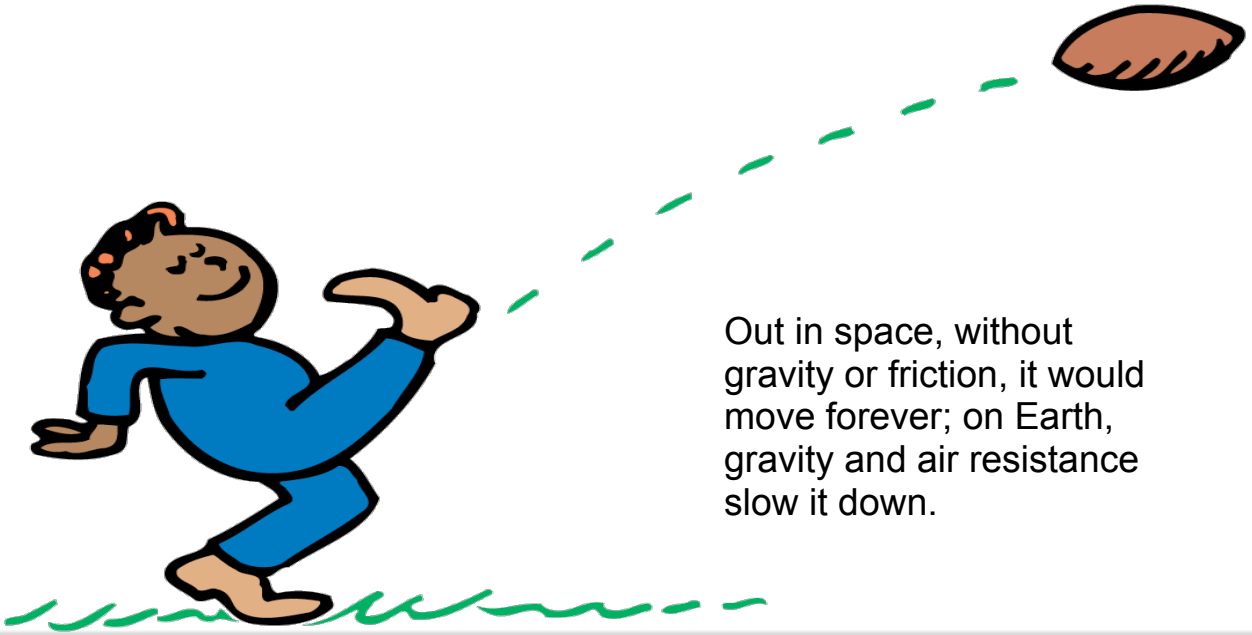
(The symbol ~ stands for "is directly proportional to.")

6.1 Force Causes Acceleration

Kick a football and it does not remain at rest.

It accelerates while the force of your foot is in contact with the ball.

The acceleration causes a change in velocity (movement)



Out in space, without gravity or friction, it would move forever; on Earth, gravity and air resistance slow it down.

6.1 Force Causes Acceleration

CONCEPT CHECK

What causes an object to accelerate?

6.2 Mass Resists Acceleration

For a constant force, an increase in the mass will result in a decrease in the acceleration.

This is because mass has inertia (inertia is the resistance to motion)

6.2 Mass Resists Acceleration

Push on an empty shopping cart. Then push equally hard on a heavily loaded shopping cart.

The loaded shopping cart will accelerate much less than the empty cart.

Acceleration depends on the mass being pushed.

6.2 Mass Resists Acceleration

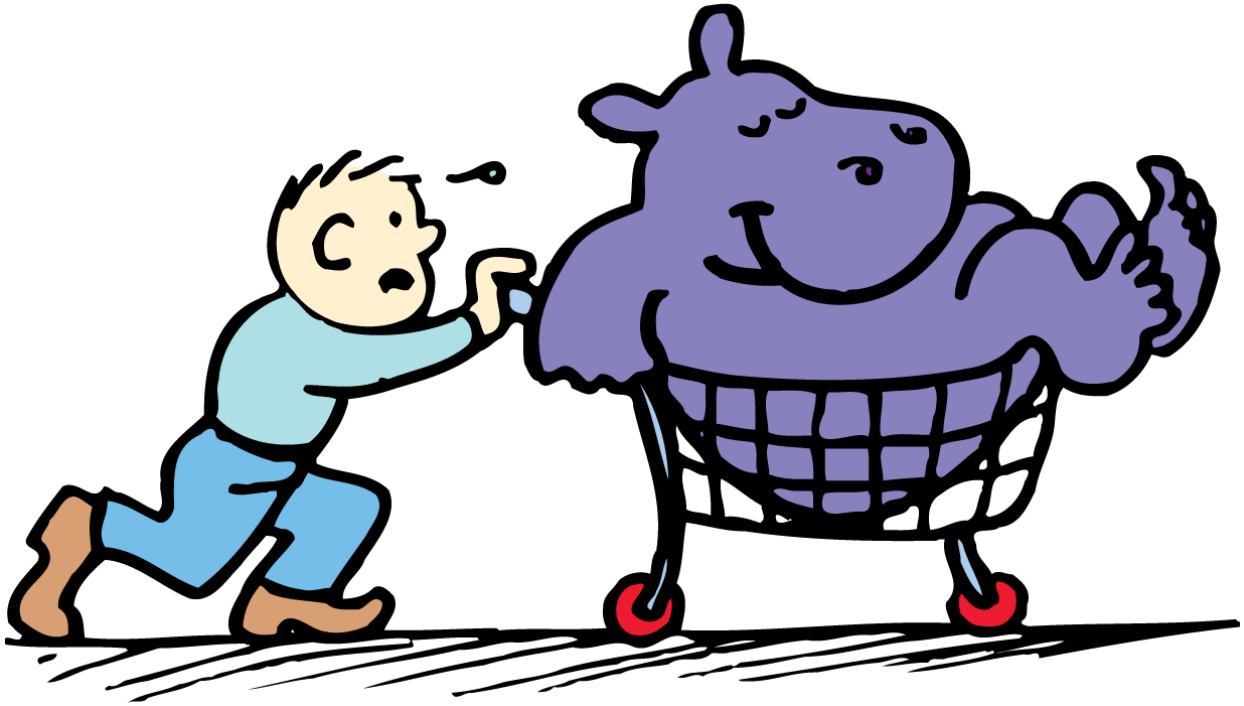
The acceleration is *inversely proportional* to the mass.

$$\text{acceleration} \sim \frac{1}{\text{mass}}$$

Inversely means that the two values change in opposite directions. As the denominator increases, the whole quantity decreases by the same factor.

6.2 Mass Resists Acceleration

The acceleration produced depends on the mass that is pushed.



6.2 Mass Resists Acceleration

CONCEPT CHECK

How does an increase in mass affect acceleration?

6.3 Newton's Second Law

Newton's second law describes the relationship among an object's mass, an object's acceleration, and the net force on an object.

$$\text{acceleration} \sim \frac{\text{net force}}{\text{mass}}$$

6.3 Newton's Second Law

By using consistent units, such as newtons (*N*) for force, kilograms (*kg*) for mass, and meters per second squared (m/s^2) for acceleration, we get the exact equation:

$$\text{acceleration} = \frac{\text{net force}}{\text{mass}}$$

If *a* is acceleration, *F* is net force, and *m* is mass,

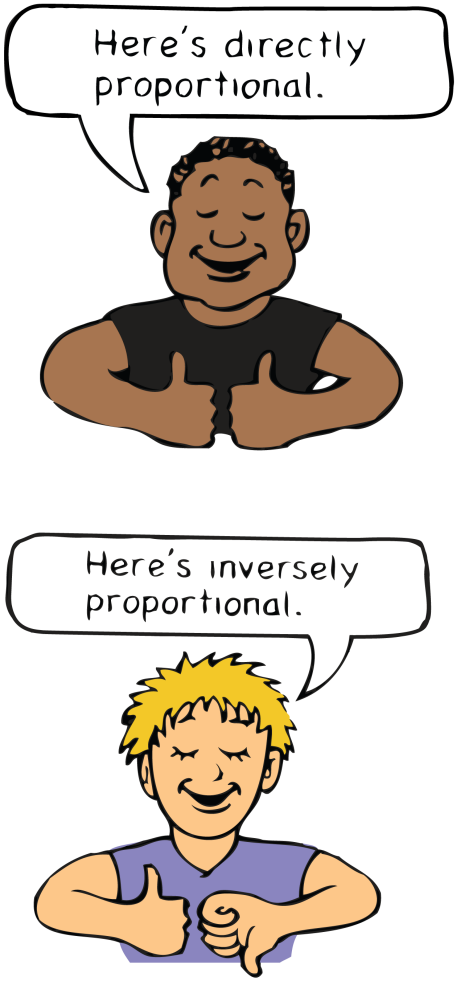
$$a = \frac{F}{m}$$

(Also written as F=ma)

6.3 Newton's Second Law

The acceleration is equal to the net force divided by the mass.

- If the net force acting on an object doubles, its acceleration is doubled.
- If the mass is doubled, then acceleration will be halved.
- If both the net force and the mass are doubled, the acceleration will be unchanged.



6.3 Newton's Second Law

think!

If a car (whose motor can supply a given force) can accelerate at 2 m/s^2, what acceleration can it attain if it is towing another car of equal mass?

6.3 Newton's Second Law

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If a car can accelerate at 2 m/s^2, what acceleration can it attain if it is towing another car of equal mass?

Answer: The same force on twice the mass produces half the acceleration, or 1 m/s^2.

6.3 Newton's Second Law

do the math!

A car has a mass of 1000 kg. What is the acceleration produced by a force of 2000 N?

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$$a = \frac{F}{m} = \frac{2000\ \text{N}}{1000\ \text{kg}} = \frac{2000\ \text{kg}\cdot\text{m/s}^2}{1000\ \text{kg}} = 2\ \text{m/s}^2$$

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do the math!

If the force is 4000 N, what is the acceleration?

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$$a = \frac{F}{m} = \frac{4000\ \text{N}}{1000\ \text{kg}} = \frac{4000\ \text{kg}\cdot\text{m/s}^2}{1000\ \text{kg}} = 4\ \text{m/s}^2$$

Doubling the force on the same mass simply doubles the acceleration.

6.3 Newton's Second Law

do the math!

How much force, or thrust, must a 30,000-kg jet plane develop to achieve an acceleration of 1.5 m/s^2?

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Arrange Newton's second law to read:

force = mass × acceleration

$F = ma$

$= (30{,}000\ \text{kg})(1.5\ \text{m/s}^2)$

$= 45{,}000\ \text{kg}\cdot\text{m/s}^2$

$= 45.000\ \text{N}$

6.3 Newton's Second Law

CONCEPT CHECK

What is the relationship among an object's mass, an object's acceleration, and the net force on an object?

Video on Newtons Laws

Assessment Questions

1. An object will accelerate when
   a. Sum of all *forces* = 0.
   b. it is moving.
   c. it is pushed or pulled with a net force.
   d. its mass increases.

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Answer: C

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2. When a net force acts on an object, its acceleration depends on the object's
   a. initial speed.
   b. mass.
   c. volume.
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Answer: B

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3. A cart is pushed and undergoes a certain acceleration. Consider how the acceleration would compare if it were pushed with twice the net force while its mass increased by four. Then its acceleration would be
   a. one quarter.
   b. half.
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