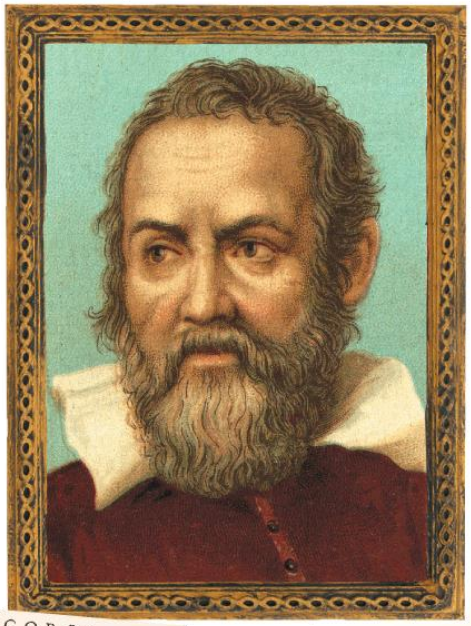
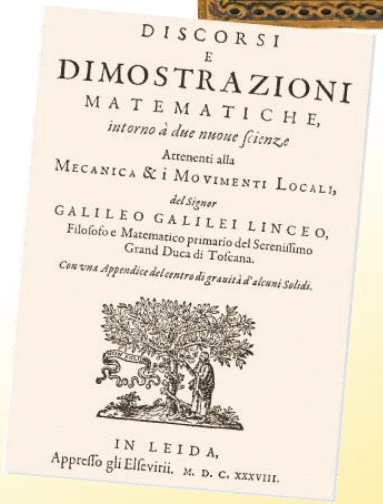
Galileo's work helped correct misconceptions about force and motion that had been widely held since Aristotle's time.




DISCORSI
E
DIMOSTRAZIONI
MATEMATICHE,
intorno à due nuoue scienze
Attenenti alla
MECANICA & i MOVIMENTI LOCALI,
del Signor
GALILEO GALILEI LINCEO,
Filosofo e Matematico primario del Serenissimo
Grand Duca di Toscana.
Con vna Appendice del centro di grauità d'alcuni Solidi.
IN LEIDA,
Appresso gli Elsevirii. M. D. C. XXXVIII.

Aristotle, Galileo, and Newton

It took about 2000 years to develop the modern understanding of the relationships between force and motion.

Aristotle, Galileo, and Newton

Aristotle

Aristotle made scientific discoveries through careful observation and logical reasoning.

Aristotle incorrectly proposed that force is required to keep an object moving at constant speed.

Aristotle, Galileo, and Newton

Galileo

Galileo Galilei studied how gravity produces constant acceleration.

- He rolled balls down wooden ramps.
- He concluded that moving objects not subjected to friction or any other force would continue to move indefinitely.

Aristotle, Galileo, and Newton

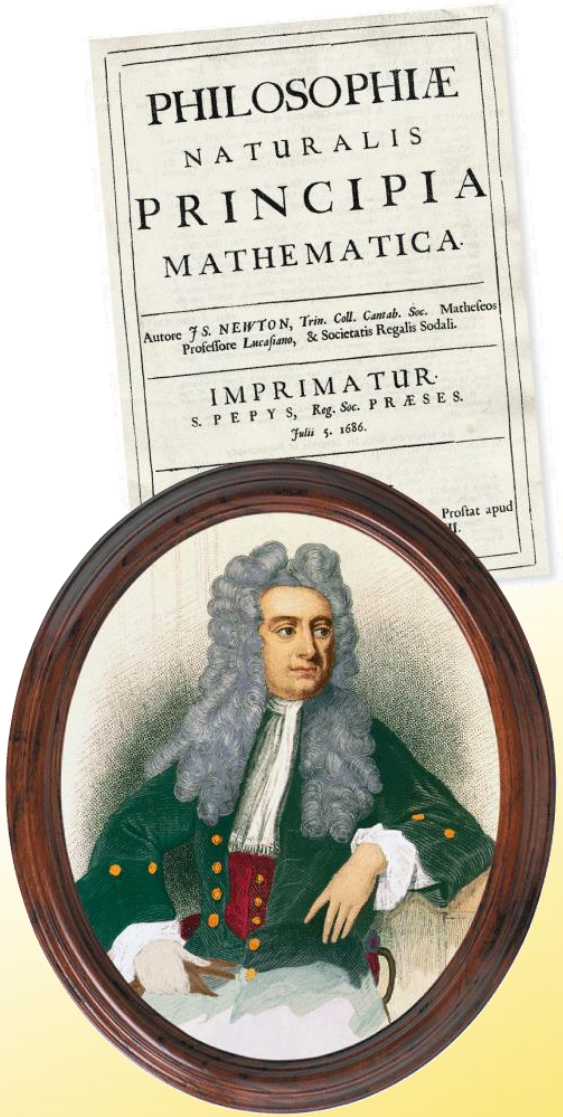
Newton

Newton built on the work of scientists such as Galileo.

- Newton first defined mass and force.
- He then introduced his laws of motion.

Aristotle, Galileo, and Newton

Isaac Newton published his work on force and motion in the book entitled *Principia.*



Newton's First Law of Motion

- How does Newton's first law relate change in motion to a zero net force?
- According to Newton's first law of motion, the state of motion of an object does not change as long as the net force acting on the object is zero.

Newton's First Law of Motion

Unless an unbalanced force acts, an object at rest remains at rest.

Unless an unbalanced force acts, an object in motion remains in motion with the same speed and direction.

Inertia is the tendency of an object to resist a change in its motion.

Newton's First Law of Motion

This crash sequence illustrates inertia. The test dummy continues its forward motion as the car slows and stops.

Newton's First Law of Motion

This crash sequence illustrates inertia. The test dummy continues its forward motion as the car slows and stops.

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Newton's First Law of Motion

This crash sequence illustrates inertia. The test dummy continues its forward motion as the car slows and stops.

Newton's Second Law of Motion

- How does Newton's second law relate force, mass, and acceleration?
- According to Newton's second law of motion, the acceleration of an object is equal to the net force acting on it divided by the object's mass.

Newton's Second Law of Motion

The acceleration of an object is directly proportional to the net force acting on it.

The acceleration of an object also depends upon its mass.

Mass is a measure of the inertia of an object.

Newton's Second Law

$$\text{Acceleration} = \frac{\text{Net force}}{\text{Mass}}, \quad \text{or} \quad a = \frac{F}{m}$$

Newton's Second Law of Motion

The acceleration of an object is always in the same direction as the net force.

When a net force acts in the direction opposite to the object's motion, the force produces a deceleration.

Newton's Second Law of Motion

Math Skills

Newton's Second Law

An automobile with a mass of 1000 kilograms accelerates when the traffic light turns green. If the net force on the car is 4000 newtons, what is the car's acceleration?

Newton's Second Law of Motion

Math Skills

1 Read and Understand

What information are you given?

Newton's Second Law of Motion

Math Skills

1 Read and Understand

What information are you given?

Mass, $m = 1000$ kg

Force, $F = 4000$ N (in the forward direction)

Newton's Second Law of Motion

Math Skills

2 Plan and Solve

What unknown are you trying to calculate?

What formula contains the given quantities and the unknown?

Newton's Second Law of Motion

Math Skills

2 Plan and Solve

What unknown are you trying to calculate?

$$\text{Acceleration}, a = ?$$

What formula contains the given quantities and the unknown?

$$\text{Acceleration} = \frac{\text{Net force}}{\text{Mass}}, a = \frac{F}{m}$$

Newton's Second Law of Motion

Math Skills

2 Plan and Solve

Replace each variable with its known value and solve.

Newton's Second Law of Motion

Math Skills

2 Plan and Solve

Replace each variable with its known value and solve.

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

$$a = 4\ \text{m/s}^2 \text{ in the forward direction}$$

Newton's Second Law of Motion

Math Skills

3 Look Back and Check

Is your answer reasonable?

Newton's Second Law of Motion

Math Skills

3 Look Back and Check

Is your answer reasonable?

Powerful sports cars can accelerate at 6 m/s^2 or more.

Thus, a smaller acceleration of 4 m/s^2 seems reasonable.

Newton's Second Law of Motion

Math Practice

1. A boy pushes forward a cart of groceries with a total mass of 40.0 kg. What is the acceleration of the cart if the net force on the cart is 60.0 N?

Newton's Second Law of Motion

Math Practice

1. A boy pushes forward a cart of groceries with a total mass of 40.0 kg. What is the acceleration of the cart if the net force on the cart is 60.0 N?

Answer: $a = F/m = 60.0\ \text{N}/40.0\ \text{kg} = 1.50\ \text{m/s}^2$

Newton's Second Law of Motion

Math Practice

2. What is the upward acceleration of a helicopter with a mass of 5000 kg if a force of 10,000 N acts on it in an upward direction?

Newton's Second Law of Motion

Math Practice

2. What is the upward acceleration of a helicopter with a mass of 5000 kg if a force of 10,000 N acts on it in an upward direction?

Answer: $a = F/m$ = 10,000 N/5000 kg = 2 m/s^2

Newton's Second Law of Motion

Math Practice

3. An automobile with a mass of 1200 kg accelerates at a rate of 3.0 m/s^2 in the forward direction. What is the net force acting on the automobile? (*Hint:* Solve the acceleration formula for force.)

Newton's Second Law of Motion

Math Practice

3. An automobile with a mass of 1200 kg accelerates at a rate of 3.0 m/s^2 in the forward direction. What is the net force acting on the automobile? (*Hint:* Solve the acceleration formula for force.)

Answer: $a = F/m$

$$F = m/a = 1200\ \text{kg} \times 3.0\ \text{m/s}^2 = 3600\ \text{N}$$

Newton's Second Law of Motion

Math Practice

4. A 25-N force accelerates a boy in a wheelchair at 0.5 m/s2. What is the mass of the boy and the wheelchair? (*Hint:* Solve Newton's second law for mass.)

Newton's Second Law of Motion

Math Practice

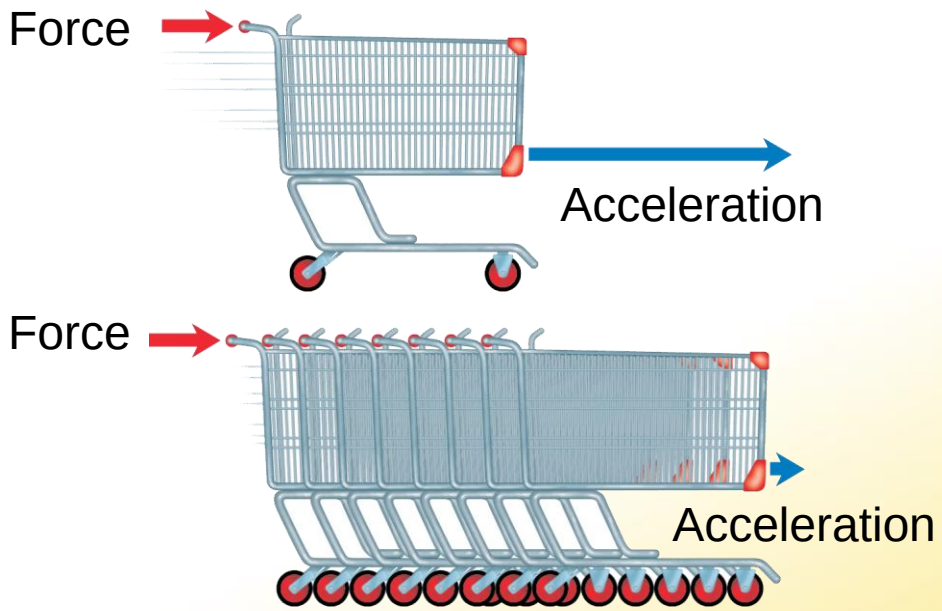
4. A 25-N force accelerates a boy in a wheelchair at 0.5 m/s2. What is the mass of the boy and the wheelchair? (*Hint:* Solve Newton's second law for mass.)

Answer: $a = F/m$

$m = F/a = 25\ \text{N}/0.50\ \text{m/s}^2 = 50\ \text{kg}$

Newton's Second Law of Motion

Acceleration depends directly on force and inversely on mass. The same force causes the single cart to accelerate eight times faster than the chain of eight carts.



Weight and Mass

- **How are weight and mass related?**
- **Mass is a measure of the inertia of an object; weight is a measure of the force of gravity acting on an object.**

Weight and Mass

Mass and weight are related but are not the same.

- Mass is the measure of the amount of material an object contains.
- **Weight** is the force of gravity acting on an object.
- Weight is the product mass and acceleration due to gravity.

Weight and Mass

W = *mg* is a different form of Newton's Second Law, *F* = *ma.*

The value of *g* in the formula is 9.8 m/s^2.

Weight Formula

$$\text{Weight} = \text{Mass} \times \text{Acceleration due to gravity}$$

$$W = mg$$

Weight and Mass

If an astronaut has a mass of 112 kilograms, what is his weight on Earth where the acceleration due to gravity is 9.8 m/s^2?

Weight = Mass × Acceleration due to gravity

= 112 kg × 9.8 m/s^2

= 1100 $kg \cdot m/s^2$ × 1100 N

Weight and Mass

On the moon, the acceleration due to gravity is only about one sixth that on Earth.

- The astronaut weighs only about one sixth as much on the moon as on Earth.
- The mass of the astronaut is the same on the moon and on Earth.

Weight and Mass

A Astronaut on Earth
Mass = 88.0 kg, Weight = 863 N

B Astronaut on Moon
Mass = 88.0 kg, Weight = 141 N

Assessment Questions

1. What is inertia?
   a. the force of gravity acting on an object
   b. forces of friction slowing an object's motion
   c. the mass of an object
   d. the tendency of an object to resist change in its motion

Assessment Questions

1. What is inertia?
   a. the force of gravity acting on an object
   b. forces of friction slowing an object's motion
   c. the mass of an object
   d. the tendency of an object to resist change in its motion

   ANS: D

Assessment Questions

2. A 3600-N force causes a car to accelerate at a rate of 4 m/s^2. What is the mass of the car?
   a. 600 kg
   b. 900 kg
   c. 14,400 kg
   d. 1200 kg

Assessment Questions

2. A 3600-N force causes a car to accelerate at a rate of 4 m/s^2. What is the mass of the car?
   a. 600 kg
   b. 900 kg
   c. 14,400 kg
   d. 1200 kg

   ANS: B

Assessment Questions

3. How would your mass and weight change if you were on the moon's surface?
   a. They wouldn't change.
   b. Your mass would remain constant, and your weight would increase.
   c. Your mass and weight would decrease.
   d. Your mass would remain constant, and your weight would decrease.

Assessment Questions

3. How would your mass and weight change if you were on the moon's surface?
   a. They wouldn't change.
   b. Your mass would remain constant, and your weight would increase.
   c. Your mass and weight would decrease.
   d. Your mass would remain constant, and your weight would decrease.

   ANS: D