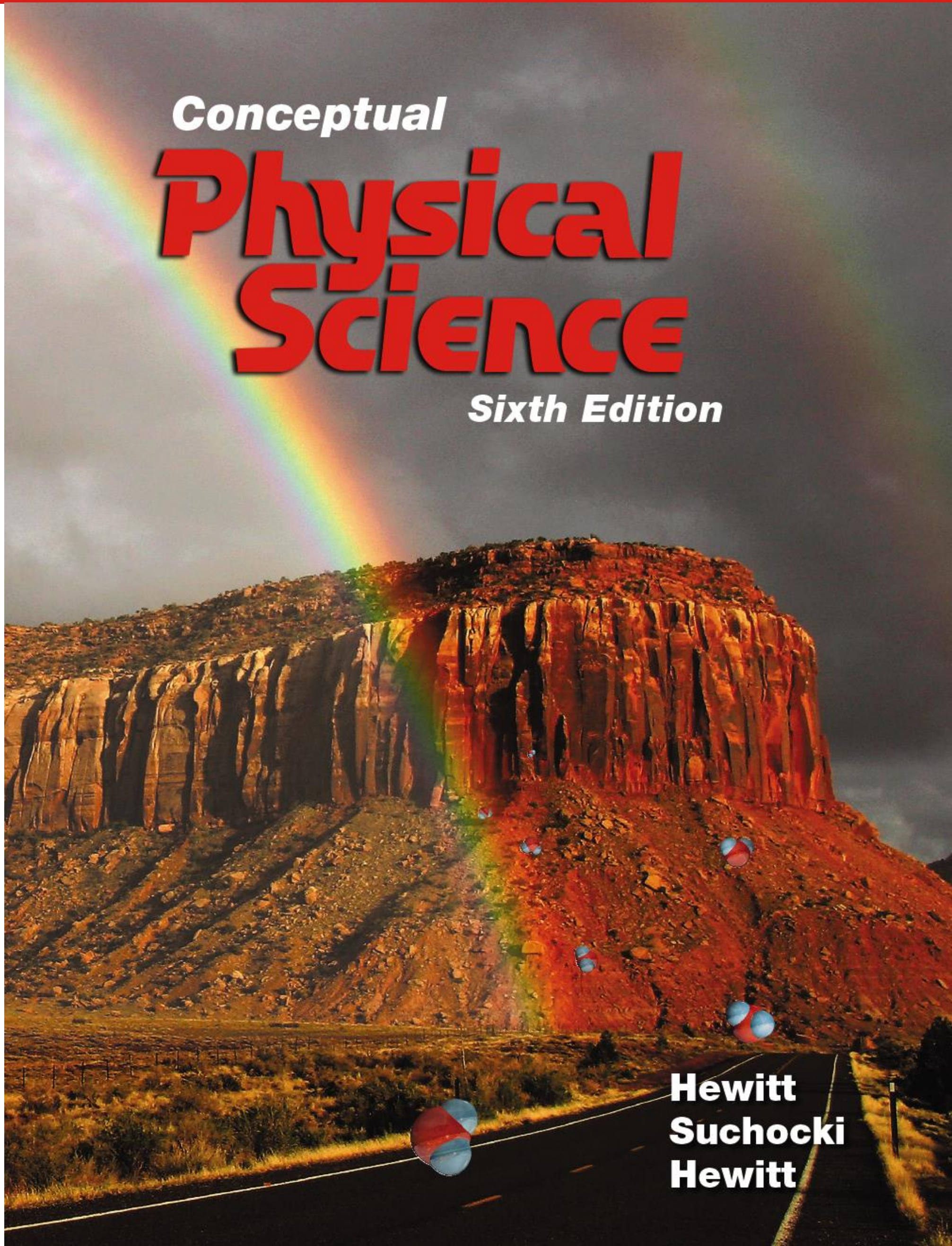
Chapter 5: Gravity, Weight and weightlessness

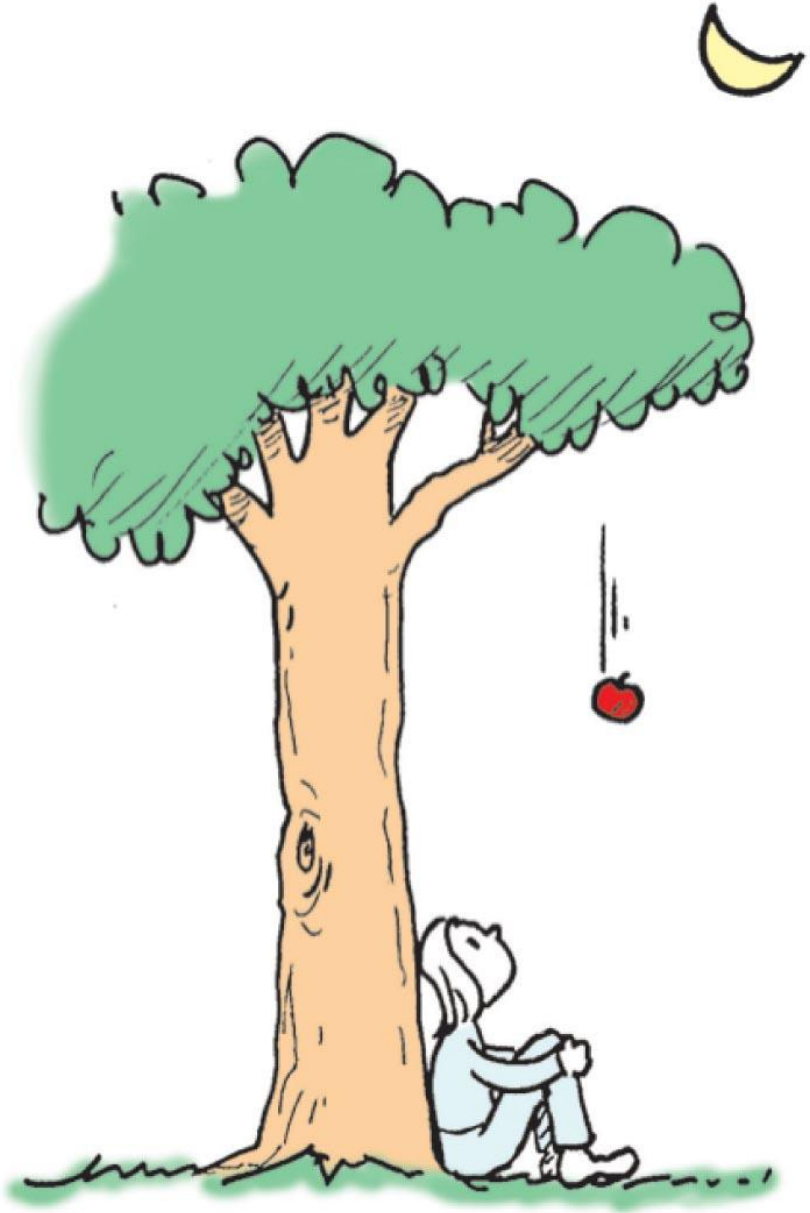


This lecture will help you understand:

- The Universal Law of Gravity
- Weight and Weightlessness

The Legend of the Falling Apple

- Newton was not the first to discover gravity. Newton discovered that gravity is *universal.*
- Legend—Newton, sitting under an apple tree, realized that the force between Earth and the apple is the same as that between moons and planets and everything else.

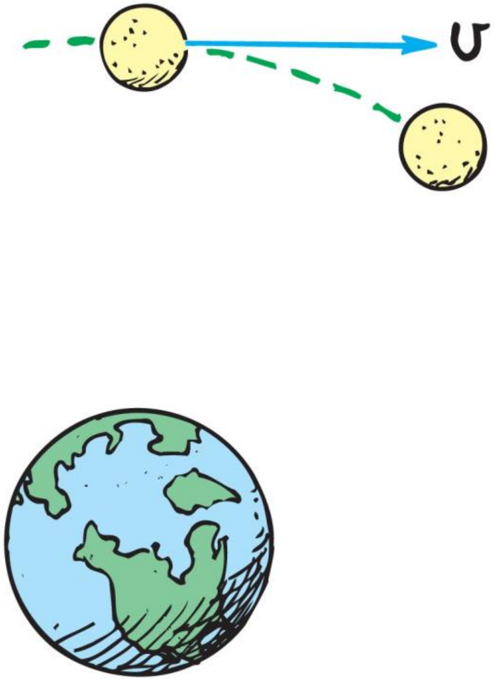


The Fact of the Falling Moon

- In ancient times, Aristotle and others believed that stars, planets, and the Moon moved in divine circles, free from forces of Earth.

The Fact of the Falling Moon

- We now know that the Moon falls around Earth in the sense that it falls beneath the straight line it would follow if no force acted on it.
- The Moon maintains a tangential velocity, which ensures a nearly circular motion around and around Earth rather than into it. This path is similar to the paths of planets around the Sun.

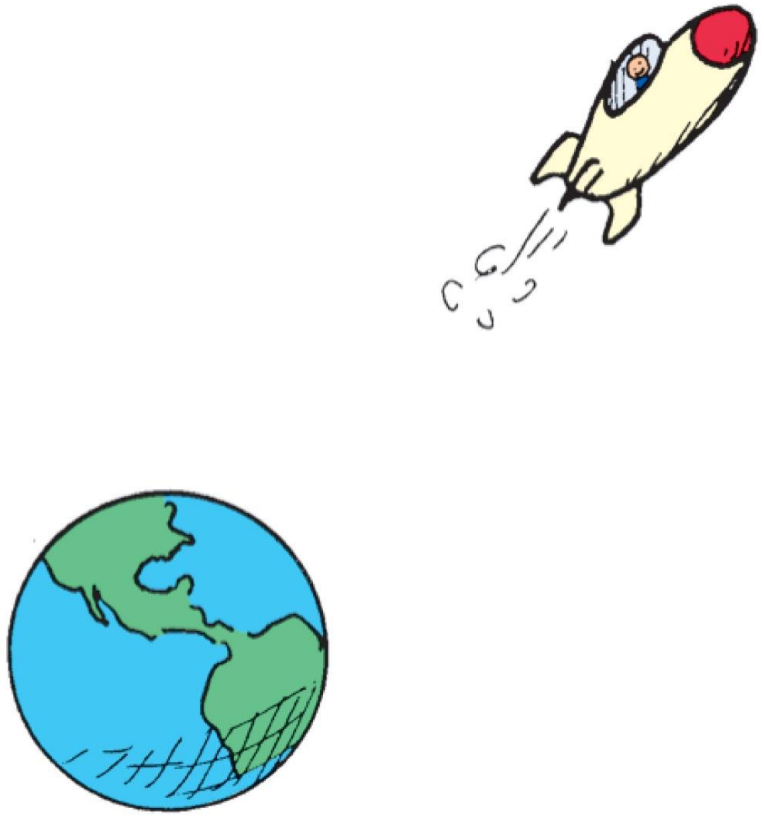


The Universal Law of Gravity

- Newton's Law of Universal Gravitation
  - Every body in the universe attracts every other body with a mutually attracting force.
  - For two bodies, this force is directly proportional to the product of their masses and inversely proportional to the square of the distance separating them,

$$F = G\frac{m_1 m_2}{d^2}$$

The Universal Law of Gravity



- Newton discovered that gravity is universal.
- Every mass pulls on every other mass.

Newton's Law of Universal Gravity

$$F = G\frac{m_1 m_2}{d^2}$$

- The greater m_1 and m_2 $\Rightarrow$ the greater the force of attraction between them.
- The greater the distance of separation d, the weaker is the force of attraction—weaker as the inverse square of the distance between their centers.

In this equation, F represents the gravitational force, m_1 is the mass of one object, m_2 is the mass of the other object, and r is the distance between their centers. The letter G is the universal gravitational constant. This is a value that is the same for objects everywhere in the universe. Its value was first determined experimentally by Henry Cavendish in 1797. Its accepted value is $G = 6.67 \times 10^{-11}\ \text{N·m}^2/\text{kg}^2$.

Look again at the equation. It shows that the strength of the gravitational force is directly proportional to the product of two objects' masses. This means that the attraction between two objects gets stronger as mass increases. The force gets weaker as mass decreases.

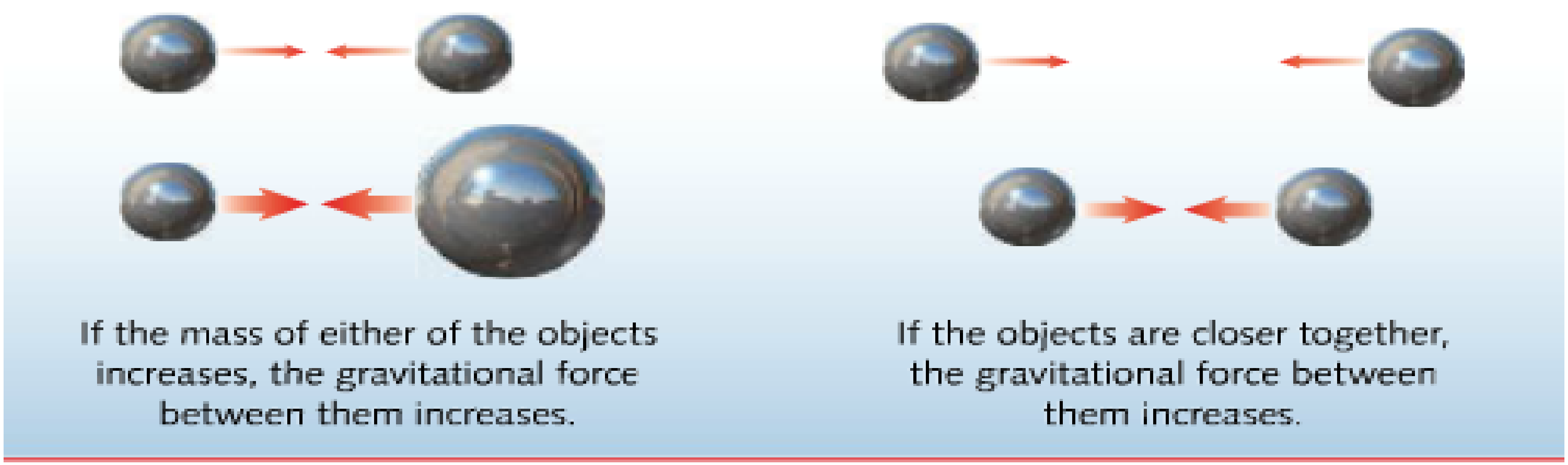


Figure 13.10 The gravitational force between two objects depends on the objects' masses and the distance between them.

The Universal Gravitational Constant, *G*

- *G* is the proportionality constant in Newton's law of gravitation.
- *G* has the same magnitude as the gravitational force between two 1-kg masses that are 1 meter apart:

  6.67×10^{-11} N.

  So $G = 6.67 \times 10^{-11}\ \text{N} \cdot \text{m}^2/\text{kg}^2$.

  $F = 6.67 \times 10^{-11}\ \text{N} \cdot \text{m}^2/\text{kg}^2 (m_1 \times m_2)/d^2$

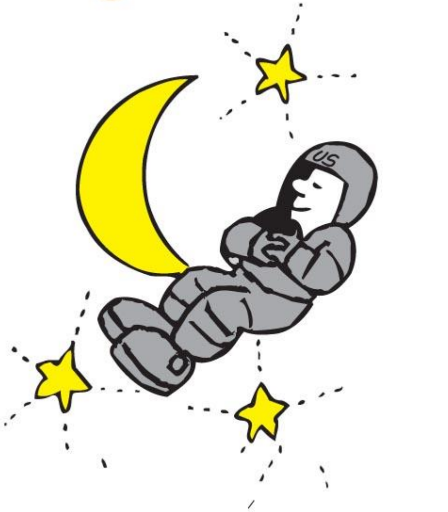
Weight and Weightlessness

- **Weight**
  - is the force exerted against a supporting floor or weighing scale.
- **Weightlessness**
  - is a condition wherein a support force is lacking—free fall, for example.

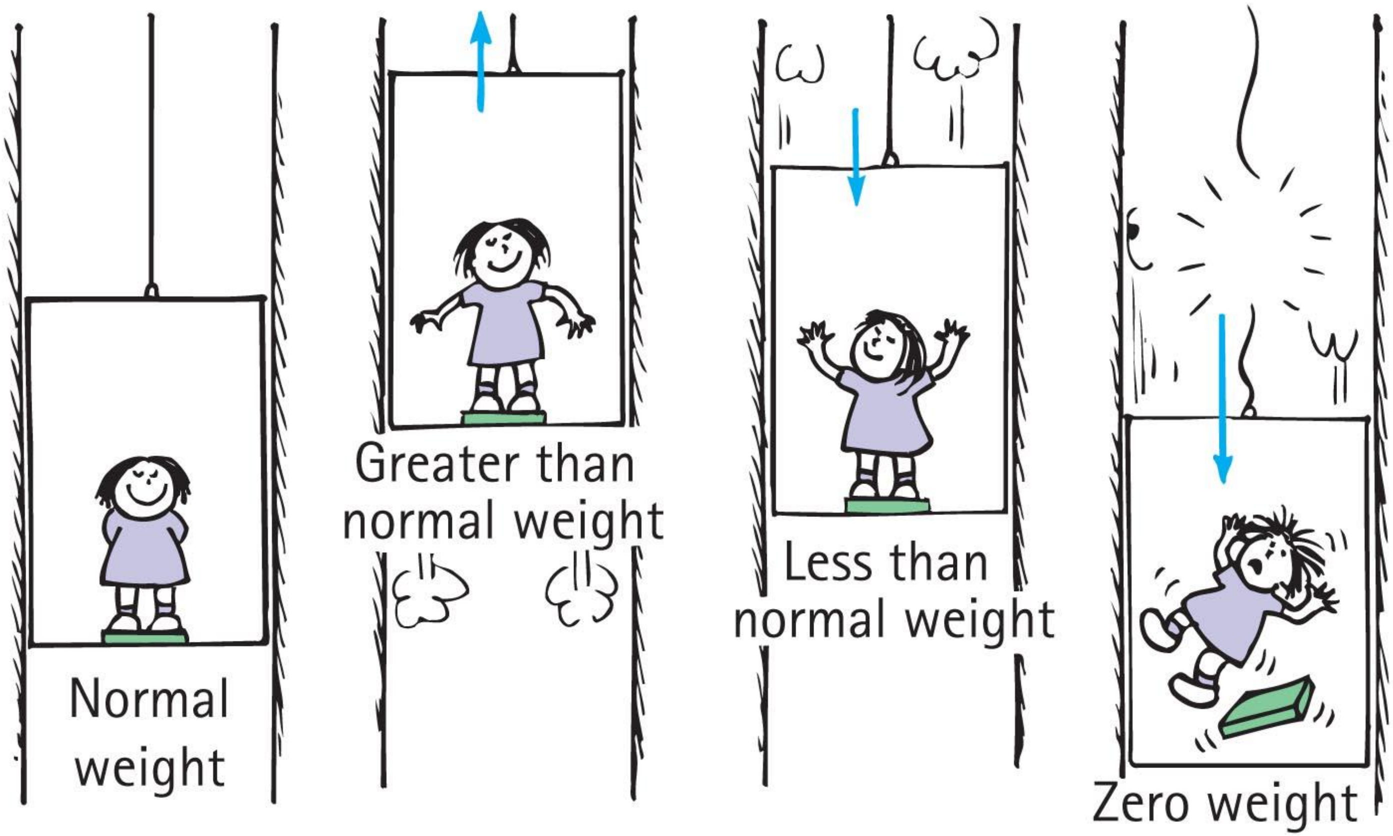
Weight and Weightlessness

- Example of weightlessness:
  - No support force.

An astronaut is weightless because he or she is not supported by anything. The body responds as if gravity forces were absent, and this gives the sensation of weightlessness.



Weight and Weightlessness



- If the elevator accelerates upward, the spring inside the scale are more compressed and your weight reading is more
- If the elevator accelerates downward, the spring inside the scale are less compressed and your weight reading is less
- If the elevator cable break and elevator fall freely, the reading on the scale goes to zero

Weight and Weightlessness
CHECK YOUR NEIGHBOR

When an elevator accelerates upward, your weight reading on a scale is

A. greater.

B. less.

C. zero.

D. the normal weight.

Weight and Weightlessness
CHECK YOUR ANSWER

When an elevator accelerates upward, your weight reading on a scale is

A. greater.

B. less.

C. zero.

D. the normal weight.

Explanation:

The support force pressing on you is greater, so you weigh more.

Weight and Weightlessness
CHECK YOUR NEIGHBOR

When an elevator accelerates downward, your weight reading is

A. greater.
B. less.
C. zero.
D. the normal weight.

Weight and Weightlessness
CHECK YOUR ANSWER

When an elevator accelerates downward, your weight reading is

A. greater.

B. less.

C. zero.

D. the normal weight.

Explanation:

The support force pressing on you is less, so you weigh less. Question: Would you weigh less in an elevator that moves downward at constant velocity?

Weight and Weightlessness
CHECK YOUR NEIGHBOR

When the elevator cable breaks, the elevator falls freely so your weight reading is

A. greater.

B. less.

C. zero.

D. the normal weight.

Weight and Weightlessness
CHECK YOUR ANSWER

When the elevator cable breaks, the elevator falls freely so your weight reading is

A. greater.

B. less.

C. zero.

D. the normal weight.

Explanation:

There is still a downward gravitational force acting on you, but gravity is not felt as weight because there is no support force. So your weight is zero.