

An artist's depiction of a planet's surface shows a world very different from Earth.

Certain universal forces are present.



12.4 Universal Forces

Observations of planets, stars, and galaxies strongly suggest four universal forces exist throughout the universe.

- electromagnetic
- strong nuclear
- weak nuclear
- gravitational

Universal forces act over a distance between particles of matter.

- The particles need not be in contact.
- Force is affected by the distance between particles.

Electromagnetic Forces



What force can attract and repel?



Electric force and magnetic force are the only forces that can both attract and repel.

Electromagnetic Forces

Electric and magnetic force are two different aspects of the electromagnetic force.

Electromagnetic force is associated with charged particles.

Electromagnetic Forces

Electric Forces

Electric forces act between charged objects or particles.

- Objects with opposite charges attract one another.
- Objects with like charges repel one another.

Electromagnetic Forces

Clothes often acquire electric charges in the dryer.

Clothes with opposite charges tend to cling together.



Electromagnetic Forces

Magnetic Forces

Magnetic forces act on

- certain metals,
- the poles of magnets, and
- moving charges.

Electromagnetic Forces

Magnets have two poles—north and south.

- Two poles that are opposite attract each other.
- Two poles that are alike repel each other.

Electromagnetic Forces

A magnetic force of attraction holds the two train cars together.



Nuclear Forces



What force holds the nucleus together?



Two forces, the strong nuclear force and the weak nuclear force, act within the nucleus to hold it together.

Nuclear Forces

The strong nuclear force overcomes the electric force of repulsion that acts among the protons in the nucleus.

The weak nuclear force is involved in certain types of radioactive processes.

Nuclear Forces

Strong Nuclear Force

The **strong nuclear force** is a powerful force of attraction that acts only on the neutrons and protons in the nucleus.

- It acts over short distances—approximately the diameter of a proton (10^{-15} m).
- It is 100 times stronger than the electric force of repulsion at these distances.

Nuclear Forces

Weak Nuclear Force

The **weak nuclear force** is an attractive force that acts only over a short range.

The weak nuclear force acts at about 10^{-18} meters, less than the range of the strong nuclear force.

Gravitational Forces



What is Newton's law of universal gravitation?

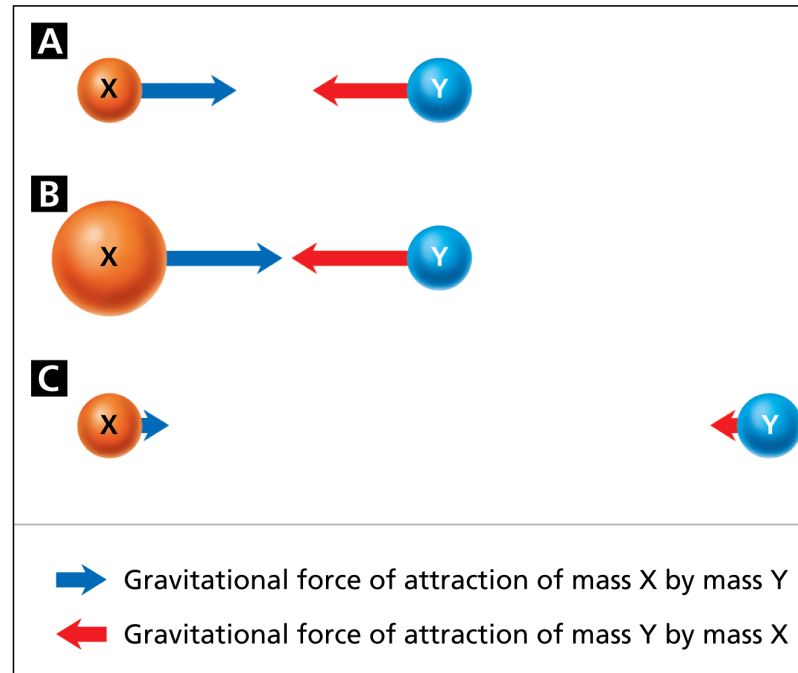


Newton's law of universal gravitation states that every object in the universe attracts every other object.

Gravitational Forces

Gravitational force is an attractive force that acts between any two masses.

Gravitational force depends upon mass and distance.



Gravitational Forces

Gravity Acts Over Long Distances

The gravitational force between two objects is proportional to their masses.

Gravitational force decreases with the square of the distance between the objects.

Gravity is the weakest universal force, but it is the most effective force over long distances.

Gravitational Forces

The Earth, Moon, and Tides

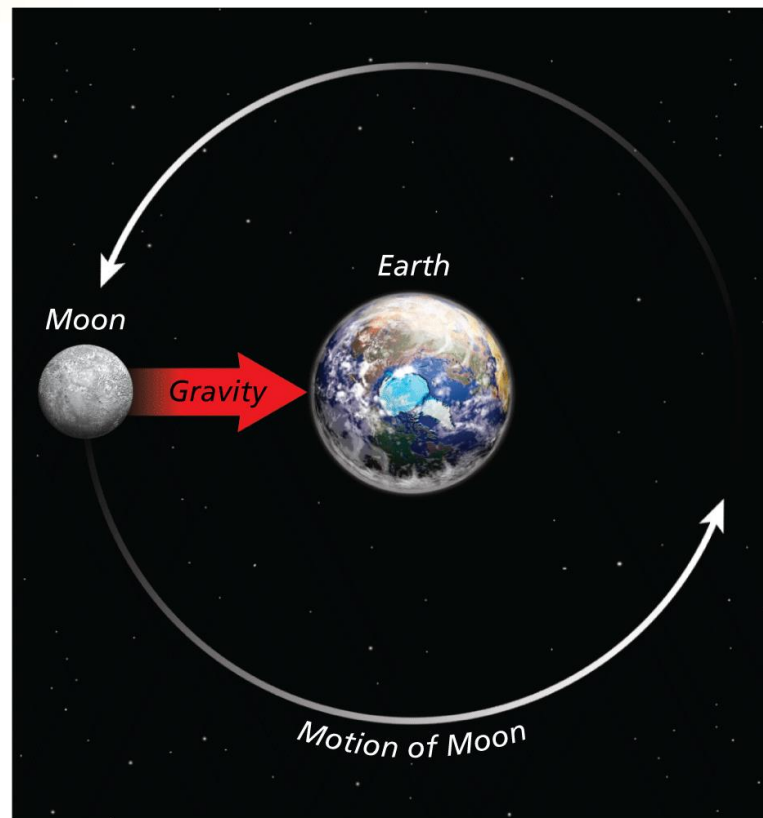
The moon's inertia acts to move it away from Earth.

Earth's gravitational attraction keeps the moon in a nearly circular orbit around Earth.

A **centripetal force** is a center-directed force that continuously changes the direction of an object to make it move in a circle.

Gravitational Forces

The moon's inertia and the gravitational pull of Earth result in a nearly circular orbit.



Gravitational Forces

The gravitational pull from the moon produces two bulges in Earth's oceans—one on the side of Earth closest to the moon, the other on the side farthest from the moon.

As Earth rotates once per day beneath these two bulges, there are two high and two low tides per day on Earth.

Gravitational Forces

Satellites in Orbit

An artificial satellite needs only its inertia and the centripetal force provided by gravity to maintain its orbit.

Satellites in a low orbit are slowed by friction with Earth's atmosphere and eventually reenter Earth's atmosphere.

Gravitational Forces

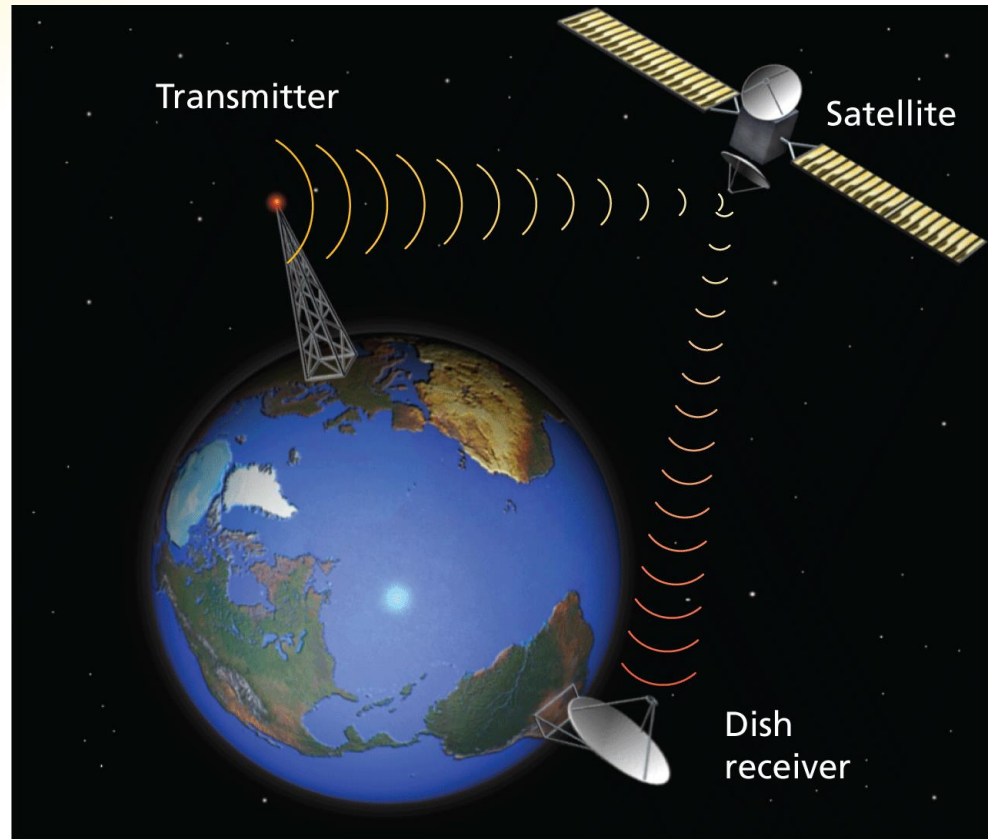
Uses of Satellites

Hundreds of artificial satellites orbit for many functions:

- monitoring Earth's weather
- creating detailed radar maps of Earth's surface
- using telescopes to study space
- studying Earth's climate
- receiving and transmitting radio and microwave signals

Gravitational Forces

Satellites are used to receive and transmit electromagnetic waves over great distances.



Assessment Questions

1. What are the only forces that can both attract and repel?
 - a. electromagnetic forces
 - b. centripetal forces
 - c. strong nuclear forces
 - d. gravitational forces

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ANS: A

Assessment Questions

2. The nucleus of an atom is held together primarily by the
- strong force and weak force.
 - strong force and gravity.
 - weak force and electromagnetic force.
 - electromagnetic force and strong force.

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Assessment Questions

3. Which of the following statements about gravitational forces is false?
- They are the weakest universal forces.
 - They act between any two objects.
 - They become stronger as the distance between two objects increases.
 - They become weaker as the mass of either two objects decreases.

Assessment Questions

3. Which of the following statements about gravitational forces is false?
- a. They are the weakest universal forces.
 - b. They act between any two objects.
 - c. They become stronger as the distance between two objects increases.
 - d. They become weaker as the mass of either two objects decreases.

ANS: C

Assessment Questions

1. A center-directed force that continuously changes the direction of an object's motion, making it move in a circle, is called the radial force.

True

False

Assessment Questions

1. A center-directed force that continuously changes the direction of an object's motion, making it move in a circle, is called the radial force.

True

False

ANS: F, centripetal force