Edgenuity

Warm-Up | Universal Law of Gravitation

Lesson Question

How does the universal law of gravitation affect all objects?

Lesson Goals

Explore how the universal law of gravitation affects all objects.

- **Explain** the relationships among gravitational force, mass, and [distance].
- **Solve** problems that involve the universal law of gravitation.
- **Describe** the effect of [gravity] on an object.

Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

direct relationship	a relationship between two variables whereby both variables increase or decrease [together]
gravitational field	the field that exists around an object due to its [mass]
gravitational force	the [attractive] force between all matter in the universe
universal law of gravitation	the natural law that states the force of attraction between two objects is affected by the masses of the two objects and the [distance] between them
weight	a measure of the [gravitational] force on an object

Warm-Up | Universal Law of Gravitation

Forces

- A force is an action that has the ability to change an object's state of motion.
  - Push or pull
  - Friction
  - Tension
  - Gravity

Instruction | Universal Law of Gravitation

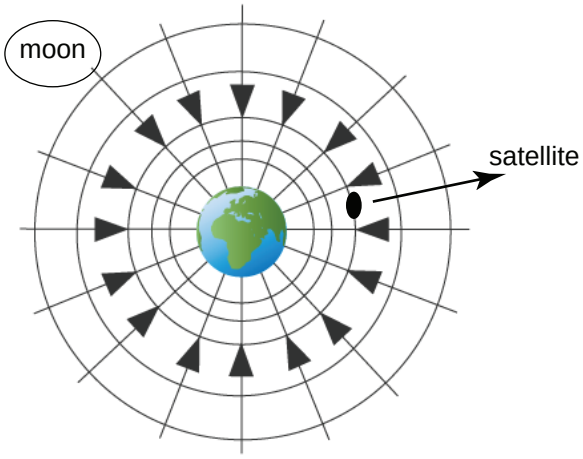
Slide 2

Universal Law of Gravitation

The **universal law of gravitation** is the natural law that states the force of attraction between two objects is affected by the [masses] of the objects and the distance between them.

Gravitational Field

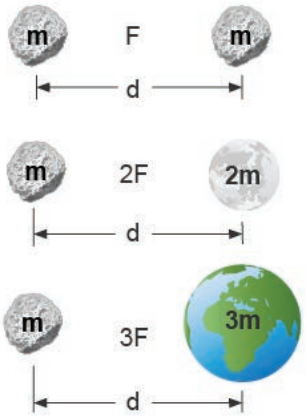
- A **gravitational field** is the field that exists around an object due to its mass.
- The strength of the field is directly proportional to the [mass] of the object.
- The [closer] together the circles are, the stronger the field is.



Slide 4

Relationship between Gravitational Force and the Mass of an Object

- The **gravitational force** between two objects has a [direct] **relationship** to the product of the masses of the objects.



1 M

[2 M]

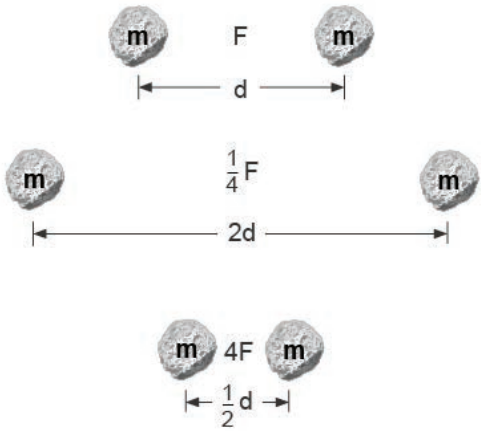
3 M

Instruction | Universal Law of Gravitation

Slide 4

Relationship between Gravitational Force and the Distance between Objects

- The gravitational force between two objects is inversely related to the [square] of the distance between the centers of the objects.



$$2 \rightarrow \left(\frac{1}{2}\right)^2 = \boxed{\frac{1}{4}}$$

$$\frac{1}{2} \rightarrow \frac{2}{1} \rightarrow 2^2 = \boxed{4}$$

Slide 7

The Universal Law of Gravitation Formula

- Variables:
  - F_g – gravitational force (measured in newtons, N)
  - G – gravitational constant
  - $= \boxed{6.67} \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$
  - m_1 – mass of object 1
  - m_2 – mass of object 2
  - d – distance between objects 1 and 2

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

Slide 7

Universal Law of Gravitation

The mass of Earth is 5.97×10^{24} kg and the mass of the moon is 7.35×10^{22} kg. If the distance between Earth and the moon is 3.84×10^{8} m, what is the gravitational force between them?

- Given:
  - $m_1 : 5.97 \times 10^{24}$ kg
  - $m_2 : 7.35 \times 10^{22}$ kg
  - d : 3.84×10^{8} m
  - G : $6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$
- Unknown: F_g

Solution:

$$F_g = \frac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.97 \times 10^{24}\ \text{kg})(7.35 \times 10^{22}\ \text{kg})}{(3.84 \times 10^{8}\ \text{m})^2}$$

$$= 1.98 \times 10^{20}\ \text{N}$$

Instruction | Universal Law of Gravitation

Slide 9

Rearrangement of the Universal Law of Gravitation Formula

- The universal law of gravitation formula can be rearranged to determine the masses of the objects or the distance between the objects.

Use	To Find	When You Know
$m_1 = \frac{F_g d^2}{G m_2}$	mass of object 1	gravitational force between objects, distance between objects, and mass of object 2
$m_2 = \frac{F_g d^2}{G m_1}$	mass of object 2	gravitational force between objects, distance between objects, and mass of object 1
$d = \sqrt{\frac{G m_1 m_2}{F_g}}$	distance between objects	gravitational force between objects and masses of objects 1 and 2

Universal Law of Gravitation

The gravitational force between Earth ($m_1 = 5.98 \times 10^{24}$ kg) and a weather satellite, GOES-15 ($m_2 = 2.19 \times 10^3$ kg), is 681 N. What is the distance between these objects?

- Given:
  - $m_1 : 5.98 \times 10^{24}$ kg
  - $m_2 : 2.19 \times 10^3$ kg
  - $F_g : 681$N
  - G : 6.6710^{-11} N·m^2/kg^2

Instruction | Universal Law of Gravitation

Slide 9

Universal Law of Gravitation

- Unknown: d
- Formula: $d =$ $\sqrt{\frac{Gm_1m_2}{F_g}}$

Solution:

$$d = \sqrt{\frac{(6.67 \times E^{-11}\ N \cdot m^2/kg^2)(5.98 \times E^{24}\ kg)(2.19 \times E^{3}\ kg)}{681\ N}}$$

$$= 3.58 \times E^{7}\ m$$

Slide 12

Gravitational Force of Earth

- The gravitational force of Earth causes objects on its surface to "fall" toward the center of Earth.
- The acceleration due to gravity on Earth is $9.8\ m/s^2$.

Weight

- **Weight** is the downward pull on an object due to gravity.
  - Mass is different from weight; mass is the amount of matter in an object.

Instruction | Universal Law of Gravitation

Slide 14

Weight Determination

- Variables:
  - F_g – force of gravity or weight
  - m – mass of object
  - g – acceleration due to gravity
- Units:
  - $\text{kg} \cdot \text{m/s}^2 = \text{N}$

$$F_g = mg$$

Earth, $g = 9.8\ \text{m/s}^2$

Moon, $g =$ 1.6 m/s²

Universal Law of Gravitation and Weight

- $F_g = \text{G}\dfrac{m_1 m_2}{d^2}$

$d = 6.3781 \times \text{E}^6\ \text{m}$

$$F_g = \frac{(6.67384\text{E}^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(40\ \text{kg})(5.9726\text{E}^{24}\ \text{kg})}{(6.3781\text{E}^6\ \text{m})^2}$$

$F_g = 391.94$ or $392\ \text{N}$

- $F_g = mg$ girl = 40 kg

$F_g = (40\ \text{kg})(9.8\ \text{m/s}^2)$

$=$ 392 N

Weight is also called force of gravity.

Summary | Universal Law of Gravitation

Lesson Question

How does the universal law of gravitation affect all objects?

Answer

(Sample answer) All objects in the universe are attracted to other objects by a gravitational force that is directly proportional to the product of the masses of the objects, and inversely proportional to the square of the distance between the centers of the objects.

Slide 2

Review: Key Concepts

- The universal law of gravitation states that the force of attraction between any two objects in the universe is:
  - directly related to the product of the masses of the objects.
  - inversely related to the square of the [distance] between the centers of the objects.
- The gravitational force, the [masses] of the objects, and the distance between the centers of the objects may be determined using the universal law of gravitation formula.

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

Summary | Universal Law of Gravitation

Slide 2

Review: Key Concepts

- The force of gravitation between Earth and an object on its surface causes the object to accelerate toward the center of Earth at 9.8 m/s^2.
- When the universal law of gravitation is applied to Earth and an object on its surface at sea level, the gravitational force is [equal] to the weight of the object.
- The force of gravity, or weight, of an object on the surface of any [planet] or moon may be determined using this formula:

$$F_g = mg$$

Use this space to write any questions or thoughts about this lesson.