8.2	Newton's Universal Law of Gravitation

LEARNING TARGETS

8.2	I can define, explain, and apply Newton's Law of Universal Gravitation to solve problems.

Circular Motion

Key Concepts

- An object moving in a circle at a constant speed accelerates toward the center of the circle, and therefore, it has centripetal acceleration.
- Centripetal acceleration depends directly on the square of the object's speed and inversely on the radius of the circle.

$$a_c = \frac{v^2}{r}$$

- A net force must be exerted toward the circle's center to cause centripetal acceleration.

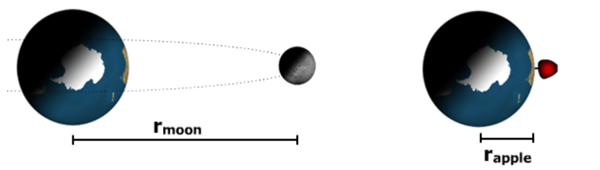
$$F_{net} = ma_c$$

- The velocity vector of an object with a centripetal acceleration is always tangent to the circular path.

Universal Gravitation

Isaac Newton

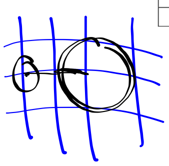
Newton's Argument for Gravity Being Universal



Gravitation Simulation

4. Drag the moon to various locations in order to determine the quantitative effect of distance upon the gravitational force. Examine the effect of doubling, tripling and quadrupling the distance of separation (as measured from planet's center). Consider the planet's surface to be a distance of one Earth-radius (1 R_{planet}). Use the table at the right to record data for whole-number multiples of R_{planet}.

Separation Distance	Force (fictional units)
2 • R_{planet}	322.4
3 • R_{planet}	137.3
4 • R_{planet}	76.8
5 • R_{planet}	49
6 • R_{planet}	
7 • R_{planet}	
8 • R_{planet}	
9 • R_{planet}	
10 • R_{planet}	
11 • R_{planet}	
12 • R_{planet}	



The Inverse-Square Law: Gravity and Distance

Inverse-square law:

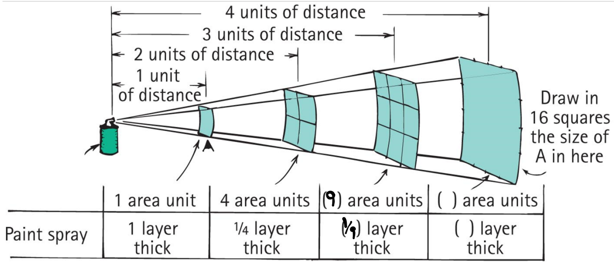
relates the intensity of an effect to the inverse square of the distance from the cause

$$Intensity \approx \frac{1}{distance^2}$$

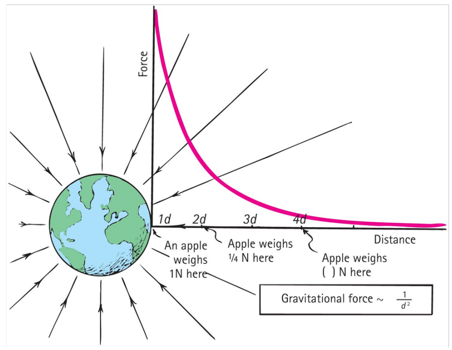
The greater the distance from Earth, the less the gravitational force on an object.

No matter how great the distance, gravity approaches, but never reaches, zero.

Inverse-Square Law



Inverse-Square Law



Gravitation Simulation

Now investigate the effect of varying masses upon the gravitational force between moon and planet. Use the sliders to alter the masses and observe the effect upon the force. Use your observations to answer the following statements:

If the mass of the moon is ...

a. ... increased by a factor of 2, then the F_{grav} is ____________ by a factor of ______.

b. ... increased by a factor of 3, then the F_{grav} is ____________ by a factor of ______.

Gravitation Simulation

If the mass of the Earth is ... (see step #4)

e. ... increased by a factor of 2, then the F_{grav} is ____________ by a factor of ______.

f. ... increased by a factor of 3, then the F_{grav} is ____________ by a factor of ______.

Universal Gravitation

Newton was confident that the same force of attraction would act between any two objects, anywhere in the universe. He proposed his law of universal gravitation, which states that objects attract other objects with a force that is ____________________________ masses and ______________________ __________ distance between them.

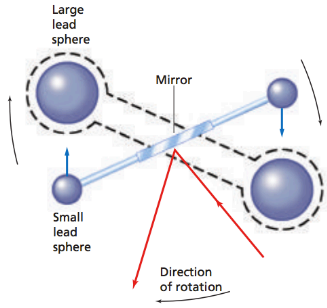
Universal Gravitation

Newton's Law of Universal Gravitation

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

Cavendish's Experiment

In 1798, Englishman Henry Cavendish used equipment similar to the apparatus shown below to measure the gravitational force between two objects.



BIG "G"

$$G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$$

Gravitational Field

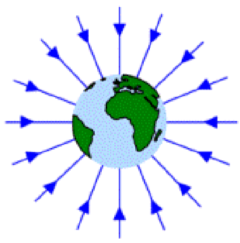
$$F_g = m_p g \qquad F_g = G\frac{m_1 m_2}{r^2} \quad (m_1 = M_p,\ m_2 = M_E)$$

$$M_p g = G\frac{M_p M_E}{r_E^2}$$

Gravitational Field

Gravitational Field $g = \frac{GM}{r^2}$

The gravitational field is equal to the universal gravitational constant times the object's mass, divided by the square of the distance from the object's center. The direction is toward the mass's center.



Universal Gravitation

5) A 50 kg person and a 70 kg person are sitting on a bench close to each other. Estimate the magnitude of the gravitational force each exerts on the other.

6) Estimate the effective value of g on the top of Mt. Everest, 8850 m (29,035 ft) above sea level.

$r_E = 6.38 \times 10^6$ m

$M_E = 5.98 \times 10^{24}$ kg

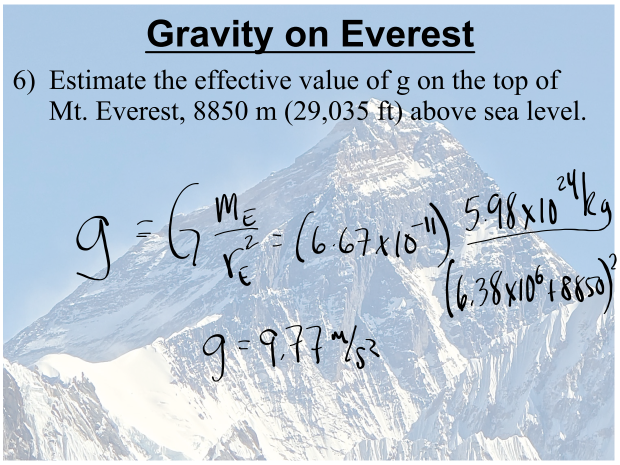
Gravitational Attraction

5) A 50 kg person and a 70 kg person are sitting on a bench close to each other. Estimate the magnitude of the gravitational force each exerts on the other.

$$F_g = G\frac{m_1 m_2}{r^2} = (6.67 \times 10^{-11})\left(\frac{50 \cdot 70}{0.5^2}\right)$$

$$F_g = 9.3 \times 10^{-7}\ N$$

0.00000093 N



PRACTICE

UNIT 8 PROBLEMS

(6-9)