Newton's Laws of Universal Gravitation

7.2

Objectives

- **Explain** how Newton's law of universal gravitation accounts for various phenomena, including satellite and planetary orbits, falling objects, and the tides.

- **Apply** Newton's law of universal gravitation to solve problems

Gravitational Force

- First off… orbiting objects (moon, planets, space shuttle, etc.) are in free fall!
- The moon
  - It is falling towards Earth AND moving away at the same time
  - Think of throwing a ball
    - It goes forward and down
    - Throw it faster and it goes farther forward and down
    - Throw it fast enough and it goes forward at the same rate it goes down, never hitting the surface

Gravitational Force

- Gravitational Force is the mutual force of attraction between ALL objects
- This magnitude of the force depends on…
  - Masses of the objects
  - Distance between the objects

Gravitational Force

- Equation

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

KEY:

Fg = Gravitational Force (N)

Memorize!

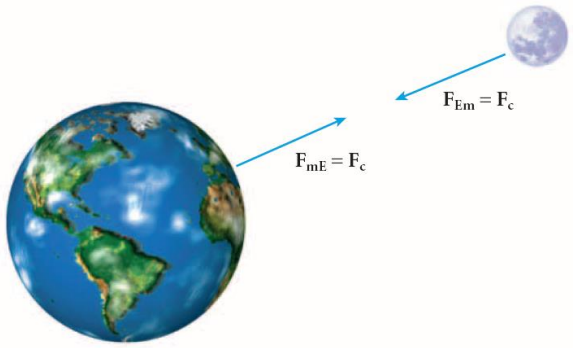
G = Universal Gravitational Constant (6.673×10^{-11} (N*m^2/kg^2)

m = mass (kg)

r = radius (distance) (m)

Gravitational Force

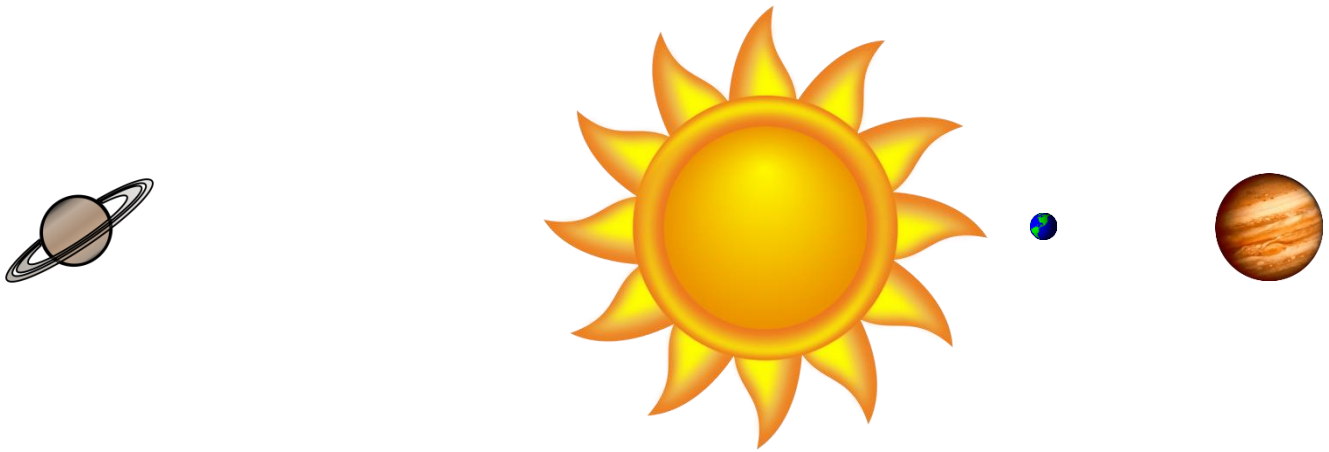
- Gravitational Forces are always <u>equal in magnitude</u> and <u>opposite in direction</u>
  - Newton's 3rd Law!
- Why does the moon orbit the Earth instead of the Earth orbiting the moon?



What will happen when these objects interact?

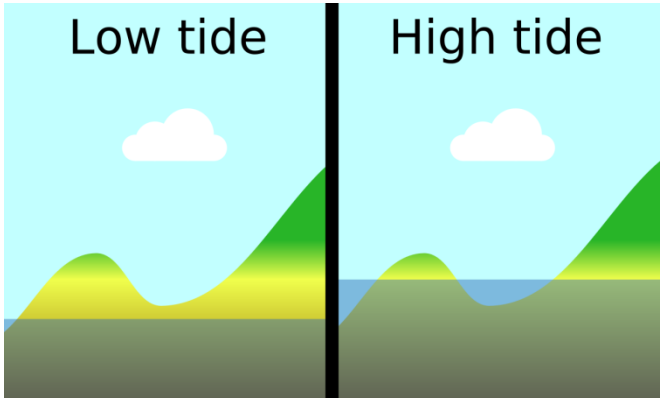
- Earth and apple
- You and Earth
- Red Box and a Green Box
- Red Box and a Green Box in space with nothing else around (Hypothetically)

Make sure to watch the Gravitational Force Math Help Video



Applying the Law of Gravitation

- On example of applying the law of gravitation to the “real world” is ocean tides
- Ocean Tides result from the moons gravitational attraction to the Earth
- The tides result from the **difference** between the gravitational force at Earth’s surface and at Earth’s center.

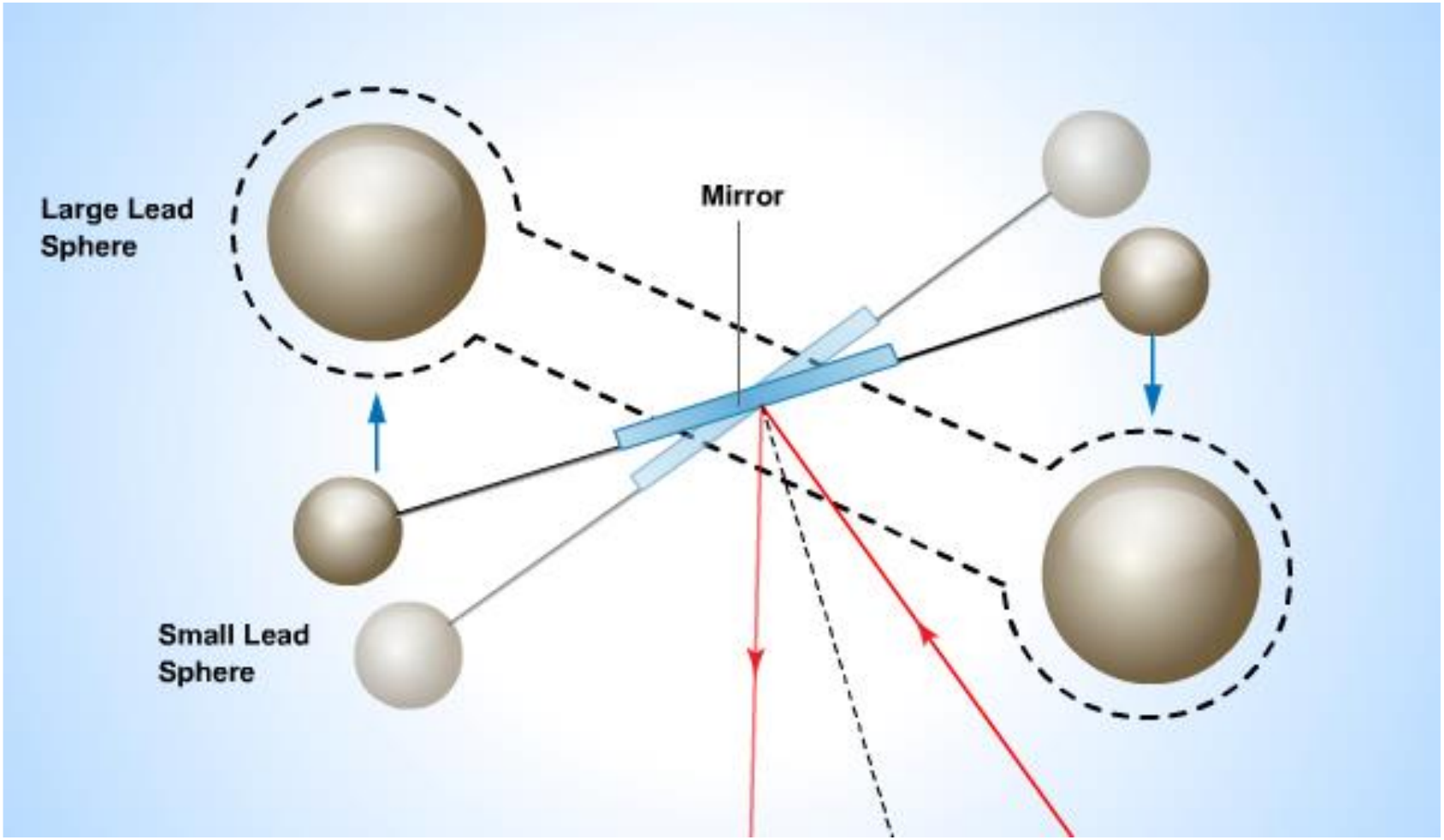


Cavendish

- Cavendish applied Newton's law of universal gravitation to find the value of *G* and Earth's mass.

- When two masses, the distance between them, and the gravitational force are known, Newton's law of universal gravitation can be used to find *G*.

- Once the value of *G* is known, the law can be used again to find Earth's mass.


Large Lead
Sphere
Mirror
Small Lead
Sphere

Applying the Law of Gravitation

- Gravity is a field force
  - This means there is an area around the object that exerts this force

- What is an example of another field force?

Weight Changes with Location

- Weight is a force

$$weight(N) = \text{mass(kg)} * gravity\ (\frac{m}{s^2})$$

$$F_g = m * g$$

- Weight changes with location in respects to the center of mass

Weight Changes with Location

$$F_g = m * g$$

So, …

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

- Substitution gives us…
  - (usually for g on a planet, moon, etc.)

$$g = \frac{G\cancel{m_1}m_2}{\cancel{m_1}r^2} \longrightarrow \boxed{g = \frac{Gm_2}{r^2}}$$

Weight Changes with Location

- So… the equation tells us free-fall acceleration does NOT depend on the mass of the object!

- $g = \frac{Gm_E}{r^2}$

Mass of Earth (or other planet)

- Pretty cool!