# The Apple, The Moon, and Universal Gravitation

**Lesson Notes**

## Learning Outcomes

- How did Isaac Newton develop the idea of the universal law of gravitation?
- What is meant by the saying *gravity is universal*?

## Gravity is More Than a Name

- Gravity is the name we associate with the cause of falling; it is the *thing* that causes objects to fall to earth.
- But it is the goal of physics to explain phenomenon in terms of underlying principles; principles that are so big and universal that they can explain a large collection of phenomenon in a consistent manner.
- We need a more sophisticated model of gravity that goes beyond the "cause of falling objects."

## Early Student Conceptions of Gravity

Students typically approach this unit with some understandings about gravity that were acquired during a unit on Newton's Laws or kinematics. These include:

- Gravity is the force that exists between the Earth and objects that are on or near it.
- **$F_{grav}$ = Weight = m•(9.8 N/kg)**
- The force of gravity, when acting alone, causes a special acceleration known as the acceleration of gravity.
- On Earth, this value is 9.8 m/s/s and is independent of the object's mass.

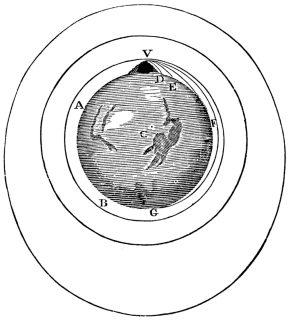
## Newton, the Planets, and the Moon

Johannes Kepler (early 1600s) - proposed three laws describing planetary motion. No explanation was given to **why** planets moved as they did.

For Newton, a description of motion without an explanation was bothersome. Newton began to ponder the question of what foundational principle governing the orbital motion of the planets and the moon.


## Newton's Cannon Thought Experiment

- Newton conjectured that the moon was a projectile - an object acted upon solely by gravity.
- His thoughts on the topic were published in The Principia and were accompanied by the diagram at the right.
- The moon is like the cannonball that *falls around the Earth* (relative to the straight-line tangential path) instead of *falling into the Earth*.
- And if the moon can be compared to the cannonball, then its motion can also be compared to the free-falling motion of the apple. Gravity is universal!

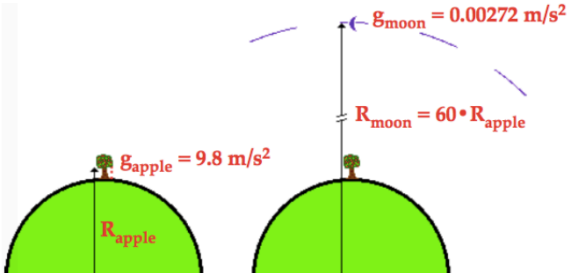


## The Apple and the Moon Argument

- Newton's challenge is to provide reasonable evidence for extending the force of gravity on Earth to the heavens.
- Somehow, the force of gravity that causes the moon's acceleration must be diluted by distance.

$a_{apple} = 9.8\ m/s/s$

$a_{moon} = 0.00272\ m/s/s$





## Inverse Square Law

- The inverse square law is at the heart of Newton's argument that the same force that causes the apple to fall into the Earth also causes the moon to fall around the Earth.

$F_{grav} \sim 1/d^2$

- The force of gravity and the accelerations that they cause is inversely proportional to the square of the distance of separation between the two attracting objects.

$$\frac{a_{apple} = 9.8\ m/s/s}{a_{moon} = 0.00272\ m/s/s} \cong \frac{(60 \bullet R_{earth})^2}{(1 \bullet R_{earth})^2} \cong 3600$$

## The Universality of Gravity

- The *law of falling bodies* on Earth is the same law that governs the motion of *heavenly bodies* - of the planets, the moon, and orbiting satellites.
- Gravity is a **universal force** … not just restricted to large objects like the Earth and the moon.
- All objects with mass attract each other.
- Newton's discovery was that gravity is universal - applies to all objects - on Earth and in *the heavens* - of big mass and of small mass - …
- … and by employing the idea of universal gravity, he was able to explain the century-old mystery of planetary motion.