Astronomy

Fall 2026

Weeks 9-10

Tuesday, October 6th

- Unit 2 Test

Thursday, October 8th

- T: **(7) Science concepts. The student knows our relative place in the solar system. The student is expected to:**
- **7B** model the scale, size, and distances of the Sun, Earth, and Moon system and identify the limitations of physical models; and
- **(11) Science concepts. The student uses models to explain the formation, development, organization, and significance of solar system bodies. The student is expected to:**
- **11A** relate Newton's law of universal gravitation and Kepler's laws of planetary motion to the formation and motion of the planets and their satellites;
- O: I will be able to describe Newton's 3 laws of motion
- D: by completing a PhET simulation and participating in a lecture and class discussion.

Journal 2.2

- Who is your hero and why?

Unit 3: Gravity and Motion

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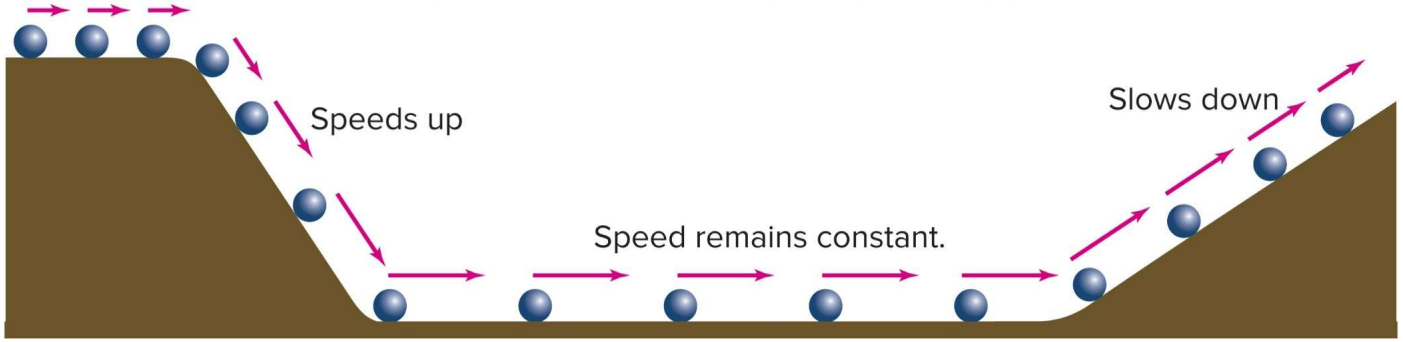
- NASA/Rick Wetherington-Tim Powers

Inertia

- Galileo established the idea of *inertia*:
- A body at rest tends to remain at rest.
- A body in motion tends to remain in motion.
- Through experiments with inclined planes, Galileo demonstrated the idea of inertia and the importance of forces (friction).

Inertia and Newton's First Law

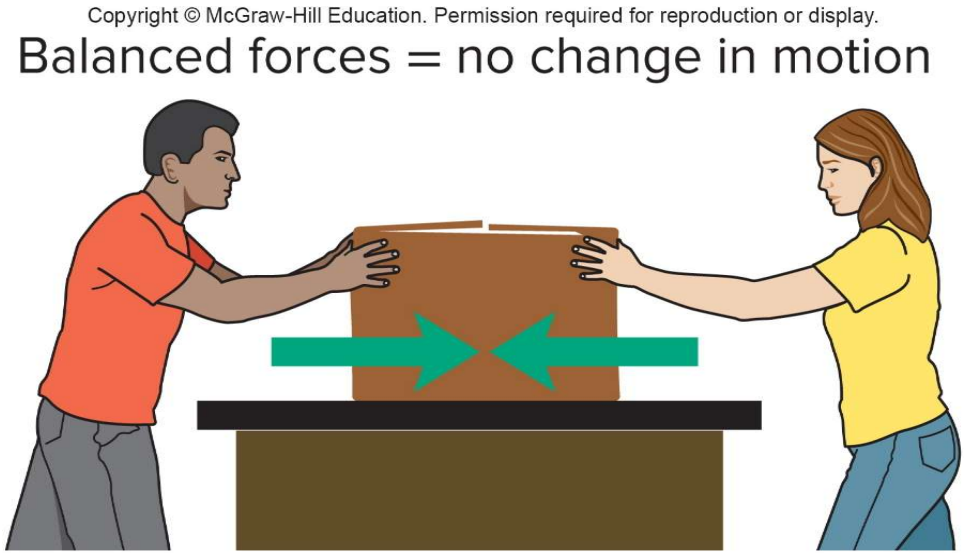
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- This concept was incorporated in *Newton's First Law of Motion:*
- A body continues in a state of rest or uniform motion in a straight line unless made to change that state by forces acting on it.

Newton's First Law

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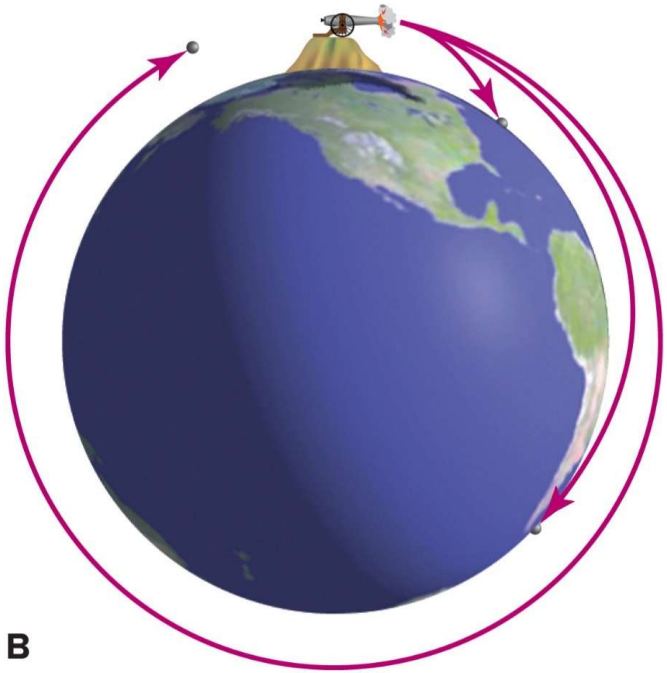


- Important ideas of Newton's First Law.
- Force: A push or a pull.
- The force referred to is a net force.
- The law implies that if an object is not moving with constant velocity, then a nonzero net force must be present.

Newton's First Law in Action

- At a sufficiently high speed, the cannonball travels so far that the ground curves out from under it.
- The cannonball literally misses the ground!
- The ball, now in orbit, still experiences the pull of gravity!

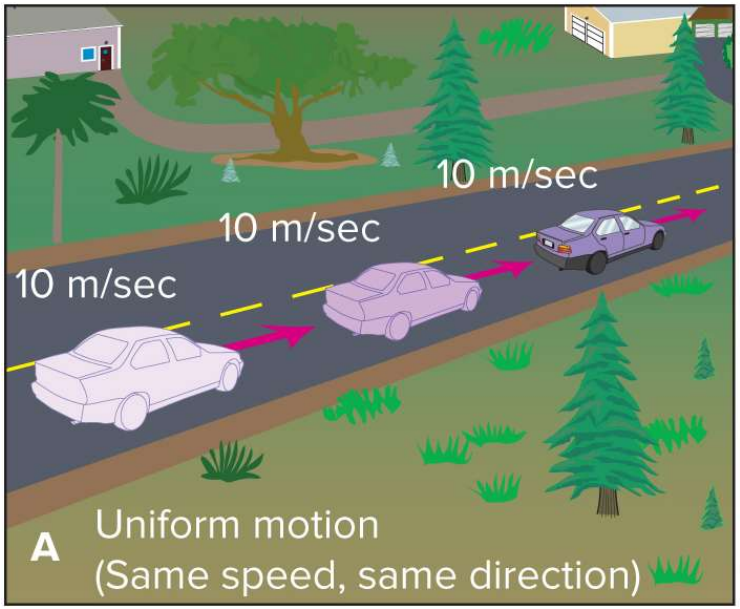
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Newton's Second Law: Motion

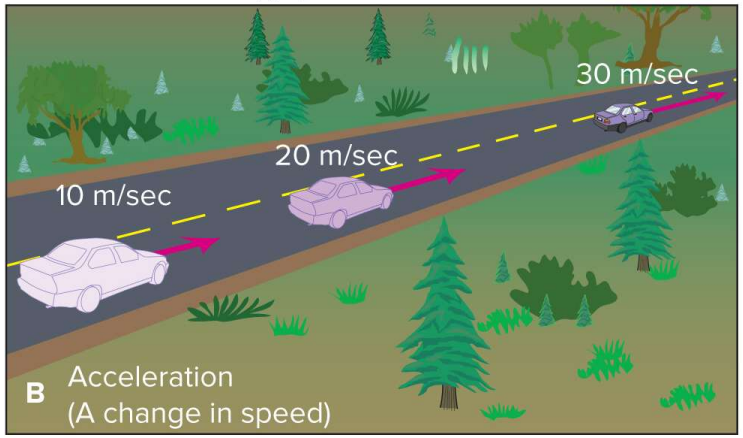
- Motion.
- An object is said to be in uniform motion if its speed and direction remain unchanged.
- An object in uniform motion is said to have a constant velocity.
- A force will cause an object to have non-uniform motion, a changing velocity.
- *Acceleration* is defined as a change in velocity.

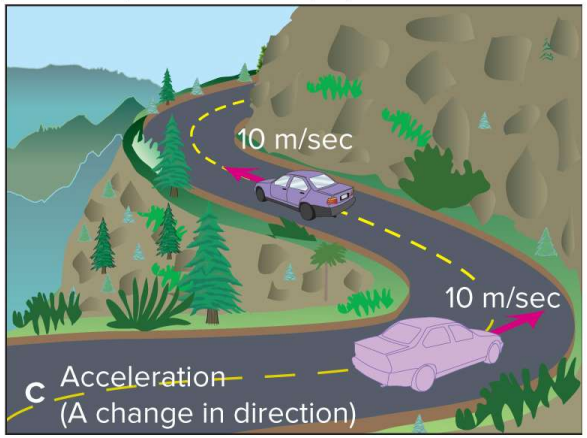
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Newton's Second Law: Acceleration

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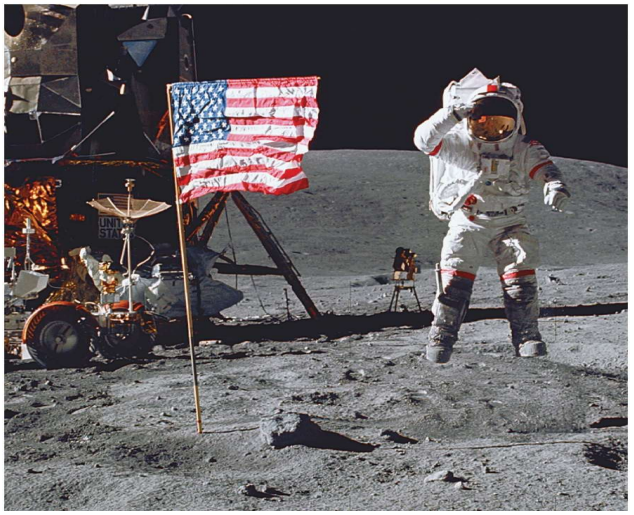
- Acceleration.
- An object increasing or decreasing in speed along a straight line is accelerating.
- An object with constant speed moving is a circle is accelerating.

- Acceleration is produced by a force and experiments show the two are proportional.

Newton's Second Law: Mass

- Mass is the amount of matter an object contains.
- Technically, *mass* is a measure of an object's inertia.
- Mass is generally measured in kilograms.
- Mass should not be confused with weight, which is a force related to gravity – weight may change from place to place, but mass does not.

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- NASA

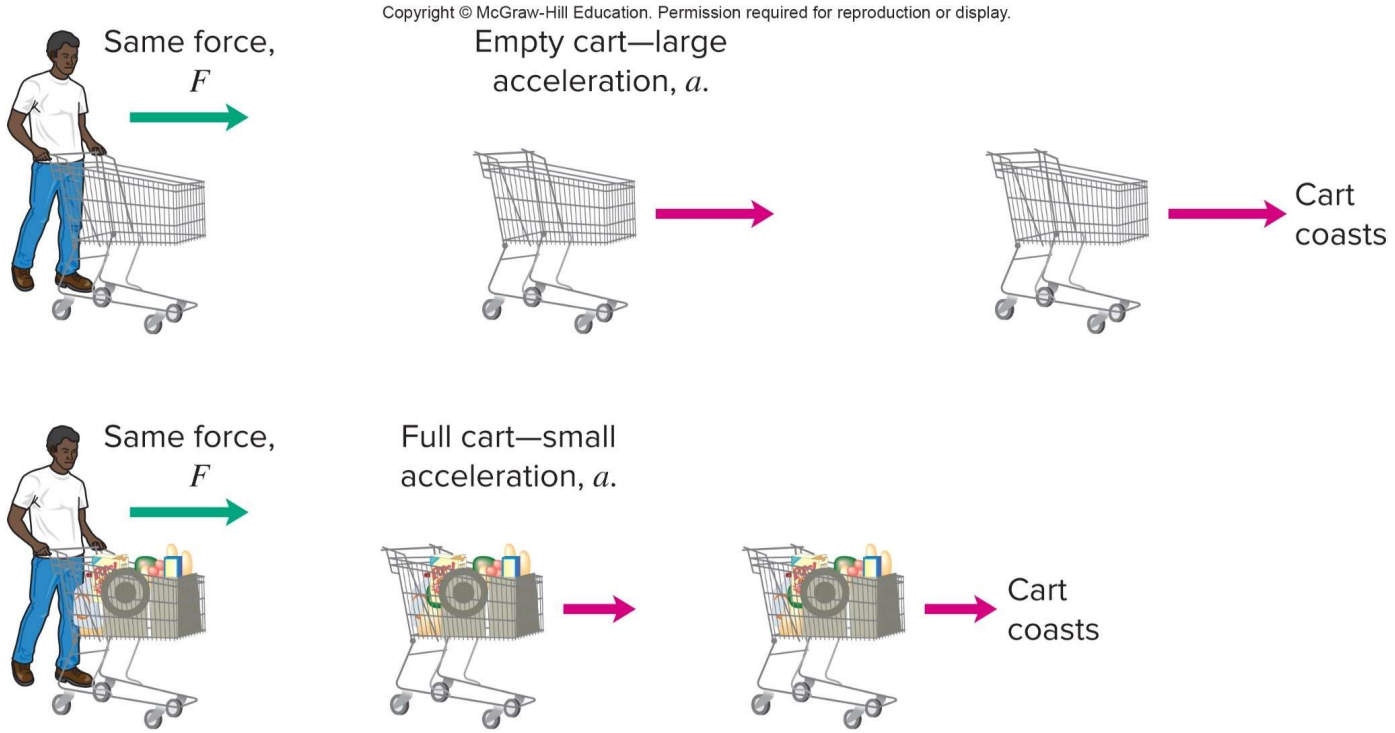
Newton's Second Law of Motion

- $F = ma$

- Equivalently, the amount of acceleration (a) that an object undergoes is proportional to the force applied (F) and inversely proportional to the mass (m) of the object.
- This equation applies for any force, gravitational or otherwise.

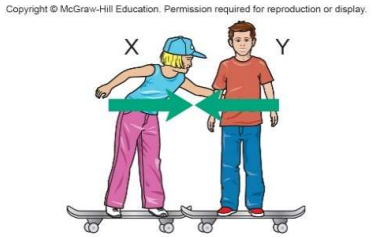
F = *ma* (or More Intuitively, *a* = *F* Over *m*)

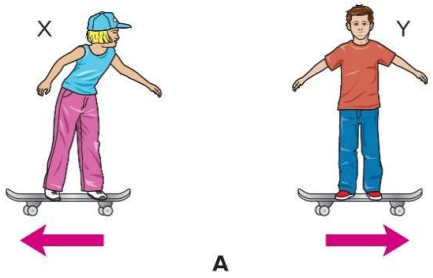
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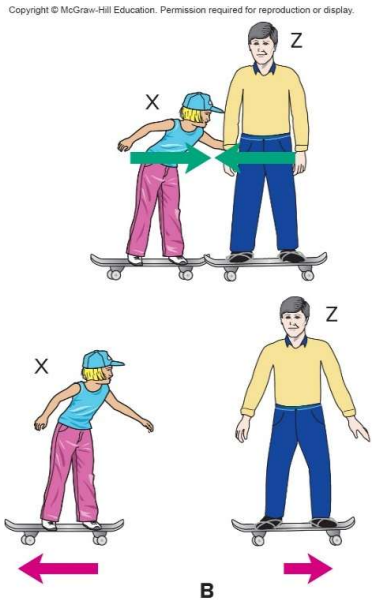


Newton's Third Law of Motion

- When two objects interact, they create equal and opposite forces on each other.
- This is true for any two objects, including the Sun and Earth!







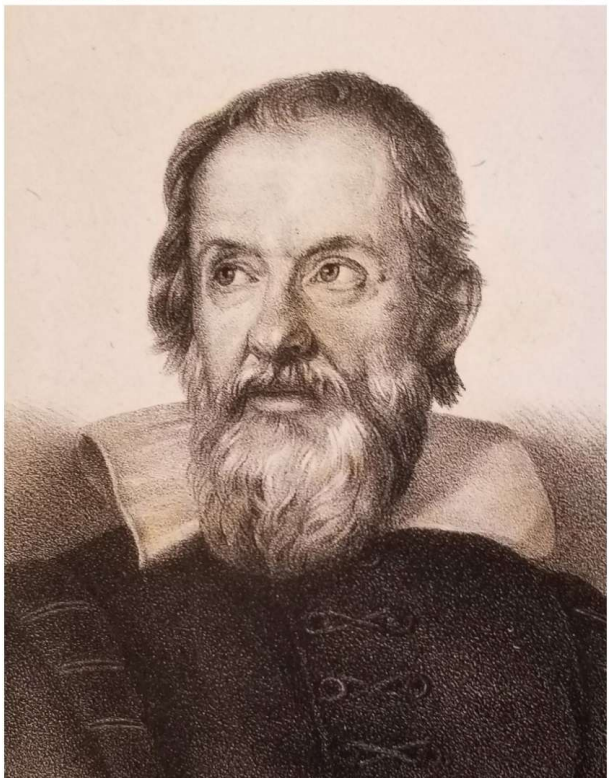
Thursday, October 15th

- T: **(7) Science concepts. The student knows our relative place in the solar system. The student is expected to:**
- **7B** model the scale, size, and distances of the Sun, Earth, and Moon system and identify the limitations of physical models; and
- **(11) Science concepts. The student uses models to explain the formation, development, organization, and significance of solar system bodies. The student is expected to:**
- **11A** relate Newton's law of universal gravitation and Kepler's laws of planetary motion to the formation and motion of the planets and their satellites;
- O: I will be able to explain gravity as it pertains to all matter
- D: by discussing the notes, completing a PhET simulation Textbook questions

- PhET Orbits
- Textbook Questions Gravity

The Problem of Astronomical Motion

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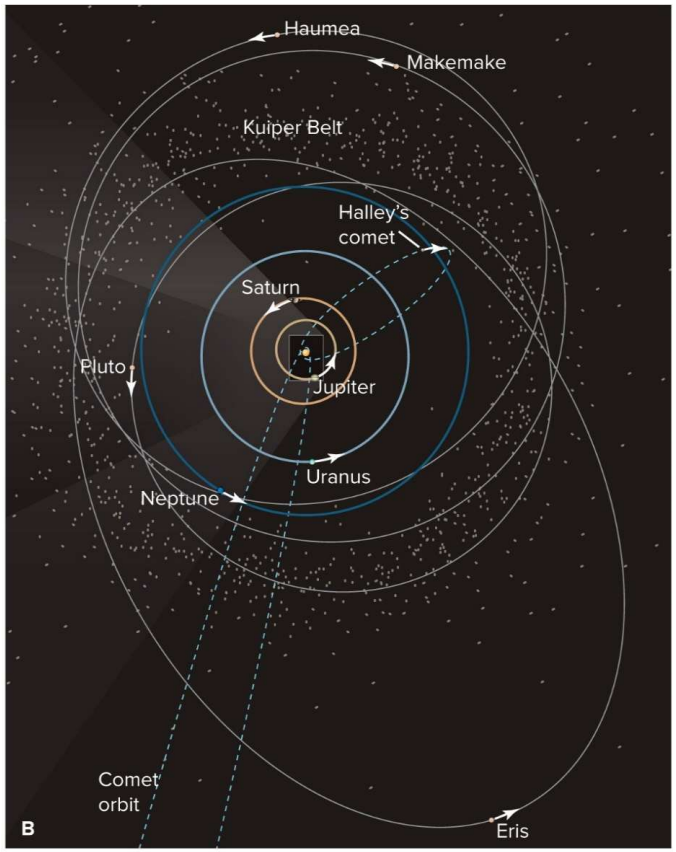
- Astronomers of antiquity did not connect gravity and astronomical motion.
- Galileo investigated this connection with experiments using projectiles and balls rolling down planks.
- He put science on a course to determine laws of motion and to develop the scientific method.

- Le opere di Galileo Galilei: Opere astronomiche. 1842 to 1853

Astronomical Motion

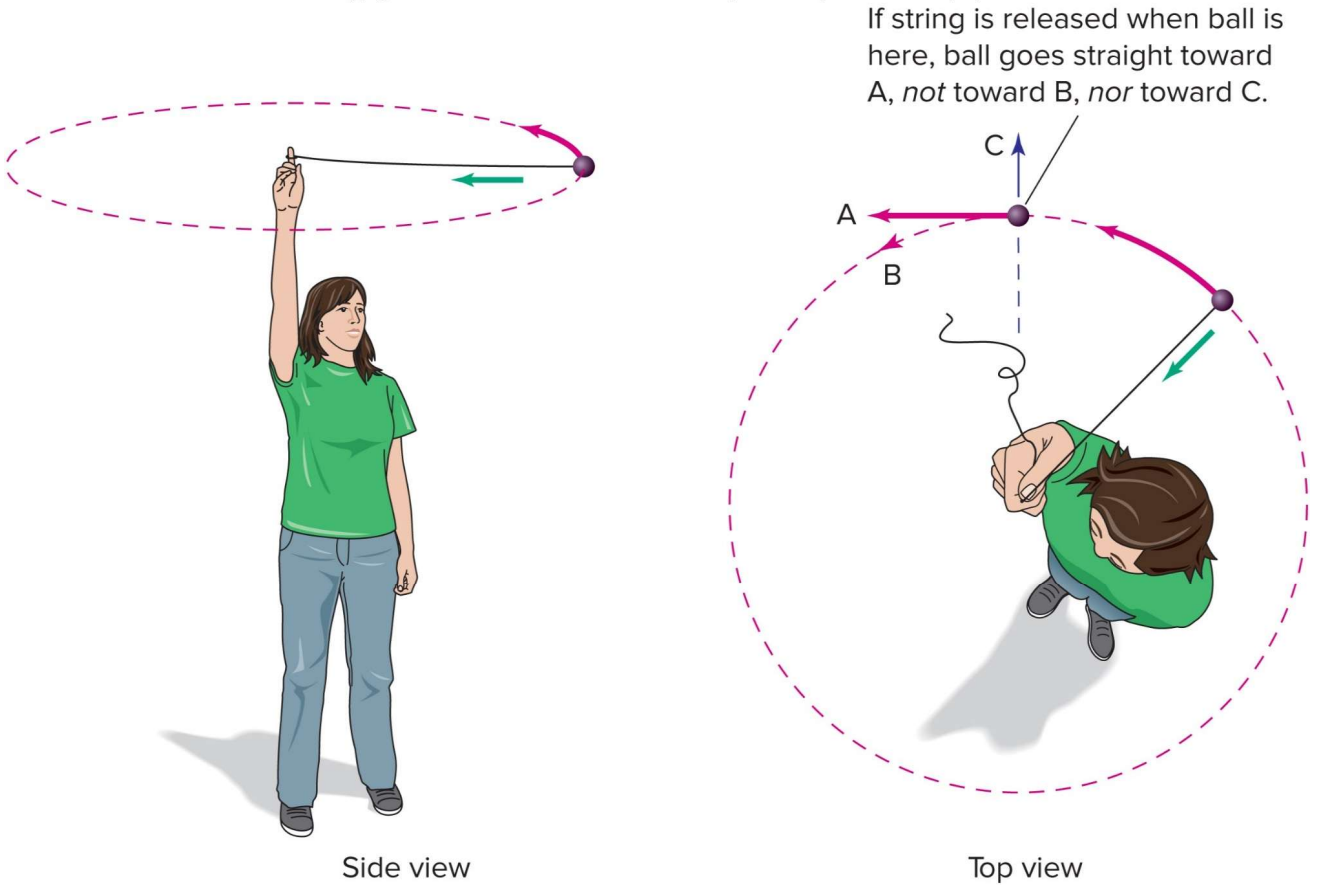
- As seen earlier, planets move along curved (elliptical) paths, or orbits.
- Speed and direction is changing.
- Must there be a force at work?
- Yes!

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Gravity is that Force!

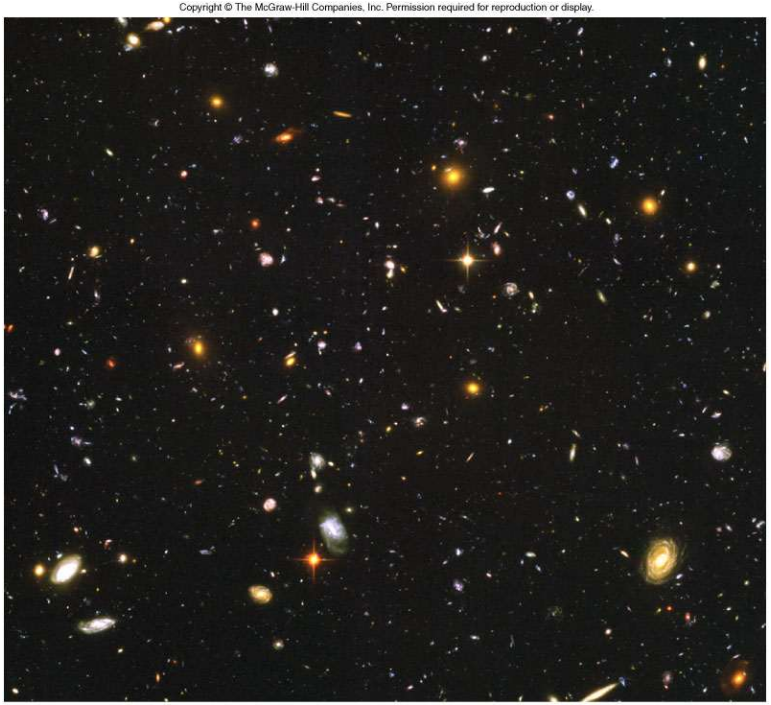
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Gravity

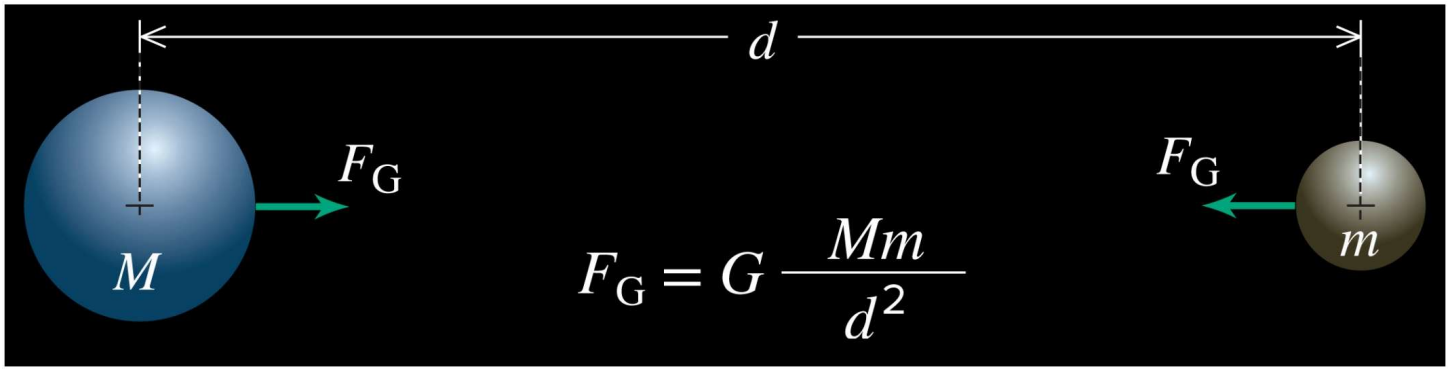
- Gravity gives the Universe its structure.
- all objects to pull on all other objects everywhere.
- It holds objects together.

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Newton's Law of Universal Gravity

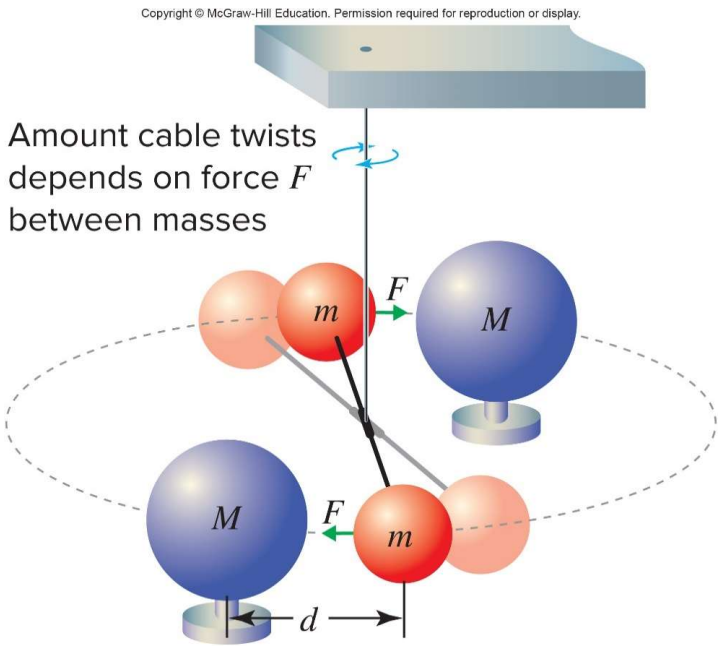
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- Everything attracts everything else!

G – The Gravitational Constant

- Henry Cavendish measured G in 1798.
- $G = 6.67 \times 10^{-11}$ N·m/kg^2.
- Determining the value of G is not easy because the gravitational force is very weak!



Orbital Motion and Gravity

- Although not the first to propose gravity as being responsible for celestial motion, Newton was the first to:
- Spell out the properties of gravity.
- Write the equations of gravity-induced motion.
- Newton deduced that:
- The Moon's motion could be explained by the existence of a force (to deviate the Moon from a straight inertial trajectory) and that such a force decreased with distance.
- Orbital motion could be understood as a projectile moving "parallel" to Earth's surface at such a speed that its gravitational deflection toward the surface is offset by the surface's curvature away from the projectile.

Friday, October 16th

- T: **(7) Science concepts. The student knows our relative place in the solar system. The student is expected to:**
  7B model the scale, size, and distances of the Sun, Earth, and Moon system and identify the limitations of physical models; and
  (11) Science concepts. The student uses models to explain the formation, development, organization, and significance of solar system bodies. The student is expected to:
  11A relate Newton's law of universal gravitation and Kepler's laws of planetary motion to the formation and motion of the planets and their satellites;
- O: I will discover and be able to understand surface gravity and escape velocity
- D: by taking notes, discussing with my group, and completing a textbook assignment.

- EdPuzzle Escape Velocity
- Textbook Questions Escape Velocity

Surface Gravity

- *Surface gravity* is the acceleration a mass undergoes at the surface of a celestial object (e.g., an asteroid, planet, or star).
- Surface gravity:
- Determines the weight of a mass at a celestial object's surface.
- Influences the shape of celestial objects.
- Influences whether or not a celestial object has an atmosphere.

Surface Gravity Calculations

- Surface gravity is determined from Newton's Second Law and the Law of Gravity:

$$ma = \frac{GMm}{R^2}$$

where M and R are the mass and radius of the celestial object, and m is the mass of the object whose acceleration *a* we wish to know

- The surface gravity, denoted by *g*, is then:

$$g = \frac{GM}{R^2}$$

Notice dependence of g on M and R, but not m

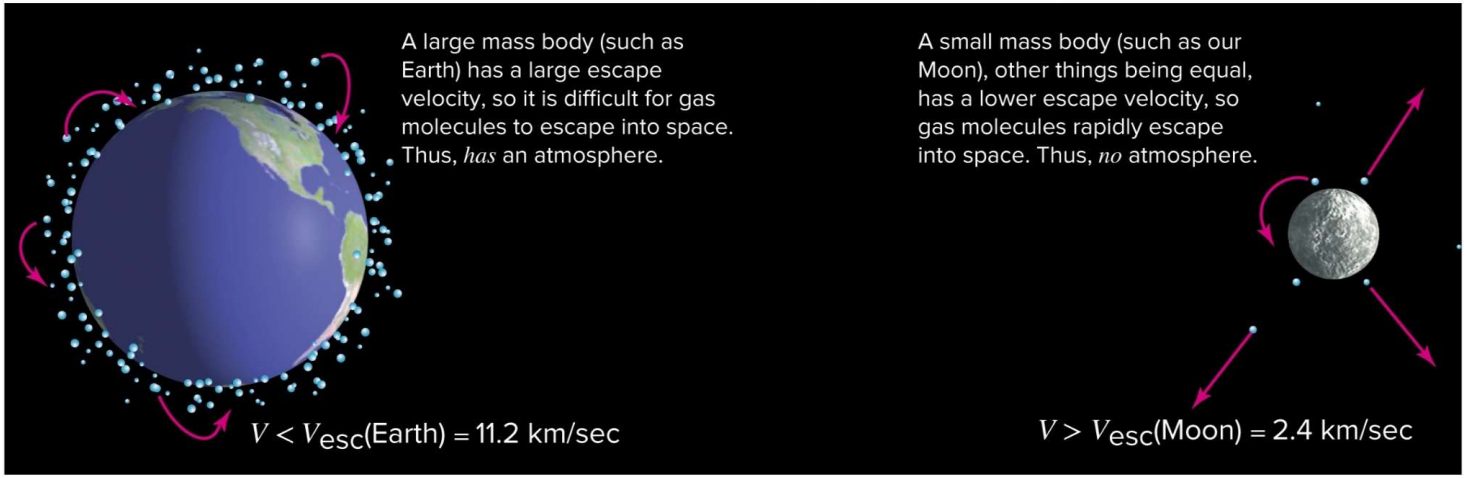
- $g_{Earth} = 9.8 m/s^2$
- $\frac{g_{Earth}}{g_{Moon}} = 5.6$ and $\frac{g_{Jupiter}}{g_{Earth}} = 3$

Escape Velocity

- To overcome a celestial object's gravitational force and escape into space, a mass must obtain a critical speed called the *escape velocity.*
- Escape velocity:
- Determines if a spacecraft can move from one planet to another.
- Influences whether or not a celestial object has an atmosphere.
- Relates to the nature of black holes.

Uses of Escape Velocity Concept

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Escape Velocity Calculation

- The escape velocity, v_{esc}, is determined from Newton's laws of motion and the Law of Gravity and is given by:

$$v_{esc} = \sqrt{\frac{2GM}{R}}$$

where M and R are the mass and radius of the celestial object from which the mass wishes to escape.

- Notice dependence of V_{esc} on M and R, but not m.

- $V_{esc,\,Earth} = 11 km/s.$

- $V_{esc,\,Moon} = 2.4 km/s.$

The Escape Velocity Formula

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