The Acceleration of Gravity ($g$)

- Galileo demonstrated that $g$ is the same for all objects, regardless of their mass!

- Confirmed by Apollo astronauts on the Moon, where there is no air resistance.

https://www.youtube.com/watch?v=5C5_dOEyAfk
September equinox

- Sat. Sept. 22 9:54 PM EDT
Cosmos
by Carl Sagan
episode 3
Harmony of the Worlds

https://www.youtube.com/watch?v=R6TdNbiAU/nE
Assignments

• For Mon., 24 Sept.
  – Read Ch. 4, “Making Sense of the Universe: Understanding Motion, Energy, and Gravity”
  – Do online quiz 02
iclicker Question

Which famous scientist/astronomer had a mother who sold drugs?

A. Galileo
B. Tycho Brahe
C. Newton
D. Kepler
E. Sagan
iclicker Question

Which famous scientist/astronomer had a mother who sold drugs?

A. Galileo
B. Tycho Brahe
C. Newton
D. Kepler
E. Sagan
iclicker Question

Which famous scientist/astronomer had gold nose?

A. Galileo
B. Tycho Brahe
C. Newton
D. Kepler
E. Sagan
iclicker Question

Which famous scientist/astronomer had gold nose?

A. Galileo
B. Tycho Brahe
C. Newton
D. Kepler
E. Sagan
Tycho Brahe (1546-1601)

- Greatest observer of his time
- Charted positions of planets
- Observed supernova in 1572
- Quite a character

http://www.nada.kth.se/~fred/tycho/index.html
• Kepler first tried to match Tycho’s observations with circular orbits.

• But an 8-arcminute discrepancy led him eventually to ellipses.

“If I had believed that we could ignore these eight minutes [of arc], I would have patched up my hypothesis accordingly. But, since it was not permissible to ignore, those eight minutes pointed the road to a complete reformation in astronomy.”
What are Kepler’s three laws of planetary motion?

**Kepler’s First Law:** The orbit of each planet around the Sun is an *ellipse* with the Sun at one focus.
Kepler’s Second Law: As a planet moves around its orbit, it sweeps out equal areas in equal times. This means that a planet travels faster when it is nearer to the Sun and slower when it is farther from the Sun.
Kepler’s Third Law

More distant planets orbit the Sun at slower average speeds, obeying the relationship

\[ p^2 = a^3 \]

\[ p = \text{orbital period in years} \]
\[ a = \text{average distance from Sun in AU} \]
Universal Laws of Motion

“If I have seen farther than others, it is because I have stood on the shoulders of giants.”

Sir Isaac Newton (1642 – 1727)
Physicist
Sir Isaac Newton (1642-1727)

- Perhaps the greatest genius of all time
- Invented the reflecting telescope
- Invented calculus
- Connected gravity and planetary forces

*Philosophiae Naturalis Principia Mathematica*
Objects in Motion

• **speed** – rate at which an object moves, i.e. the distance traveled per unit time [m/s; mi/hr]

• **velocity** – an object’s speed in a certain direction, e.g. “10 m/s moving east”

• **acceleration** – a change in an object’s velocity, i.e. a change in either speed or direction is an acceleration [m/s²]
Acceleration of Gravity

- As objects fall, they accelerate.

- Acceleration from Earth’s gravity is 10 m/s each second, or $g = 10 \text{ m/s}^2$.

- The higher you drop the ball, the greater its velocity will be at impact.
The Acceleration of Gravity (g)

- Galileo demonstrated that g is the same for all objects, regardless of their mass!

- Confirmed by Apollo astronauts on the Moon, where there is no air resistance.

https://www.youtube.com/watch?v=5C5_dOEyAfk
Forces

- **momentum** = mass times velocity
- **force** – cause a change in an object’s momentum
- As long as the object’s mass does not change, the force causes a change in velocity, or an...
Newton’s Laws of Motion

1. A body at rest or in motion at a constant velocity remains in that state unless acted upon by an outside force.

   If $F=0$, then $V = \text{constant}$
Newton’s Laws of Motion

2 The change in a body’s velocity due to an applied force is in the same direction as the force and proportional to it, but is inversely proportional to the body’s mass.

\[ a = \frac{F}{m} \quad \Leftrightarrow \quad F = m \cdot a \]
Newton’s Laws of Motion

3 For every applied force, a force of equal size but opposite direction arises.

\[ F_A = -F_B \]
Newton’s Laws of Motion

A baseball accelerates as the pitcher applies a force by moving his arm. (Once released, this force and acceleration cease, so the ball’s path changes only due to gravity and effects of air resistance.)

A spaceship needs no fuel to keep moving in space.

A rocket is propelled upward by a force equal and opposite to the force with which gas is expelled out its back.
Universal Law of Gravitation

\[ F_g = -G \frac{M_1 M_2}{d^2} \]
Weight & mass

• Weight $W = m \cdot g$

• For planet of mass $M$ and radius $R$
  – $g = \frac{GM}{R^2}$
  – for earth, $g = 9.8 \text{ m/s}^2$ (round to 10 m/s$^2$)

• combine $F_g = m \cdot a$

• $a = \frac{F_g}{m} = \frac{W}{m} = \frac{m \cdot g}{m} = g$

• So all falling objects accelerate at same rate $a = g$
Mass vs. Weight?

- **mass** – the amount of matter in an object
- **weight** – a measurement of the *force* that acts on an object
- **When in “free-fall,” you are weightless!!**
Gravity on different planets

• for planet of mass M and radius R
  – \( g = \frac{GM}{R^2} \)
  – for earth, \( g_E \approx 10 \text{ m/s}^2 \)

• for other planets
  – \( g = g_E \left( \frac{M}{M_E} \right) \left( \frac{R}{R_E} \right)^2 \)