Eclipses and Forces

Jan 21, 2004

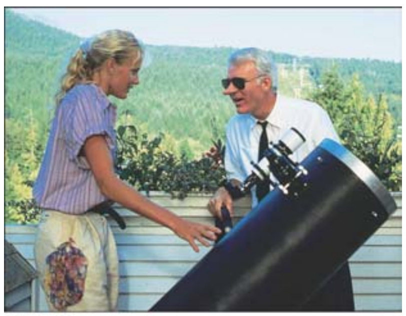
1) Review
2) Eclipses
3) Kepler's Laws
4) Newton's Laws

Review

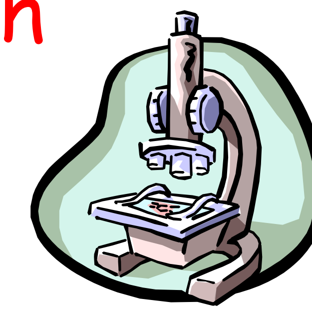
- Lots of motion
- The Moon revolves around the Earth
- Eclipses
  - Solar
  - Lunar
  - the Sun, Earth and Moon must all be in a line
- Did you know that all this motion and tilting was happening?

How to do Science

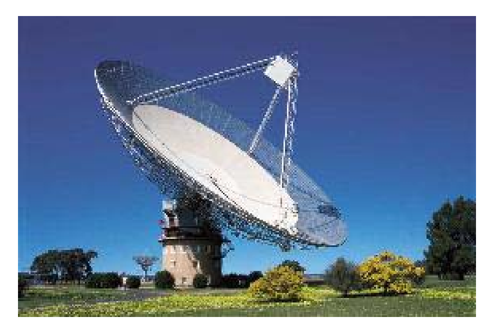
- Use scientific method
  - test and re-test



- Presentations and publish

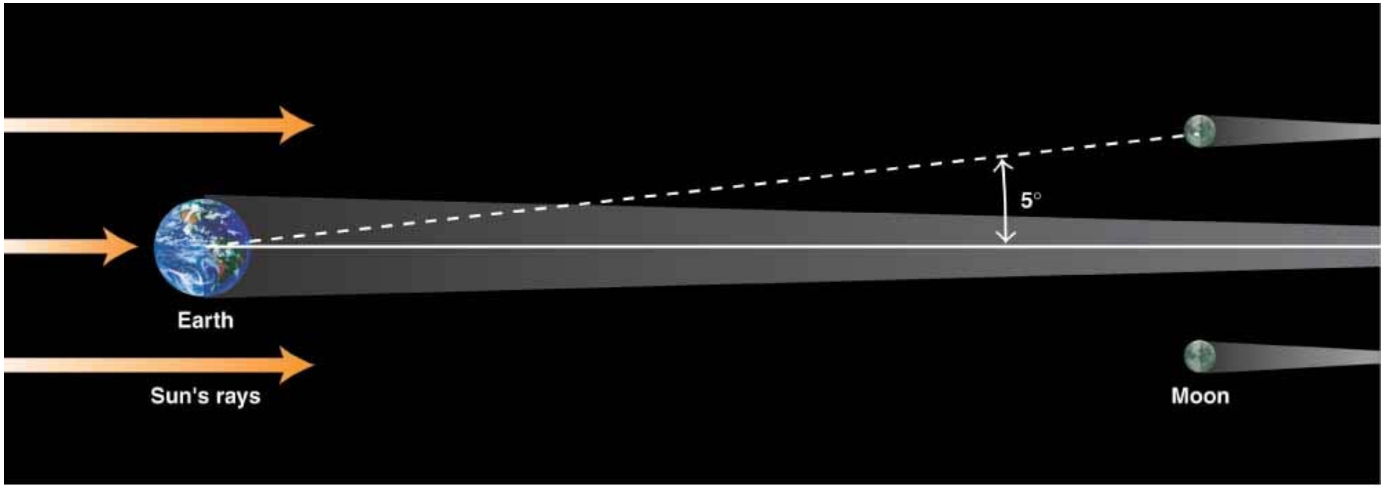


- Peer scrutiny
- Reproducible
  - others must be able to redo the experiment and produce similar results



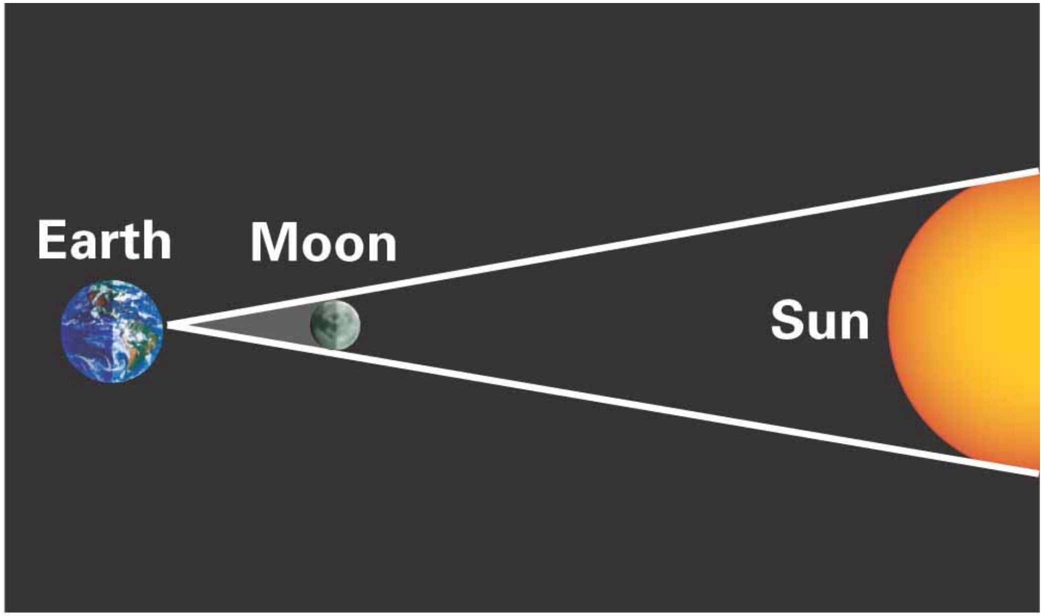
Eclipses

- Eclipses occur when the Sun, the Earth and the Moon all lie along a straight line
  - They must line up in all 3 dimensions + time
  - the Moon's orbit is tilted 5^{o} with respect to the ecliptic, so there are only two times a year when the paths overlap



Solar Eclipse

- The Moon is between the Sun and the Earth
  - as seen from the Earth, the Moon blocks the Sun either partially or fully
- A truly amazing sight



Solar eclipse

Total Solar Eclipse

Pictures of the total solar eclipse on Dec. 4, 2002 from Australian outback

- taken by former FSU physics graduate student

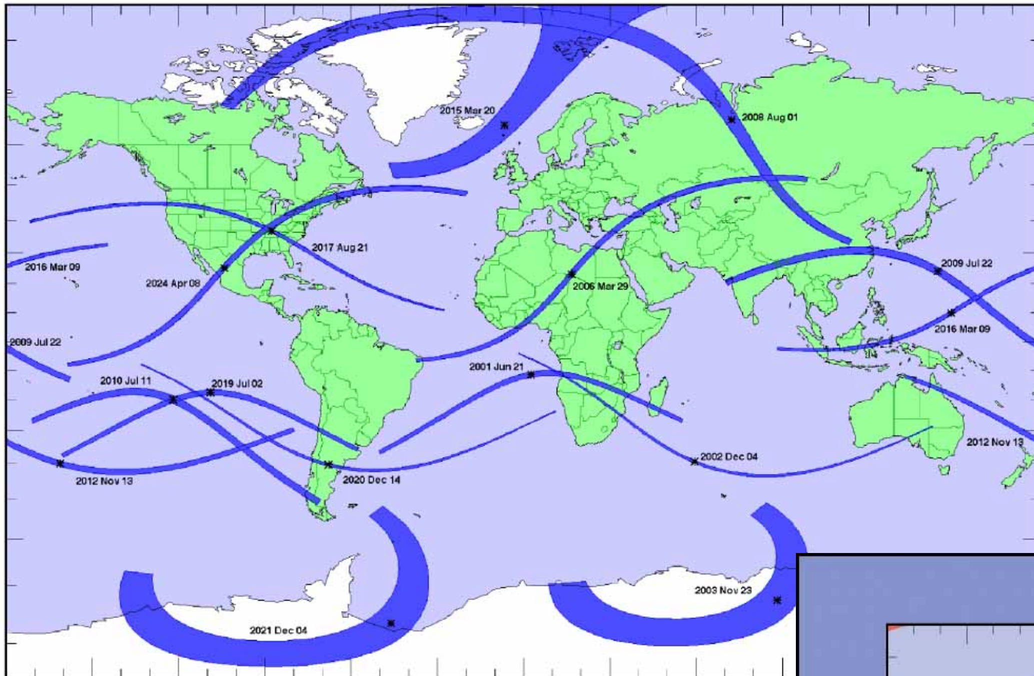
Solar Eclipse (cont)

- The Sun and the Moon have the same apparent size in the sky ($\frac{1}{2}^{\circ}$ wide)
  - Sun is 400 times larger than the Moon, but 400 times farther away
  - Earth to Moon distance varies (elliptical orbit) so sometimes the Moon won't totally block the Sun
  - area of total eclipse is small (0 to 175 km wide)
  - time of total eclipse is small (0 to 7 minutes)

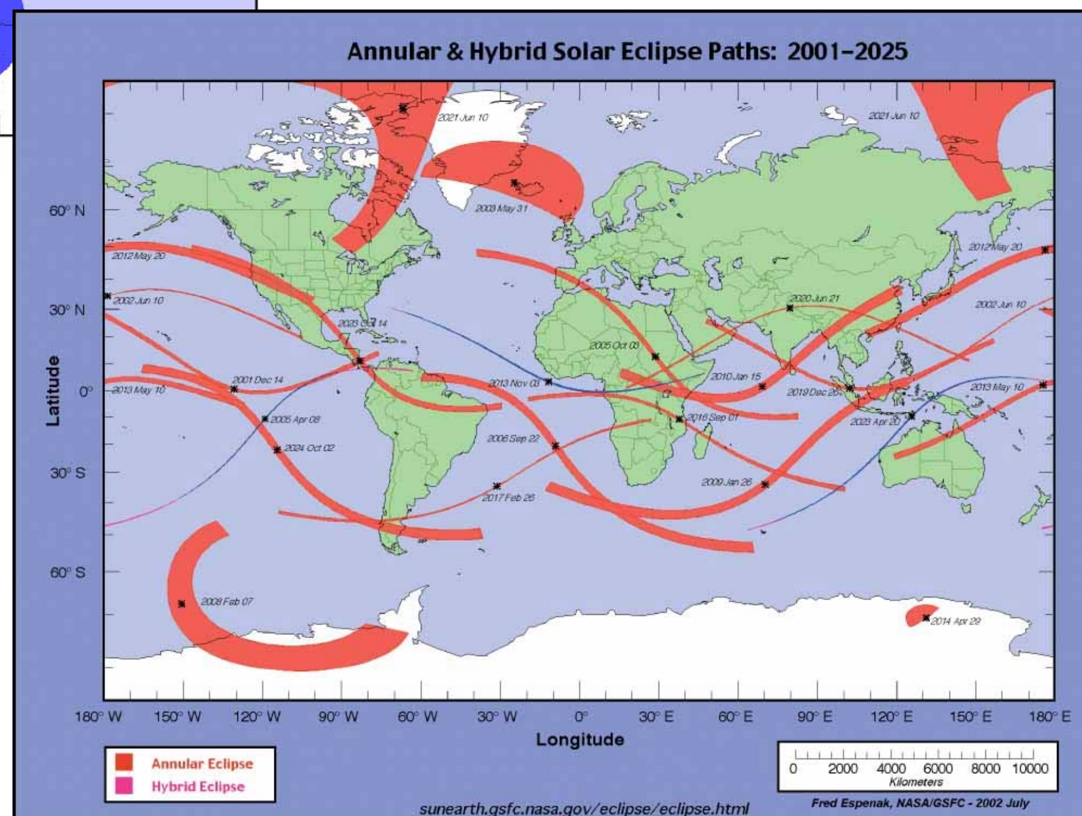
Upcoming Solar Eclipses

Date	Duration of Totality (minutes)	Where Visible
Dec. 4, 2002	2.1	South Africa, Australia
Nov. 23, 2003	2.0	Antarctica
April 8, 2005	0.7	South Pacific Ocean
Mar. 29, 2006	4.1	Africa, Asia Minor, Russia
Aug. 1, 2008	2.4	Arctic Ocean, Siberia, China
July 22, 2009	6.6	India, China, South Pacific
July11, 2010	5.3	South Pacific Ocean
…		
Aug. 21, 2017	2.7	Pacific Ocean, USA, Atlantic Ocean
…		
April 8, 2024	4.5	South Pacific, Mexico, Eastern USA

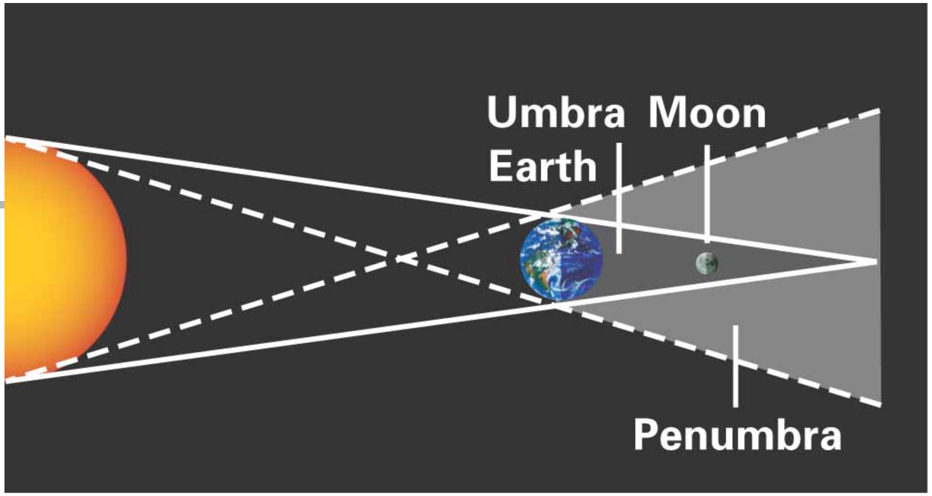
Total eclipses



Annular eclipses



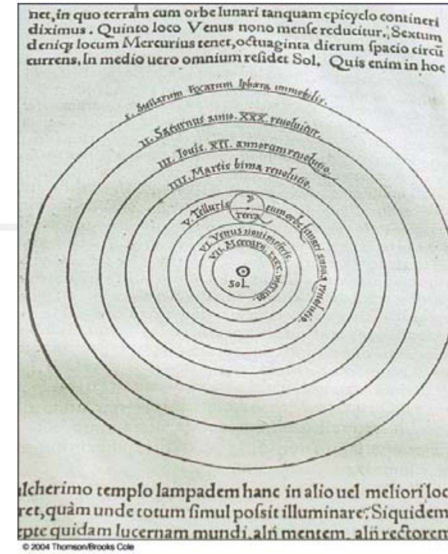
Lunar Eclipse



Lunar eclipse

- The Earth is between the Sun and the Moon
- Lunar eclipses are visible from anywhere on the night side of Earth
  - The Earth's shadow is much larger
- So, lunar eclipses are much more common
  - Every 2-3 years
  - Totality lasts up to 1 hour 40 minutes

Nicholas Copernicus

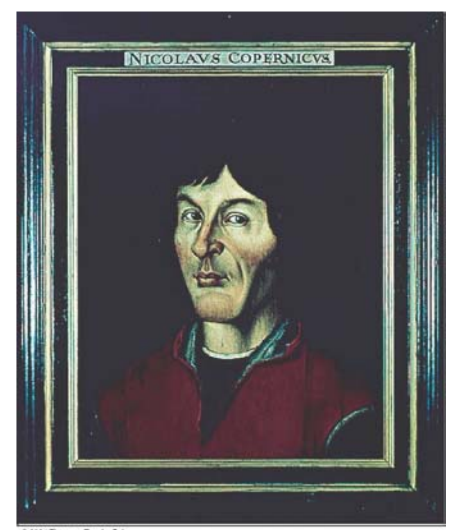


- Early people believed the Earth was the center of the Universe

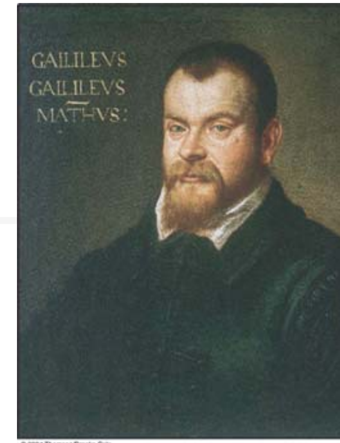
Nicholas Copernicus (1473-1543) was the first recorded person to suggest the Earth revolved around the Sun

  - He suggested the planets went around in circles

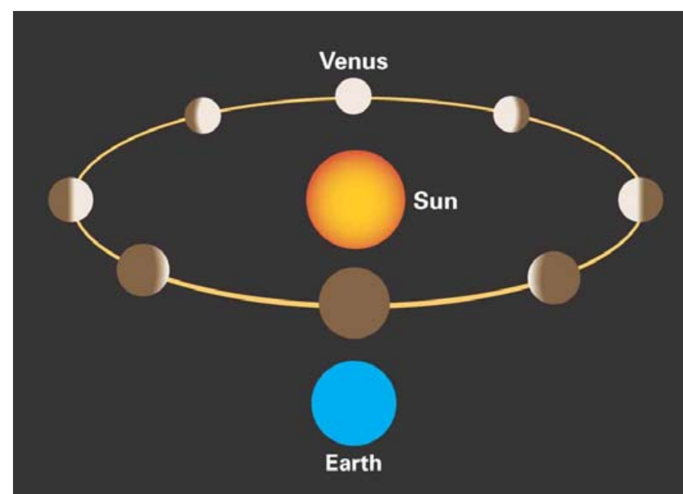
- Not readily accepted



Galileo Galilei (1564-1642)



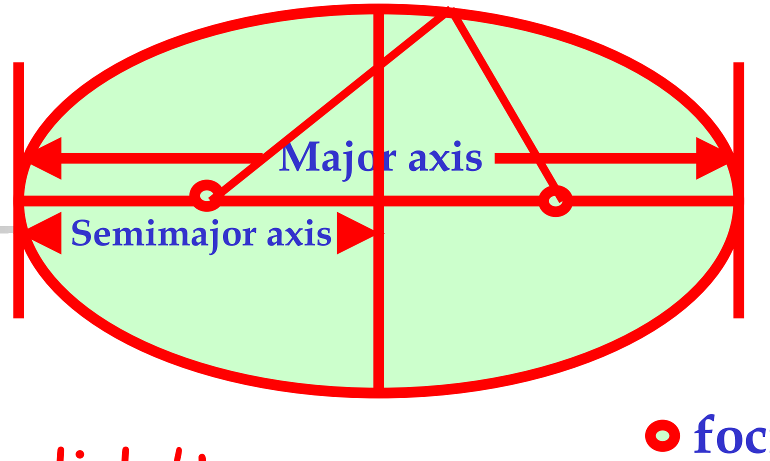
- Italian mathematician
- Developed use of the telescope
- First to see Jupiter and its moons
  - mini-solar system
- Saw Venus went through phases
- Viewed sunspots



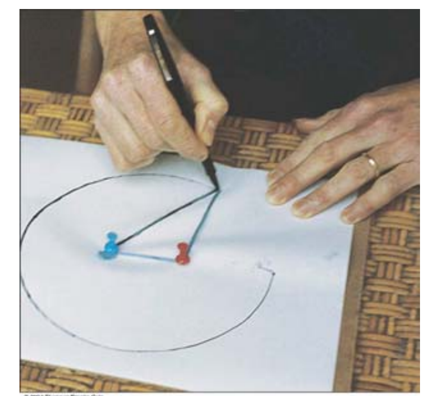
Brahe and Kepler

- Tycho Brahe (1546-1601)
  - Brahe spent decades observing and recording the positions of the planets in the sky
- Johannes Kepler (1571-1630)
  - Compared the data from Brahe to Copernicus' theory of planets revolving around the Sun in circular orbits
  - The data did NOT support this theory
    - What does the scientific method say we should do?

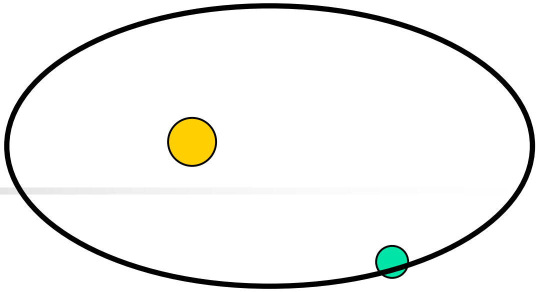
Ellipses



- Kepler began by assuming orbits were circles, but that didn't work so he tried ellipses
- An ellipses is a flattened out circle
  - *eccentricity* is a measure of how flat it is
- Circle: eccentricity = 0
- Ellipse: the distance from one focal point to the edge to the other focal point is constant
- An ellipse can be described by its semimajor axis and its eccentricity



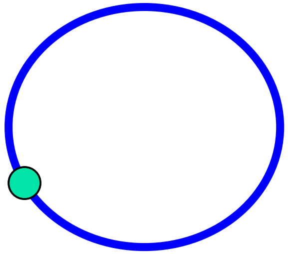
Kepler's First Law

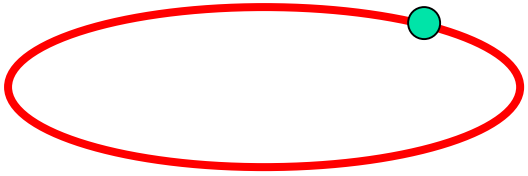


- Kepler's First Law of planetary motion

Planets move in orbits which are ellipses with the Sun at one of the focal points

- This is an empirical theory
  - it doesn't explain why
  - but, it matched the data
- Earth has a fairly circular orbit
  - Earth's eccentricity = 0.017
- Pluto has a more elliptical orbit
  - Pluto's eccentricity = 0.224

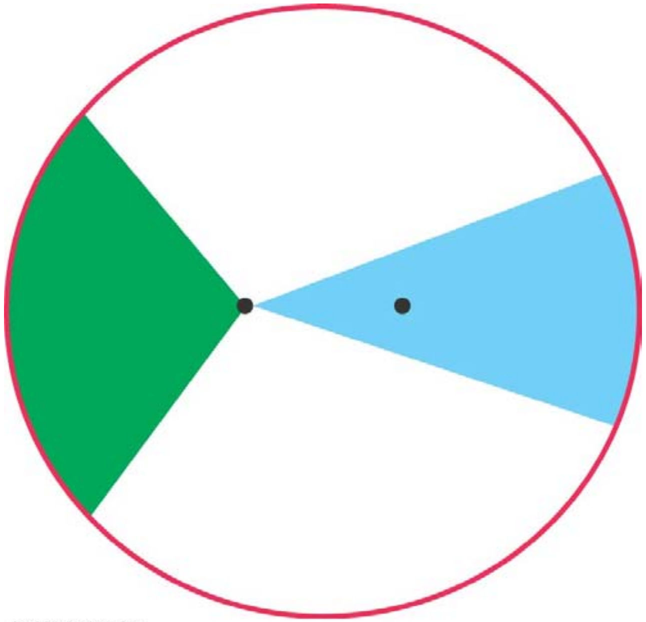




Kepler's Second Law

Planets sweep out equal areas in equal times

- Planets move fastest when they are closest to the Sun
- They move slowest when they are farthest from the Sun



Kepler's Third Law

The square of a planet's orbital period equals the cube of the orbit's semi-major axis

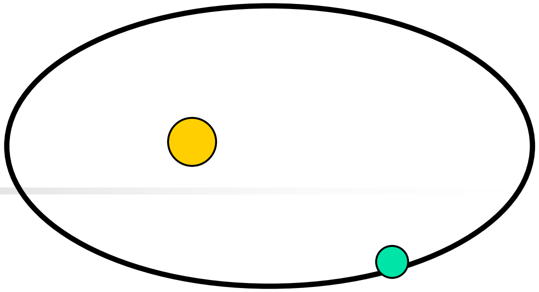
$$(P_{years})^2 = (A_{AU})^3$$

- Orbital period = time the planet takes to go around the Sun once
  - measured in years
- Length of semi-major axis of orbital ellipse
  - measured in astronomical units (AU)

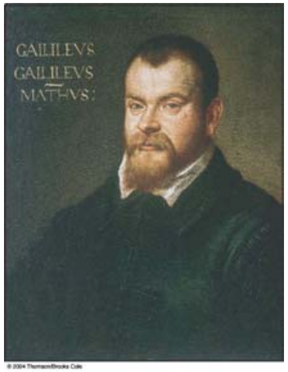
Example of Keplar's 3rd Law

- Mars has a semi-major axis of 1.52 AU. What is it's orbital period?

But WHY???



- Kepler's Laws
  - they don't tell us why the planets move this way
- Science tries to learn how and why
- Two great scientists helped answer these questions
  - Galileo Galilei (1564-1642)
  - Sir Isaac Newton (1642-1723)
- Newton's Laws of Motion



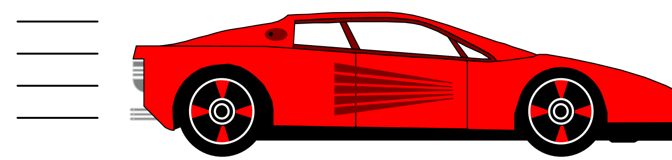
Newton's First Law

An object at rest will stay at rest,
an object in motion will remain in motion

- …unless an unbalanced force acts upon it
- The first part seems obvious
- The second part seems less obvious
  - you are used to an object sliding across the floor and slowing down
  - but it really does want to keep moving
- Now we need some definitions…

Definitions

- Distance (m) and Time (s)
- Speed (m/s)
  - how fast you are moving
- Velocity (m/s)
  - speed + direction
- Acceleration (m/s^2)
  - how quickly your velocity is changing
- Mass (kg)
  - a measure of how much matter an object has
  - different than weight, but related
- Inertia
  - the amount an object resists changes in motion



Newton's Second Law

An unbalanced force will change an object's motion

- The change in motion (acceleration) will be proportional to the amount of force
  - the harder you push the more the motion will change
  - the harder you push the greater the acceleration

F=ma

$$a = \frac{F}{m}$$

Newton's Third Law

For every action there is
an equal and opposite reaction

- Not intuitively obvious
- Examples,
  - two carts
  - baseball hitting a bat or tennis ball hitting a racket
  - Earth pulls on the Moon, Moon pulls on the Earth
  - Space Shuttle launch
    - gas goes one way, Shuttle the other

Summary

- Kepler discovered empirical laws which described the motion of the planets, but didn't explain them
- Newton developed 3 laws of Nature which describe how the planets behave as well as how things on Earth act