Venus Phases & Newton's Laws

Homework: Questions?

- Seasons: Count the number of days! Winter is shortest (in northern hemisphere)
- Copernicus did away with major but not minor epicycles

- Thanks a lot for feedback on the last HW!
  - Boldface definitions
  - More figures
  - Color?

Scientific Method – Applied by Galileo to Sunspots

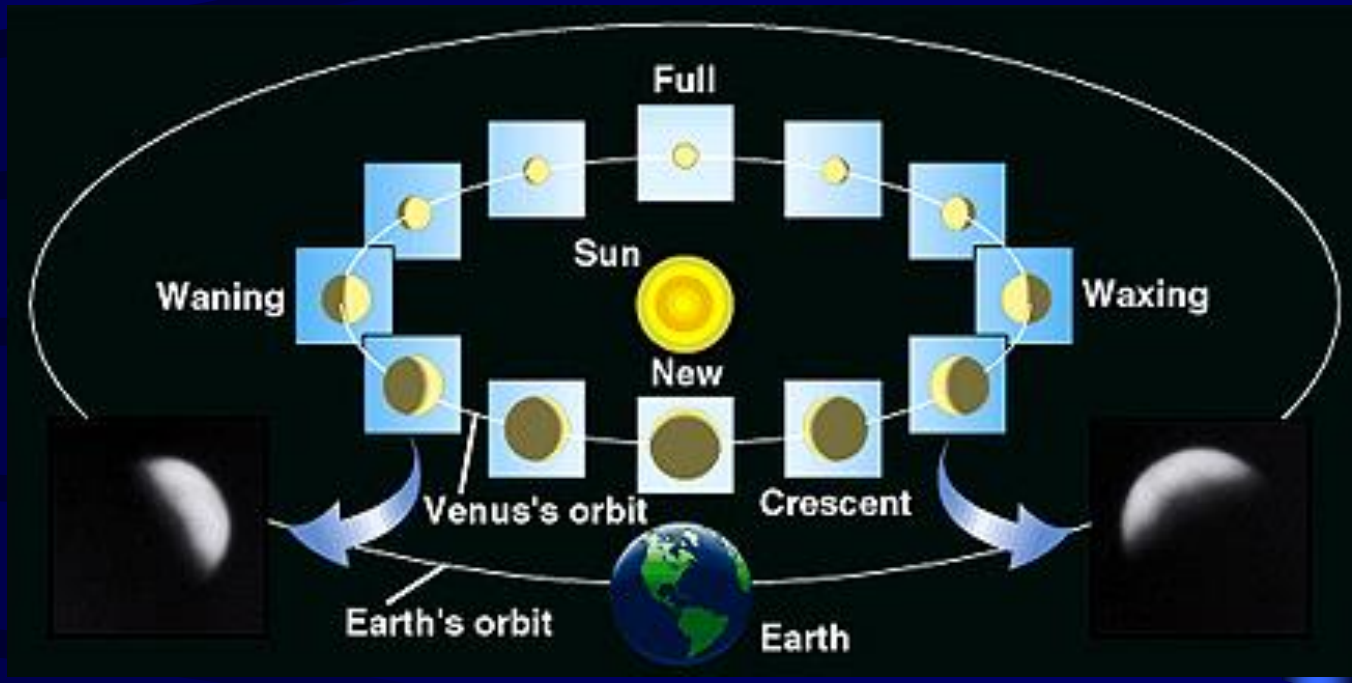
- Careful observation of a phenomenon
  - Observes sunspots (as did others before him)
  - Follows them over several weeks
- Deriving conclusions from "data"
  - Concludes that these are things very close to the Sun's surface
- Making new predictions
  - Deduces that the sun rotates around itself in 26 days
  - Makes a prediction as to the Sun's rotational axis
- Publishing results "for everyone" [in Italian]
  - "Letters on Sunspots" (1612)
- Anticipates his opponents arguments, and nullifies them by using stringent logic
  - Shows that sunspots can't be inner planets

Geocentric vs Heliocentric: How do we know?

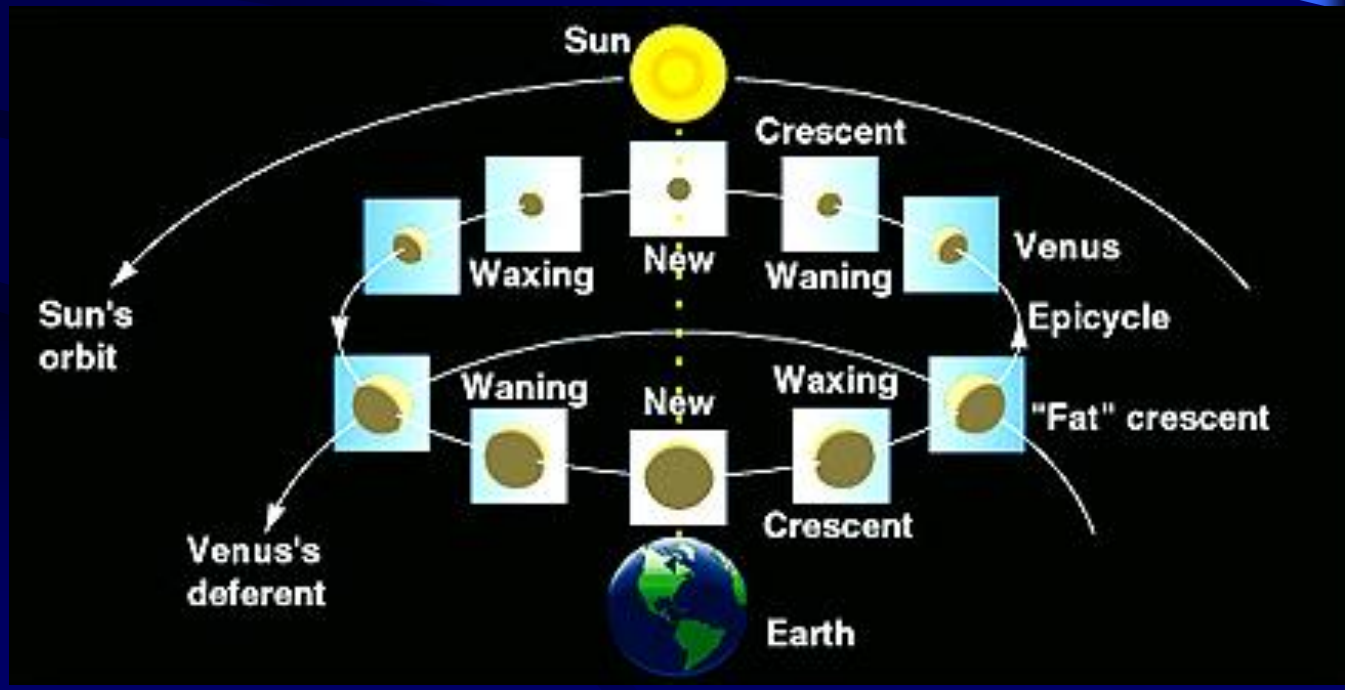
- Is the Earth or the Sun the center of the solar system?
- How do we decide between these two theories?
- Invoke the scientific method:
  - both theories make (different) predictions
    - NOT about planetary motion BUT phases of Venus
  - Compare to observations
  - Decide which theory explains data

Phases of Venus

Heliocentric

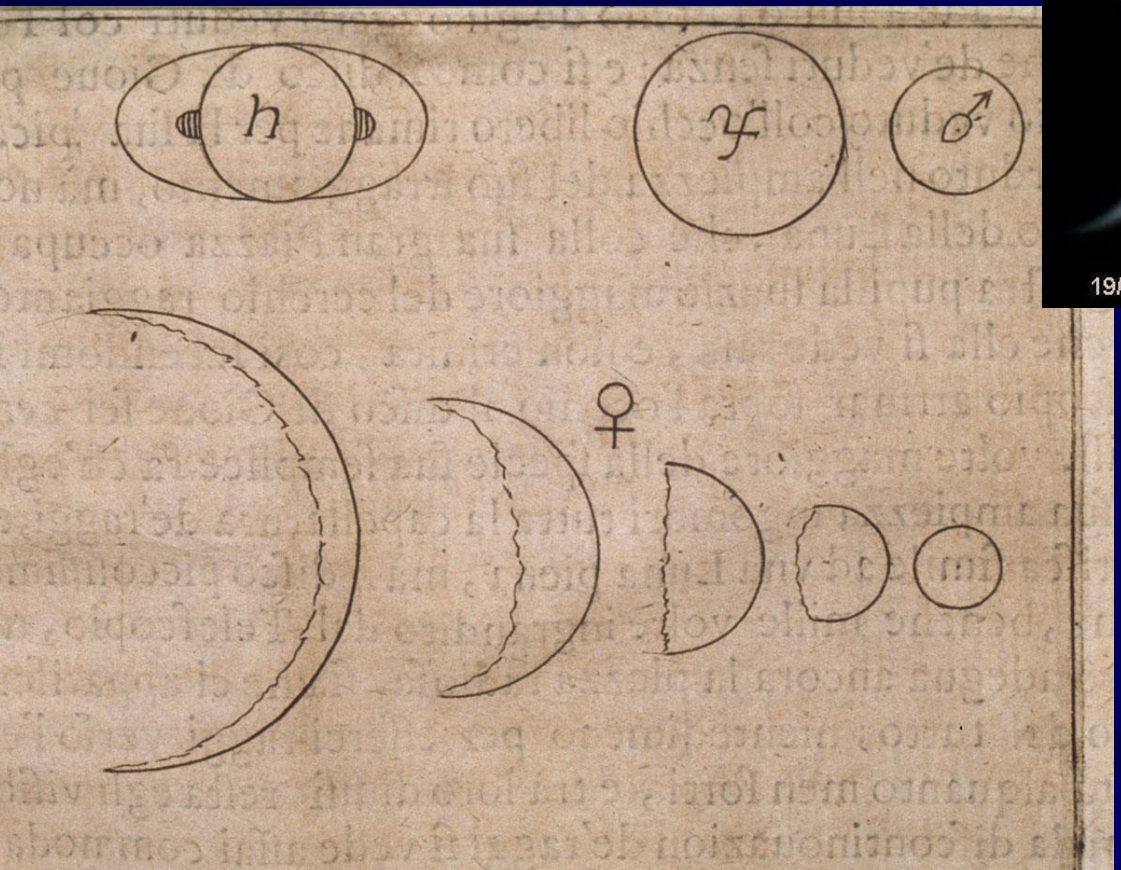


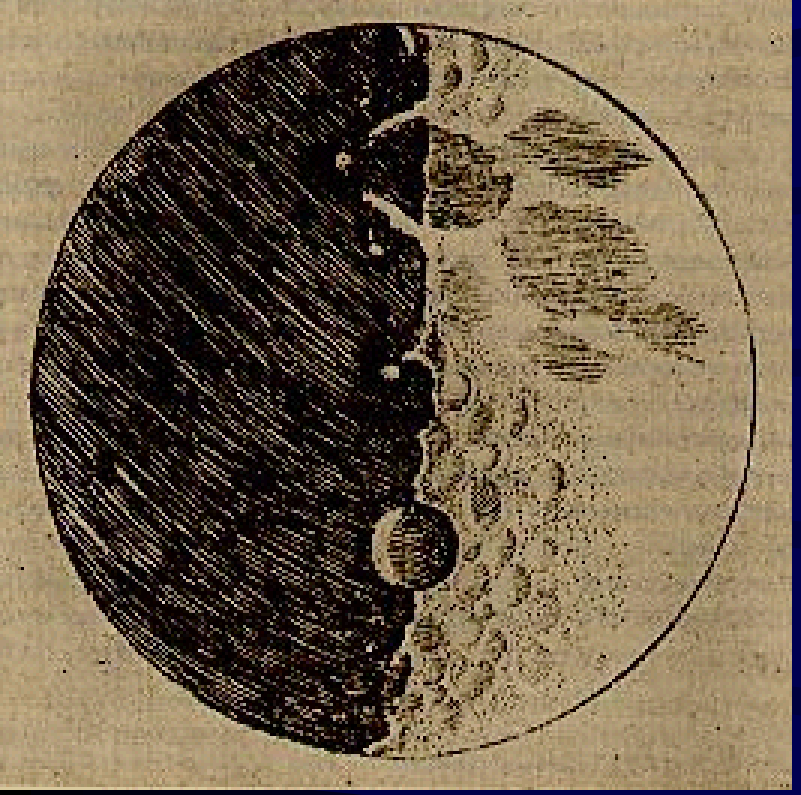
Geocentric



Venus Phases

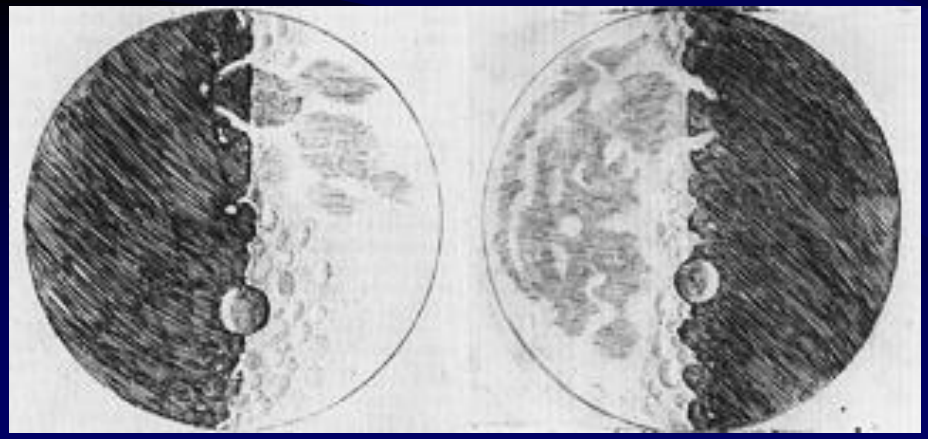
- Galileo's eyepiece sketches





Mountains on the Moon

- Galileo observed the mountains of the Moon with his telescope
- Estimated their elevation correctly



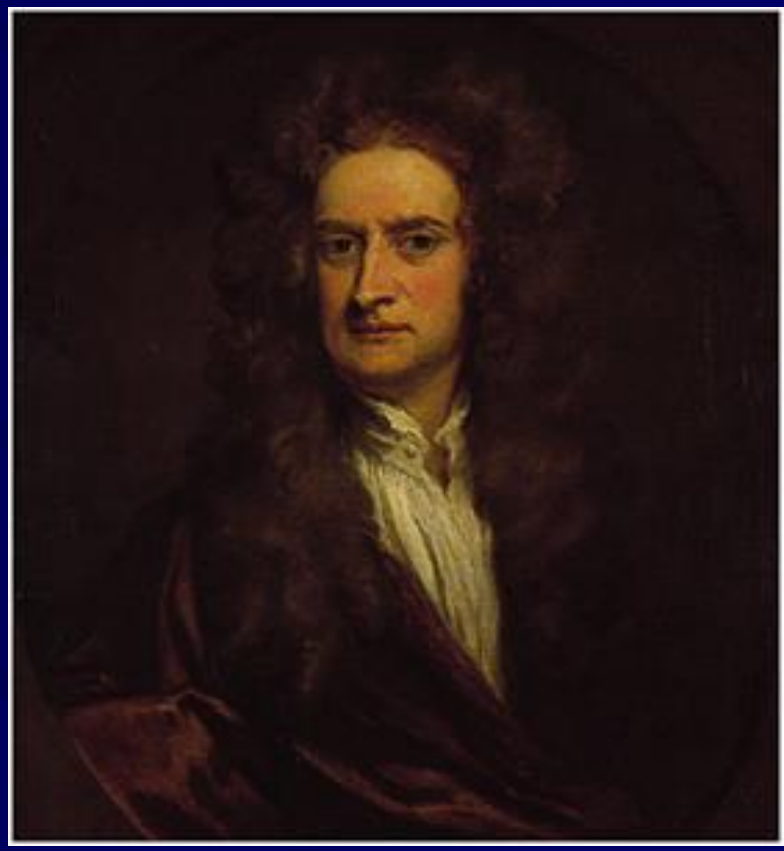
Isaac Newton – The Theorist

- Key question:

  Why are things happening?

- Invented calculus *and* physics while on vacation from college

- His three Laws of Motion, together with the Law of Universal Gravitation, explain all of Kepler's Laws (and more!)



Isaac Newton (1642–1727)

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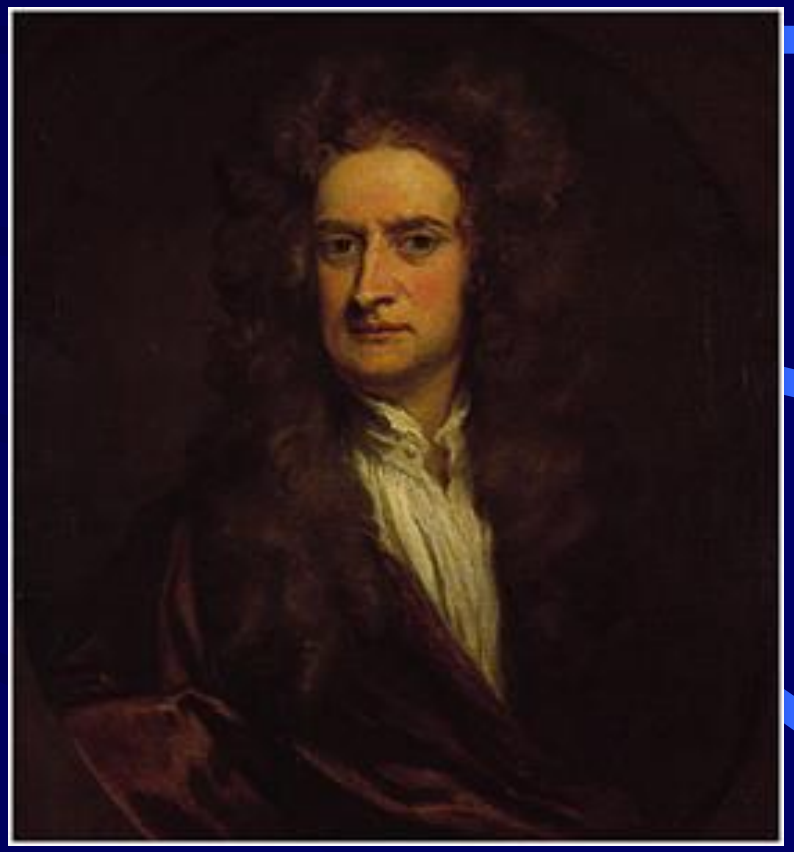
Major Works:

- Principia (1687)

  [Full title: Philosophiae naturalis principia mathematica]
- Opticks [sic!](1704)

- Later in life he was Master of the Mint, dabbled in alchemy, and spent a great deal of effort trying to make his enemies miserable



Newton's first Law

- In the absence of a net external force, a body either is at rest or moves with constant velocity.
  - Contrary to Aristotle, motion at constant velocity (may be zero) is thus the natural state of objects, not being at rest. Change of velocity needs to be explained; why a body is moving steadily does not.

Mass & Weight

- Mass is the property of an object
- Weight is a force, e.g. the force an object of certain mass may exert on a scale

Newton's second Law

- The net external force on a body is equal to the mass of that body times its acceleration

  F = *m***a**.
- Or: the mass of that body times its acceleration is equal to the net force exerted on it

  ma = F
- Or: a=F/m
- Or: m=F/a

Newton's 3rd law

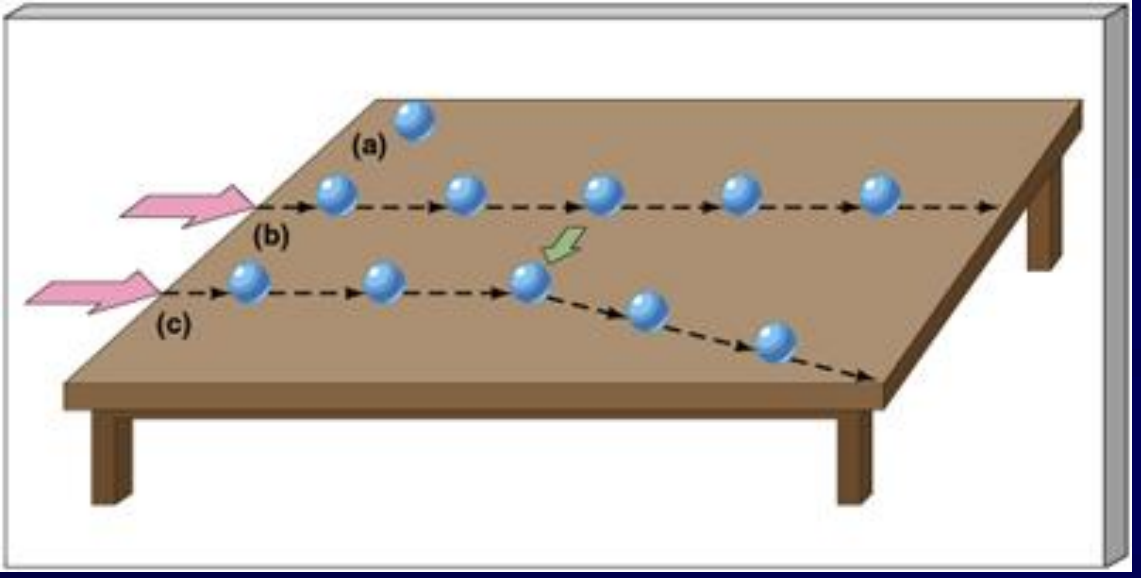
- For every action, there is an equal and opposite reaction
- Does not sound like much, but that's where all forces come from!

Newton's Laws of Motion (Axioms)

1. Every body continues in a state of rest or in a state of uniform motion in a straight line unless it is compelled to change that state by forces acting on it (law of inertia)

2. The change of motion is proportional to the motive force impressed (i.e. if the mass is constant, $F = ma$)

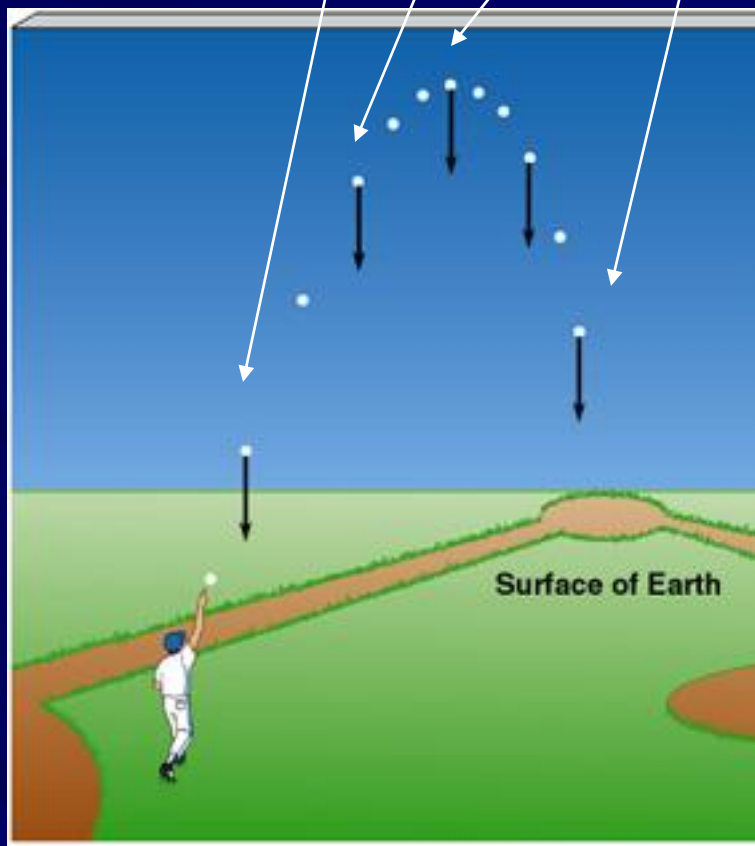
3. For every action, there is an equal and opposite reaction (That's where forces come from!)



Newton's Laws

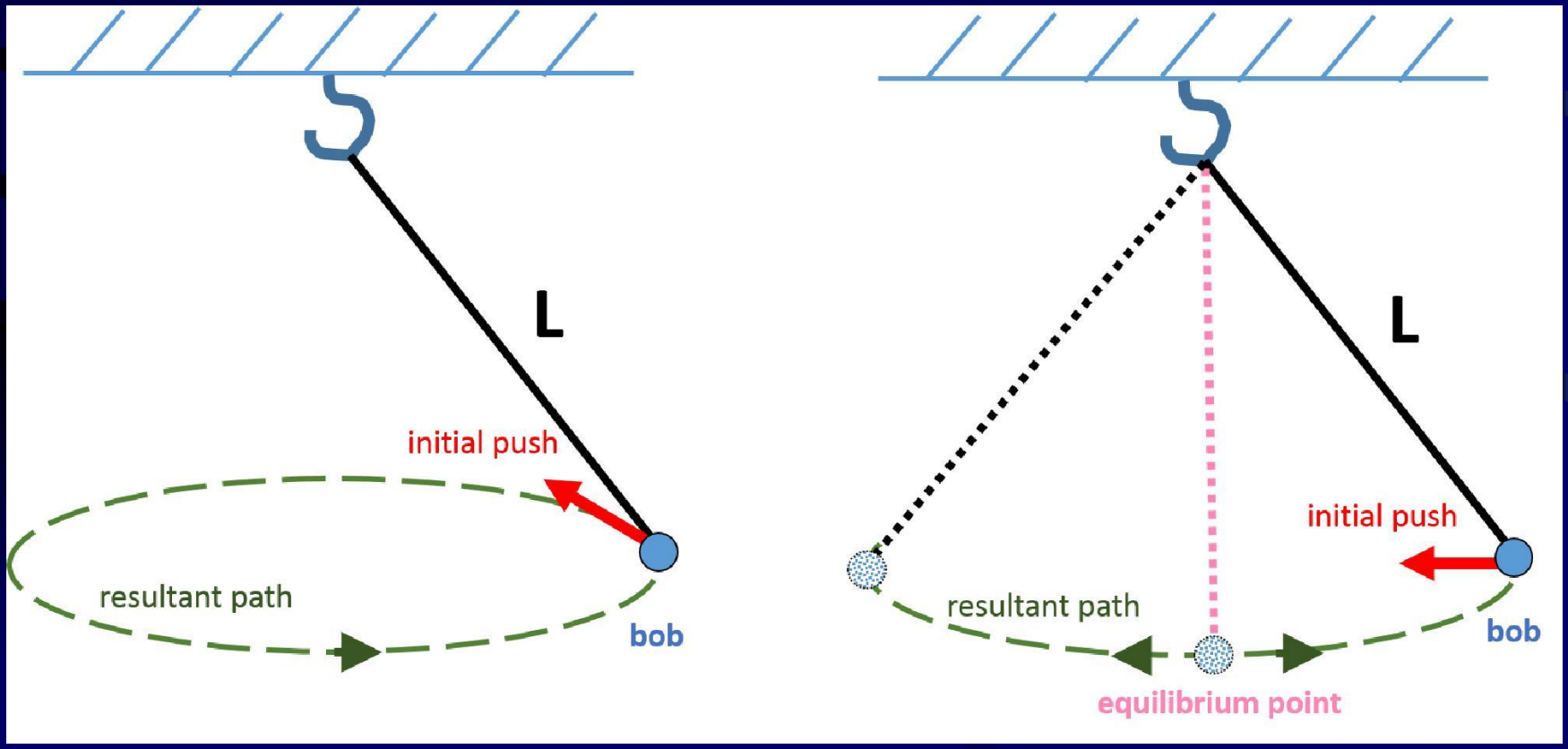
a) No force: particle at rest
b) Force: particle starts moving
c) Two forces: particle changes movement

Gravity pulls baseball back to earth by continuously changing its velocity (and thereby its position)

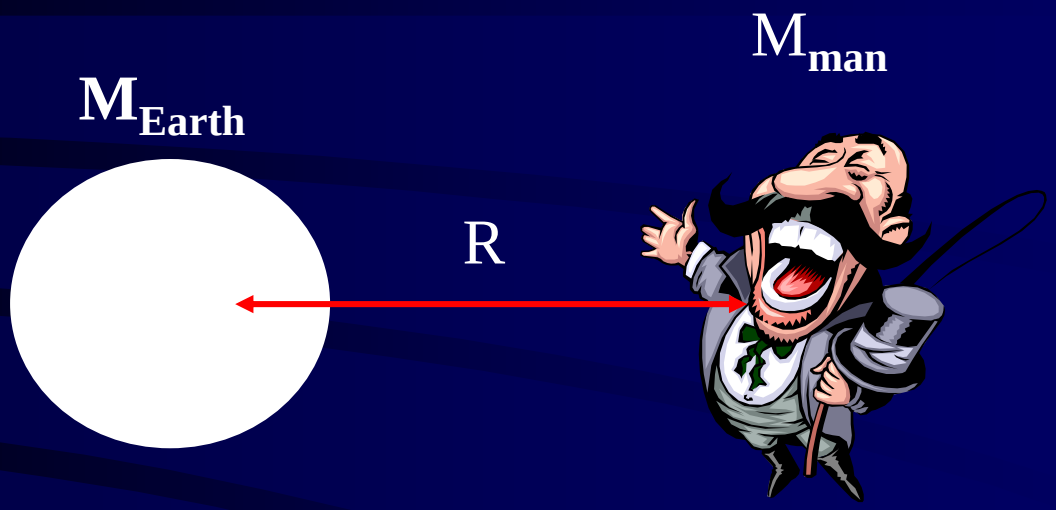


On the way to inventing gravity

- Robert Hooke's (FRS) demo or model of gravity
- Two different effects of gravity: the falling stone and the orbiting planet



Law of Universal Gravitation

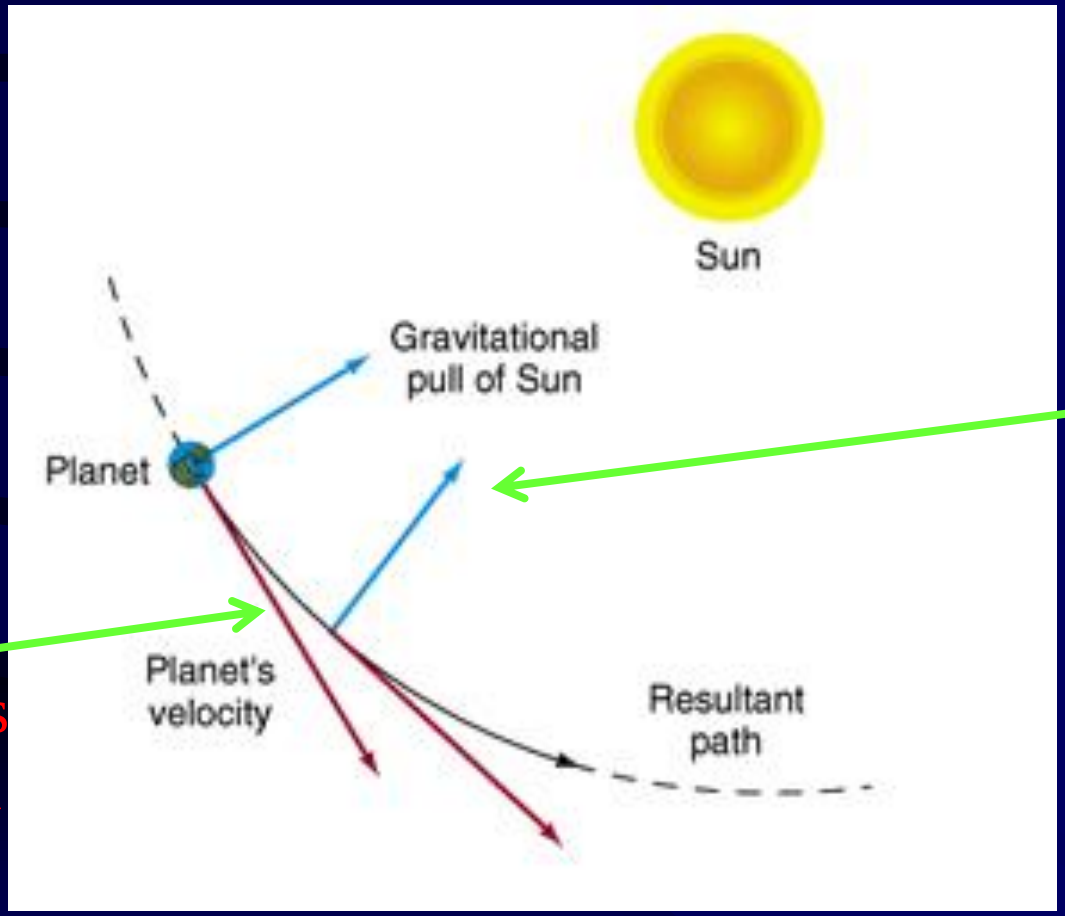


$$\text{Force} = G\, M_{earth}\, M_{man} / R^2$$

Executive summary of Newton's universal gravity

- Shortest: Math (formula)
- Explained:
  - Force of gravity goes up linearly with mass of either object: mass twice as large ➔ force twice as strong
  - Force of gravity falls off quadratically with distance between objects: distance twice as large ➔ force four times weaker

Orbital Motion = Kepler Explained



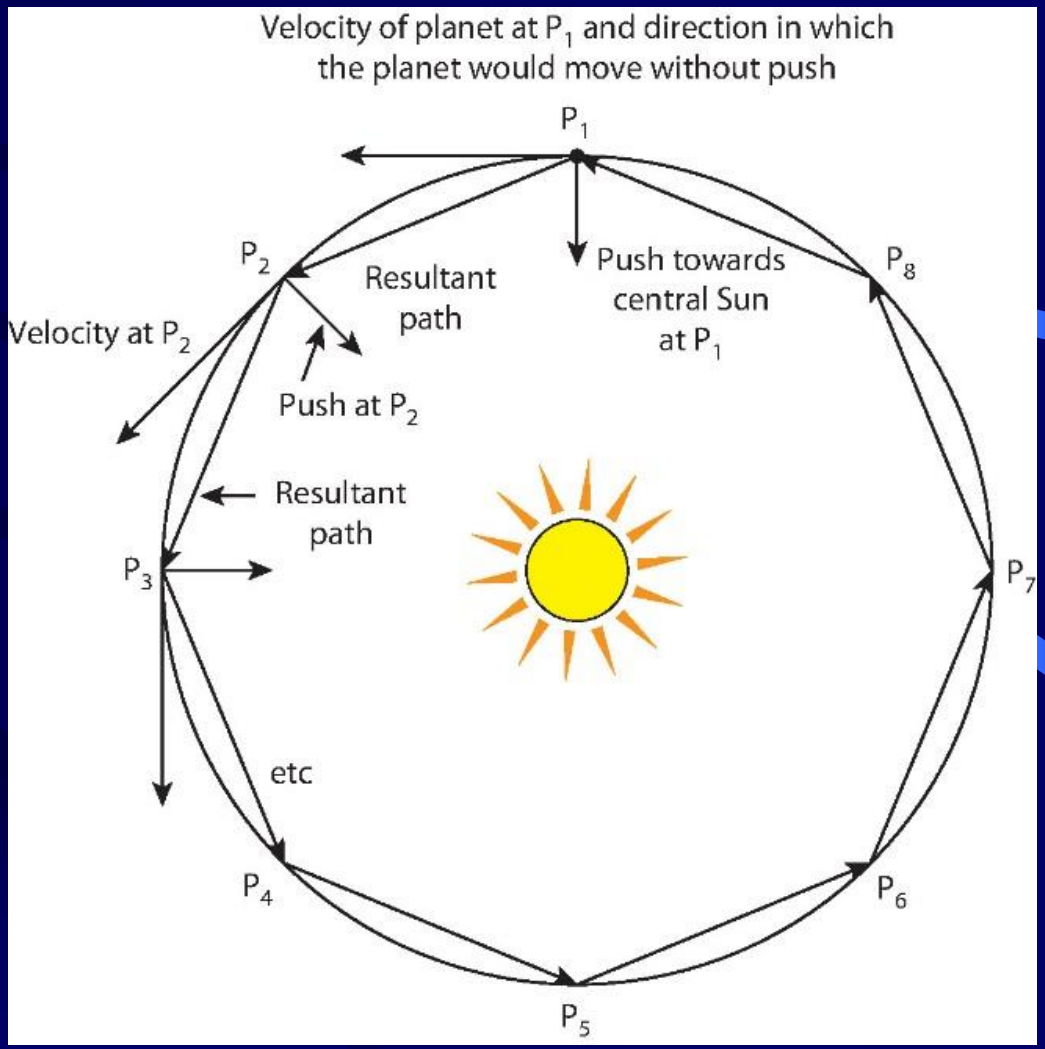
Sun's gravitational pull forces planet into orbit by changing direction of planets velocity

Planet wants to move in a straight line of constant velocity (Newton 1)

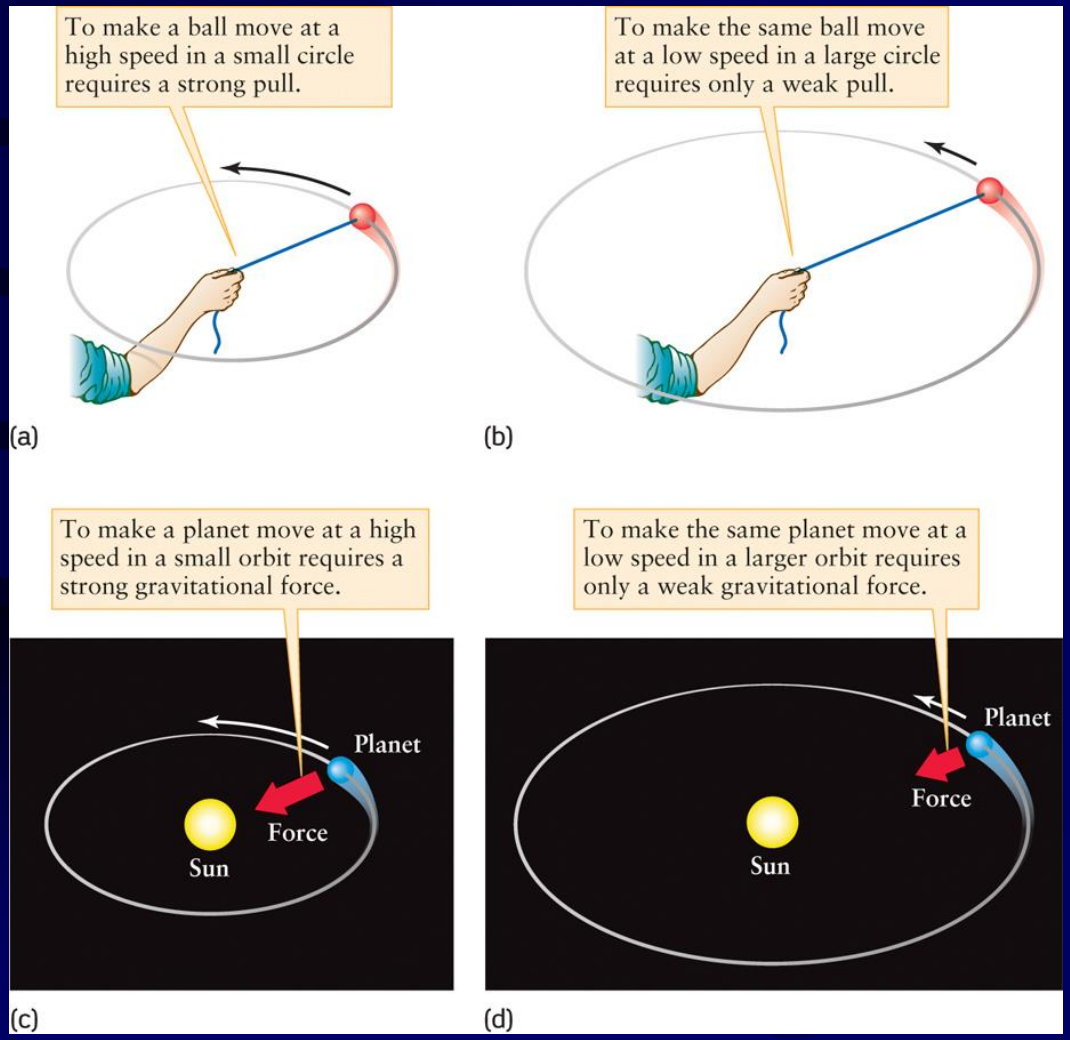
➔"Compromise": planet moves in curved orbit

Hooke's Polygon Model

- Alternative way of thinking about gravity's influence on the planets



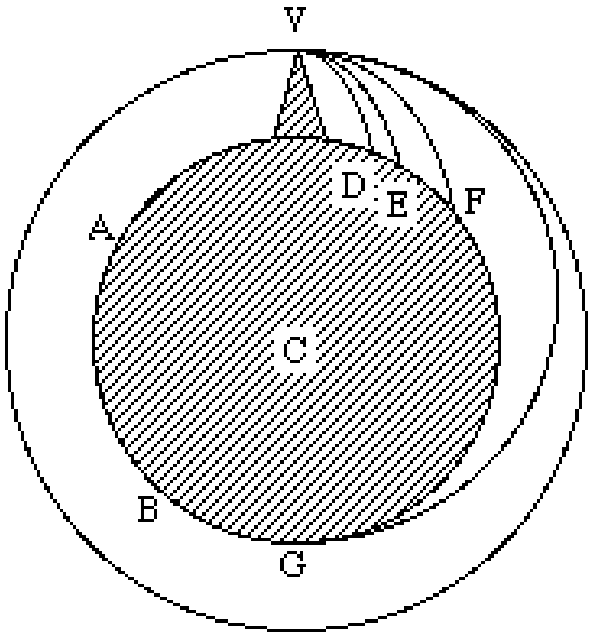
It takes a stronger force to make a high speed planet move in an orbit



Newton explains many, many patterns in nature; only one of them is planetary motion!

- Baseball, cannonball, water motion
- Tides
- Atoms (negative electrons, positive protons)
- Moon around earth, earth around sun, sun around galactic center, etc.
- Many more (see bulk of Principia)

Cannon "Thought Experiment"



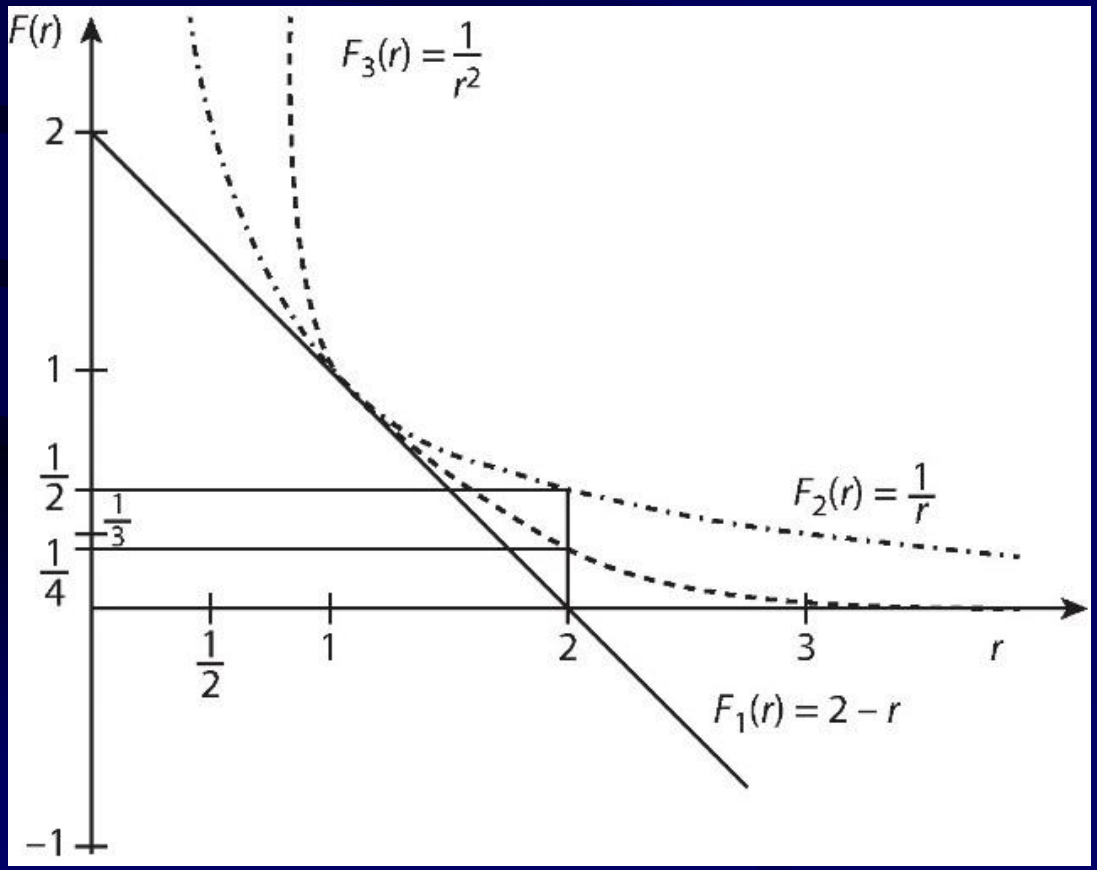
"The manner in which planets are held in fixed orbits by gravitational forces can be understood from the motions of projectiles. When a stone is thrown, its is deflected from a straight line by its own weight, and describing a curve in the air, if finally falls to earth. If it is projected with greater speed, it goes further. It is possible, by increasing the velocity, to cause it to describe an arc of one, two, five, ten, 100, 1000 miles, until finally, continuing beyond the ends of the Earth [the horizon], it would no longer fall to Earth.

"Let A-F-B designate the surface of the Earth; C its center; and VD, VE, and VF the the trajectories described by a projectile thrown horizontally, with successively increasing velocities, from the vertex, V on the peak of a very high mountain. To avoid taking into account air resistance, which hardly retards the motion of celestial bodies, let us ignore it, or assume that it offers no resistance [a reasonable assumption at altitudes over one or two hundred miles]. Then the same law that causes a body with low velocity to describe the smaller arc VD; and, with greater velocity, the greater arc VE; and, with still greater velocity causes it to reach f, and further to G; will cause a body, it the velocity continues to increase, to go beyond the entire circumference of the Earth and return to the top, whence it was projected.... Moreover, maintaining its velocity, it will continue by the same law to revolve over and over."

- http://physics.weber.edu/schroeder/software/NewtonsCannon.html

Different Declines with Distance

- Linear, inverse, inverse quadratic declines



Why inverse quadratic?

- Because the influence "thins out" as the area of the sphere as the distance from the source increases (scales like area)