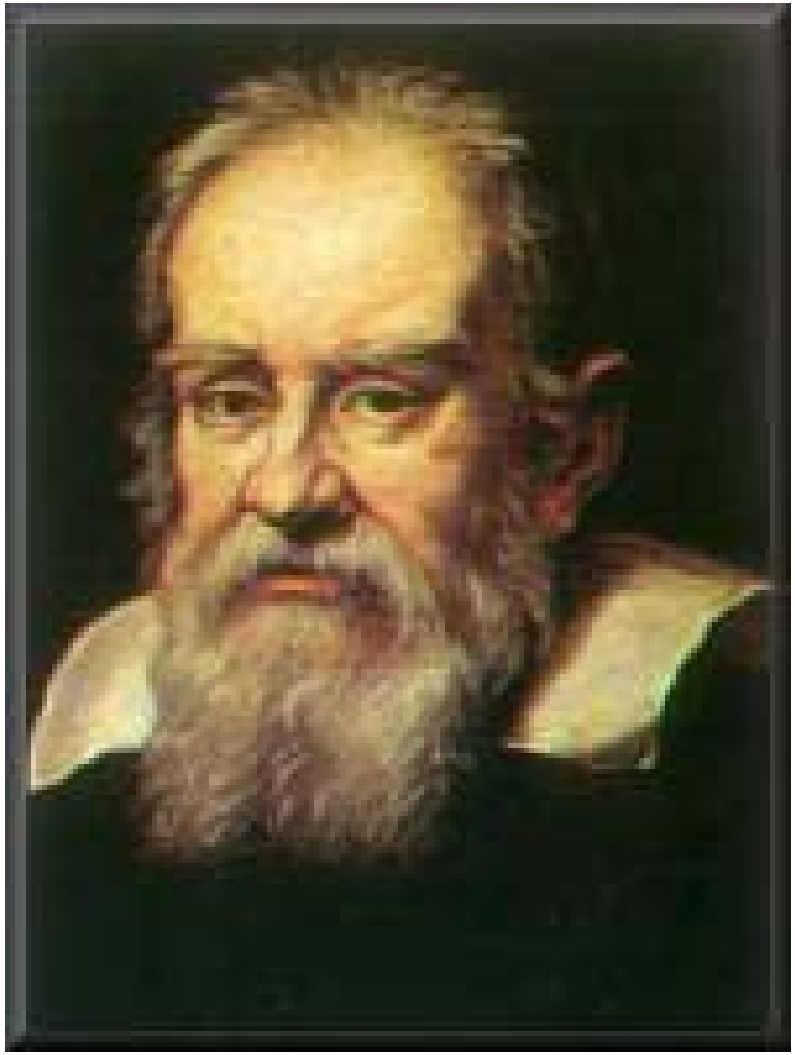
- Homework #1 was due at 11:50am! Now it's too late!
- Homework #2 is online and is due next Friday!
- New format for lectures– 4 sheets per page PDF.
- Planetarium shows are getting full.
- Solar Observing starts Monday!
- Nighttime observing starts in < 2 weeks.

Outline

- Galileo's Observations using the telescope.
- Explanation of speed, velocity, acceleration, and force.
- Newton's Laws of Motion
  - A body remains in motion unless acted upon by a force
  - The Acceleration of an object is equal to the Force applied, divided by its Mass
  - Every action has an equal and opposite reaction

Galileo Galilei (1564-1642)

- As we learned, he used the telescope to make ground breaking discoveries about the Solar System
- Worked on the concept of Velocity, Speed, Acceleration, and Gravity



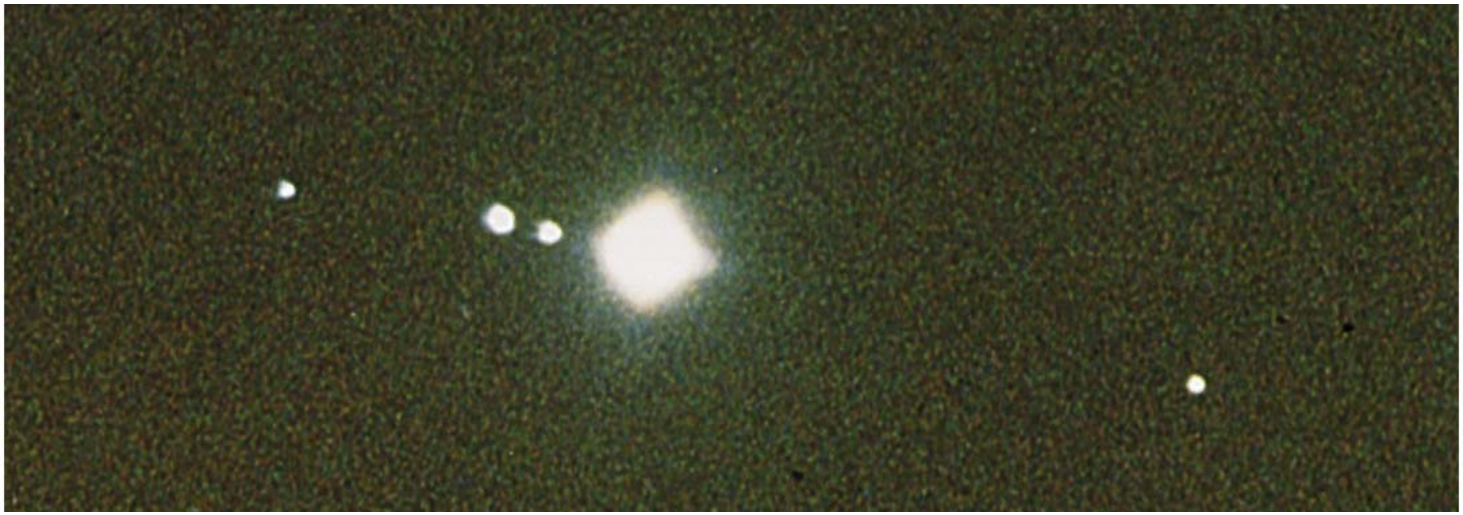
http://www.unet.univie.ac.at/~a9503672/astro/history/galilei.htm

Galileo (1610)

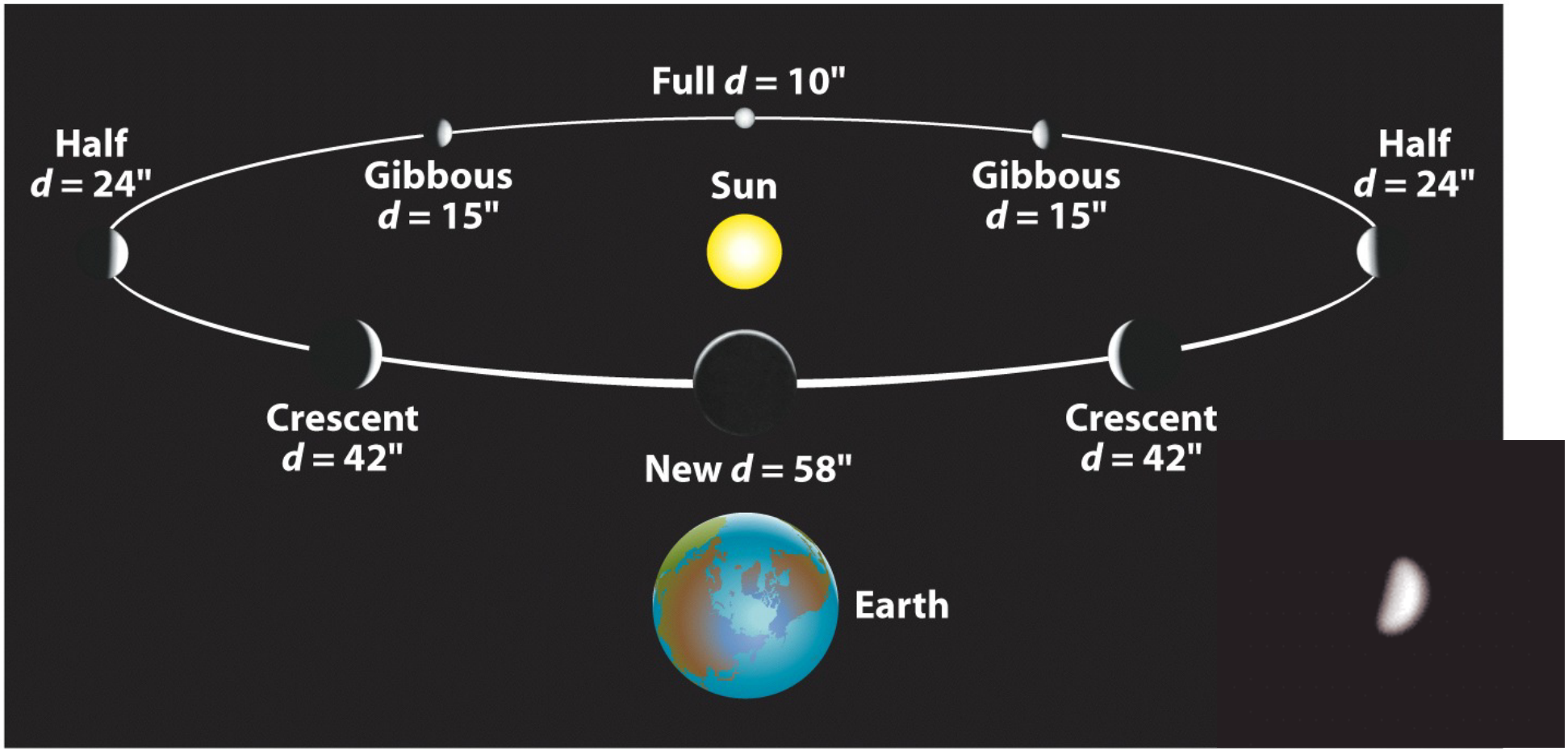
First to systematically use the telescope (but did not invent it).

- Moon has mountains and valleys
- Milky Way consists of faint stars
- Saturn is elongated
- Venus shows phases
- Jupiter has moons (now called Galilean moons)

Wow! Big stuff. The moons of Jupiter did not orbit the Earth!



The Phases of Venus



Could not be explained with the Geocentric model

http://www.calvin.edu/academic/phys/observatory/images/venus/venusb.html

Phases of Venus

Compare the Heliocentric to Geocentric models to explain the phases of Venus.

http://www.astro.ubc.ca/~scharein/a310/SolSysEx/phases/Phases.html

Galileo (1610)

- Disproved Ptolemaic system
- Rome bullied him into recanting (cleared in 1992)
- Now we understand the motions and the fact that the solar system MUST be Heliocentric?

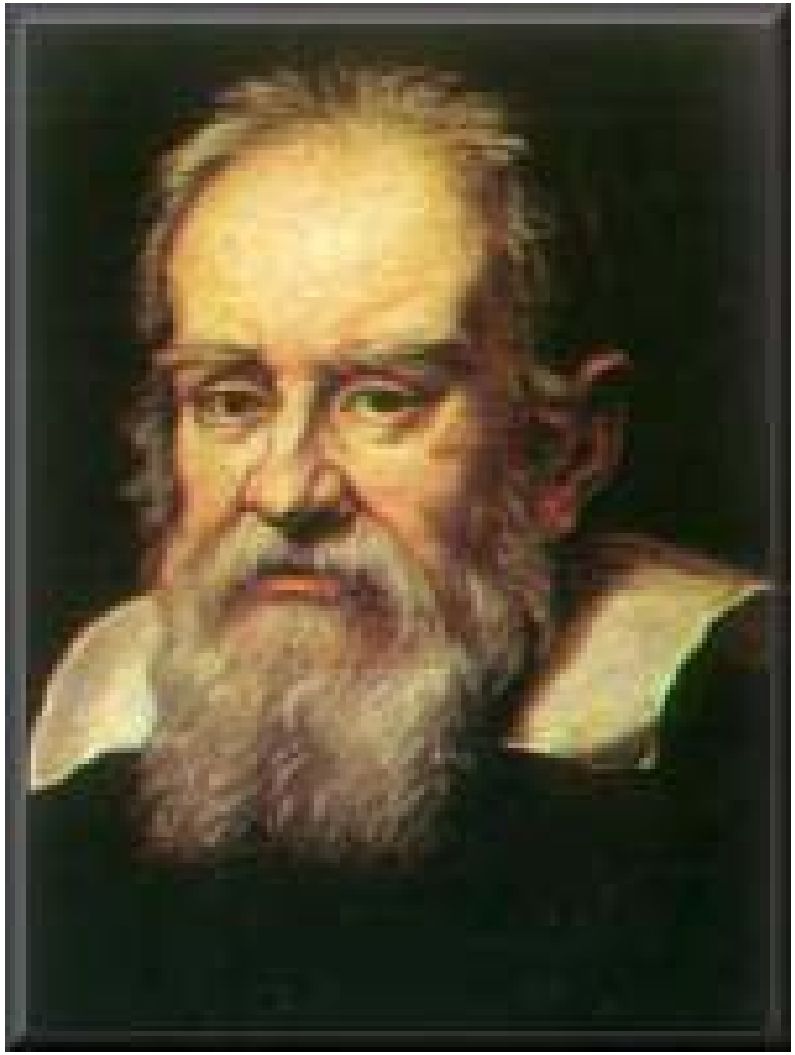
Kepler's Laws

Kepler discovered these patterns in nature by using the data that Tycho collected, BUT the world had to wait until someone could understand the Natural Law that predicts Kepler's Laws.

The real problem: On Earth we're use to things that move but always come quickly to a rest. Why didn't the planets stop?

Galileo Galilei

- For Aristotle, the distance of an object was a fundamental attribute.
- Galileo broke with the traditional concept and realized that time was important– distance and time being the key.



http://www.unet.univie.ac.at/~a9503672/astro/history/galilei.htm

Speed or Velocity

What's the difference between speed and velocity?

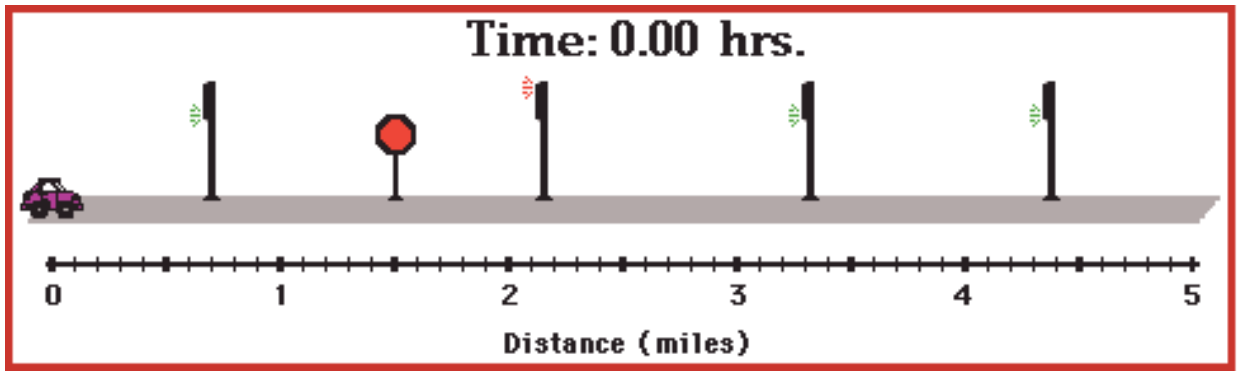
$$speed = \frac{distance}{time}$$

Measured in km/h, miles/hr, cm/s, AU/century, etc…

http://www.physicslessons.com/speed.jpg

Average Speed

You notice when you drive you can never keep a constant speed due to stop signs, traffic, whatever… Your instanteous speed is what your speedometer reads.



$$\text{Ave. Speed} = \frac{5 \text{ miles}}{0.2 \text{ hours}} = 25 \text{ miles/hour}$$

http://www.physicsclassroom.com/mmedia/kinema/trip.html

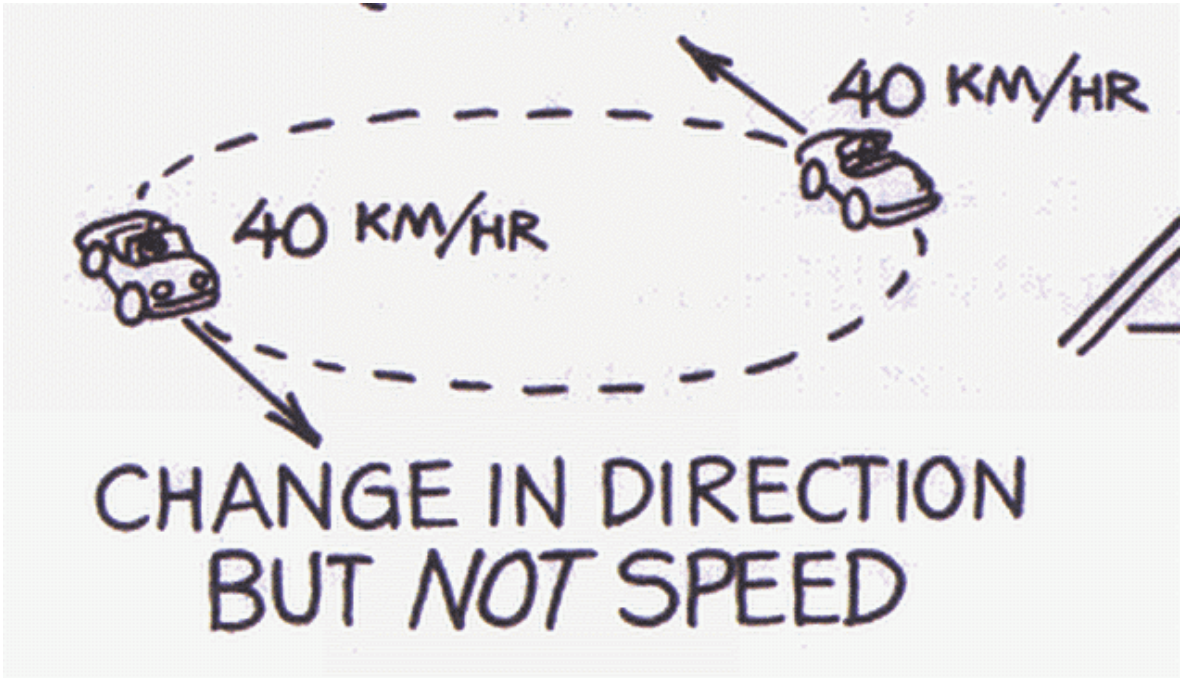
Speed or Velocity

We use the terms loosely today, but there is a distinction.

Velocity is a speed AND direction. See the arrow?

Speed and Velocity

Take as an example, a car driving in a circle. The car is always going the same speed, but it's direction, or velocity, is constantly changing.

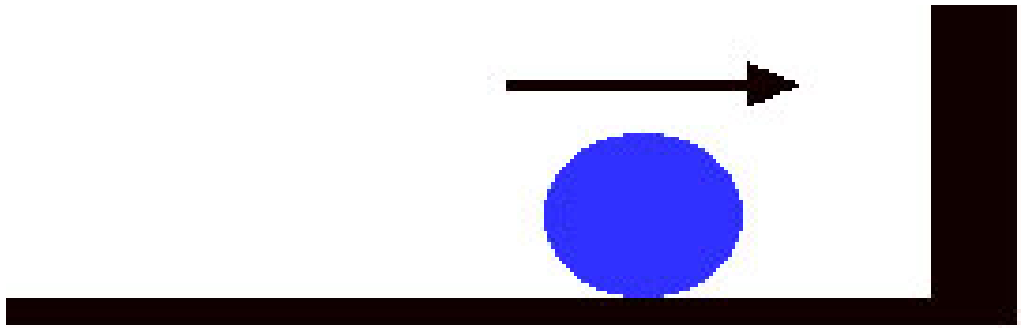


From *Conceptual Physics*

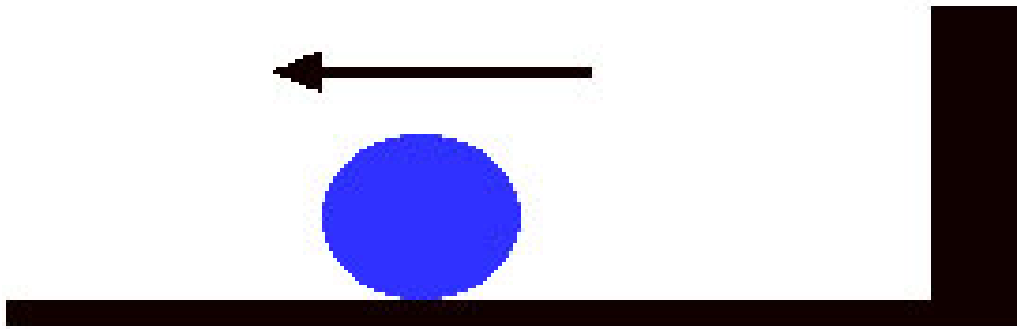
Acceleration

Acceleration is a change to velocity, either in the speed of the object or in the direction

Velocity is to the right.



Velocity is to the left.



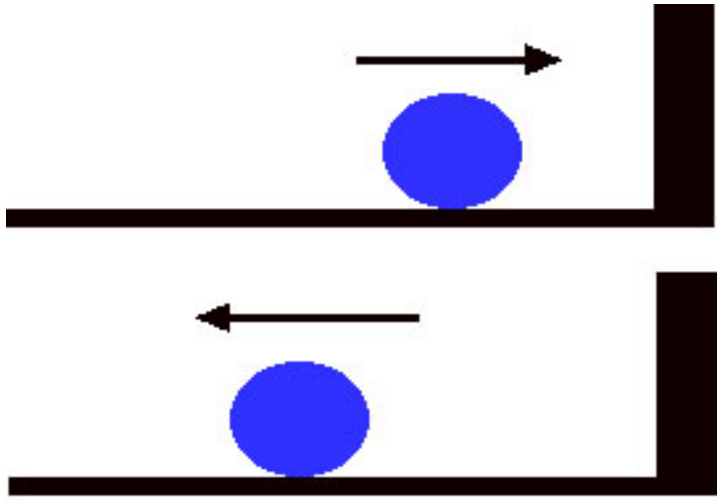
http://www.physics.montana.edu/physed/misconceptions/acceleration/zerovzeroa/discover.html

Acceleration

As velocity is the change of distance with time, acceleration is the change of velocity with time. The units for acceleration are meters per second per second (or m/s^2), $miles/hr^2$, etc.

Velocity is to the right.

Velocity is to the left.



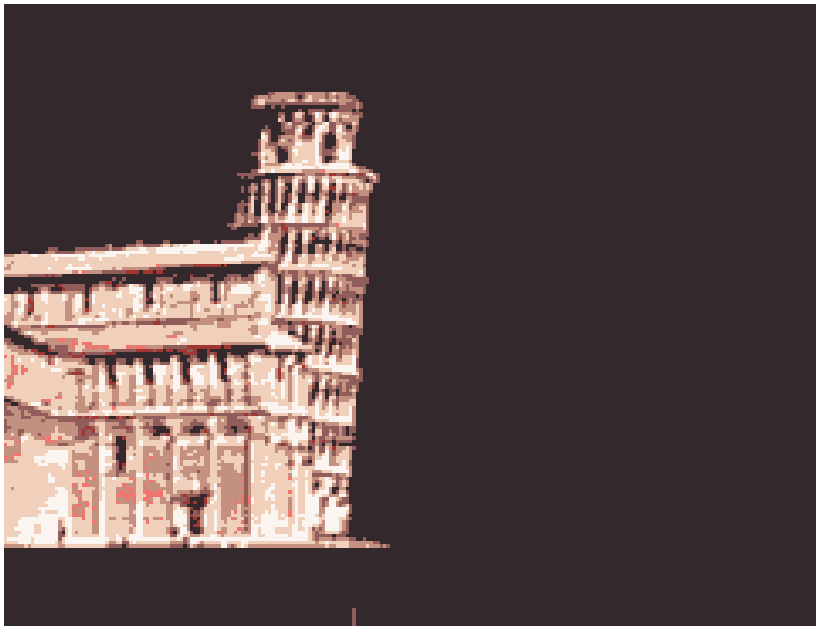
http://www.physics.montana.edu/physed/misconceptions/acceleration/zerovzeroa/discover.html

A Feather and a Hammer

http://www.solarviews.com/cap/apo/apo15g.htm

Nature of Gravity

- Gravity is a force, producing acceleration
- On the surface of the Earth, the acceleration due to gravity is 9.8 meters per second per second
- Drop a ball off the leaning tower of Pisa:



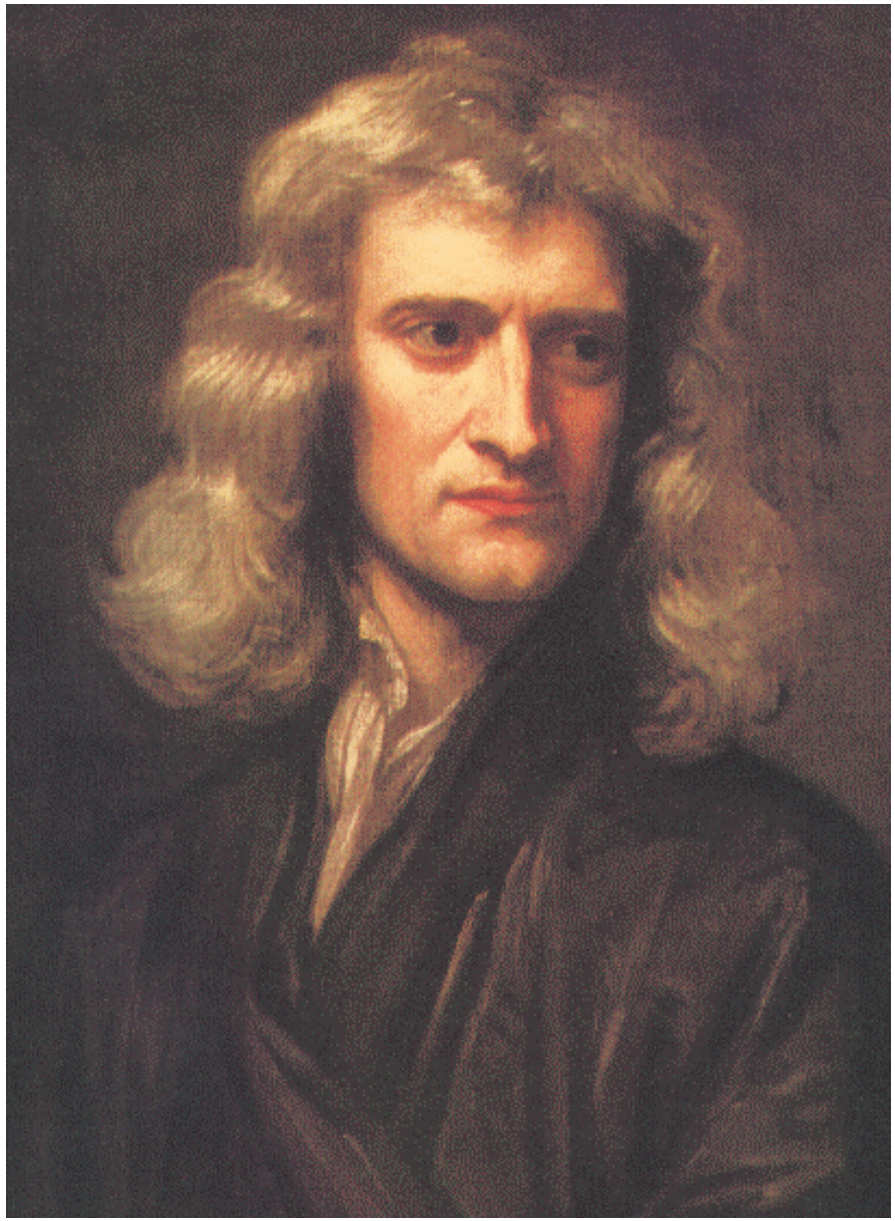
Time (seconds)	Velocity (m/s)	Accel. (m/s^2)
0	0	9.8
1	9.8	9.8
2	19.6	9.8
3	29.4	9.8

Isaac Newton (1642-1727)

- Arguably the most famous scientist of all time
- Born in England in 1642 (the year of Galileo's death)
- Studied at Cambridge where he also became a professor of mathematics in 1669

Isaac Newton

- At Cambridge he studied physics, optics, astronomy, thermodynamics, +
- His greatest work described how things moved (Laws of Motion) and presented a law of gravity
- To do this, he developed calculus (with Leibniz)



http://www.hao.ucar.edu/public/education/sp/images/newton.html

Isaac Newton

- Gave us a reason why– GRAVITY and its description mathematically
- Kepler's 3rd law now became a way to probe the structure of the Universe!

http://www.windows.ucar.edu/tour/link=/people/enlightenment/newton.html

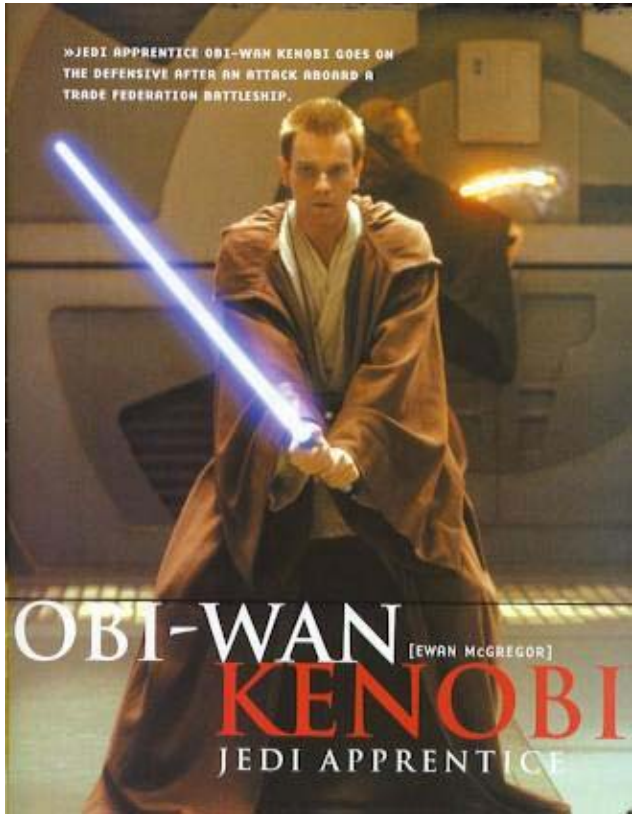
Newton's 1st Law of Motion

An object in motion will stay in motion and an object at rest will stay at rest unless acted on by a net outside force

- Objects keep on doing what they're doing (e.g. kids and TV and the force is mom or dad)
- Similar to what Galileo said– also called inertia

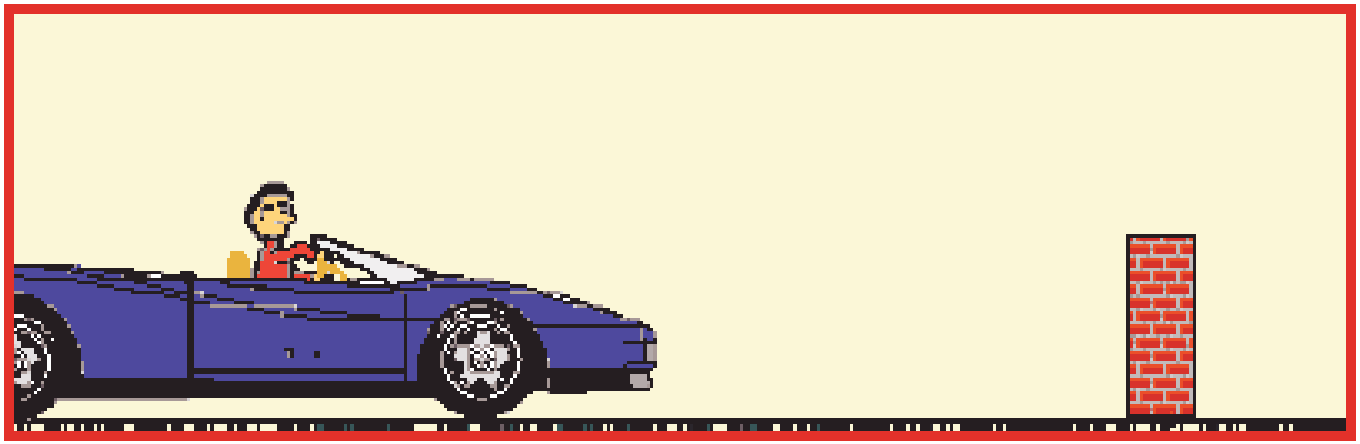
What is a Force?

- NO not THE Force
- Force in the simplest sense is a push or pull. It may be from gravity, electrical, magnetic, or muscle efforts.
- In metric units, Force is measured in Newtons (N)



http://members.aol.com/PrinceG0R0/jedi.html

Newton's 1st Law of Motion



The brick wall acts (applies force) against the car. Since the driver did not wear a seatbelt, he had no other force acting on him, and he kept going.

http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/newtlaws/cci.html

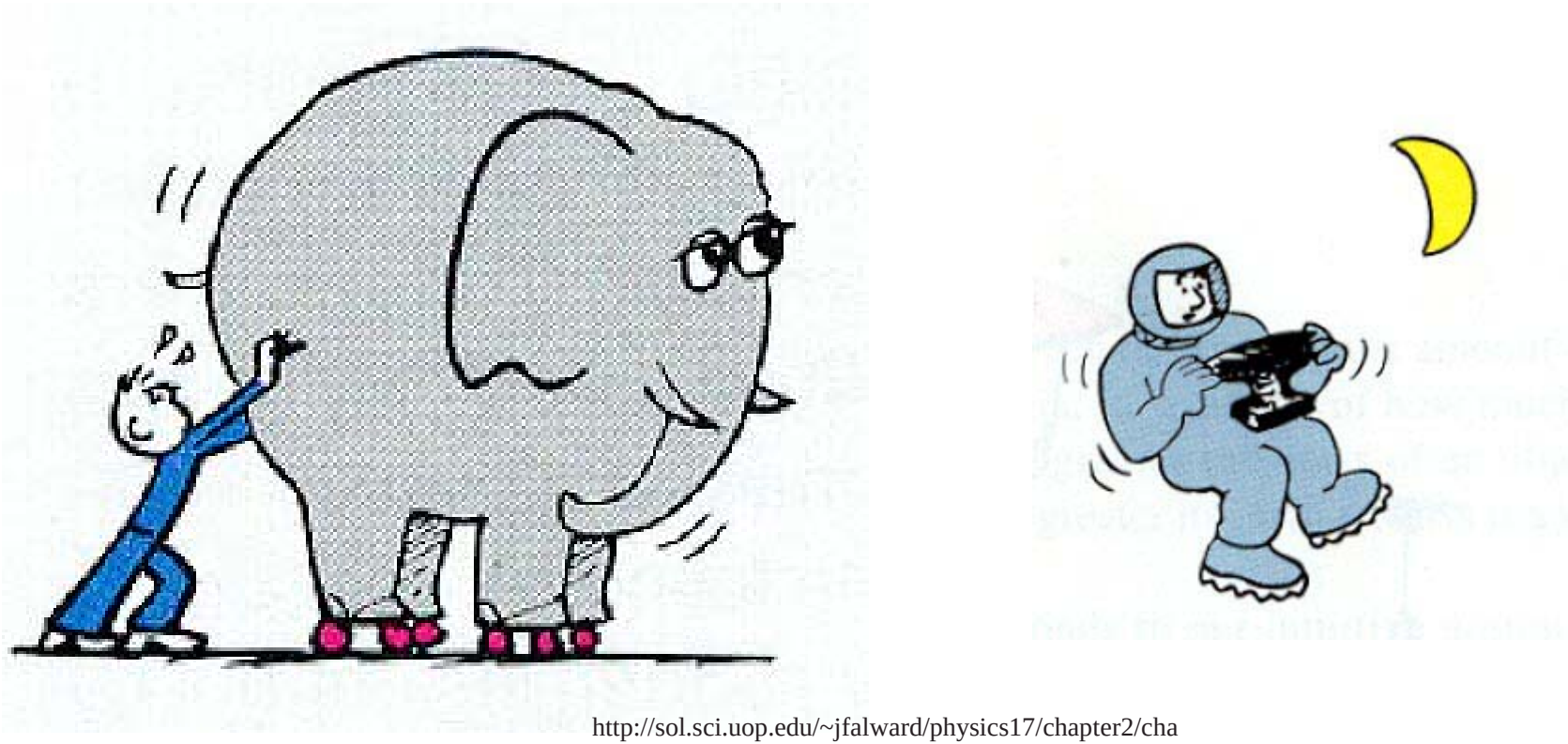
Newton's 1st Law of Motion

The small car acts (applies force) against the truck. Since the ladder was not latched, it had no other force acting on it, and it kept going

http://www.geocities.com/Athens/Academy/9208/il.html

Elephant at rest

Takes a big force, or the Elephant stays at rest. Or an anvil in space– weightless.



http://sol.sci.uop.edu/~jfalward/physics17/chapter2/chapter2.html

Why was it so hard to see this?

Usually we have Friction! Friction is a possible net outside force that Newton was talking about. Remember the feather/hammer experiment? Air Friction dominates the feather causing this to fail in the classroom.

http://www.abc.net.au/juniors/pages/2000/transport/land/img/friction.jpg

http://www.vimff.org/images02/films/Desert%20Friction%20-%20image%202.jpg

Effects of Friction

http://library.thinkquest.org/CR0215468/friction.htm

What is Mass?

- The total amount of material in an object.

- Measured in kg for example
  - Mass of Sun is 2×10^{30} kg
  - Mass of Hydrogen atom is 1.7×10^{-27} kg
  - Mass of me is 90 kg

- Do not confuse mass with weight. Weight will actually depend on where you are on the Earth's surface.

What is Weight?

- Your weight is the Force you feel from your mass in the presence of the Earth's Gravity.
- I would weigh nothing in the space shuttle, but my mass would still be 90 kg. It's the force with which the Earth pulls on me.
- If I was in a fighter jet, pulling some g's, my weight would be heavier, but I would still have the same mass.

http://www.incredible-adventures.com/capetown.html

Newton's 2nd Law of Motion

The Acceleration of an object is equal to the Force applied, divided by its Mass

$a = F / m$ or $F = m \times a$

- Acceleration is a change in velocity (speed and/or direction, think of the 1st law) in meters per second per second
- To Accelerate something you have to apply a Force
- Mass is a fundamental property of any object, measured in grams or kilograms. Your weight is the Force.

Newton's 2nd Law of Motion

$$a = F / m \quad \text{or} \quad F = m \times a$$

- It accelerates in the direction you push it.
- If you push twice as hard, it will accelerate twice as much.
- If it has twice the mass, it will accelerate only half as much.

Simple Proof

http://library.thinkquest.org/CR0215468/newtons_second_law.htm

Newton's 3rd Law

Every action has an equal and opposite reaction– action-reaction.

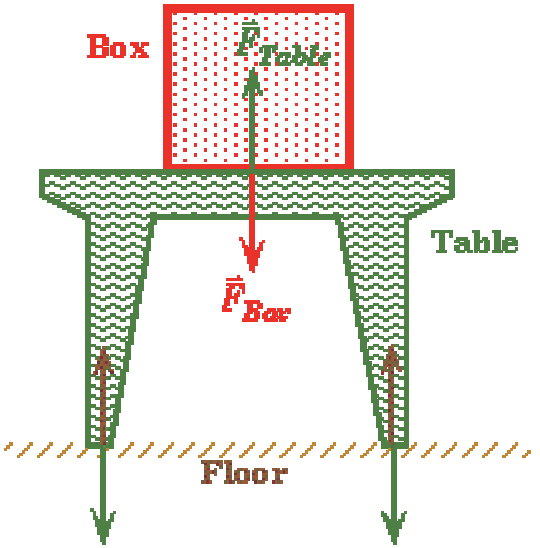
That's how rockets or guns work. As the black powder expands, the gun pushes the bullet and the bullet pushes the gun. Which has the higher acceleration?

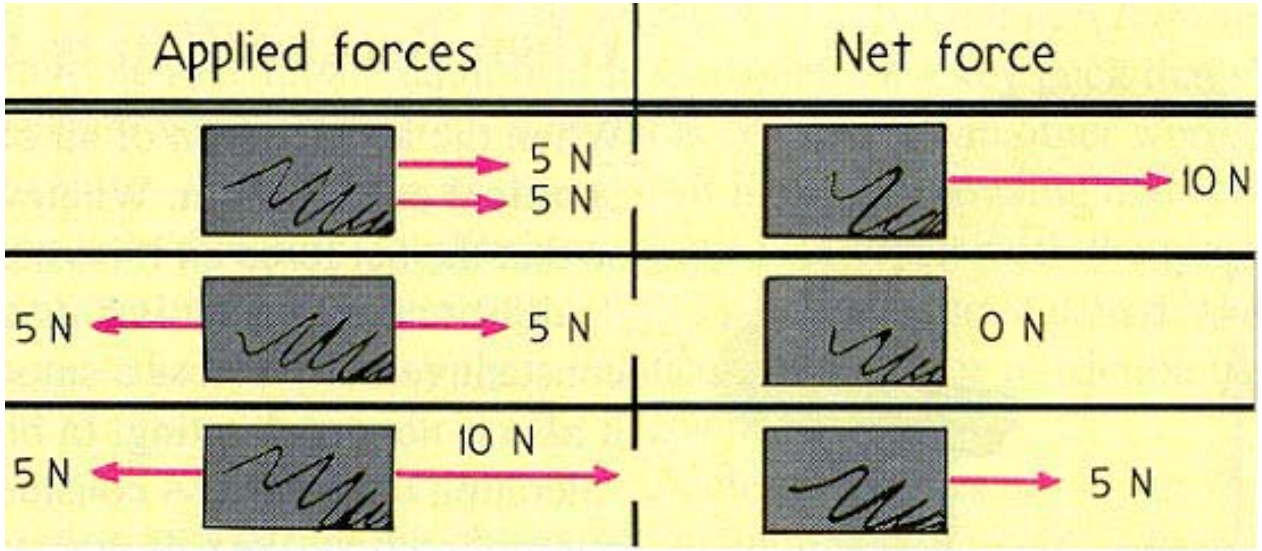
http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l4a.html

Newton's 3rd Law

http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l4a.html

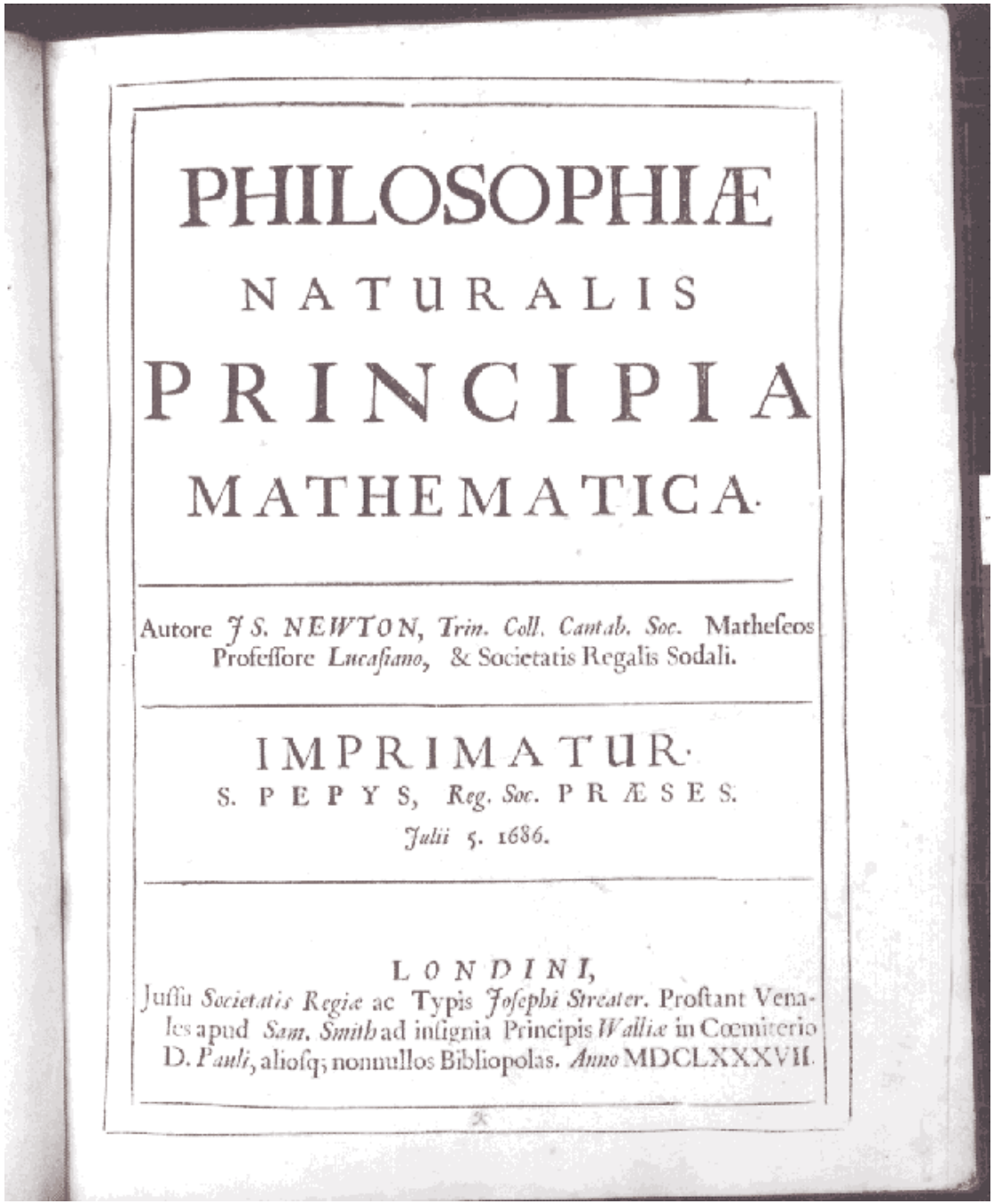
Equal Forces– and no acceleration





http://sol.sci.uop.edu/~jfalward/physics17/chapter2/chapter2.html

http://www.ac.wwu.edu/~vawter/PhysicsNet/Topics/Dynamics/ThirdLaw.html



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore *J S. NEWTON, Trin. Coll. Cantab. Soc.* Matheſeos Profeſſore *Lucaſiano,* & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

LONDINI,
Juſſu *Societatis Regiæ* ac Typis *Joſephi Streater.* Proſtant Venales apud *Sam. Smith* ad inſignia Principis *Walliæ* in Cœmiterio D. *Pauli,* alioſq; nonnullos Bibliopolas. *Anno* MDCLXXXVII.

http://www.lib.udel.edu/ud/spec/exhibits/treasures/science/newton.html

Newton

Principia is one of great science works. By demonstrating that the motion of all bodies was controlled by the same universal laws, Isaac Newton brought to the scientific community a vision of an orderly, harmonious universe.