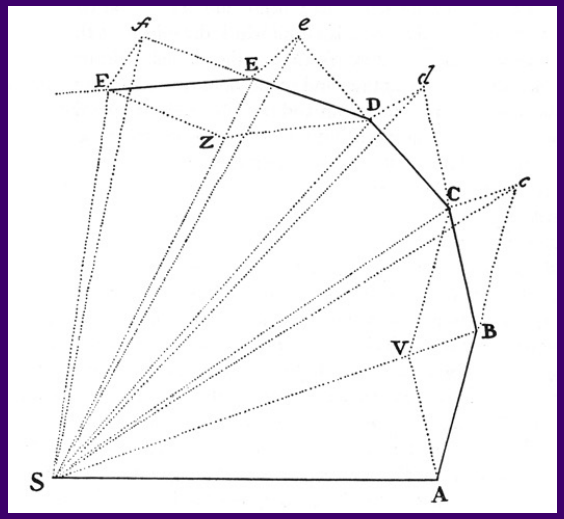
Copernicanism may be fine for astronomy, but . . .

- If the earth is moving, why don't we feel the motion?
- Why aren't we thrown off a spinning, orbiting earth?
- What possible mechanism could cause planets to move in elliptical orbits?
- If gravity isn't a tendency of stuff to fall toward the center of the universe, then what is it?



Newtonian Mechanics

Today:

- The law of inertia
- How the motion of an object changes due to interactions with nearby objects

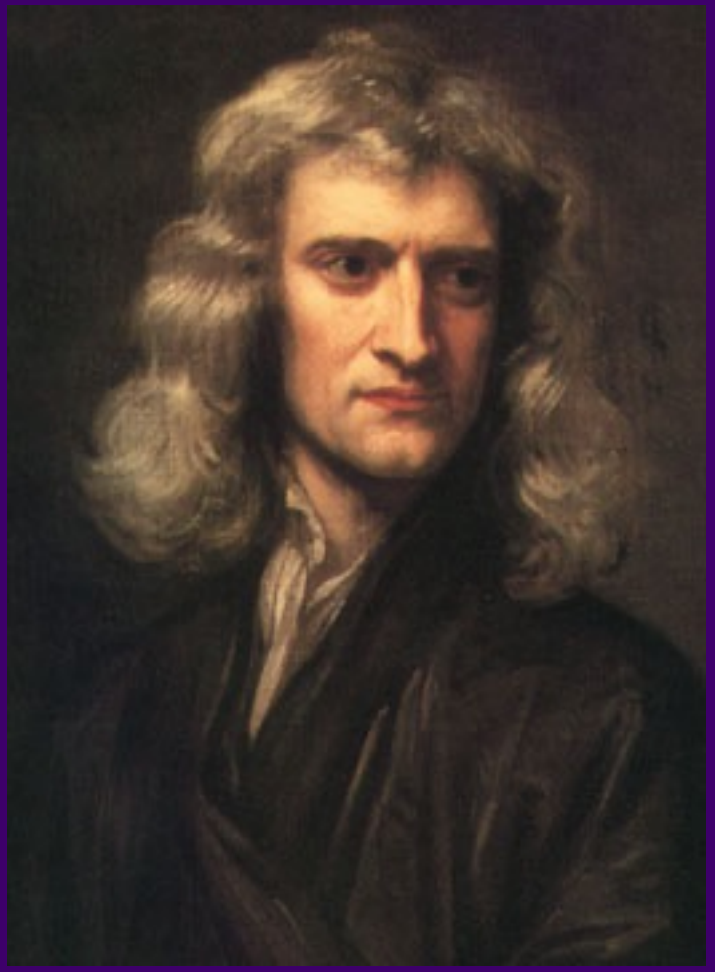
Universal Laws of Motion

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

Sir Isaac Newton (1642 – 1727)
Physicist

Isaac Newton

English scientist and mathematician, 1642 - 1727



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.* Proſtat apud plures Bibliopolas. *Anno* MDCLXXXVII.

Why do things move?

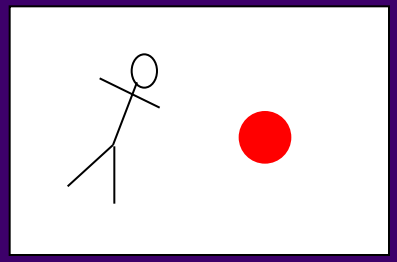
Aristotle: To seek their natural place in the universe.

Newton: No reason. Motion just happens.

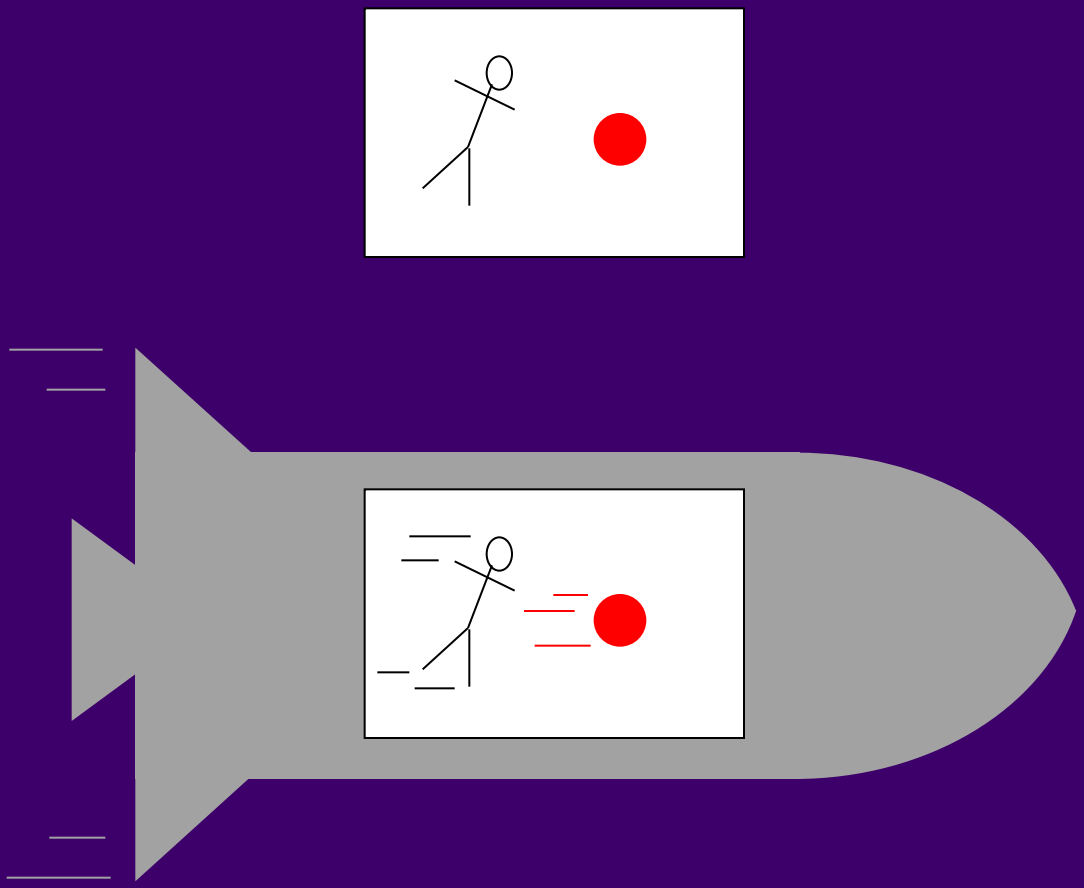
More precisely: Isolated objects will coast along in a straight line, at constant speed, forever. (Speed = zero is just one example.)

"Law of Inertia" or "Newton's First Law"

Consequence: Motion is relative.



Consequence: Motion is relative.

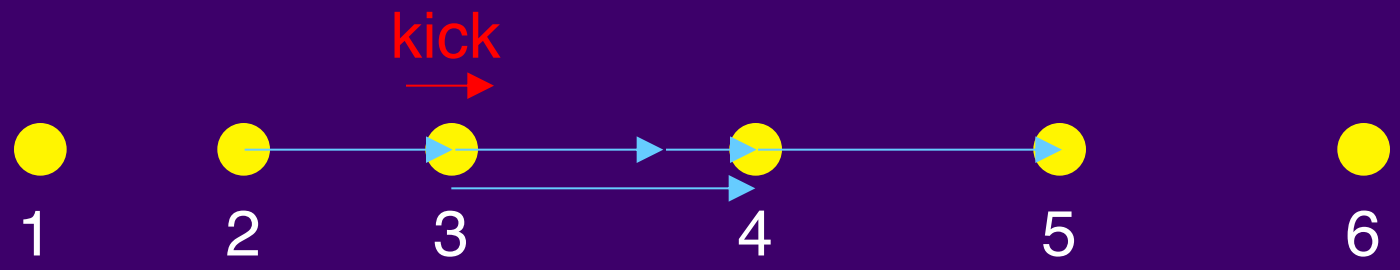


There’s no way to tell who’s *really* moving!

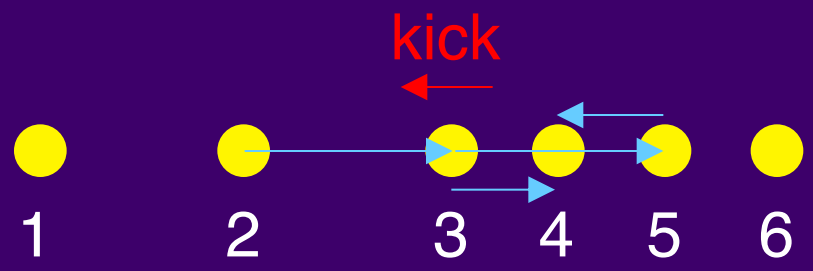
Strobe Diagrams

- Isolated object, moving to the right:

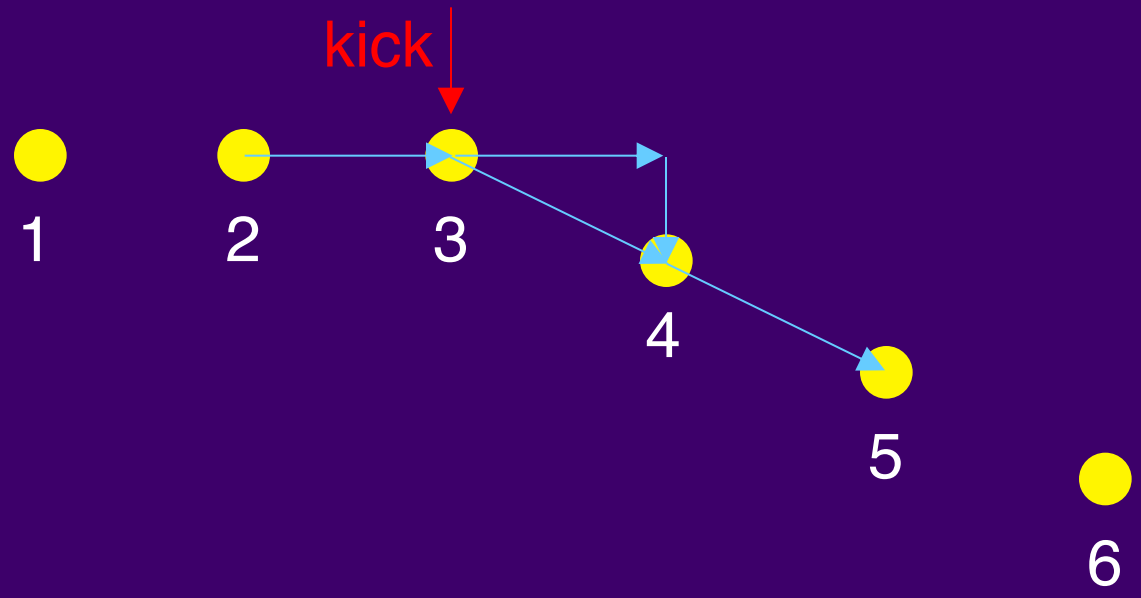
- Kick from the left at point 3:



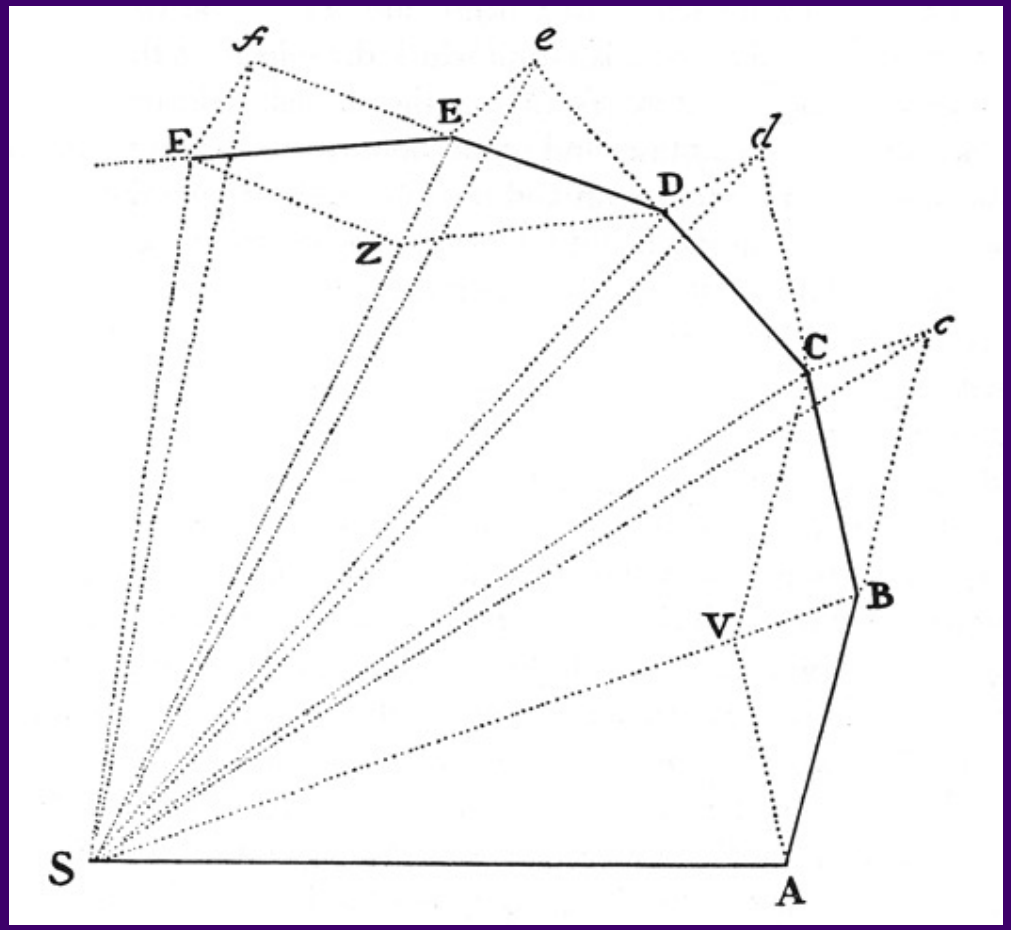
- Kick from the right at point 3:



- Kick from above at point 3:



Continual kicks toward a fixed point



(*Principia*, page 40)

Newton's Second Law

$$\textit{Change}\text{ in motion} = \frac{\text{Force applied}}{\text{Mass of object}}$$

So the same force applied to a ping-pong ball produces a *bigger* change in motion than when applied to a bowling ball.

AXIOMS, OR LAWS OF MOTION[1]

LAW I

Every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it.

PROJECTILES continue in their motions, so far as they are not retarded by the resistance of the air, or impelled downwards by the force of gravity. A top, whose parts by their cohesion are continually drawn aside from rectilinear motions, does not cease its rotation, otherwise than as it is retarded by the air. The greater bodies of the planets and comets, meeting with less resistance in freer spaces, preserve their motions both progressive and circular for a much longer time.

LAW II[2]

The change of motion is proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.

If any force generates a motion, a double force will generate double the motion, a triple force triple the motion, whether that force be impressed altogether and at once, or gradually and successively. And this motion (being always directed the same way with the generating force), if the body moved before, is added to or subtracted from the former motion, according as they directly conspire with or are directly contrary to each other; or obliquely joined, when they are oblique, so as to produce a new motion compounded from the determination of both.

LAW III

To every action there is always opposed an equal reaction: or, the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

Whatever draws or presses another is as much drawn or pressed by that other. If you press a stone with your finger, the finger is also pressed by the

[1 Appendix, Note 14.] [2 Appendix, Note 15.]

Forces

- Forces change the motion of objects.
- As long as the object's mass does not change, the force causes a change in velocity, or an…

acceleration

Newton's Laws of Motion

#1 A body at rest or in motion at a constant speed along a straight line remains in that state of rest or motion unless acted upon by an outside force.

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.

$$F \propto a$$

The proportionality constant is mass:

$$F = m\,a$$

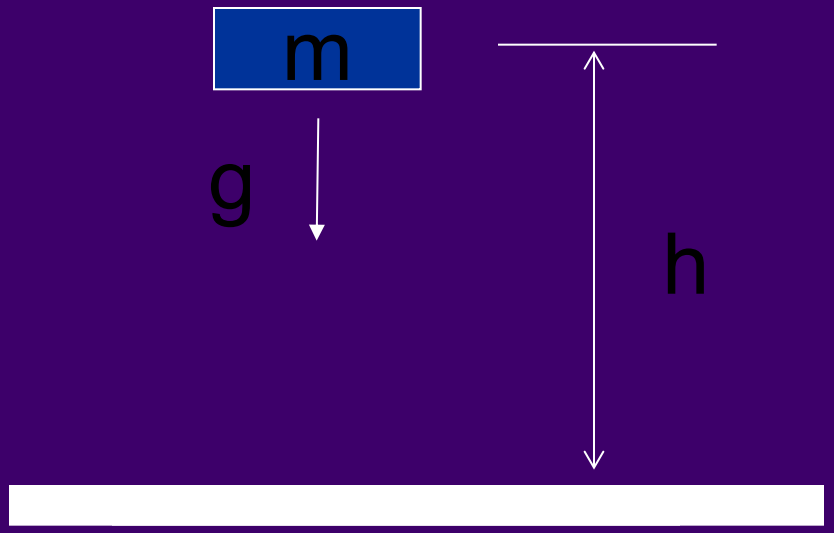
Gravity:

$$F = mg$$

g is the gravitational acceleration (9.8 m/s^2)

Gravitational Potential Energy

$E = F \bullet h = mg \bullet h$



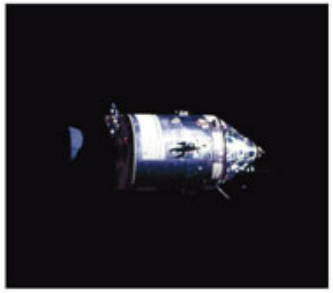
Newton's Laws of Motion

3

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

Newton's Laws of Motion

A spaceship needs no fuel to keep moving in space.



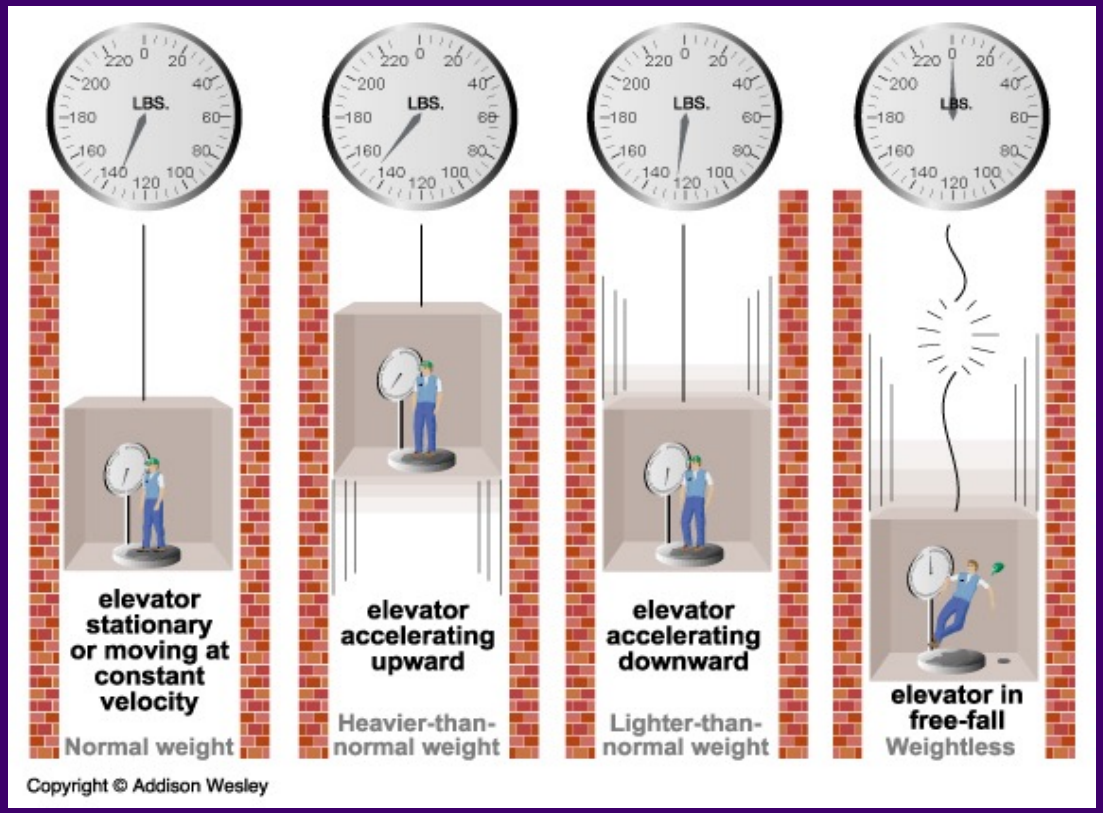
A baseball accelerates as the pitcher applies a force by moving his arm. (Once released, this force and acceleration cease, so the ball's path changes only due to gravity and effects of air resistance.)

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

Is Mass the Same Thing as Weight?

- **mass** – the amount of matter in an object
- **weight** – a measurement of the *force* which acts upon an object

When in "free-fall," you are weightless!!



Forces

- Forces change the motion of objects – cause accelleration.
- **momentum** – the (mass x velocity) of an object

$$p = mv \qquad [\text{kg m/s}]$$

- **force** – anything that can cause a change in an object's momentum

$$F = \Delta(mv) = m\Delta v = ma \quad [\text{kg m/s}^2 = \text{N}]$$

Escape velocity !

- Can an object escape the gravitational attraction of the Earth?
- Does it have enough kinetic energy to overcome the gravitational potential energy of the Earth?

$$mgh \quad \rightleftarrows \quad \tfrac{1}{2}\, mv^2 \quad ????$$