Lecture 33
Newton on Space, Time, and Motion

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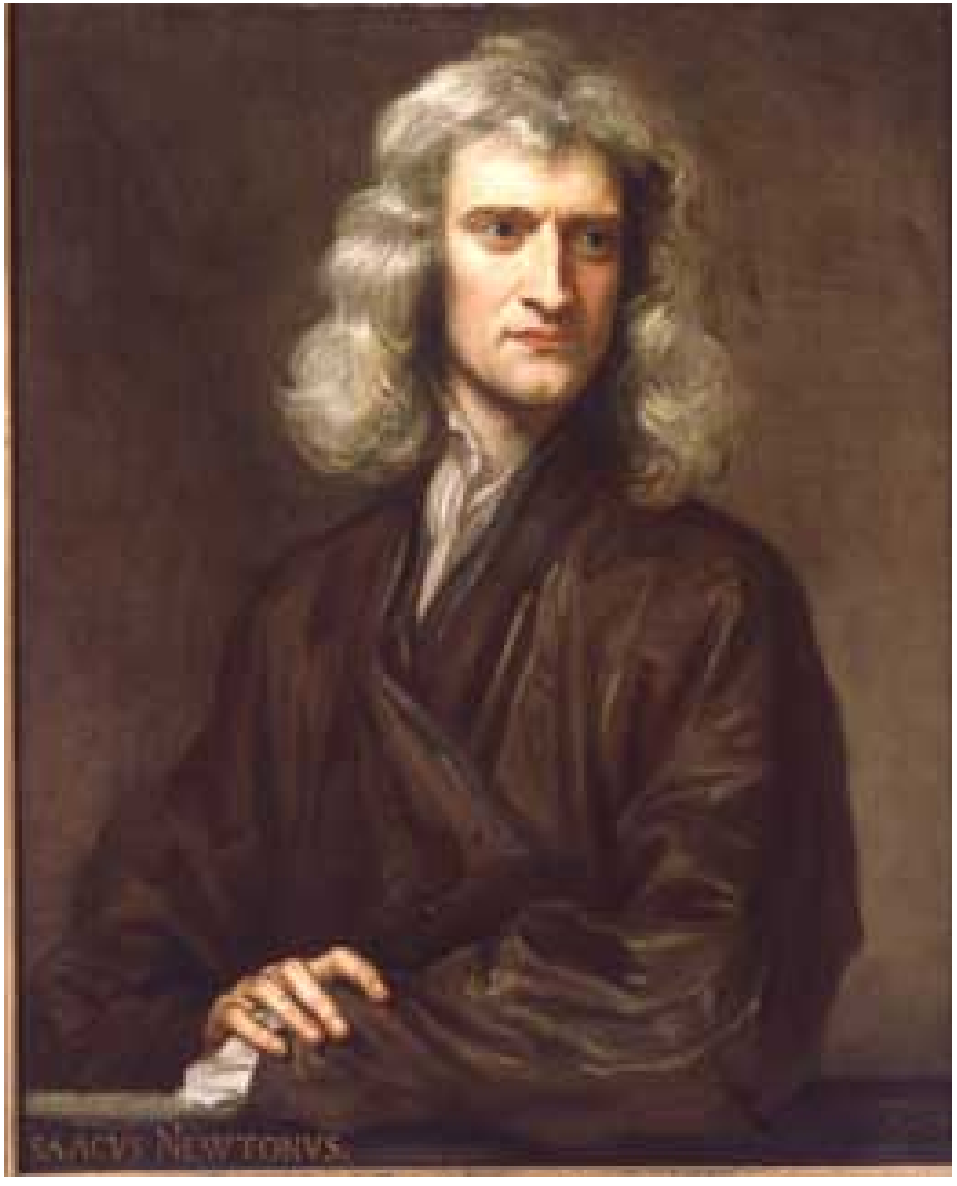
Scientific Thought I
Fall 2009

Isaac Newton



1642: Born in a rural area 100 miles north of London, England.

1669: Professor of mathematics at Cambridge University.

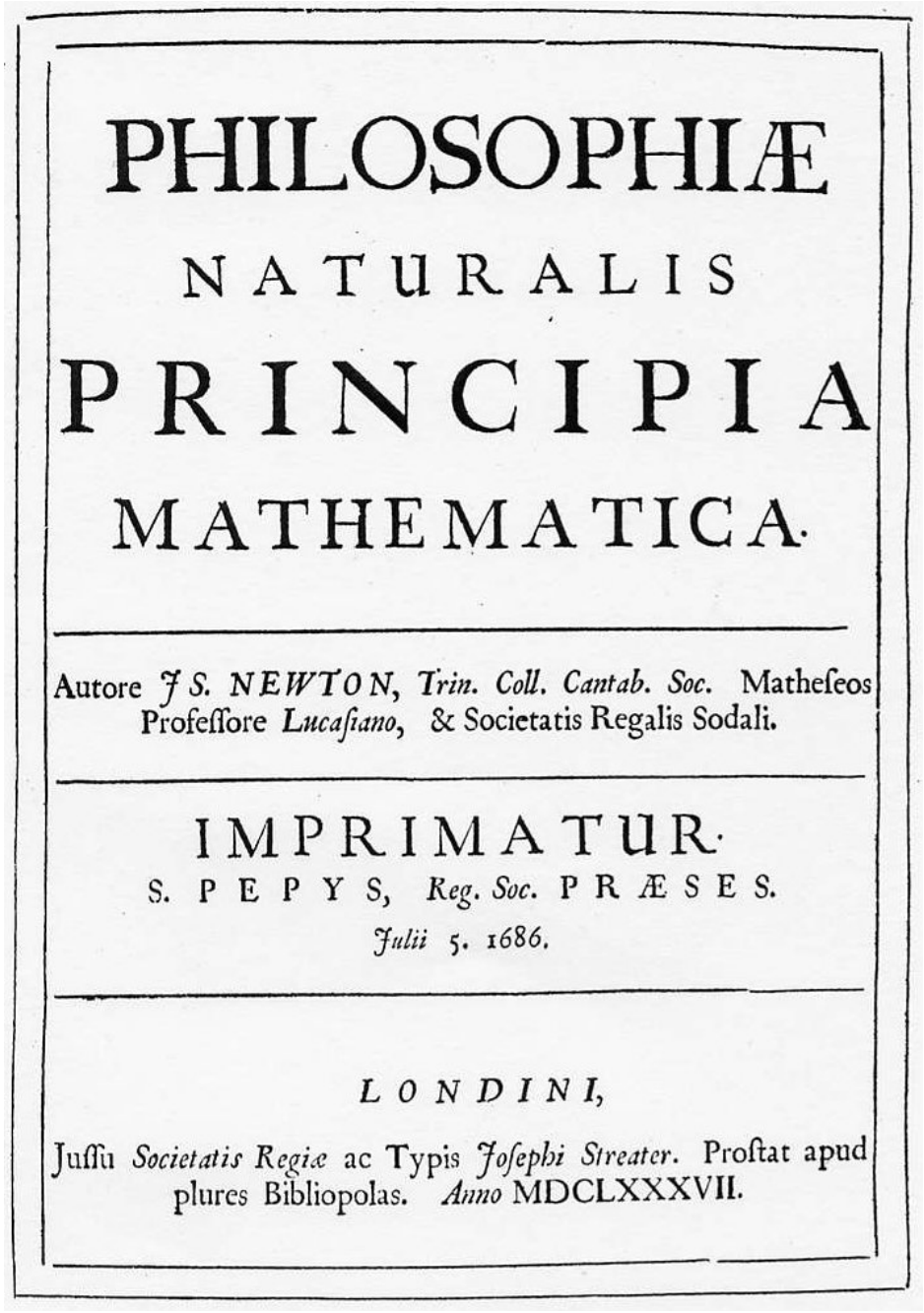
1687: *Principia* published.

1689: This portrait painted.

1704: *Opticks* published.

1727: Died in London.

Principia



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.

Here Newton stated the laws of mechanics and gravitation still taught in beginning physics courses.

The book is set out in the manner of Euclid.

Definitions

Definition 1 (403)

Quantity of matter is a measure of matter that arises from its density and volume jointly.

Quantity of matter = density $\times$ volume = mass.

Definition 2 (404)

Quantity of motion is a measure of motion that arises from the velocity and the quantity of matter jointly.

Quantity of motion = mv = momentum.

Scholium

Although time, space, place, and motion are very familiar to everyone, it must be noted that these quantities are popularly conceived solely with reference to the objects of sense perception. And this is the source of certain preconceptions; to eliminate them it is useful to distinguish these quantities into absolute and relative, true and apparent, mathematical and common. (408)

Time

- Relative time is time measured relative to some perceptible motion. E.g., we measure time by clocks or by motions of heavenly bodies (sun, stars).
- Measures of relative time may not be accurate. A clock can run fast or slow. The heavenly bodies don't move with exactly constant speeds.
- What we are trying to measure by these means is absolute time. It "flows uniformly." But we can't perceive absolute time directly, which is why we use relative time.

Space

- Relative space is space measured relative to perceptible bodies. E.g., we may talk about the space in this room, defined by its walls.
- The bodies with respect to which we measure space may be moving. E.g., if the earth is moving, then this room is moving. So relative space can move.
- Absolute space is immovable.

Motion

- Relative motion is motion with respect to relative space.
- Absolute motion is motion with respect to absolute space.
- Example where they differ: When sitting in class, you have no motion relative to the room but if the earth is moving you have absolute motion.

Laws of motion

Law 1 (416)

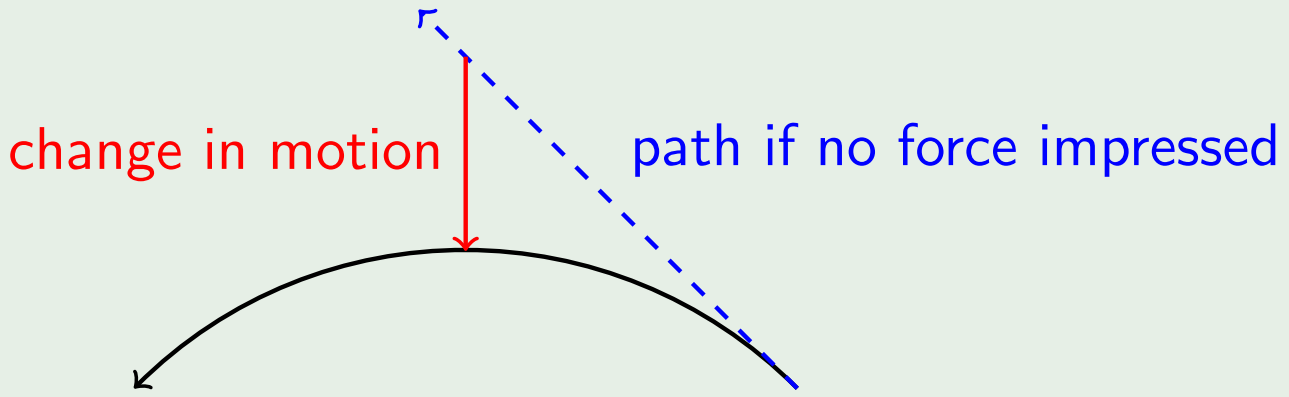
Every body perseveres in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by forces impressed.

Aristotelian way of expressing it: For all bodies, the natural motion is to be at rest or to continue moving in a straight line in whatever direction they were going; any other motion is due to an impressed force, not natural.

Law 2 (416)

A change in motion is proportional to the motive force impressed and takes place along the straight line in which that force is impressed.

Example of body moving in a circle

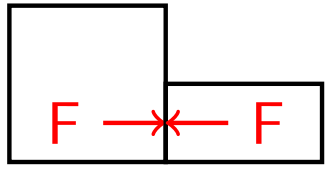


- "Change in motion" is change in quantity of motion, i.e., change of mv, which (per unit time) is ma. The modern formulation of this law is: $F = ma$.
- The law isn't correct if relative motion is used. That's why Newton introduced absolute motion.

Law 3 (417)

To any action there is always an opposite and equal reaction; in other words, the actions of two bodies upon each other are always equal and always opposite in direction.

Here "action" means force. Picture:



Examples (417)

If anyone presses a stone with a finger, the finger is also pressed by the stone. If a horse draws a stone tied to a rope, the horse will (so to speak) be drawn back equally toward the stone, for the rope, stretched out at both ends, will urge the horse toward the stone and the stone toward the horse by one and the same endeavor to go slack and will impede the forward motion of the one as much as it promotes the forward motion of the other.

Questions

1. Explain what relative time is, give an example of it, and say how it differs from absolute time.
2. Explain what relative space is, give an example of it, and say how it differs from absolute space.
3. Explain what relative and absolute motion are. Give an example in which they differ.
4. A stone is thrown horizontally and eventually falls to the ground. Explain how Newton's laws of motion imply that there is a force acting on the stone after it has been thrown, and the direction of this force. (Assume the earth is at rest.)
5. A magnet and a piece of iron are floating in separate dishes in a basin of water. The magnet is twice as heavy as the iron. The iron has acceleration a towards the magnet. Use Newton's laws of motion to determine the magnitude and direction of the acceleration of the magnet; indicate which laws you are using and where they are used.

Reference


Isaac Newton.
The Principia: Mathematical Principles of Natural Philosophy.
University of California Press, 1999.
Translation by I. Bernard Cohen and Anne Whitman.
(Numbers in parentheses are page numbers of this book.)