Kepler

Johannes Kepler (1571 – 1630).
German mathematician,
astronomer, and astrologer.

The Great Comet of 1577, which Kepler witnessed as a child,
attracted the attention of astronomers across Europe.

"The boy was precocious above all in illness, being beset by small pox, headaches, boils, rashes, worms, pules, the mange, and worst of all for an aspiring astronomer, defective eyesight"

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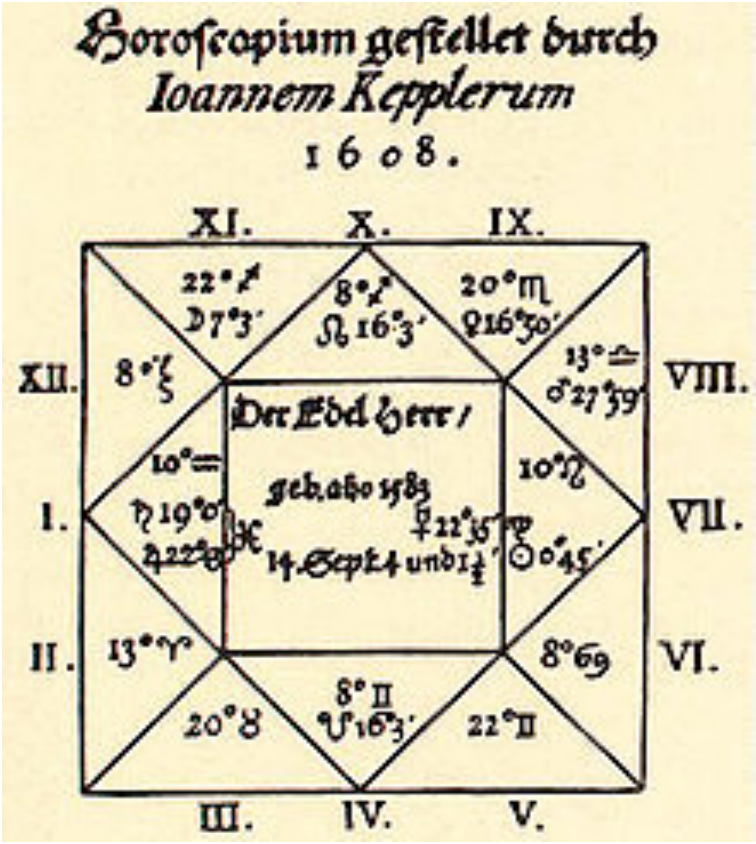

Kepler's horoscope for General Wallenstein

a man's got to earn a living...

Kepler

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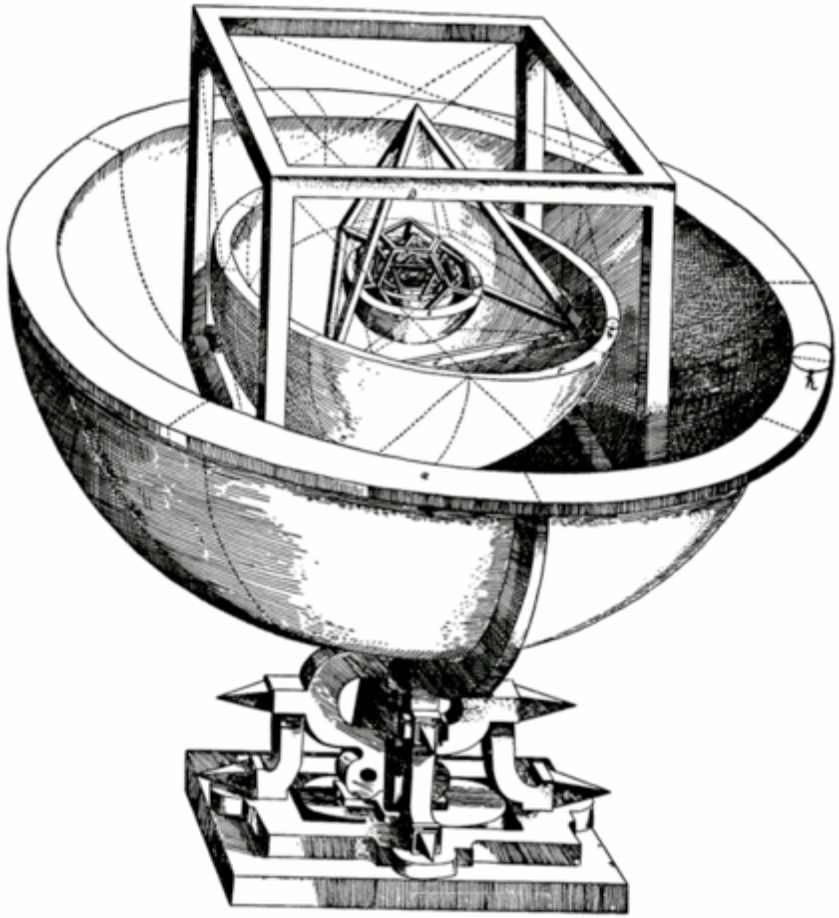


attempts to explain the orbits in terms of Platonic solids

Kepler

Johannes Kepler (1571 – 1630). German mathematician, astronomer, and astrologer.

Kepler "appropriated" Brahe's data upon his death. Brahe was Kepler's boss, famous for his wealth, brass nose, and pet elk that got drunk and died when it fell down the stairs at Brahe's castle.

Tycho Brahe's new astronomical measurements were accurate to 2 arc minutes (previous were good to > 10 arc minutes). Both Copernican and Ptolemaic systems did not agree with the new data.

Kepler wrote, "On this 8 minute discrepancy, I will yet build a theory of the universe."

It took him 16 years.

"What sixteen years ago I urged as a thing to be sought, that for which I joined Tycho Brahe ... at last I have brought to light and recognise its truth beyond my fondest expectations ... The die is cast, the book is written, to be read either now or by posterity. I care not which. It may well wait a century for a reader, as God has waited 6000 years for an observer."

Kepler

Johannes Kepler (1571 – 1630). German mathematician, astronomer, and astrologer.

what he did for the 16 years....

* Kepler's first law of planetary motion. (1609)

He then set about calculating the entire orbit of Mars, using the geometrical rate law and assuming an egg-shaped ovoid orbit. After approximately 40 failed attempts, in early 1605 he at last hit upon the idea of an ellipse, which he had previously assumed to be too simple a solution for earlier astronomers to have overlooked. Finding that an elliptical orbit fit the Mars data, he immediately concluded that all planets move in ellipses, with the sun at one focus.

Kepler

Johannes Kepler (1571 – 1630).
German mathematician,
astronomer, and astrologer.

* Kepler's second law of planetary motion. (1609)

planets sweep out equal areas in equal times—Kepler's second law of planetary motion (1609)

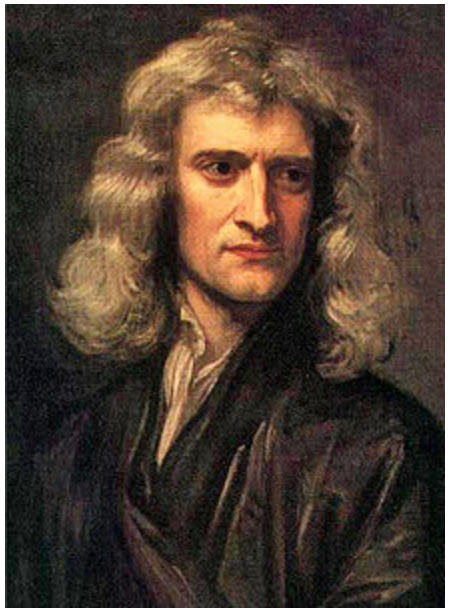
* Kepler's third law of planetary motion. (1609)

The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit. (1619)

[Kepler enunciated this third law in a laborious attempt to determine what he viewed as the "music of the spheres" according to precise laws, and express it in terms of musical notation.]

Newton and Universal Gravitation

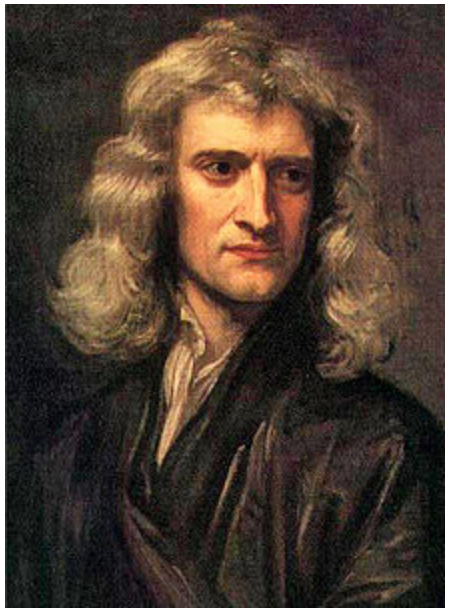
Newton -- life



Sir Isaac Newton (1642 – 1727)

- son of a prosperous farmer who died just before Newton's birth
- mother remarried and Newton was brought up by his grandmother
- mother attempted to make him farm at age 17, but he hated it
- he went to Cambridge and eventually became a professor there and master of the mint in later life
- apparently slowly poisoned himself handling mercury
- died an excruciating death due to a kidney stone

Newton -- reputation



Sir Isaac Newton (1642 – 1727)

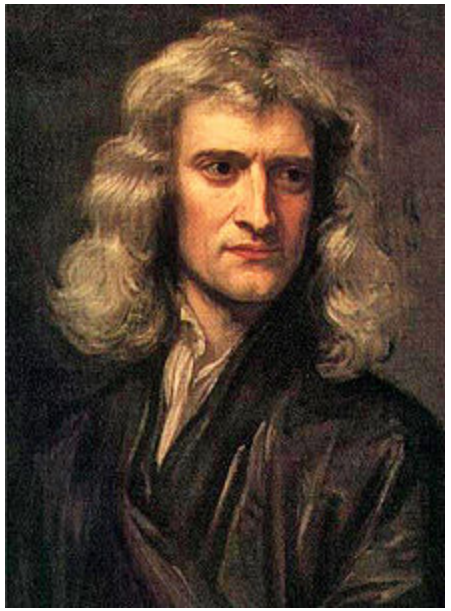
Newton is widely regarded as the greatest scientist who ever lived.

"Nature and nature's laws lay hid in night;
God said `Let Newton be' and all was light."
-- Alexander Pope

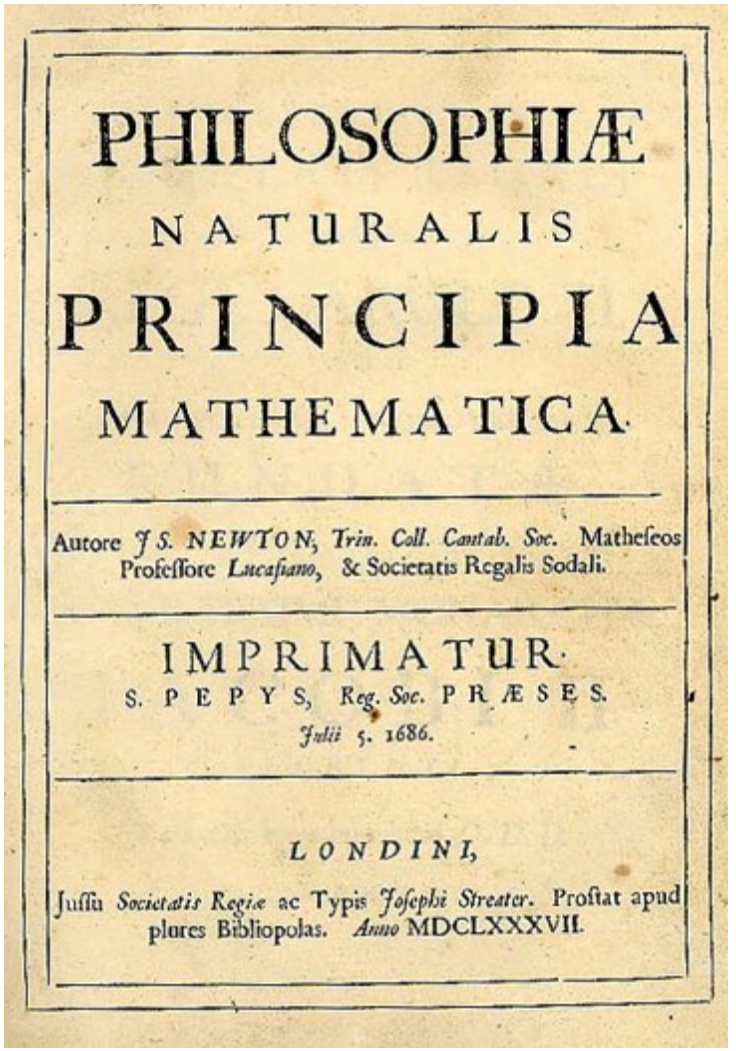
"Does he eat and drink and sleep? Is he like other men?"
-- Marquis de l'Hôpital

The mathematician Joseph-Louis Lagrange often said that Newton was the greatest genius who ever lived, and once added that Newton was also "the most fortunate, for we cannot find more than once a system of the world to establish."

Newton -- the *Principia*



Sir Isaac Newton (1642 – 1727)



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

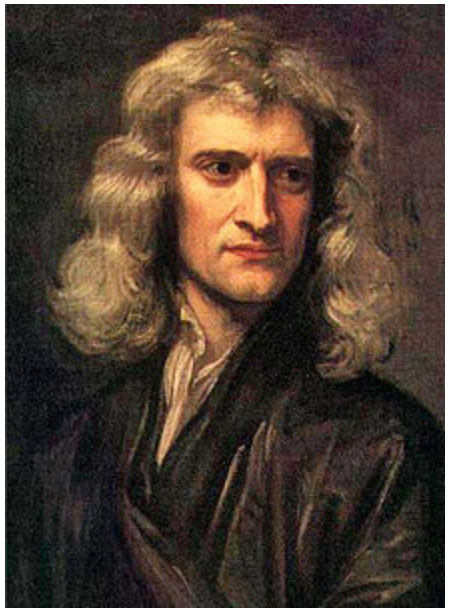
Autore *J S. NEWTON, Trin. Coll. Cantab. Soc.* Matheſeos Profeſſore *Lucaſiano,* & Societatis Regalis Sodali.

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

LONDINI,
Juſſu *Societatis Regiæ* ac Typis *Joſephi Streater.* Proſtat apud plures Bibliopolas. *Anno* MDCLXXXVII.

marks the end of the Scientific Revolution

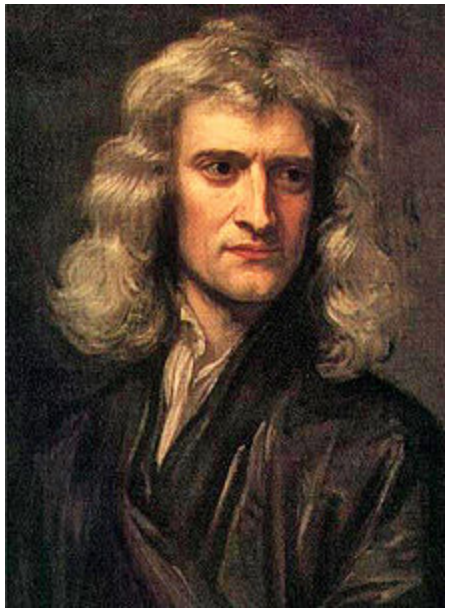
Newton -- work



Sir Isaac Newton (1642 – 1727)

- F=ma
- invented calculus
- postulated universal gravity
- explained the solar system in far greater detail than had ever been achieved

Newton -- aside on F=ma



Sir Isaac Newton (1642 – 1727)

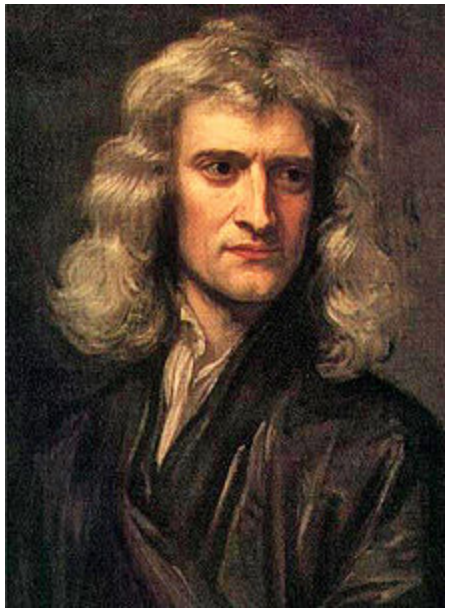
In general Newton's equation is regarded as an "equation of motion". Namely one supplies the force F as a function of position and then solves

$$m\frac{d^2x}{dt^2} = F(x)$$

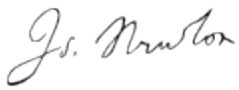
for $x(t)$.

This means that *m,* the mass must be known. But there is no definition of mass -- it is a fundamental quantity that must be defined *operationally*. In this case, one takes a known force, measures a, and then gets m = F/a.

Newton -- impressions



Sir Isaac Newton (1642 – 1727)

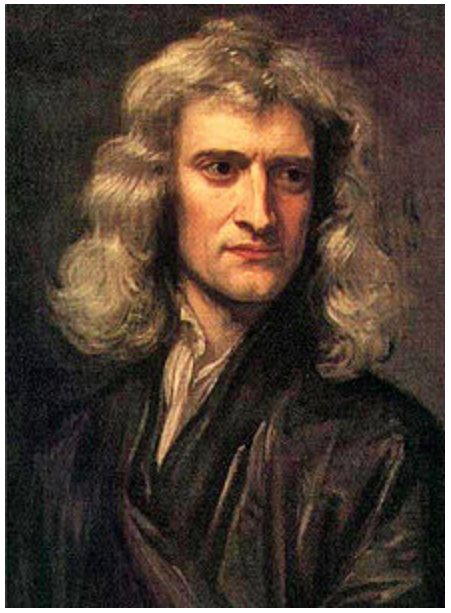


Kepler, Newton, et al were men of their times.

"I do not know what I may appear to the world, but to myself I seem to have been only like a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me"

"This rod and the male and femail serpents joyned in the proportion 3:1:2 compose the three-headed Cerebus which keeps the gates of Hell. For being fermented and digested together they resolve and grow dayly more fluid ... and put on a green colour and in 40 days turn into a rotten black pouder. The green matter may be kept for ferment. Its spirit is the blood of the green Lion. The black pouder is our Pluto, the God of wealth."

Newton -- gravity



Sir Isaac Newton (1642 – 1727)

Later Newton showed that it still follows if the masses are spherical.

Using Kepler's Laws and calculus, Newton was able to show the gravitational force

(i) is directed toward the Sun
(ii) has a magnitude that is inversely proportional to the square of the distance to the Sun

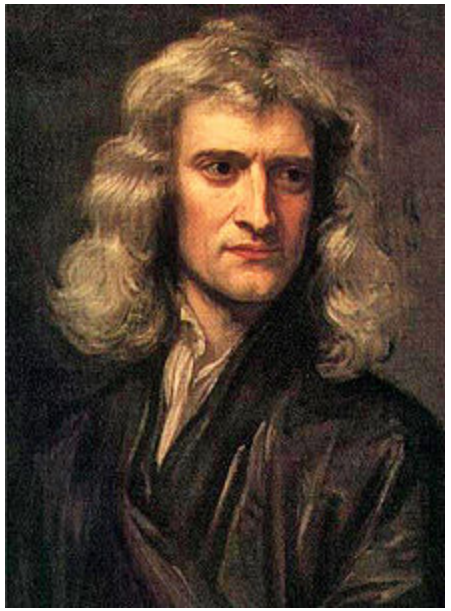
This suggests that the sun is the source of gravity and every planet is thus attracted toward the sun.

But one can imagine two suns, which must attract each other, thus all masses have a force of gravity and attract each other.

Kepler's elliptic orbits are the solution to Newton's equations if one assumes a single point mass orbiting another heavy point mass.

The theory reproduced all of Kepler's laws and predicted many corrections to them, some of which were quickly confirmed. [Earth's 72 year nutation]

Newton -- action at a distance

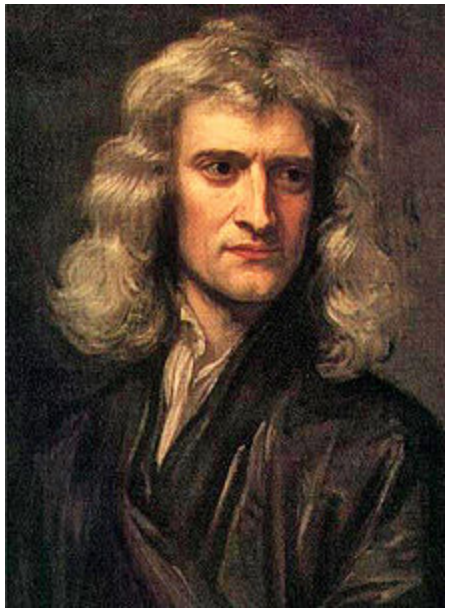


Sir Isaac Newton (1642 – 1727)

Cartesians (Leibniz and Huygens) regarded Newton as unscientific since he brought back the ideas of a vacuum and of action at a distance. The latter especially smelled of rebuked occult properties of matter. Newton himself speculated that gravity was a tendency to move to rarer ether, or was simply produced by God.

It took 200 years to resolve this problem.

Newton -- action at a distance

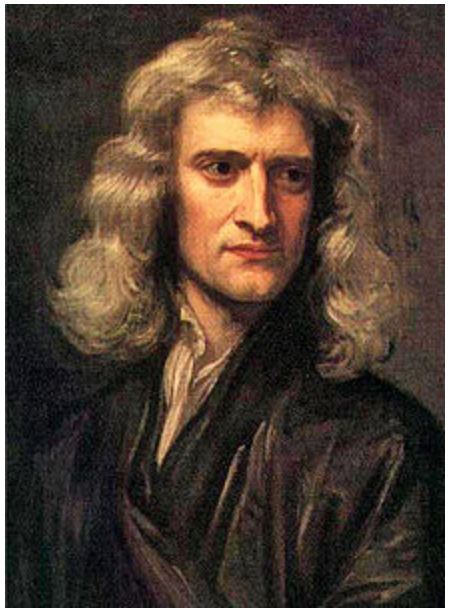


Sir Isaac Newton (1642 – 1727)

Action at a distance: is the idea that objects that are not touching each other can have an effect on each other (often, an *instantaneous* effect).

As we have seen this was regarded as occult. Thus static electricity and magnetism caused philosophical tension for thousands of years.

Newton -- other forces



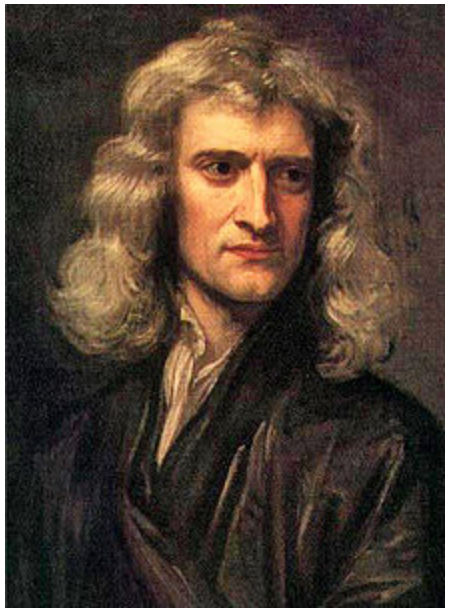
Sir Isaac Newton (1642 – 1727)

"If only we could derive the other phenomena of nature from mechanical principles by the same kind of reasoning!" .

"For many things lead me to have a suspicion that all phenomena may depend on certain forces by which the particles of bodies, by causes not yet known, either are impelled toward one another and cohere in regular figures, or are repelled from one another and recede." -- Newton

Newton postulates that similar reasoning describes all of nature, not just the planets.

Newton -- conception of space-time

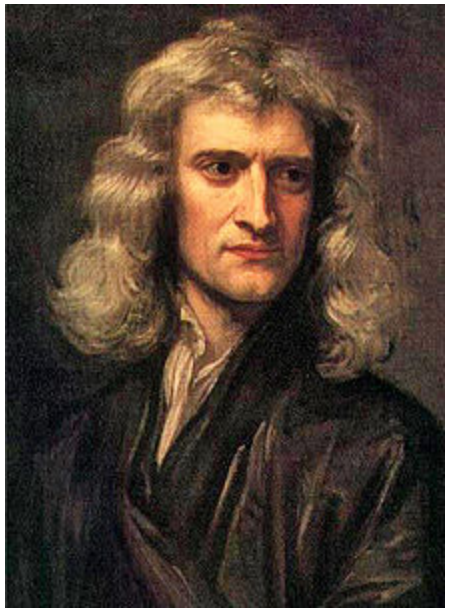


Sir Isaac Newton (1642 – 1727)

Newton's conception of space-time: space is an inert scaffolding in which things happen; time passes uniformly regardless of the things happening. Thus one can imagine a vast space with nothing in it. Also, it is possible to discuss absolute motion (ie motion with respect to space) rather than relative motion.

This contrasts strongly with ancient and current views that empty space does not exist, and the perception of space is given by the things in it. Similarly time does not pass unless things happen to mark its passing.

Newton -- conception of space-time



Sir Isaac Newton (1642 – 1727)

Note that Galilean relativity implies that Newton's conception of absolute velocity cannot be experimentally measured.

Gottfried Wilhelm Leibniz

(1646 – 1716)

German mathematician, philosopher, lawyers, and diplomat.

"As for my own opinion, I have said more than once, that I hold space to be something merely relative, as time is, that I hold it to be an order of coexistences, as time is an order of successions." -- Leibniz

Wrote fluently in Latin, German, and French. Wrote about 15000 letters, many pamphlets, books, etc.