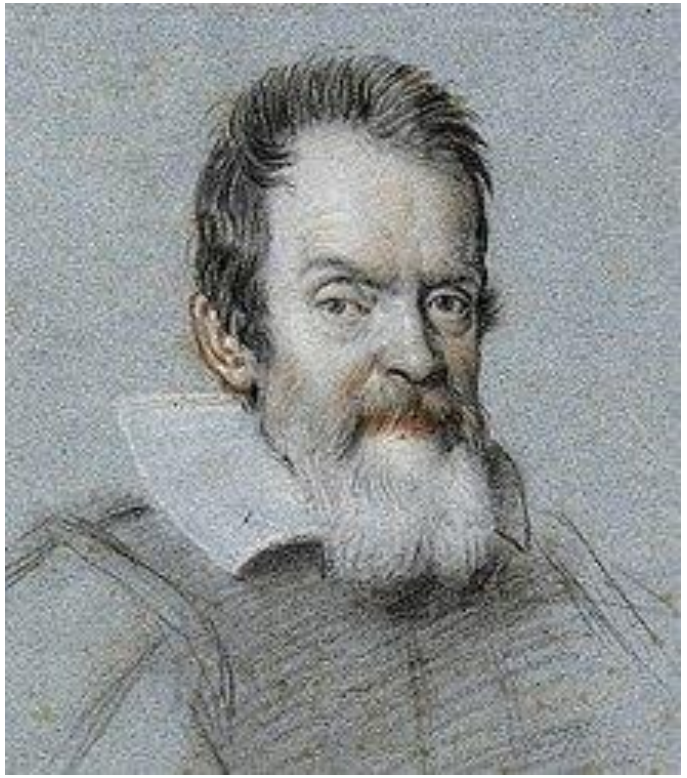
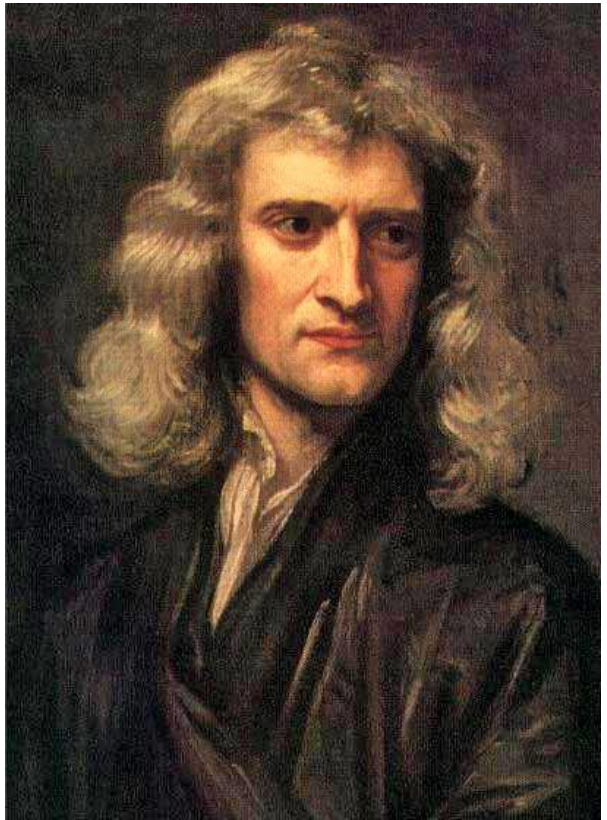
The Scientific Revolution:

Challenging Western Christendom, 1543-1687



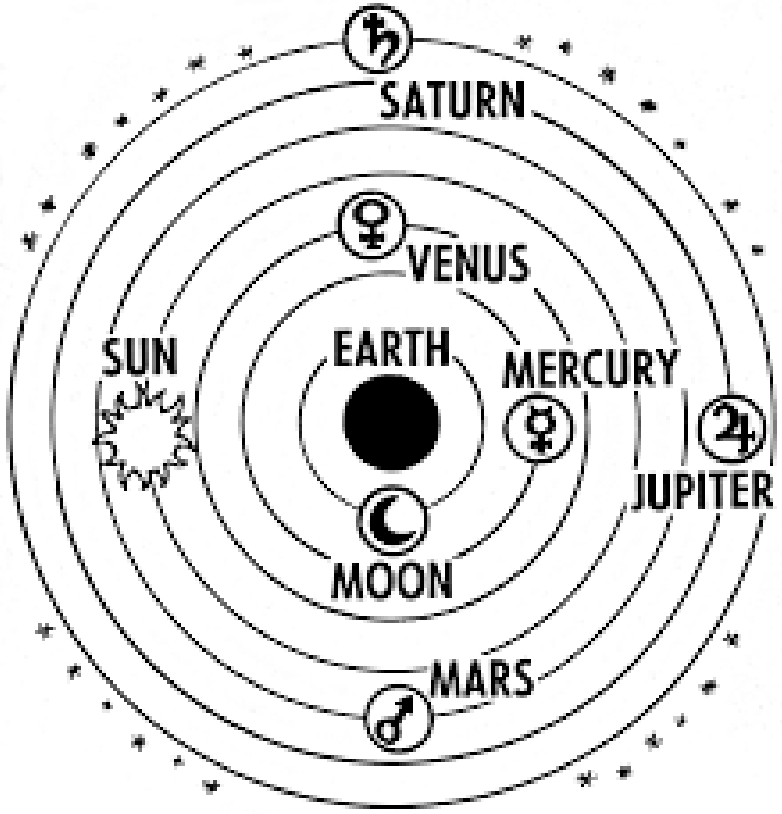
GALILEO (1564–1642)



SIR ISAAC NEWTON (1642-1727)

- The Scientific Revolution was a series of events that marked the emergence of modern science during the early modern period.
- Developments in mathematics, physics, astronomy, biology (including human anatomy) and chemistry transformed the thinking of people in Europe about man, nature and God.
- Many of the developments in the sciences during this time challenged the prevailing Christian worldview.
- The emerging ideas of the Scientific Revolution served as part of the basis for the Enlightenment.

- The 1543 publication of Nicolaus Copernicus's "On the Revolutions of the Heavenly Spheres" is often cited as marking the beginning of the Scientific Revolution.
- Copernicus offered an alternative model of the solar system to Ptolemy's geocentric system, which had been widely accepted since ancient times.



GEOCENTRIC SYSTEM

What is the significance of a geocentric system vs. a heliocentric system?

- The Ptolemaic system, developed by the Hellenistic astronomer Claudius Ptolemaeus in the 2nd century AD standardized ***geocentrism***.
- His main astronomical work, the ***Almagest***, was the culmination of centuries of work by Hellenistic, Persian and Babylonian astronomers.
- For over a millennium European Christian and Middle Eastern and African Islamic astronomers assumed it was the correct cosmological model.
- Some Christians pointed to specific Bible passages that seemed to support geocentrism.

- For example, some asserted that Joshua 10:12-14 shows that the daily apparent motions of the Sun and the Moon are due to their actual motions around the Earth rather than due to the rotation of the Earth about its axis:

Then Joshua spoke to the LORD on the day when the LORD turned the Amorites over to the sons of Israel, and he said in the sight of Israel,

"Sun, stand still at Gibeon, And moon, at the Valley of Aijalon!"
So the sun stood still, and the moon stopped,
Until the nation avenged themselves of their enemies.

Is it not written in the Book of Jashar? And the sun stopped in the middle of the sky and did not hurry to go *down* for about a whole day. **14** There was no day like that before it or after it, when the LORD listened to the voice of a man; for the LORD fought for Israel.

- For ancient and medieval Christians, the idea of the earth as occupying the center position of the universe is supported by the creation account in Genesis.
- If the earth is where God placed man, and if the earth is to one day be filled with the glory of God, then the earth is central to God's purposes.
- The other celestial bodies have their place in the firmament, and they "serve as signs and for seasons, and for days and years; and they shall serve as lights in the expanse of the heavens to give light on the earth."

(Gen. 1:14-15)

- Another Scripture cited as support for a geocentric system is Psalm 93:1:

  The LORD reigns, He is clothed with majesty;
  The LORD has clothed and encircled Himself with strength.
  Indeed, the world is *firmly* established; it will not be moved.

- For many, as far as what could be physically observed, and what was assumed based on ancient writings and religious texts, the sun, planets and stars appeared to literally revolve around the earth.
- Some ancient Greek and medieval Islamic scholars did question the idea that the earth was stationary and that the earth was the center of the universe.

- How did Copernicus come to propose a heliocentric system?
- His conclusion was not based on physical observations.
- His assertions were based on the work of Islamic astronomers that supported a heliocentric system and described the movement of the earth in such a system.

- So as not to get in trouble with the Church, his work *On the Revolutions of the Heavenly Spheres* had a preface written by a Lutheran theologian, Andreas Osiander.

- Osiander stated that Copernicus had simply developed a mathematical hypothesis, not an account that contained truth or even probability.
- The work also contained a letter from the Archbishop of Capua, urging Copernicus to publish his theory.
- In a lengthy introduction, Copernicus dedicated the book to Pope Paul III.
- He noted the inability of earlier astronomers to agree on an adequate theory of the planets.
- He also suggested his system would allow the Church to develop a more accurate calendar.

- The Copernican system was widely criticized in Europe.
- Tycho Brahe, Danish nobleman and astronomer, appreciated the elegance of the Copernican system.
- But he objected to the idea of a moving Earth on the basis of physics, astronomy, and religion.

- The Copernican Revolution took more than a century to displace the widespread acceptance of the geocentric system with the heliocentric system.
- While not warmly received by his contemporaries, his model did have a large influence on later scientists such as **Galileo** and **Johannes Kepler**, who adopted, championed and sought to improve it.
- Some astronomers did acknowledge that Copernicus's system more adequately explained the four seasons by showing that the Earth's axis is not perpendicular to its orbit.

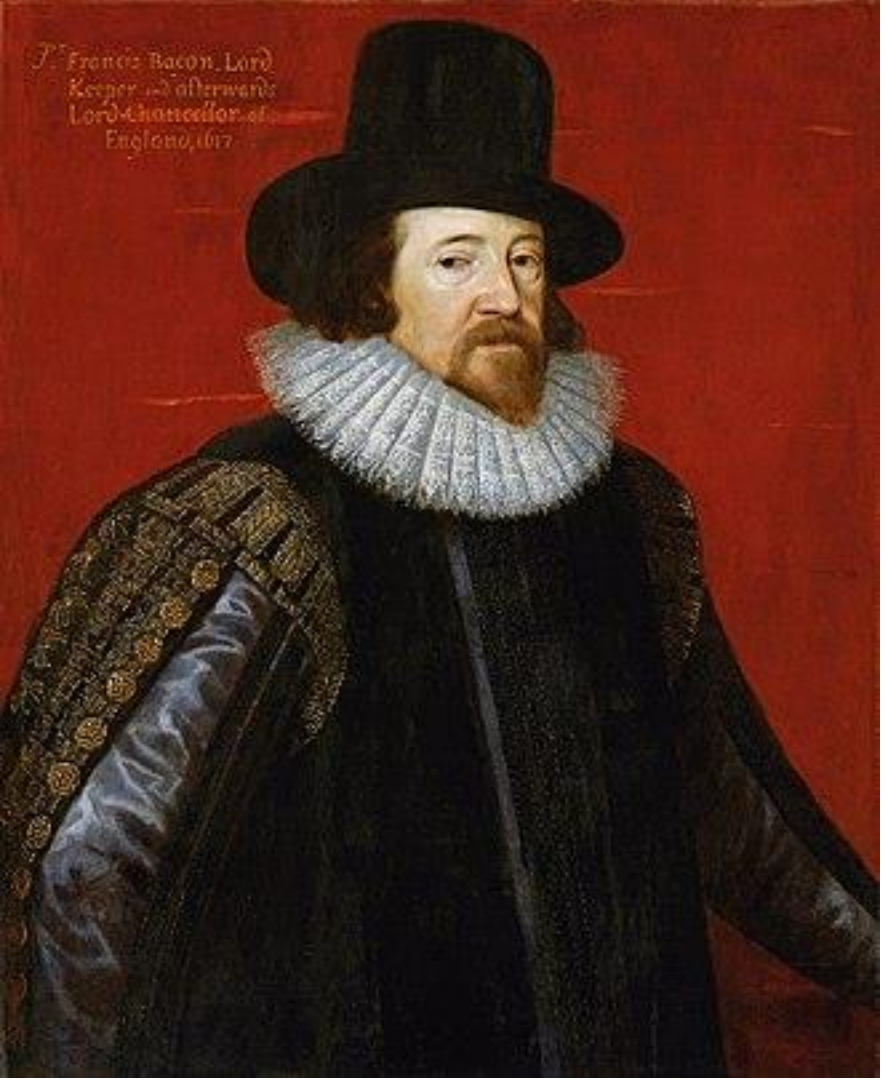
During the 17th century, several further discoveries eventually led to the wider acceptance of heliocentrism:

- Johannes Kepler's 1609 work *Astronomia nova* showed that the orbits of the planets were elliptical rather than circular, while retaining the heliocentric concept.
- Using the newly invented telescope, in 1610 Galileo discovered the:
  - four large moons of Jupiter (evidence that the Solar System contained bodies that did not orbit Earth).
  - phases of Venus (the first observational evidence not properly explained by the Ptolemaic theory).
  - rotation of the Sun about a fixed axis as indicated by the apparent annual variation in the motion of sunspots.

- With a telescope, Giovanni Zupi saw the phases of Mercury in 1639.
- In 1687 Isaac Newton proposed universal gravity and the inverse-square law of gravitational attraction to explain Kepler's elliptical planetary orbits.
- The invention of the refracting telescope ranks with the invention of the compass as one of the most significant in human history.


Johannes Hevelius observing with one of his telescopes (1647).

- The earliest existing record of a refracting telescope was a 1608 patent submitted to the Dutch government by Middelburg spectacle maker Hans Lippershey.
- The actual inventor is unknown but word of it spread through Europe.
- Galileo heard about it and, in 1609, built his own version, and made his telescopic observations of celestial objects.
- With the telescope, man is now able to see things that only God has seen thus far in history.
- Various inventors continued developing the telescope and produced many different kinds.



FRANCIS BACON (1561-1626)

The philosophical underpinnings of the Scientific Revolution were laid out by Englishman Francis Bacon, who has been called the father of *empiricism*. His works established and popularized inductive methodologies for scientific inquiry, often called the Baconian method, or simply the *scientific method*.

Bacon argued for careful observation of events in nature, as opposed to philosophical arguments and deduction.

- Bacon was a devout Anglican.
- He believed that while the natural world can be studied inductively, knowledge of God can only come from special (divine) revelation.
- Bacon also held that knowledge was cumulative and should be advanced, rather than just preserved.
- "Knowledge is the rich storehouse for the glory of the Creator and the relief of man's estate," he wrote.
- "…a little philosophy inclineth man's mind to atheism, but depth in philosophy bringeth men's minds about to religion."

- A 19th century biographer of Bacon wrote: “Bacon's influence in the modern world is so great that every man who rides in a train, sends a telegram, follows a steam plough, sits in an easy chair, crosses the channel or the Atlantic, eats a good dinner, enjoys a beautiful garden, or undergoes a painless surgical operation, owes him something.”-- William Hepworth Dixon, The Story of Lord Bacon's Life (1862)
- Another early empiricist was William Gilbert (1544-1603).
- Gilbert rejected both the prevailing Aristotelian philosophy and the Scholastic method of university teaching.
- His book *De Magnete* was written in 1600, and he is regarded by some as the father of electricity and magnetism.

- In *De Magnete*, Gilbert describes many of his experiments with his model Earth called the *terrella*.
- From these experiments, he concluded that the Earth was itself magnetic and that this was the reason compasses point north (previously, some believed that it was the pole star (Polaris) or a large magnetic island on the north pole that attracted the compass).
- He was the first to argue, correctly, that the center of the Earth was iron, and he considered an important and related property of magnets was that they can be cut, each forming a new magnet with north and south poles.

- The English word "electricity" was first used in 1646 by Sir Thomas Browne, derived from Gilbert's 1600 New Latin *electricus*, meaning "like amber."
- The term had been in use since the 13th century, but Gilbert was the first to use it to mean "like amber in its attractive properties".
- He recognized that friction with these objects removed a so-called "effluvium", which would cause the attraction effect in returning to the object, though he did not realize that this substance (electric charge) was universal to all materials.

- Gilbert also studied static electricity using amber (fossilized tree resin, considered to be a gemstone).
- Amber is called *elektron* in Greek, so Gilbert decided to call its effect the electric force.
- He invented the first electrical measuring instrument, the electroscope, in the form of a pivoted needle he called the *versorium*.
- *De Magnete* was influential not only because of the inherent interest of its subject matter, but also for the rigorous way in which Gilbert described his experiments and his rejection of ancient theories of magnetism.

- Galileo Galilei has been called the "father of modern observational astronomy," the "father of modern physics," the "father of science," and "the Father of Modern Science."
- His original contributions to the science of motion were made through an innovative combination of experiment and mathematics.

GALILEO GALILEI
(1564-1642)

Galileo was one of the first modern thinkers to clearly state that the laws of nature (physics) are mathematical.

- In The Assayer he wrote "Philosophy is written in this grand book, the universe ... It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures;....”
- His mathematical analyses are a further development of a tradition employed by late scholastic natural philosophers, which Galileo learned when he studied philosophy.
- His work marked another step towards the eventual separation of science from both philosophy and religion; a major development in human thought.

- He was often willing to change his views in accordance with observation.
- In order to perform his experiments, Galileo had to set up standards of length and time, so that measurements made on different days and in different laboratories could be compared in a reproducible fashion.
- This provided a reliable foundation on which to confirm mathematical laws using inductive reasoning.
- Galileo's championing of Copernican heliocentrism (Earth rotating daily and revolving around the sun) was met with opposition from within the Catholic Church and from some astronomers.

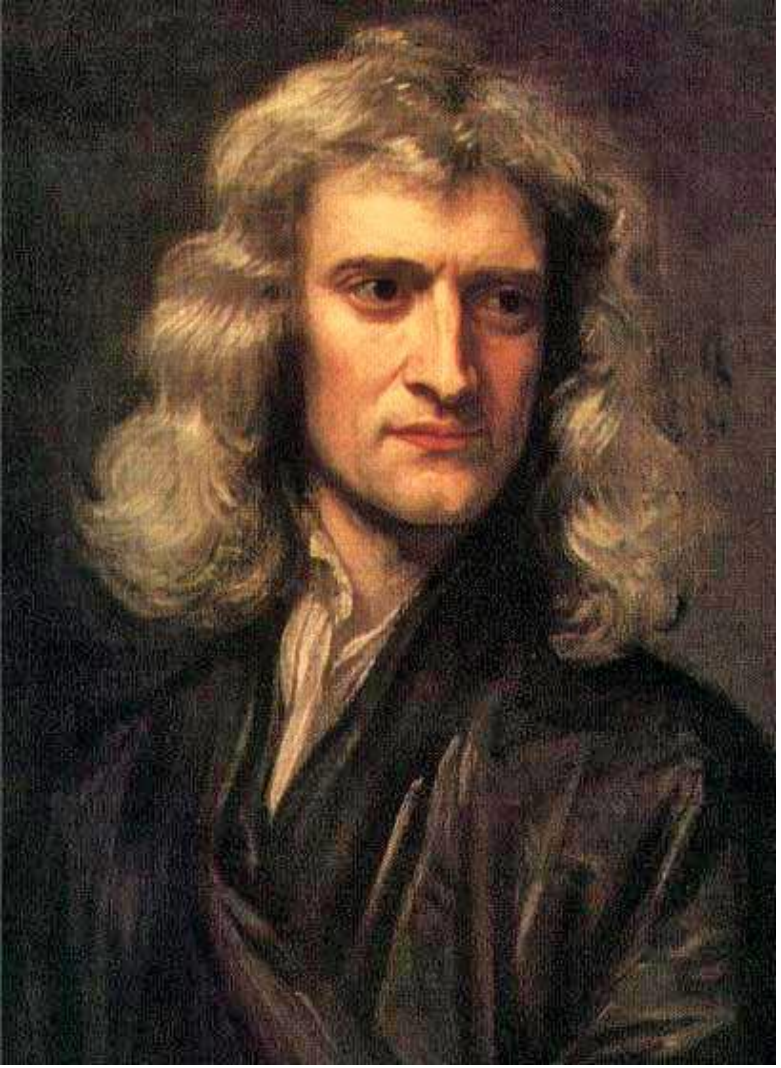
- The matter was investigated by the Roman Inquisition in 1615, which concluded that heliocentrism was foolish, absurd, and heretical since it contradicted Holy Scripture.
- Galileo later defended his views in Dialogue Concerning the Two Chief World Systems (1632), which appeared to attack Pope Urban VIII and thus alienated both the Pope and the Jesuits, who had both supported Galileo up until this point.
- He was tried by the Inquisition, found "vehemently suspect of heresy", and forced to recant. He spent the rest of his life under house arrest.

- During this time, he wrote Two New Sciences (1638), primarily concerning kinematics (the geometry of motion) and the strength of materials, summarizing work he had done around forty years earlier.
- Galileo, a devout Roman Catholic, had considered becoming a priest as a youth, but his father wanted him to become a physician.
- He became interested in physics while studying medicine and wanted to become a mathematician.
- However, after accidentally attending a lecture on geometry, he talked his reluctant father into letting him study mathematics and natural philosophy instead of medicine.

- Galileo was also interested in the visual arts, and in 1588, obtained the position of instructor in the Accademia delle Arti del Disegno in Florence, teaching perspective and *chiaroscuro*.
- In 1589, he was appointed to the chair of mathematics in Pisa.
- In 1592, he moved to the University of Padua where he taught geometry, mechanics, and astronomy until 1610.
- During this period, Galileo made significant discoveries in both pure fundamental science and practical applied science.

- He also had to continue staying away from the geocentric vs. heliocentric universe controversy in order to continue working and teaching.
- Warned by Rome and the Jesuits not to continue holding to a heliocentric system, Galileo found it increasingly difficult to avoid upholding the heliocentric system.
- By 1633, the Inquisition found him “suspect of heresy” and he was forced to officially recant heliocentrism.
- The Inquisition banned all of his works, including those he would write in the future.
- His works had to be smuggled out of Italy to be published.

- His final work, Two New Sciences, was praised many years later by no less than Albert Einstein, and it was Einstein who called Galileo “the father of modern physics – indeed the father of modern science.”
- Among Galileo’s inventions or innovations are:
  - The use of the refracting telescope to demonstrate many astronomical principles and observations.
  - Geometric and military compasses.
  - The thermometer.
  - The compound microscope.



SIR ISAAC NEWTON
(1642-1727)

Sir Isaac Newton PRS (Dec. 25, 1642 – March 20, 1726/27) was an English mathematician, physicist, astronomer, theologian, and author (described in his time as a "natural philosopher") who is widely recognized as one of the greatest mathematicians and most influential scientists of all time and as a key figure in the scientific revolution.

- His book Mathematical Principles of Natural Philosophy, first published in 1687, established classical mechanics (physics).
- Newton also made seminal contributions to optics, and shares credit with German mathematician Gottfried Wilhelm Leibniz for developing the infinitesimal calculus.
- In the Principles, Newton formulated the laws of motion and universal gravitation that formed the dominant scientific viewpoint until it was superseded nearly three centuries later by Einstein's theories of special and general relativity.

- Newton used his mathematical description of gravity to derive Kepler's laws of planetary motion, account for tides, the trajectories of comets, the precession of the equinoxes and other phenomena, eradicating doubt about the solar system's heliocentricity.
- Newton built the first practical reflecting telescope and developed a sophisticated theory of color based on the observation that a prism separates white light into the colours of the visible spectrum.
- His work on light was collected in his highly influential book Opticks, published in 1704.

- He also formulated an empirical law of cooling, made the first theoretical calculation of the speed of sound, and introduced the notion of a Newtonian fluid.
- In addition to his work on calculus, as a mathematician Newton contributed to the study of power series, generalized the binomial theorem to non-integer exponents, developed a method for approximating the roots of a function, and classified most of the cubic plane curves.
- Among his contemporaries, his work in mathematics was said to have “distinctly advanced every branch then studied.”

- Newton studied at Trinity College, Cambridge, and became a fellow there in 1667.
- Fellows were required to become ordained priests in the Church of England, but Newton did not want to take holy orders.
- Although born into an Anglican family, by his thirties Newton held a Christian faith that, had it been made public, would not have been considered orthodox by mainstream Christianity, with one historian labelling him a heretic.
- He studied early church writings extensively.

- Newton wrote extensively on religious topics but kept all of his writings and views secret.
- After his death, his religious works revealed that his view of the Arian controversy of the early 300s AD came down firmly on the side of Arius.
- The Arian concept of Christ is based on the belief that the Son of God did not always exist but was begotten within time by God the Father, therefore Jesus was not co-eternal with God the Father.
- In Newton's eyes, worshipping Christ as God was idolatry.

- Newton also owned and read several Socinian works, leading some scholars to conclude that Newton was a Socinian sympathizer.
- Socinianism is a collection of heretical beliefs that include rejection of the existence of Christ before the incarnation and held that Jesus did not exist until he was conceived as a human being.
- Socinians also reject the idea of original sin and the substitutionary atonement of Christ to redeem man.
- Many scholars believe that Newton was essentially an anti-Trinitarian monotheist.

- Although the laws of motion and universal gravitation became Newton's best-known discoveries, he warned against using them to view the universe as a mere machine, as if akin to a great clock.
- He said, "So then gravity may put the planets into motion, but without the Divine Power it could never put them into such a circulating motion, as they have about the sun.”
- Perhaps unwittingly, Newton serves as a preface to further developments in modern thought, leading to rationalism, Deism and the Enlightenment.