Isaac Newton

A new era in science

Waseda University, SILS, Introduction to History and Philosophy of Science

Newton's Legacy

Newton brought to a close the astronomical revolution begun by Copernicus. He combined the *dynamic* research of Galileo with the *astronomical* work of Kepler.

He produced an entirely new cosmology and a *new way of thinking* about the world, based on the *interaction between matter and mathematically determinate forces*.

He joined the mathematical and experimental methods: the so-called hypothetico-deductive method.

His work became a model for *rational mechanics* as it was later practiced by mathematicians, particularly during the Enlightenment.



William Blake's Newton (1795)





Newton 3/15

Newton's De motu coporum in gyrum

Edmond Halley (of the comet) visited Cambridge in 1684 and talked with Newton about inverse-square forces ($F \propto \frac{1}{d^2}$).

Newton stated that he had already shown that inverse-square force implied an ellipse, but could not find the documents.

Later he rewrote this into a short document called *De motu corporum in gyrum* ("on the motion of bodies in orbits"), and sent it to Halley.

Halley was excited and asked for a full treatment of the subject.

Two years later Newton sent Book I of *The Mathematical Principals of Natural Philosophy (Principia).*

Key Point

The goal of this project was to derive the orbits of bodies from a *simpler set of assumptions* about motion. That is, it sought to explain Kepler's Laws with a simpler set of laws.

- I. The planets move in ellipses with the sun at a focus.
- II. Equal areas are swept out in equal times.
- III. Periods are as the three halves power of the distances ($P^2 \propto D^3$).

Newton was able to show how all of Kepler's laws depended on certain simple *mathematical assumptions* about the nature of motion and force.

The structure of the *Principia* is as follows:

- Book I: The mathematics of dynamic systems in void spaces.
- Book II: The mathematics of dynamic systems in gases and fluids.
- Book III: The application of these general methods to the solar system, comets and mechanics that is, to our world.

Newton, Principia

"I consider *philosophy* rather than [mechanical] arts and write not concerning manual but natural powers, and consider chiefly those things which relate to gravity, levity, elastic force, the resistance of fluids, and the like forces, whether attractive or impulsive; and therefore I offer this work as the *mathematical principles of philosophy*, for the whole burden of philosophy seems to consist in this – from the phenomena of motions to investigate the forces of nature, and then from these forces to demonstrate the other phenomena; and to this end the propositions in the first and second Books are dedicated.

Newton, Principia

"In the third Book, I give an example of this in the exposition of the *System of the World*; for ... I derive from the celestial phenomena the forces of gravity with which bodies tend to the Sun and the several planets. Then from these forces, by other propositions, which are also mathematical, I deduce the motions of the planets, the comets, the Moon, and the sea."

Newton's Principia, 1687 (1713, 1726): Laws of motion

AXIOMATA _{sive} LEGES MOTUS

[13]

Lex. I. Corpus onne perfeverare in flatn fue quiefcendi vel movendi nutformiter in directum, nif quaterne a critibus impreffis cogiur flatum illum innare.

Projectilia perfeverant in mothus fiin aff quaterna a refiftentia aeris teratennur & vi gravitatis inpelluatur doorfum. Trochus, cuius partes colaverado perpeturo territanis field a motibus refullincis, non ceffar totari niti quaterna ab aere retardatur. Majori autern Planetrum & Cometarum corpora momus finos & progreflivos & circulares in fpatiis minus refiftentibus ficios conferent duritus.

Lex. II.

Mutationem motus proportionalem effe vi motrici impreff.e. & fieri fecundum lineam vestam qua vis illa imprimitur.

Si via aliqua notum quenvia genecet, dupla duplam, tripta triplum generabit, Iver fund keimel, five gradatim & faccelliveimpretta faceir. Et hic motus quotian in candem fomper plagan cumvi generatrice determinatur, fi corputatiene movelatur, motrigin vel configuration di programa de la companya de la quo obligue adjeitur, & cumzeo fecundum utrialej, determinatioem componitor.

[13] Lex. III.

Astioni contrariant femper & equalem effe reactionem : from corporum duorum astiones in femutno femper effe æquales & in partes contrarias dirigi.

Quicquid premievel trahi alterum, natuundena beo premiau, vertanitura. Sieuu lapiden füur portuis, premiura Kehnju digitua Japide. Siequus Ingdem fum alteguton trahit, retrakturetum Kenguan, naturung, internet missionen auf anternet uum promovet progrefium alteruu. Si corpus abguod incorpus alud impingen, notun quis fui aquonodocum attureteti, idem quoque vicilim in more proprio canden mutatoretti i alud impingen, notun quis fui aquonodocum attureteti, idem quoque vicilim in more proprio canden mutatoretti i pren contrarium si alteruis. Si corpus abguod incorpus fui contrarium si alteruis (Asquadatetta preficioni matura) fod motuma, (falicet in exposibation attural) fod motuma, (falicet in exposibation antifalicitation motios aqualitet mutatura, funt corporibus redproce proportiondes.

Corol. I.

Corpus viribus conjunctis diagonalem parallelogrammi eodom tempore defcribere, quo latera feparatis.

Si corpus datotempore, vi íola M, ferreturab A ad B, & vi íola N, ab A ad C, compleatur parallelogrammum ABDC, & vi utraq; feretur id codem tempore ab A ad D. Nam quoniam vis N agit fecundum lineam



AC ipfi BD parallelam, huc vis nihil mutabit velocitatem accedendi ad lineam illam BD a vi altera geniram. Accedet igitur corpus codem tempore ad lineam BD five vis N imprimator, five non, atq; adco in fine illius temporis reperietur aliciabi in linea

Newton's Laws

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." [Inertia]

Law II

"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." [F = ma]

Law III

"To every action there is always opposed an equal reaction, or the mutual action of two bodies upon each other are always equal, and directed to contrary parts." [Equal and opposite reactions] Newton used the ideas of limits developed in the calculus to develop a geometry of forces.

Principia, Prop. 1 shows that a body which is continuously acted upon toward a center of force will move in a *closed curve*.



By investigating the *geometrical objects* that model the force, Newton was able to show what kinds of forces would produce what kinds of curves.

In this way he was able to show that a force that acts inversely as the square of the distance ($F \propto \frac{1}{d^2}$, such as gravity) will produce an ellipse.



At the end of the *Principia*, in a section called the General Scholium, Newton introduces the concept of God and explains how God functions in his philosophy. This section explains that God is always and everywhere acting on the world to maintain the laws of nature.

God is the *active cause* of gravity.

God's presence produces the two absolute substrates in which all action occurs: Absolute Space and Absolute Time.

God's constant action preserves the world in its present state. He maintains the forces that control matter. Much of Newton's actual interests and activities were stripped away from the public memory of his *style of science*.

In France, Newton was held up as a key figure of the Enlightenment (by for example Voltaire, Laplace).

When we talk about *Newtonianism*, and the Newtonian worldview, we are talking about this public image created by Enlightenment thinkers.

Attributed to Newton by David Brewster

"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 seashore, and diverting myself now and then by finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."