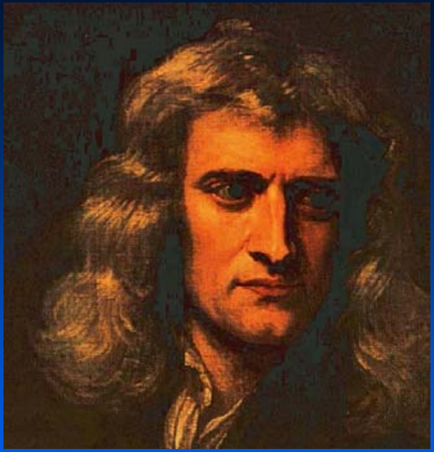
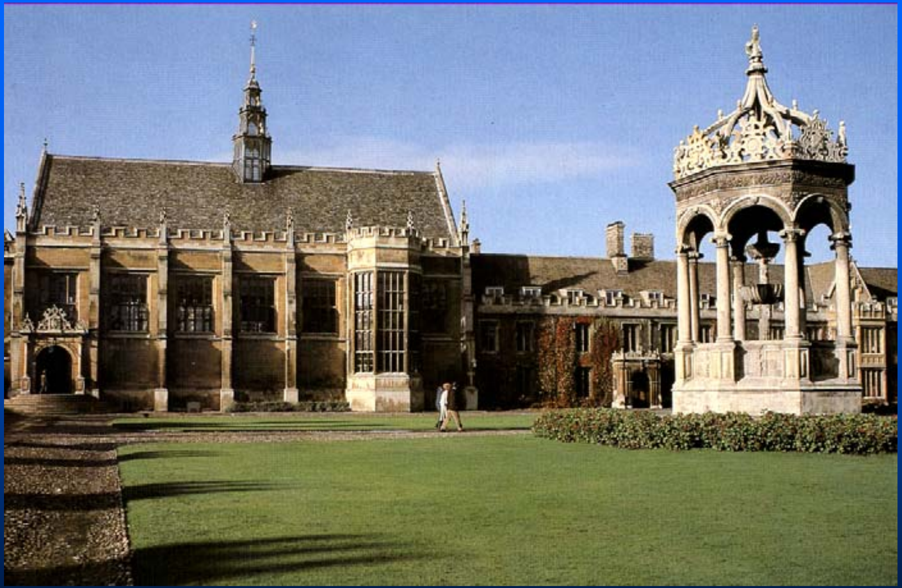
SIR ISAAC NEWTON (1642-1727)

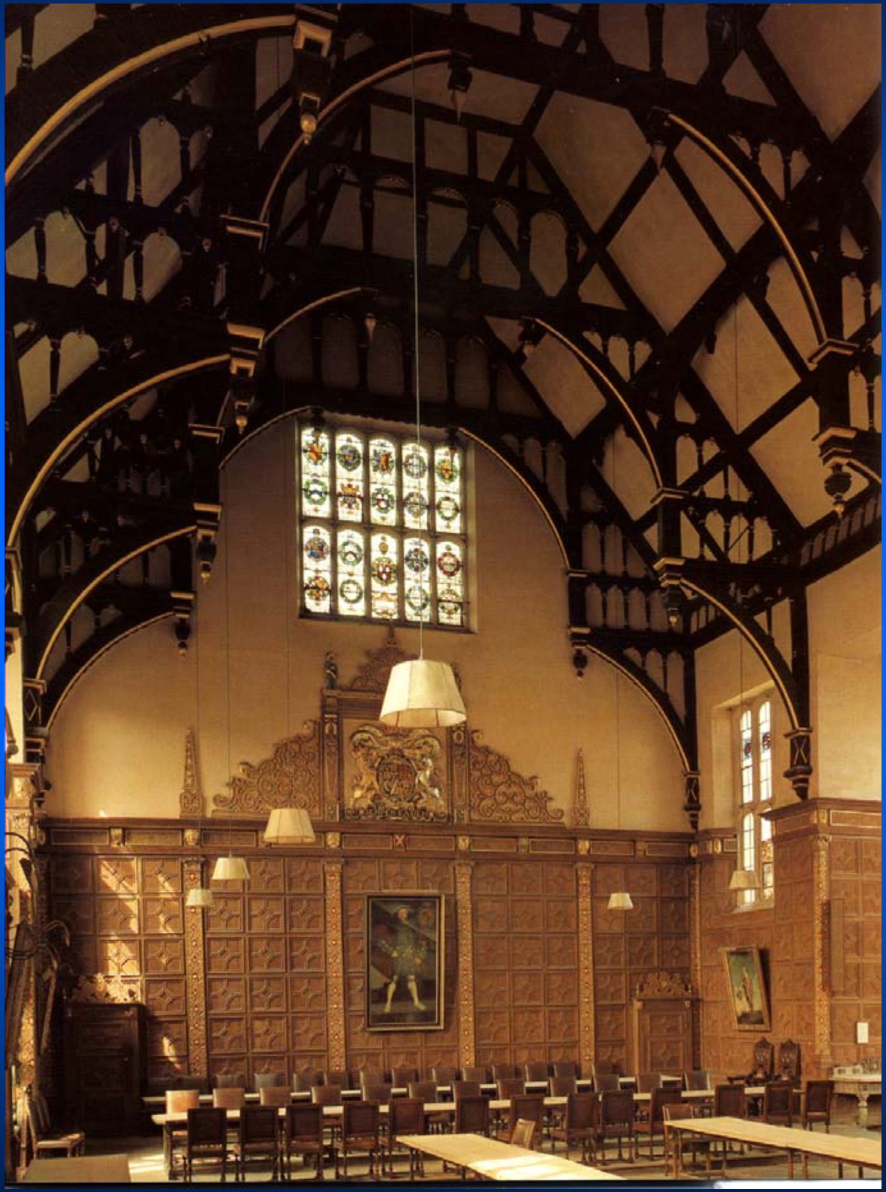


The young Newton

Born in the small village of Woolsthorpe, Newton quickly made an impression as a student at Cambridge- he was appointed full Prof. there in 1669, at the age of 27! He remained there until 1696, when he moved to London to work at the Royal Mint, where he worked for 30 yrs, and reformed the British monetary system.



Trinity College in Cambridge (refectory at left)



High Table inside the refectory, with Henry VIII

NEWTONIAN DYNAMICS (I)

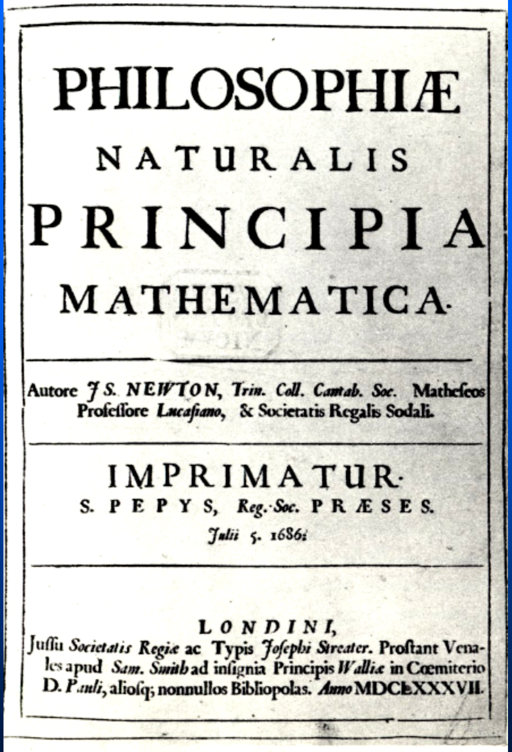
Although Newton published his complete theory in 1686, some of the important ideas in it date back to the period 1666-68, when he left Cambridge to spend the period of the plague at his mother’s home, Woolsthorpe Manor in Lincolnshire (see right). His reasons for delaying have interested historians ever since (see course notes).

In 3 volumes the Principia set forth the basic ideas and rules of Newtonian dynamics, and the law of gravitation, followed by a detailed analysis of their consequences. This involved a derivation of the dynamics of planets and comets, showing their motion would be that of a conic section (ellipse, parabola, hyperbola). Then there was a lengthy analysis of fluid and gas mechanics, & of the rotation of the earth, its shape, tides, and atmosphere. This hardly exhausts the material in a book of over 500 pages, with in parts very involved mathematical derivations.

Apart from the mathematical formulation of the dynamics, Newton also introduced a number of assumptions about the structure of space, time, and matter. Chief amongst these:

(i) In complete contrast to all prevailing ideas, he supposed space was empty and ‘absolute’ (as was time).

(ii) the gravitational force acted ‘at a distance’, through empty space.



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*. Proſtant Venales apud *Sam. Smith* ad inſignia Principis *Walliæ* in Cœmiterio D. *Pauli*, alioſq; nonnullos Bibliopolas. *Anno* MDCLXXXVII.

NEWTONIAN DYNAMICS (II)

As everyone learns in high school, 'Newton came up with his laws of dynamics and his law of gravitation, and this changed the world'. The basic results were summed up as follows:

(1) Every body continues in a state of uniform (ie., unaccelerated) motion unless acted upon by a force.

(2) The force **F** and acceleration **a** of a body with mass **m** are related by **F = ma**

(A) The laws of dynamics were

(3) For every force acting on a body, there will be an equal and opposite reactive force acting somewhere.

(B) The universal law of Gravitation: that between any mass m_1 and another mass m_2 separated by a distance **r**, there will be an attractive force

$$F = G \frac{m_1 m_2}{r^2}$$

where **G** is a constant (now called the 'constant of gravitation').

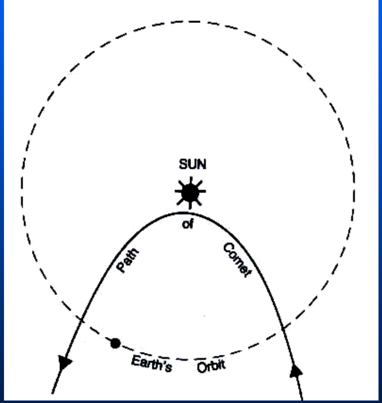
In addition to these laws (which he did not really formulate in this way), Newton also gave arguments for the existence of what he called 'Absolute space' & 'Absolute time'. These assumptions caused debate even at that time (particularly with Leibniz) and turned out to be inessential to the theory- however the points raised are very important (see notes, and also Newton's "scholium", reprinted in the supplementary notes).

NEWTONIAN DYNAMICS (III)

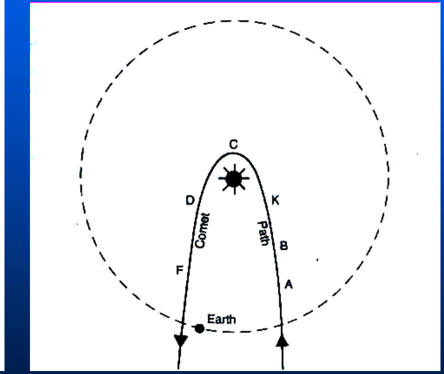
To unpack Newtonian dynamics means looking at the assumptions which underlie their formulation- in particular, the meaning attached to lengths, times, masses, and forces, and how they were supposed to defined in the real world. These assumptions raise a number of subtle Questions, particularly when one is dealing with non-inertial (ie., accelerated) frames of reference.


Edmund Halley
(1646-1742)

Just as important is knowing how to use these laws to understand the motion of objects, of fluid & gas mechanics, etc… This is part of the education of, eg., a modern engineer. Naturally the first applications by Newton and later by others was to 'simple' problems like planetary and comet motion, the shape of the earth, etc. As an example, consider the dynamics of comets, which in those days were considered to be rather mysterious. Extensive observations of these had been accumulated since Tycho, and the English "Astronomer Royal" Flamsteed was one of the authorities on cometary movements- his picture of their orbits is shown below. This nicely illustrates the huge gap in understanding that was bridged by Newton's work- a by-product of his law of Gravitation was that the comets must follow conic section orbits (ellipses, parabolae, hyperbolae), with calculable deviations coming from their interactions with the planets. The picture of Newton's is from a letter he wrote to Flamsteed. Using Newton's ideas his friend Halley predicted the return of the famous comet in 76 yrs.



Flamsteed's picture

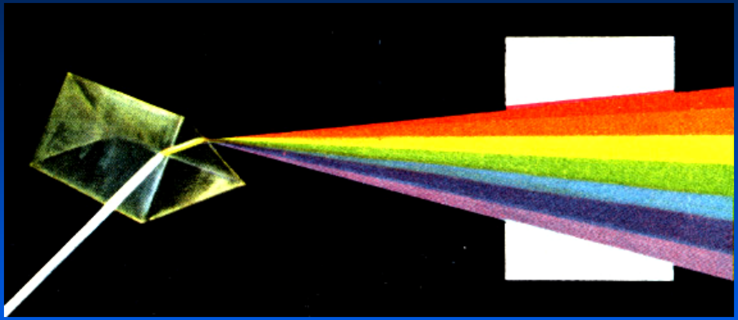


Newton's picture

NEWTON: OPTICAL RESEARCH

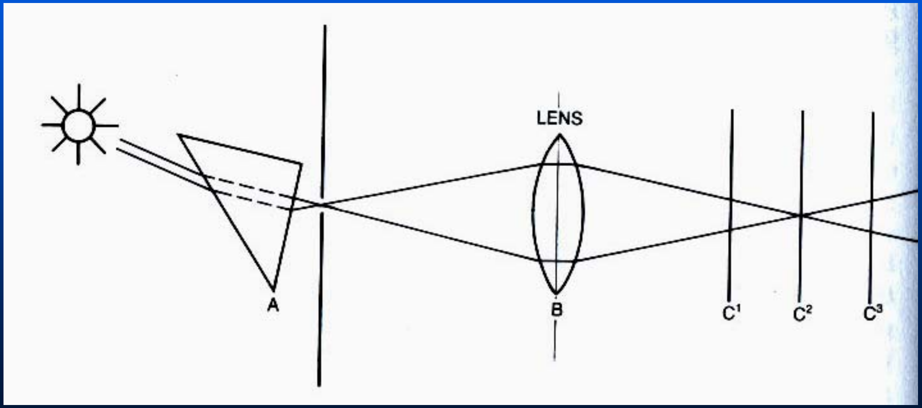
Newton's 2nd reflector (1671)

Newton began his optical work very early- already in 1670 he had presented his reflecting telescope to the Royal Society- these use a mirror to gather light instead of a lens. Such telescopes would later revolutionize 20th century astronomy. However at the time his most noted result was the demonstration of the composition of light spectra, using multiple prisms. By recombining light of different colours, (as shown below) he was able to understand a great deal about the nature of colour perception. For Newton this was a classical example of the 'experimental philosophy' in action.

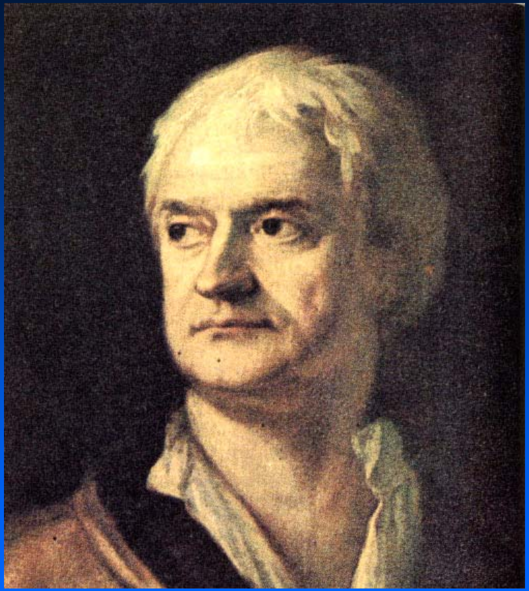


Refraction of white light by a prism

Newton believed that light was made up of tiny particles (light 'corpuscles') which obeyed the same dynamics as ordinary matter. His ideas on this are a little obscure- for more details see the notes. Certain facts about light propagation had to be explained in any reasonable theory- the laws of reflection and refraction (including the way in which the amplitudes of these varied with angle of incidence on a boundary between 2 media), the difference in these angles for different colours, and the nature of the colours. As we saw previously, there was also a competing theory- the wave theory of Huyghens.



NEWTON'S LEGACY



I. Newton, around 1700

G.W. Leibniz
(1646-1716)

Only 2 of Newton's contemporaries were really able to understand the full implications of his work. Leibniz was not only one of the most important mathematicians of all time, but also a central figure in the development of rationalist philosophy (see course notes). His relations with Newton were very bad, because of the dispute over priority in the invention of the calculus. Of more interest to us now was their debate over the existence of absolute space and "action at a distance", conducted between Leibniz & Newton's proxy Clarke. The problems raised by Leibniz would not be fully solved until Einstein's general theory of relativity (1916).

In the same way the points raised by Huyghens, concerning both the question of action at a distance, and the nature of light, would not be solved until the 20th century. These questions are central to the whole of physics.

Nevertheless the change wrought by Newton's work was colossal. Quite apart from the formulation of what is now called 'Classical Mechanics' (whose subsequent application changed the course of history), Newton's work wrought a huge change in the way we thought about the world and our relation to it.

C, Huyghens (1629-95)