2. The Problem of Motion

HOW SHOULD WE THINK ABOUT MOTION?

- CLEARLY: DEFINITIONS (we require valid scientific theories)

- PRICESELY: MEASUREMENTS (we require mathematics)

Ancient Greek science

Aristotle:

“Everything in the right place…”

Early ideas about motion

ZENO (450BC):

Motion is impossible (paradoxes)

ARISTOTLE (335BC):

- Actions follow logically from causes

- "Natural" and "violent" motion

  - Natural motion implies falling at a speed proportional to the weight of the object and inversely proportional to the density of the medium
  - Violent motion happens whenever there is a force acting and the speed is proportional to the force

STRATO (250 BC):

Natural motion is an *acceleration*

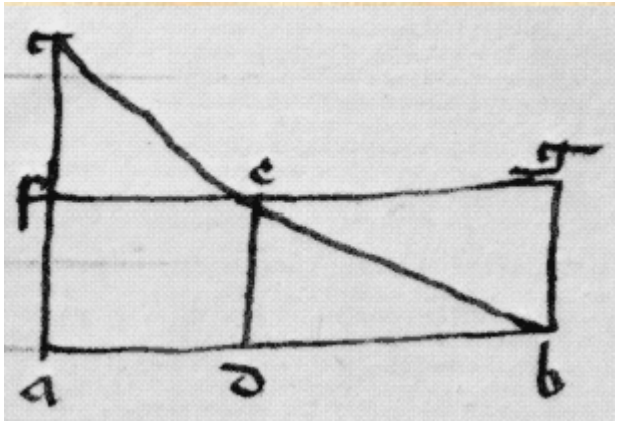
ARCHIMEDES (250 BC):

Experimentalist: concentrated on statics

Medieval kinematics

Jean Buridan (ca. 1300 – after 1358):
Impetus - The initial force imparts motion to the objects, which gradually diminishes as gravity and air resistance act against this initial force.

Nicole Oresme (c. 1323 - 1382)
Used graphs to describe motion; unwittingly used the notion of differentiation and integration



Later developments: Mechanics now described in mathematical language

Galileo (1564 - 1642) - KINEMATICS

- *Demonstrated* that "naturally" falling objects accelerate
- Realised that for "violent" motion, velocity is constant in the absence of friction
- Described projectile motion

Newton (1642 - 1727) - DYNAMICS

- Force produces an *acceleration*
- Universal gravitation

Maupertuis, Lagrange, Hamilton, etc (1700-1900)

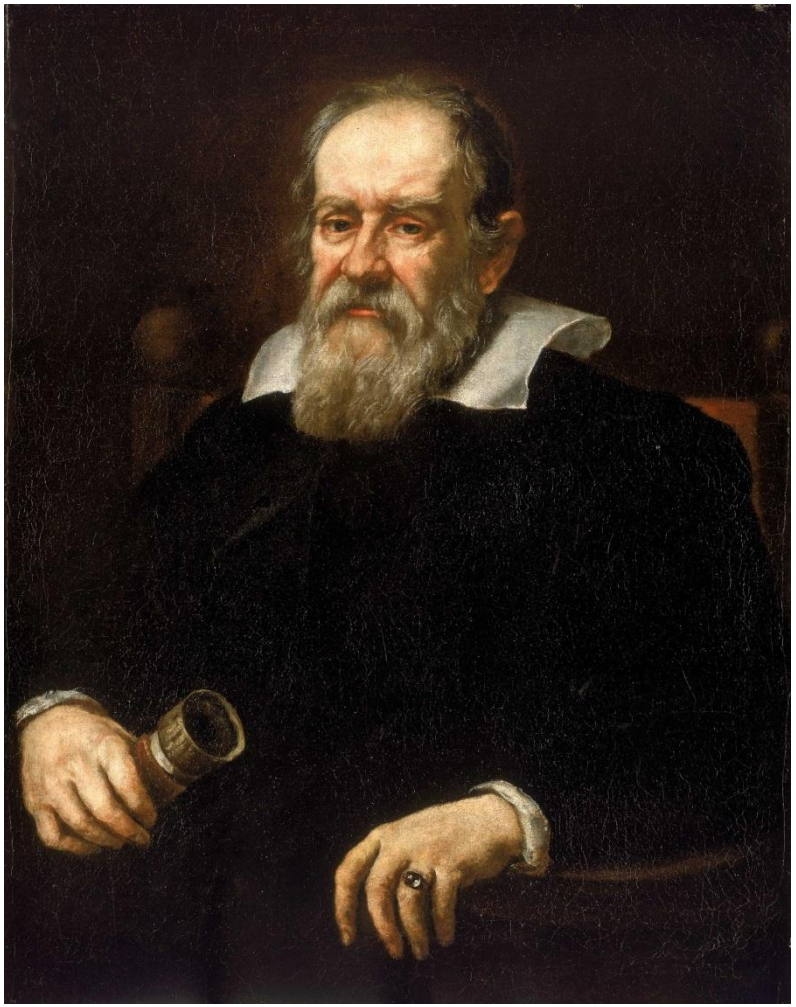
- Variational principles (Principle of least action; Lagrangian; action)
- All information at one point is described by one quantity

Einstein (1879-1955)

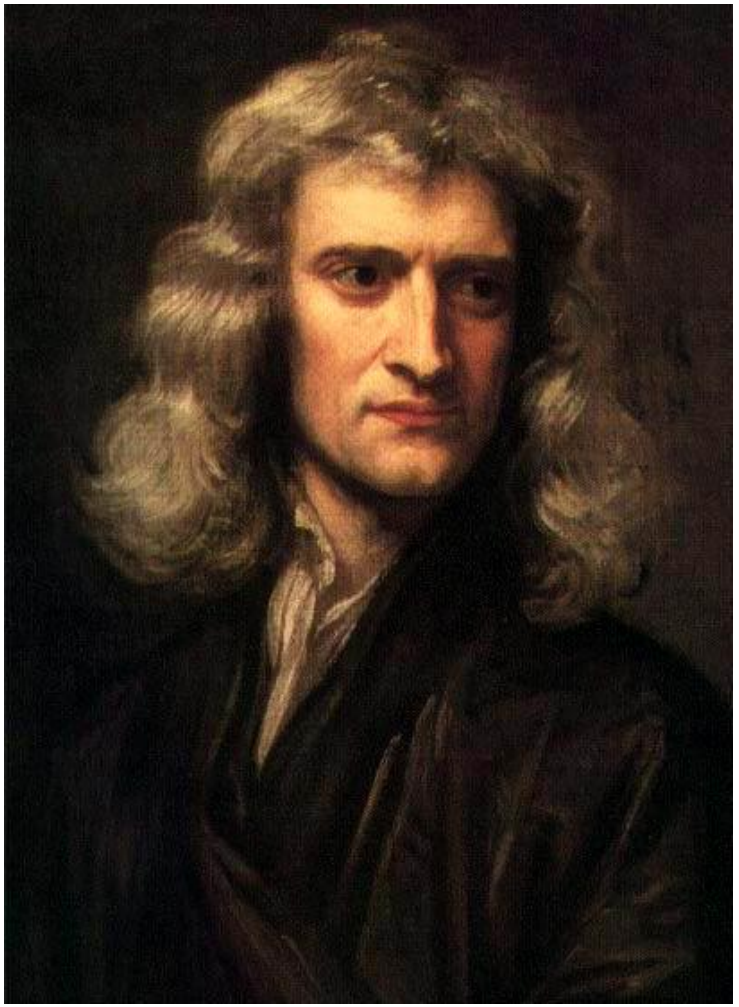
- Relativity

Planck, Bohr (1900 -)

- Quantum mechanics

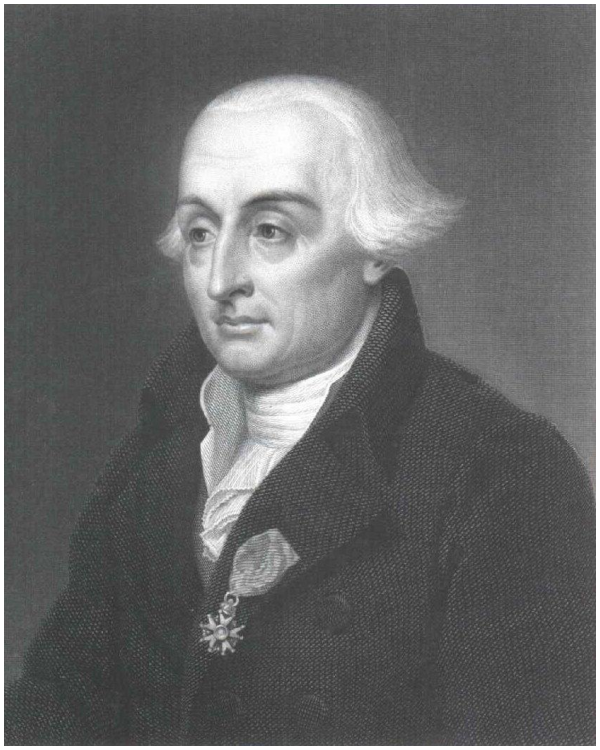


Galileo (1564 - 1642)

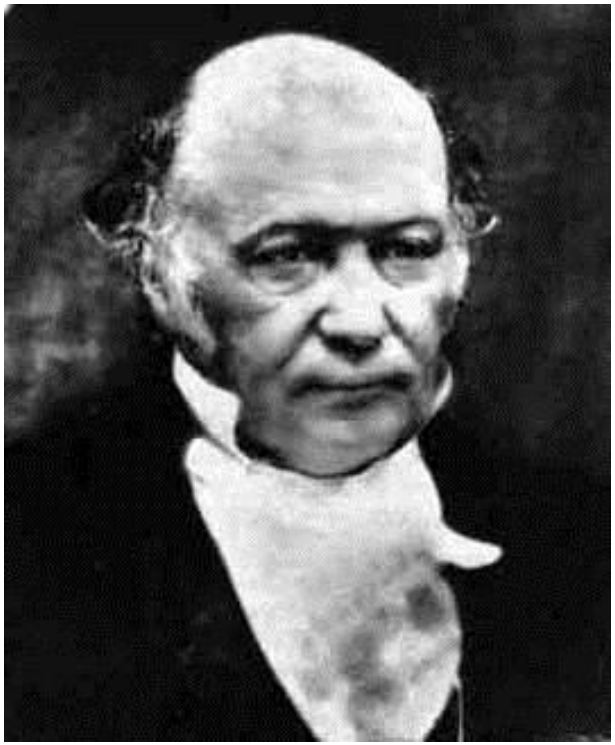


Newton (1642 - 1727)

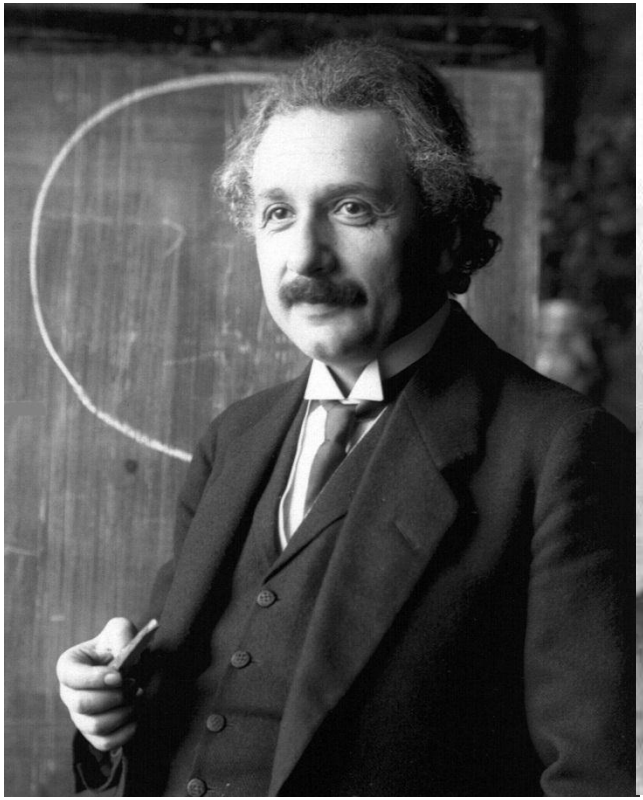
Maupertuis (1698 – 1759)



Lagrange (1736 – 1813)



Hamilton (1805 – 1865)



Einstein (1879-1955)

Planck (1858-1947)

Bohr (1885-1962)

Q. What is motion?

A. Motion is the change of position over time

(TEXTBOOK DEFINITION)

Mechanics (The study of the motion of objects)

Statics

The study of stationary objects and the forces acting on them:

- **Equilibrium**
- **Buoyancy**
- **The lever**

Kinematics

The description of the motion of objects

e.g.

- **Uniform motion**
- **Uniform acceleration**
- **Projectiles**
- **Circular motion**

Dynamics

The interaction of forces with motion

- **Newton's laws**

Q. What is position ?

A. Position is the distance and direction from a fixed point

Position is a vector

The properties of distance reflect the geometry of the space it is measured in

Assumption of classical mechanics: Space is flat (Euclidean)

Q. What is distance (length) ?
A. Distance is what is measured by a ruler

The unit of length is the metre

1983: 1 m is the distance travelled by light in a vacuum in 1/299792458 s.

Note: This assumes the constancy of the speed of light and the definition of the second.

Earlier definitions of the metre

- Length of a particular stick (later a metal bar) kept in Paris
- 1/40 000 000th of the circumference of the Earth
- The length of a pendulum which will complete one swing (1/2 cycle) in 1s.

Time

Q. What is time?

A. Time is what is measured by a clock

The unit of time is the second

Since 1967, the second has been defined to be the duration of **9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom**

1970s: atom at mean sea level

Added in 1997: This definition refers to a caesium atom at rest at a temperature of 0 K.

Solving equations in physics

- Try to find simplest formulation possible
- **Analytical solution:** how the model will behave under any condition.
- Use approximations if necessary
- Find a semi-analytical solution
- Very often, models are too complicated
- **Numerical solution:** Use you equations to calculate the change in the value of variables over some period of time.
- Most of modern physics is about finding better numerical methods.
- Sooner or later, we will all become programmers.