



Lecture 6
Newton's laws:
The foundation of
modern science

- Better data

Tycho Brahe

- Final touch-up of the model

Johannes Kepler

- Promotion of the new model

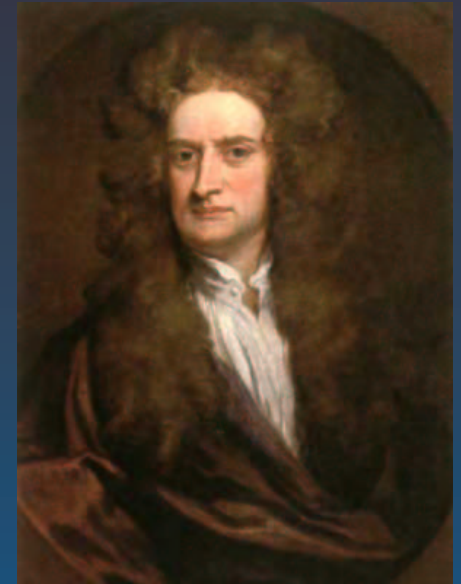
Galileo Galilei

Still missing: someone to put the pieces together in order to form a coherent physical theory in the modern sense

⇒ **Sir Isaac Newton**

Sir Isaac Newton

(1643-1727)



- Fundamental contributions in optics, physics and mathematics:
 - invented calculus (independently: Leibnitz)
 - invented the mirror telescope
 - discovered that white light is composed of colored light
 - Theory of mechanics
 - Theory of gravity
 - demonstrated that Kepler's laws are a consequence of the theory of mechanics and gravity: *Principia*

Newton's three laws of motion

Newton's first law: A body at rest or in the state of uniform motion will remain at rest or in uniform motion, unless acted upon by a net external force.

Consequences of Newton I

- Following Galileo, a force is required to **change** motion, but not to maintain it.
- Change in motion means
 - moving faster
 - moving slower
 - changing the direction

**Question: How many accelerators
has a car ?**

Answer: three !

- The accelerator (speeding up)
- The break (slowing down)
- The steering wheel (changing direction)

Short math excursion:

Scalars and Vectors

- **Scalar:** a quantity, which can be completely specified by one single number
- **Vector:** a quantity, which in addition requires the specification of a direction
- **Examples:**
 - **Scalar:** volume, temperature, weight
 - **Vector:** velocity, acceleration, force

Newton's three laws of motion

Newton's second law (law of inertia):

The acceleration of an object is equal to the net force applied to it, divided by its mass.

$$\mathbf{F} = \mathbf{m} \times \mathbf{a}$$

Example: Why can you throw a baseball farther than a bowling ball?

Answer:

- The force you apply to both balls is the same
- The bowling ball has a larger mass [inertia]
⇒ the acceleration is smaller

Newton's three laws of motion

Newton's third law: For every action, there is an equal and opposite reaction.

Examples:


- Recoil of a gun
- Jump from a boat onto the shore
- two ice skater pushing each other
- rocket in space

Crash test: all three laws at work

- Initially, car and driver in uniform motion
- Car hits wall
 - Newton 1: wall exerts a force onto the car
⇒ car stops
 - Newton 2: car stops ⇒ acceleration is large ⇒ forces are large ⇒ car deforms
- A priori no forces on driver
 - Newton 1: driver keeps on moving on a straight line at constant speed

Crash test: all three laws at work

- driver buckled up: seat belt exerts force onto driver, slows him down (Newton 1+2)
- driver not buckled up: driver's head exerts force onto windshield, bursts it, flies through windshield, keeps on going until he eventually hits ground (Newton 1)
- Newton 3:
 - car bounces back
 - buckled driver falls back into his seat
 - unbuckled driver: windshield exerts force on driver's head, smashes driver's head.



Kepler's three laws, Newton's three laws, what is the difference ?

Kepler's three laws

Kepler's first law: Planets orbit the Sun in an ellipse, with the Sun at one focus.

Kepler's second law: The line from the Sun to the planet sweeps out an equal area in an equal time.

Thus planets move faster if they are nearer the Sun.

Kepler's third law: The square of the period of the orbit is equal to the cube of the semimajor axis of the ellipse.

Empirical laws

Newton's three laws

Newton's first law: A body at rest or in the state of uniform motion will remain at rest or in uniform motion, unless acted upon by a net external force.

Newton's second law: The acceleration of an object is equal to the net force applied to it, divided by its mass.

Newton's third law: For every action, there is an equal and opposite reaction.

Axioms