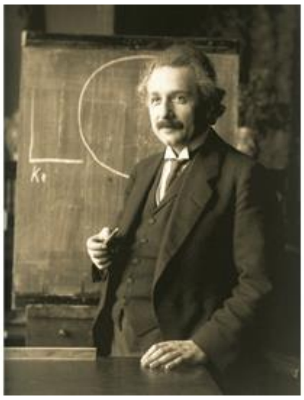
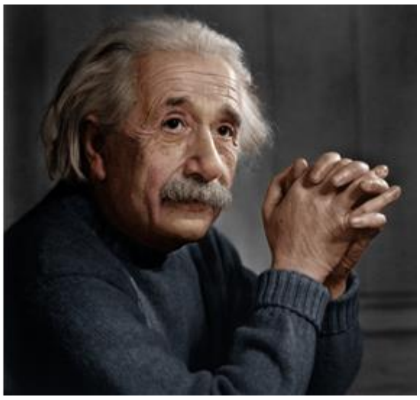
How fast can things go?

Lesson 5: Introduction to Einstein's Theory of Special Relativity

Albert Einstein (born in 1879 and died in 1955)
German born theoretical physicist who invented …………………………… ………………………………… in 1905.

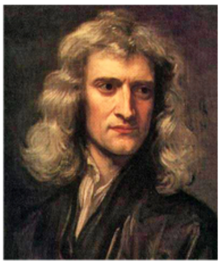




Newton's First Law of Motion

An object will continue in a state of rest or uniform velocity unless acted upon by a net unbalanced force.

But here is nothing special or .... about the state of rest or ....velocity.



Sir Isaac Newton
(1642-1726)

Earth moves around the Sun at 110,000 kmph

The Sun moves around galactic centre at 720,000 kmph

Galaxies are moving away from each other at very high speed.

There is no such thing as …………………… rest.

This also implies that there are no ………………………… to space and no ………………………………..

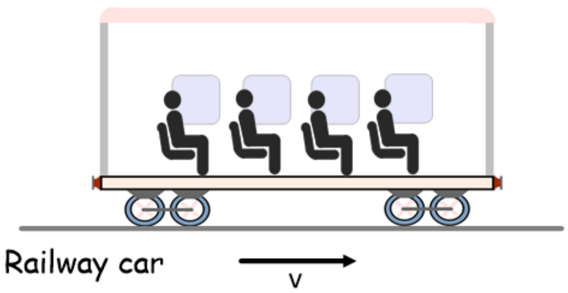
All motion or rest is only in relation to other observed objects or **frames of reference.**

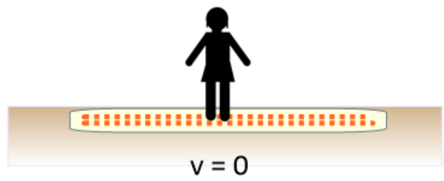
A frame of reference is a method of describing the position, velocity and acceleration of an object. This is usually some type of coordinate system.

It is important to distinguish between **inertial** and **non-inertial** frames of reference

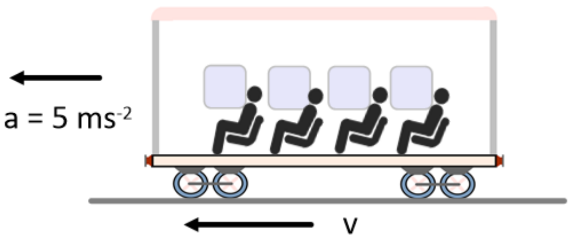
An **inertial** frame of reference is one which remains at rest or moves with .... linear velocity.

These are both **inertial** frames of reference.

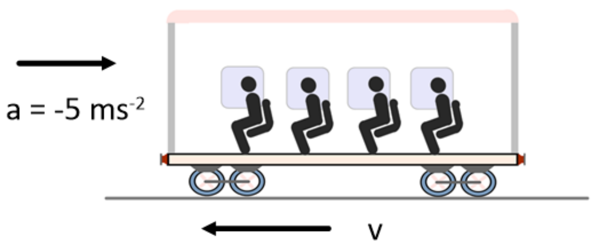




A **non-inertial** frame of reference is one that is ....



OR



Galilean Relativity or the Galilean/Newtonian Principle of Relativity

All motion or rest is only in relation to other observed objects or **frames of reference.**

It is not possible to have a velocity relative to .... itself.

Einstein extended this to say that

There is no experiment that can tell if you are at rest or moving uniformly (that is, moving in a straight line with constant velocity)

The laws of physics must apply .... in any non-inertial frame of reference.

Michael Faraday was an English scientist who performed experiments to discover many of the fundamental principles of electricity and magnetism.

In the 1830's he suggested that light may be some sort of electromagnetic .... phenomenon.

Michael Faraday
(1791 - 1867)

In the 1860's **James Clerk Maxwell** developed Faraday's idea into his famous electromagnetic equations.

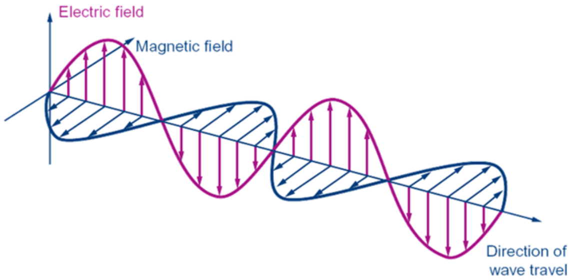
$$\oint \vec{E}\cdot d\vec{A} = q/\epsilon_0 \qquad \oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{B}\cdot d\vec{A} = 0 \qquad \oint \vec{B}\cdot d\vec{s} = \mu_0\epsilon_0\frac{d\Phi_E}{dt} + \mu_0 i$$

James Clerk Maxwell

(1831–1879)

The equations suggested that accelerating charges might produce .... waves which propagate through space.



Maxwell's equations predicted that the speed of electromagnetic radiation (light) would be given by a simple expression involving electric and magnetic field constants.

$$c = \frac{1}{\sqrt{\varepsilon_o \mu_o}} = 3.00 \times 10^8\ ms^{-1}$$

where

ε_o = ... constant (permittivity of free space)

μ_o = ... constant (permeability of free space)

Einstein noted that nothing in the equation or its derivation suggested that the speed should depend on any ………………………… motion.

Maxwell's formula predicted the value of the speed of light before it was accurately measured by Fizeau and Foucault in 1849-50. The measured value ………………………………….with Maxwell's prediction.

But this expression suggested that electromagnetic waves would travel at this fixed speed in **any** frame of reference.

Most physicists, including Maxwell, thought this must be wrong and that perhaps this speed was relative to an aether.

They postulated the existence of a ………………………………. called the **aether** (or ether) which filled all space and 'carried' electric and magnetic fields.

It was thought that any measured speed would have to be adjusted to account for the observer's own speed through that medium (the aether).

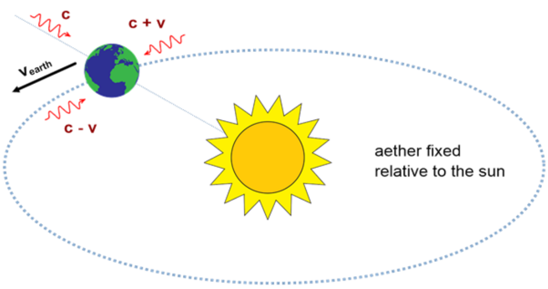
Einstein saw this as a real problem.

If the speed of light depended on the velocity of an inertial frame of reference (the aether), it would conflict with the principal of Galilean relativity which Einstein was reluctant to abandon.

The Michelson-Morley Experiment

In 1831, two American scientists, Michelson and Morley, set up an experiment using light and mirrors to detect the aether.

They hypothesised that if the Earth moves around the Sun then it must travel through the aether.

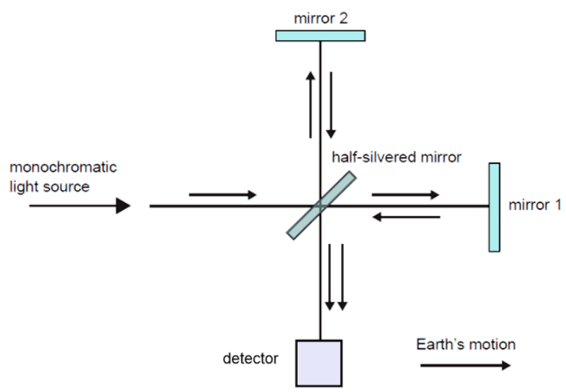


There should be a difference in the measured speed of light depending on whether light is travelling ………………….. or ……………………………. to the direction of the Earth's movement through the aether.

The apparatus was set up so that light travelling towards mirror 2 was travelling ……………………………. to the motion of Earth around the Sun.

Light travelling towards mirror 1 was in the direction of Earth's motion in its orbit.

The situation is similar moving upstream in a boat against the current.



There should be a difference in the measured speed of light depending on whether light is travelling parallel or perpendicular to the direction of the Earth's movement through the aether.

The Michelson Morley experiment detected ……………………… variation in the speed of light.

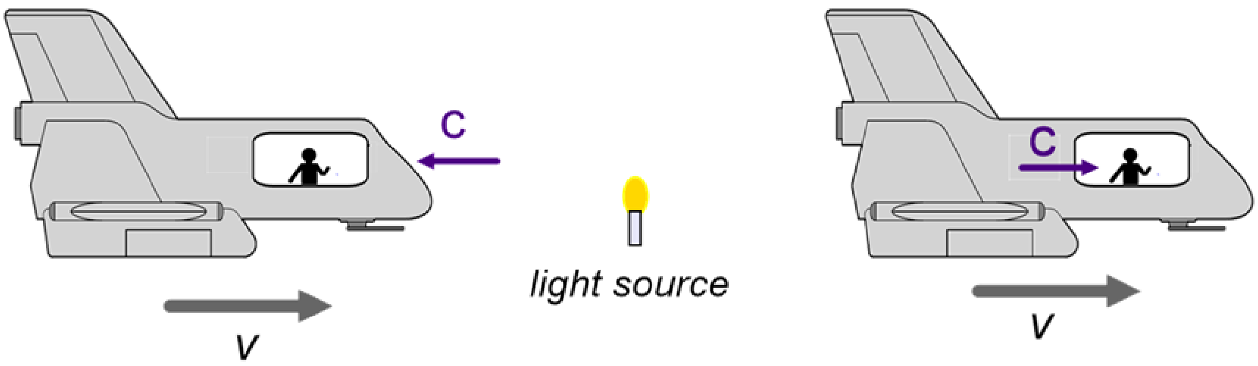
Due to this **null result**, scientists gradually …………………………….the idea of the ether.

They began to accept the idea that the speed of light is the ………………………………. in all directions.

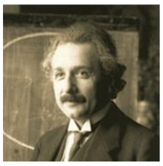
Einstein decided that the aether was simply unnecessary and ignored it.

Electromagnetic waves could move through space without a …………………………….

Einstein accepted both Galileo's and Maxwell's theories even though they appeared to be contradictory.



How could observers travelling towards and away from a light source, see the same light beam travelling at the same speed?



To resolve the problem, Einstein reconsidered the assumptions on which Newton based his theories.

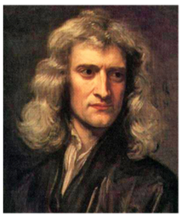
In 1687 Newton published his famous Principia, the work which was the foundation for all of physics in the following two centuries.

Newton stated

The following two assumptions are assumed to be evident and true:

Absolute, true and mathematical time, of itself, and from its own nature, flows equably without relation to anything external.

Absolute space, in its own nature, without relation to anything external, remains always similar and immovable.



Einstein realised that these assumptions may not be valid, particularly when speeds approach the speed of light and huge distances are involved

The only way in which Einstein's two postulate can be true is if both **……………………… and ………………………. are not fixed and unchangeable.**

All motion is ………………………………., there is no absolute frame of reference.

However changes of velocity are absolute, acceleration is absolute.

These seem quite simple and straight forward, but in classical (Newtonian) physics they are inconsistent.

Einstein's postulates for the theory of special relativity

This led to his two famous postulates:

I The laws of physics are the same in all .... frames of reference.

II The speed of light in free space has the .... value *c* in all inertial frames of reference.

This implied that time seems to be ....!