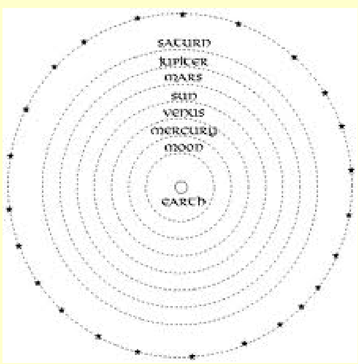
Agenda

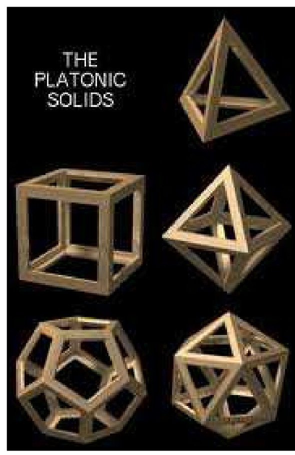
Introduction
- Space, Time and Matter ✓
- Early views of the cosmos ✓
- Important Ideas from Classical Physics ✓

Two 20th Century revolutions in Physics
- Relativity
- Quantum Theory

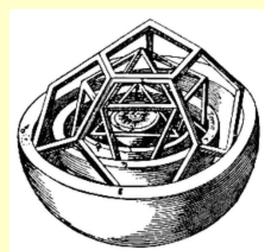
Interwoven with Ideas from Astronomy and Cosmology

The Early (Geo-centric) Universe





Tetrahedron	Fire
Hexahedron	Earth
Octahedron	Air
Dodecahedron	Water
Icosahedron	Ether



The Big Ideas (so far)

1. Pythagoras – What we observe we can understand. But no one said it would be easy!

2. Anonymous –Heliocentric solar system.

3. Copernicus – There is no preferred place in the cosmos. This implies that the laws of the universe are the same everywhere.

4. Galileo – Father of Experimental Science

5. Isaac Newton – Calculus, Laws of Motion, Laws of Gravity

The phenomena we seek to describe takes place in Space and over Time

… so we must be able to describe these two quantities.

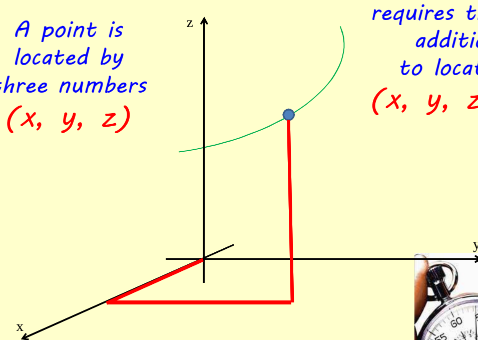
Rene Descartes
(1596 – 1650)
French philosopher and mathematician

"Cogito ergo sum"

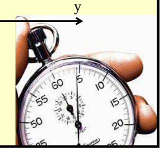
Developer of analytic geometry

Cartesian Coordinate System

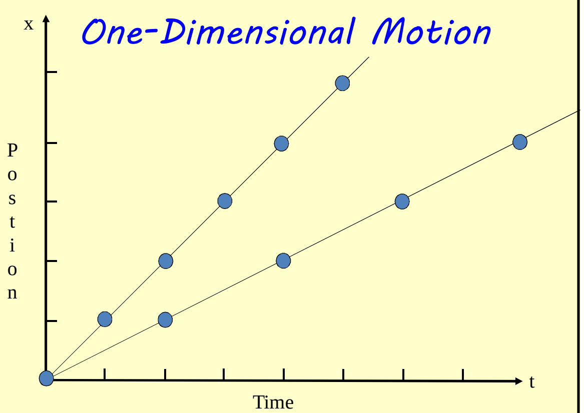
A point is located by three numbers
(x, y, z)



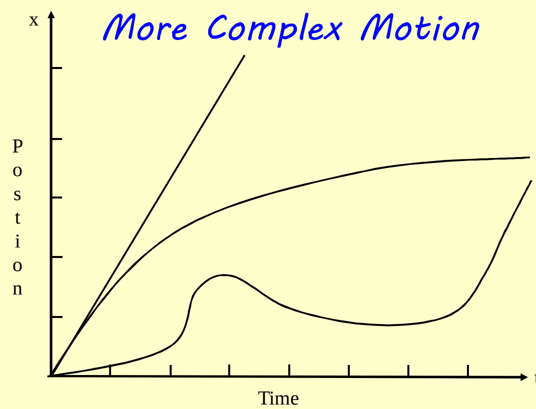
Motion of that point requires time in addition to location
(x, y, z)(t)



One-Dimensional Motion



More Complex Motion



Inertia

All objects have a resistance to changing their motion.

It is easier to throw a book than a bookcase.

… because the bookcase has a larger inertia than a book.

It is easier to throw a cricket ball than your brother.

… it is easier to throw your brother than a car.

Mass

We quantify the Inertia of an object by its mass.

Measured in kilograms.

Inertia is the resistance to motion. Sometimes forces act so fast that inertia holds an object back.

Newton's Law of Inertia

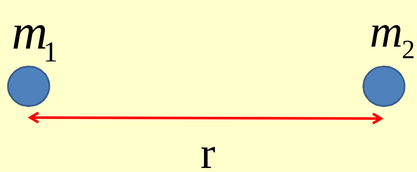
An object in motion at a constant speed will remain in motion at that speed unless acted on by an outside force.

The constant speed could be zero.

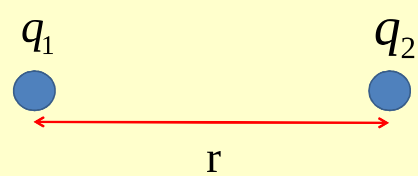
It takes a force to change motion.

The Universal Forces in Nature

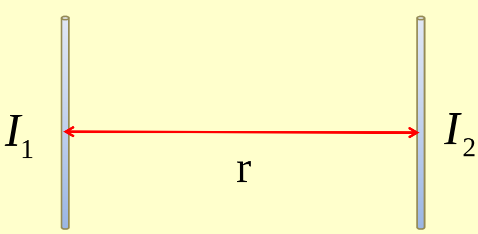
- Long range forces can act without contact?
  - Gravity
  - Electricity
  - Magnetism
- There is one other force that we cannot demonstrate – Nuclear force



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



$$F_{electric} = k_e \frac{q_1 q_2}{r^2}$$



$$\frac{F_{magnetic}}{Length} = 2k_m \frac{I_1 I_2}{r}$$

James Clerck Maxwell (1831 –1879)

$$\frac{k_e}{k_m} = c^2$$

$$c = \text{speed of light}$$

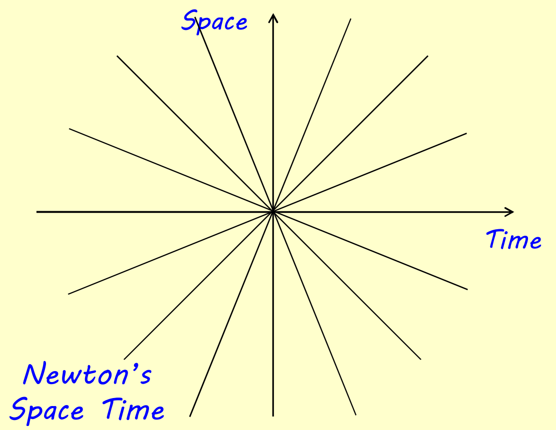
This result forces a change in how we think of space and time.

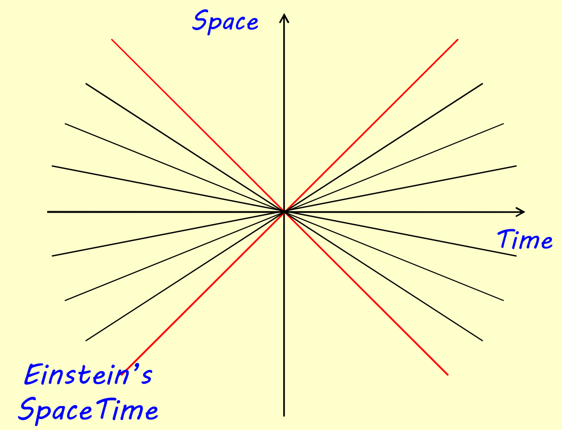
Axioms of Special Relativity

1) The laws of physic are the same for all observers moving uniformly with respect to each other.

2) The speed of light, c, does not depend on the speed of the emitter.

C is a speed limit

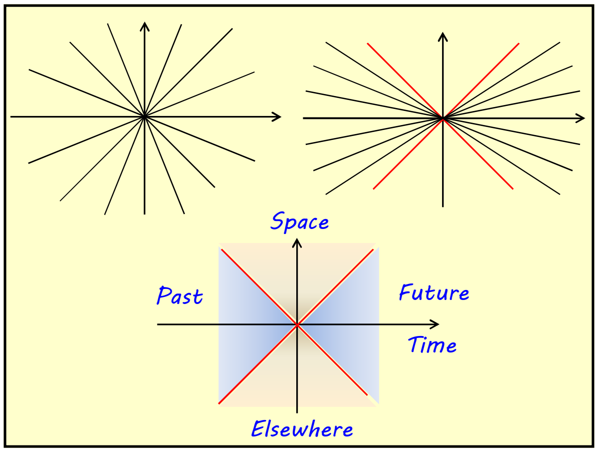


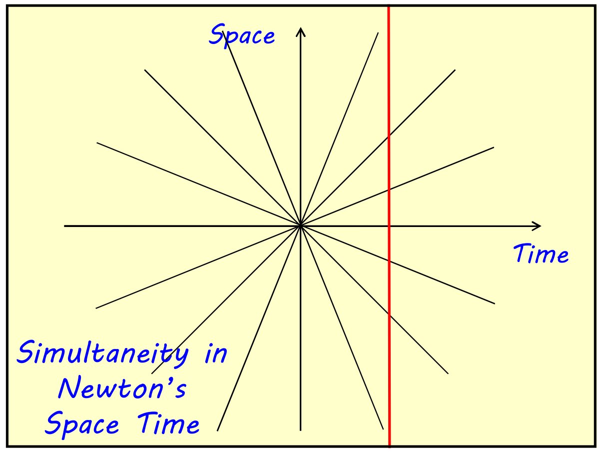


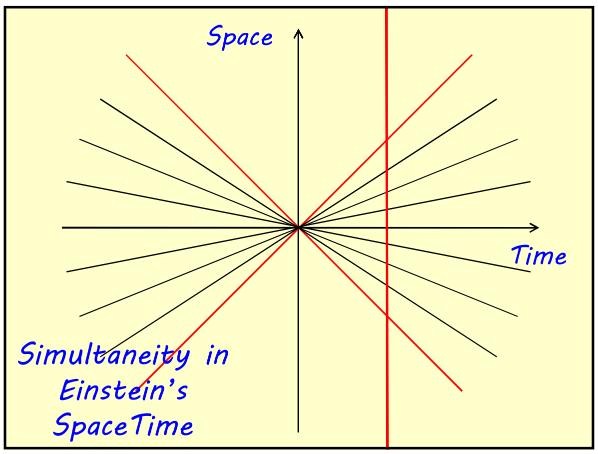
To reconcile the universality of the speed of light from Maxwell's theory of electromagnetism, we need to change our concept of space and time.

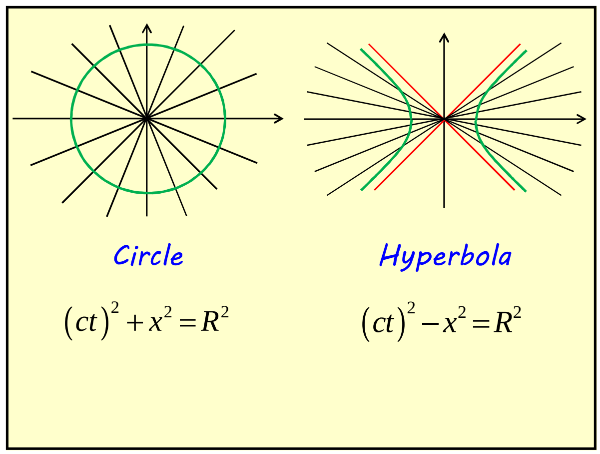
Frame of Reference
Newton's Space and Time
(x, y, z) (t)
3-d + 1-d

Einstein's Spacetime
(x, y, z, ct)
4-d









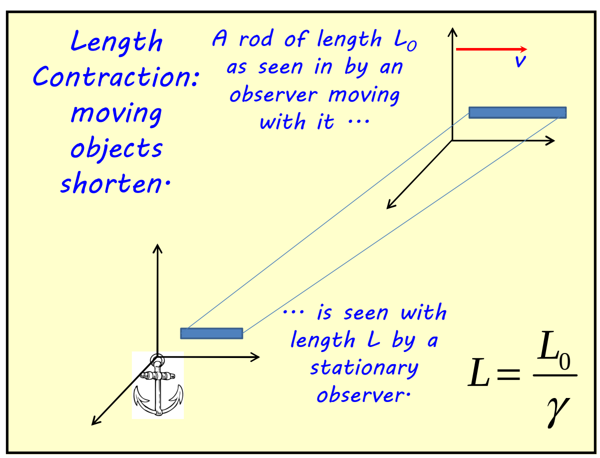
Consequences of Special Relativity

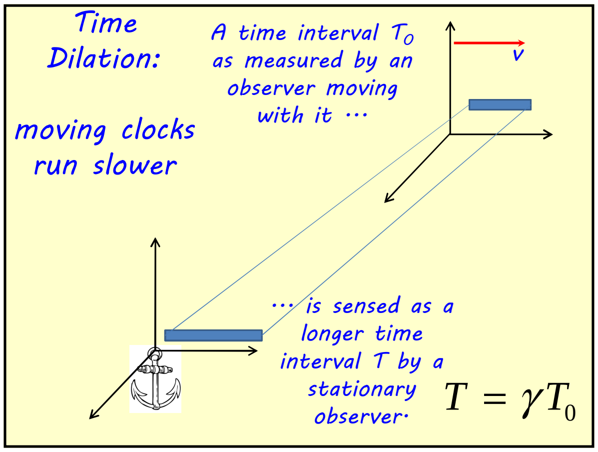
Simultaneity
Length contraction
Time dilation
Velocity combination
Change in conception of energy & momentum
Interchangeability of mass and energy

$$E = mc^2$$

$$m = \gamma m_0 = \gamma(\text{rest mass})$$

$$\gamma = 1 \Big/ \sqrt{1 - v^2/c^2}$$




Time Dilation:
moving clocks run slower
A time interval T_0 as measured by an observer moving with it …
v
… is sensed as a longer time interval T by a stationary observer.
$T = \gamma T_0$