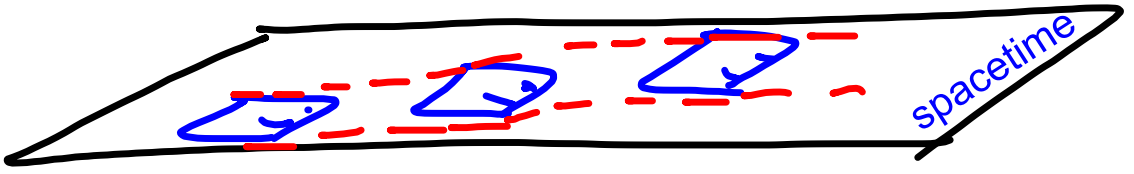
Our Spacetime has 3 Dimensions + Time

If you could get outside of Spacetime, what would you see?

All space at all times.

"the bulk"



"the bulk"

Newton & Gravity

Gravity is universal

- Every mass attracts every other mass.
- Proportional to the two masses multiplied.

Gravity weakens with distance

- Proportional to $1/d^2$

distance	1x	2x	3x	4x	...	10x
force of gravity	1	1/4	1/9		...	

6.67×10^{-11} 0.00000000000667

Universal Law of Gravitation

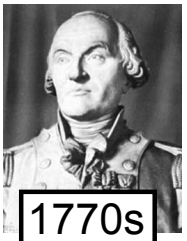
$$F = \frac{Gm_1m_2}{d^2}$$

Newton & Gravity

Action at a distance?

"Hypothesis non fingo"

ELECTRICITY & MAGNETISM



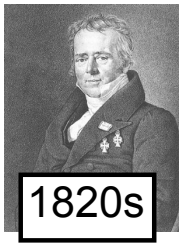
Charles de Coulomb

Force between electrical charges & force between magnets behave the same way.

$$F = \frac{Kq_1q_2}{d^2}$$

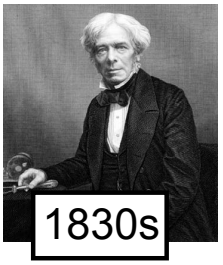
9×10^9

9,000,000,000



Hans Christian Ørsted

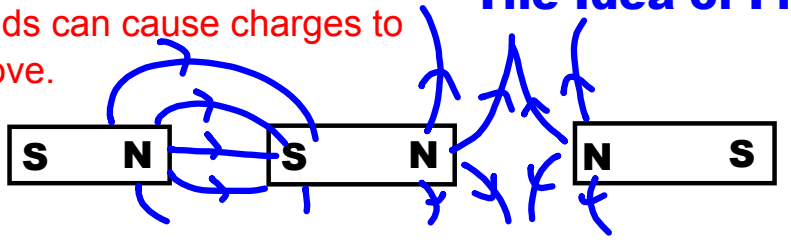
Moving charges have magnetic fields.



Michael Faraday

Moving or changing magnetic fields can cause charges to move.

The Idea of Field



James Clerk Maxwell

Comprehensive picture & system of equations governing all electromagnetic phenomena

Maxwell's Equations

Prediction of Electromagnetic Waves

Visible light, radiowaves, ultraviolet, infrared, microwaves, x-rays, gamma radiation are all electromagnetic waves that differ in frequency.

Measuring the Speed of Light was tricky!

Edward Morley

Albert Michelson

300,000,000 m/s

186,000 miles/sec

About 6 trillion mi/hr

One issue:

What is the medium for light?

Special Relativity

But attempts to measure the speed of light while moving (catching up to it) showed no change in its speed.

Einstein (1905): what if...

1) The speed of light is constant no matter how you move.

2) The laws of physics have to work for everyone, no matter how you move.

Inescapable Conclusions:

Time and space are connected.

Your time & space are distorted by motion.

Spacetime: 4-dimensional

General Relativity

1) Accelerations distort spacetime.

2) Accelerations cause:

- Time to tick more slowly.
- Space to be contracted.
- Mass to increase.

3) Gravity is an acceleration.

Of everything you're seeing in the film, the time differences are the most well-confirmed by direct evidence.

Gravity bends spacetime

The path of light and moving objects are bent by it