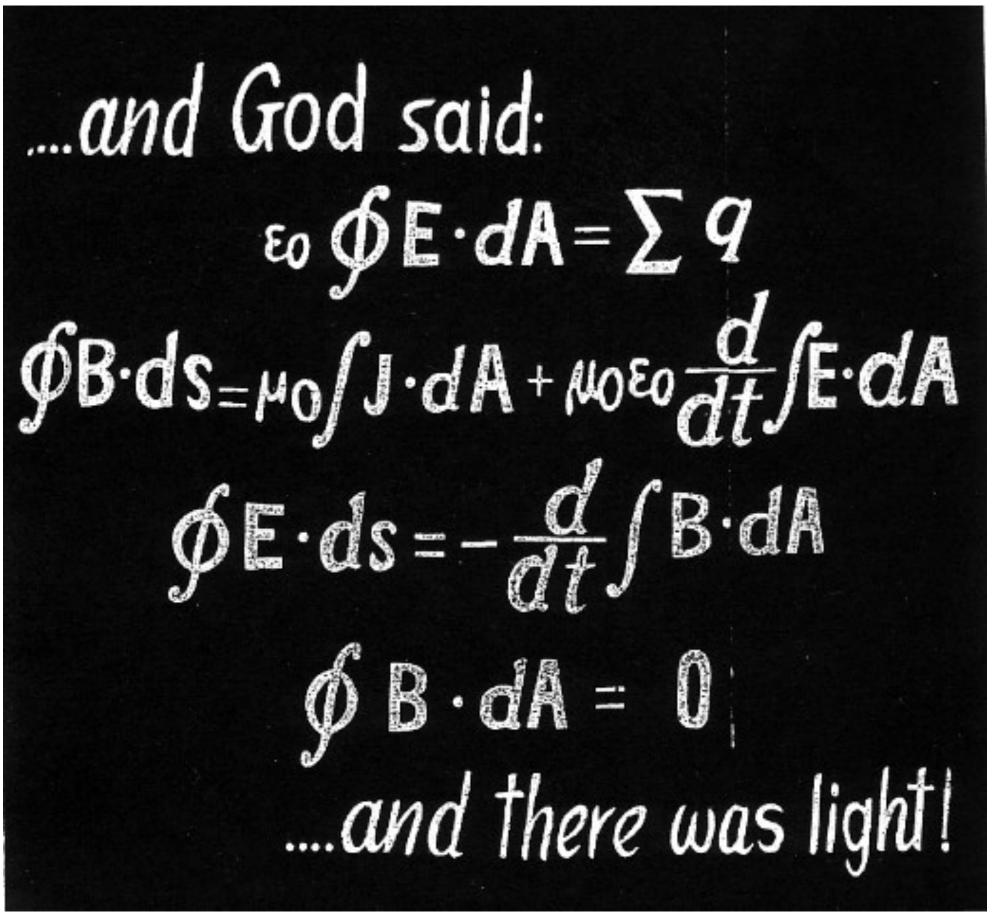
James Clerk Maxwell 1831-79

He took up the study of electromagnetism and light where **Michael Faraday** (1791-1867) left off, and developed a complete description of all classical electromagnetic phenomena.

He summed all what was then known about electromagnetism in a set of 4 equations – MAXWELL's EQUATIONS.



Exercise I

$$x' = x - vt$$
$$y' = y$$
$$z' = z$$

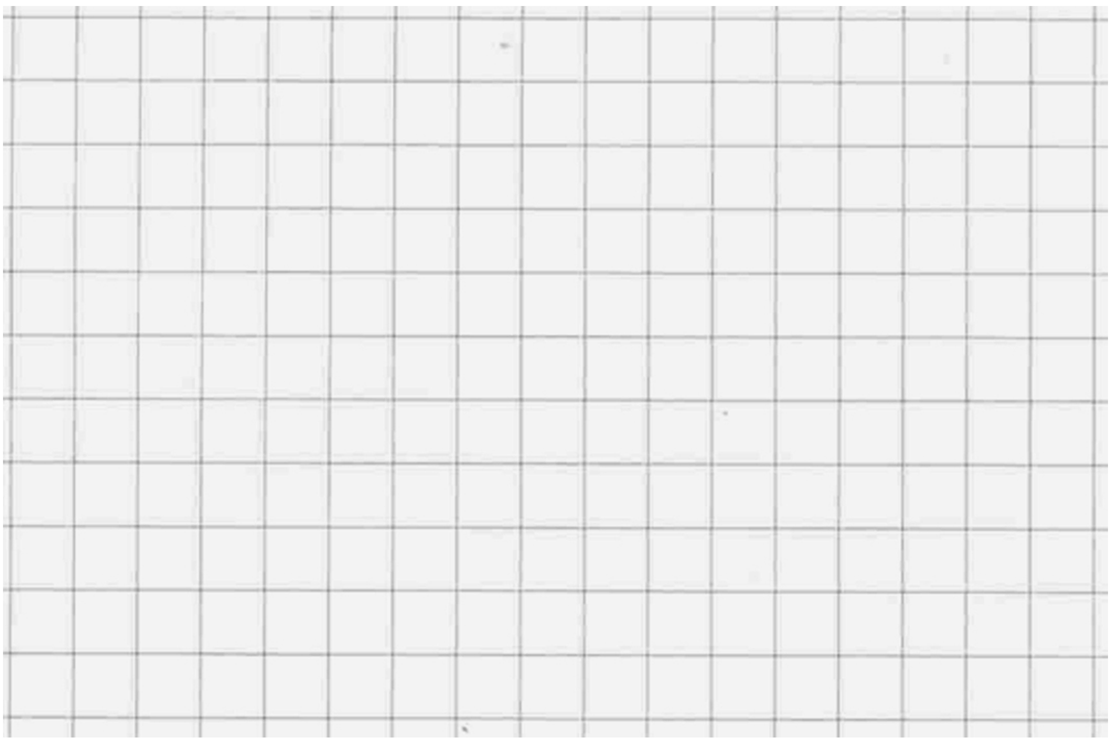
$$u' = u - v$$

$$t' = t$$

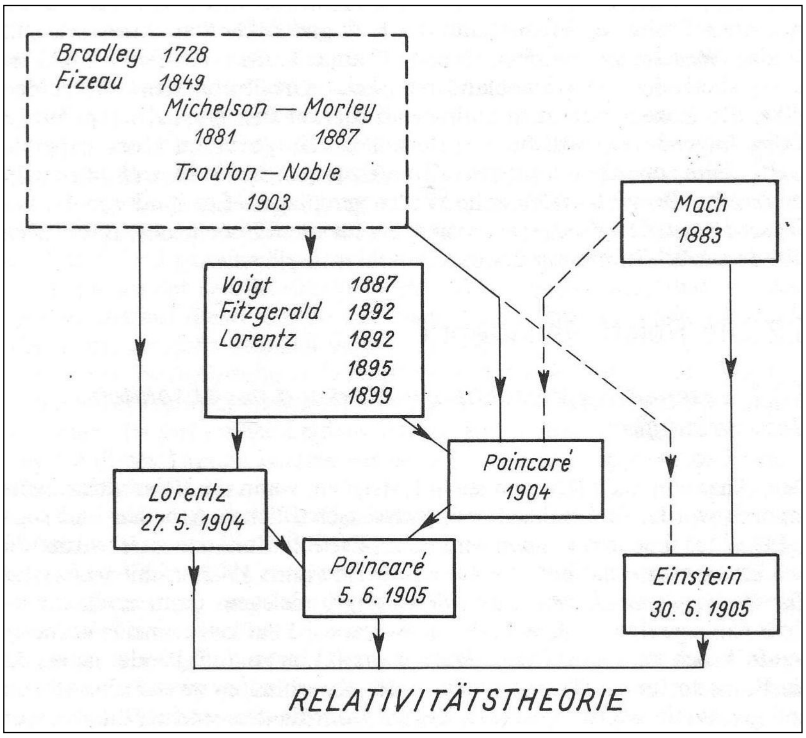
$$x = x' + vt$$
$$y = y'$$
$$z = z'$$

$$u = u' + v$$

$$t = t'$$



How did Relativity Theory develop?



The Lorentz Transformation

$\beta = v/c$

v = relative velocity of the 2 observers

c = velocity of light

$$x' = \frac{1}{\sqrt{1-\beta^2}}(x - vt), \qquad x = \frac{1}{\sqrt{1-\beta^2}}(x' + vt'),$$

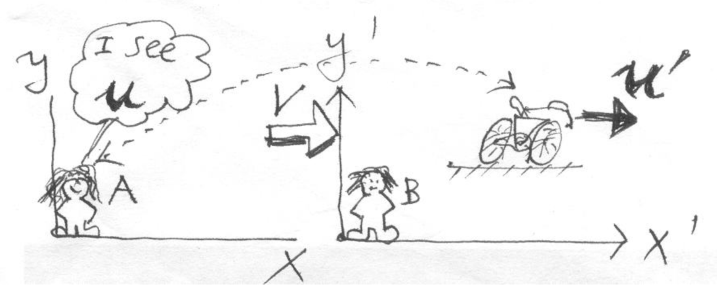
$$y' = y, \qquad y = y',$$

$$z' = z, \qquad z = z',$$

$$t' = \frac{1}{\sqrt{1-\beta^2}}\left(t - x\frac{v}{c^2}\right), \qquad t = \frac{1}{\sqrt{1-\beta^2}}\left(t' + \frac{v}{c^2}x'\right).$$

The Addition of velocities

according to relativity theory



Galilei-Transformation: $u = u' + v$

Relativity (with Lorentz-Transformation) : $$u = \frac{u' + v}{\left(1 + \frac{u' \cdot v}{c^2}\right)}$$

u is the velocity of "something" moving observed by someone A at rest

v is the velocity of the moving system, in which the observer B lives

u' is the velocity of "something" moving within the moving system, as observed by B

c is the speed of light (300000 km/s)

To understand better, let us analyze how u develops.

We choose the following values:

$v = 0.5\,c = c/2$

and 8 values for u':

$u' =$ 0 , $0.2c$, $0.3c$, $0.4c$, $0.5c$, $0.7c$, $0.8c$, c

Calculate u for all these 8 values of u' in both transformations and draw the graphs! Don't use the numerical value for c, just use the **letter c !**

The increase of mass with velocity

according to Relativity Theory

Galilei and Newton thought that the mass of a body is always the same, even if the mass is moving relative to an observer. So the *moving mass* and the *rest mass* were the same for them, let us call it $\boldsymbol{m_0}$**.** Mass was seen as ***absolute.***

According to Relativity Theory however, the mass $\boldsymbol{m}$ of a body (as seen or measured by an observer A at rest) increases more and more when it becomes faster. But an observer B moving together with the body will measure the constant value m_0. Mass now is recognized as ***relative.*** The transformation gives this famous formula:

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

v is the velocity of the moving system, in which the observer B "lives" together with the moving body

c is the speed of light (300000 km/s)

To understand better, let us analyze how *m* develops, when v increases.

We choose the following values:

$m_0 = 5$ kg

and 12 values for v from $v = 0$ to $v = c$ in steps of $0.1c$ plus the value $0.95c$.

Calculate *m* for all these 12 values of *v* in both transformations and draw the graphs!

Don't use the numerical value for *c*, just use the **letter *c* !**

2 Exercises for those loving mathematics like Dawa:

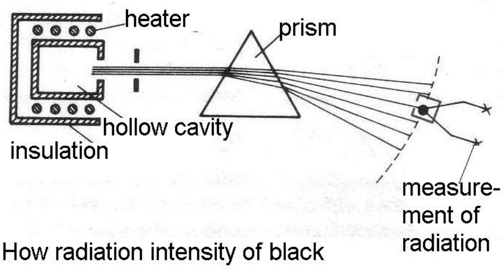
1. How many times the rest mass is the moving mass of an electron when it travels at 0.999c **?**

2. How fast must an electron travel to have 10 times its rest mass?

Planck's Constant *h* : Where does it come from?

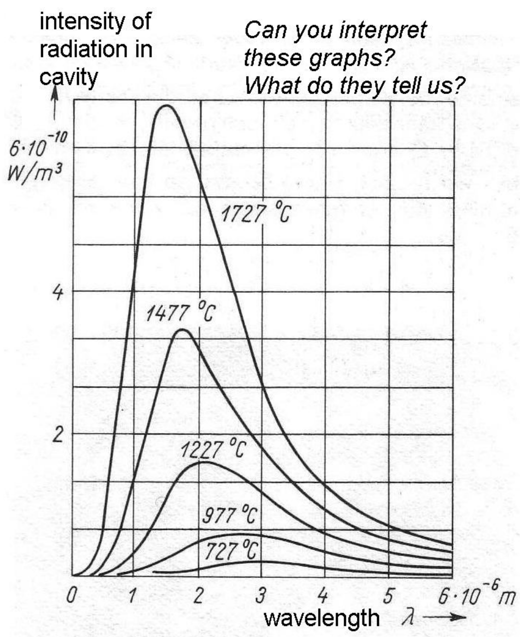
The black body radiation: A *completely* black body absorbs all radiation that hits it and it doesn't reflect any radiation. But it emits radiation, as we can feel when we hold our hand or our face near a hot body. A white body will emit less radiation and a completely black body has the maximum emission. **Max Planck** (1858-1947) mainly studied black body radiation.

Planck was a theoretical physicist. So he didn't carry out experiments himself but tried to understand theoretically what other scientists had measured.



How radiation intensity of black body was measured . It was done for 5 different temperatures

Here you can see the apparatus and the measurements of black body radiation experiments. The atoms and electrons of the walls within the hot hollow space (the cavity) are moving. It is the electrons which send out (electromagnetic) radiation and are filling this space with the corresponding photons (Planck at his time did not speak of photons, just of waves).
Through the small opening in the hollow space the radiation escapes and is sent to a prism. There the radiation is split up into the different wavelengths and can be measured.
The five measured curves tell us about the properties of the radiation at 5 different temperatures.



Western Science is mainly based on mathematics. Planck now tried to find a mathematical formula for these curves. After many years he finally found this formula for the **radiation intensity *u*** at a certain **frequency *ν*** ("nu") and for a certain absolute **temperature *T***. (*e* is a numerical constant: *e* = 2.71828…)

$$u_\nu = \frac{8\pi\nu^2}{c^3}\frac{h\nu}{e^{\frac{h\nu}{kT}}-1}$$

Here the constant h = **$6.63 \cdot 10^{-34}$ Js** appeared for the first time in the history of physics!

Planck only could find this formula by accepting that the radiation was quantized. That means: The photons within the hollow space could only accept very distinct quantums of energy. Not every quantum was allowed, only certain values! This was the birth of quantum mechanics! Planck himself was not happy by this trick but he finally had to admit that there was no way to avoid it. Nature in the atomic realm shows quantization.