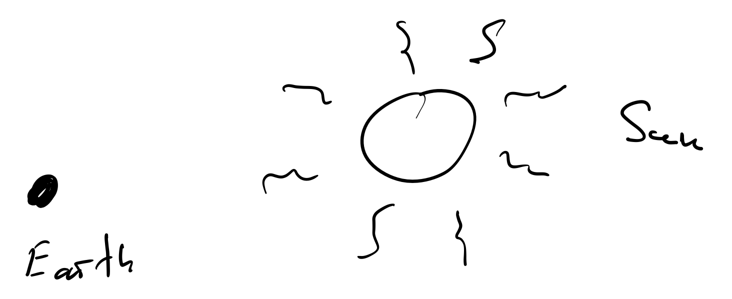
Planck's constant and photoelectric effect



Let's imagine we forgot all the laws of gravitation, but we can measure mass of the Sun and distance from Earth to the Sun.

$M = 5.9 \cdot 10^{24}$ kg
$R = 1.5 \cdot 10^{11}$ m → How we can know the duration of year?

Year is seconds, but we need to build it from M and R

$g = 6.7 \cdot 10^{11} \frac{m^3}{kg \cdot s^2}$

$$\boxed{T = \sqrt{\frac{R^3}{M g}}}$$

π geometry e differentiation
g gravity
c EM theory
h Quantum theory

Within the frame of classical physics we cannot understand experimental curve of black body radiation. However, this problem was successfully solved by Planck ≈ 1900.

$$\boxed{f(\nu, T) = \frac{a_1 \nu^3}{e^{a_2 \frac{\nu}{T}} - 1}}$$ October 19, 1900

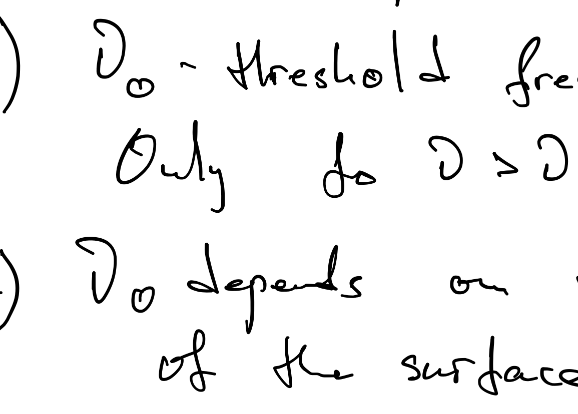
$a_1 = \frac{2h}{c^2}$ $a_2 = \frac{h}{k_B}$

Next morning, Rubens confirmed by experiment. Next 2 month Planck worked on its physical derivation.

The only way he was able to derive it if the following assumed. Energy is absorbed or emitted by portions. Quant will have energy proportional to frequency of radiation.

In 1905 Einstein used this idea to explain photoeffect. Einstein suggested that not only thermal radiation is quantized, but all energy is quantized.

Photoelectric effect by Heinrich Hertz 1877



What was special about this experiment?

1) ν_0 - threshold frequency
Only for $\nu > \nu_0$ there is a current.
2) ν_0 depends on metal and roughness of the surface.
3) Magnitude of current proportional to light intensity
4) If you can observe energy of photoelectrons (speed), it is independent of intensity
5) E_{e^-} increases linearly with ν.
(Hertz couldn't do it at the time)

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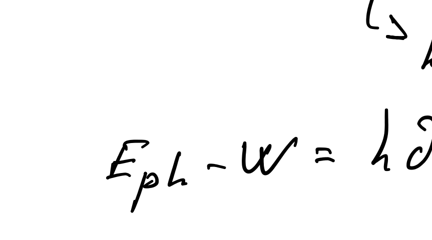
1905 Einstein proposed light comes as bundles.
He was non-committal :)
(1920 photons was given name by Lewis)

$E = h\nu$ – energy of photon
same constant

Einstein idea!



W – work function
energy to escape

Then
$E_{e^-} = \frac{1}{2} m v^2 = E_{ph} - W$
kinetic energy

$E_{ph} - W = h\nu - W$ ~ prediction by Einstein

It took 10 years for experimental proof by Millikan (1915)
- verifies $E_{e^-} = h\nu - W$
- measures $h \pm 1\%$!

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It was not well accepted even by Einstein. Idea of particles come with duality and Maxwell theory was too successful.

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Light 290 nm
$W = 4.05$ eV E_{e^-}? and v?

$E = h\nu = \frac{hc}{\lambda} = \frac{2\pi \hbar c}{\lambda}$

$\hbar c \approx 200 \cdot 10^{-9}$ eV·m

$E = \frac{2\pi \cdot 200 \cdot 10^{-9}}{290 \cdot 10^{-9}} \frac{eV \cdot m}{m} \approx 4.28$ eV

$E_{e^-} = E - W = 0.23$ eV $= \frac{1}{2} m v^2$

$v \sim 300 \frac{km}{s}$