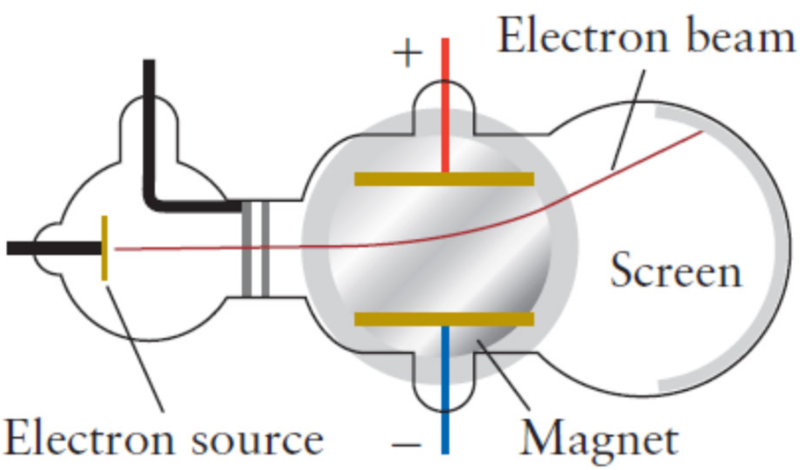
Late 1890's: Theoretical structure of the "universe" complete

- Atomic Theory of Matter
- Newtonian Mechanics

"Our Future Discoveries must be looked for at the 6^{th} Decimal Place"

Discovery of Electron: J J Thompson



- In 1897J. J. Thomson was investigating "cathode rays," the rays that are emitted when a high potential difference (a high voltage) is applied between two metal electrodes in an evacuated glass tube

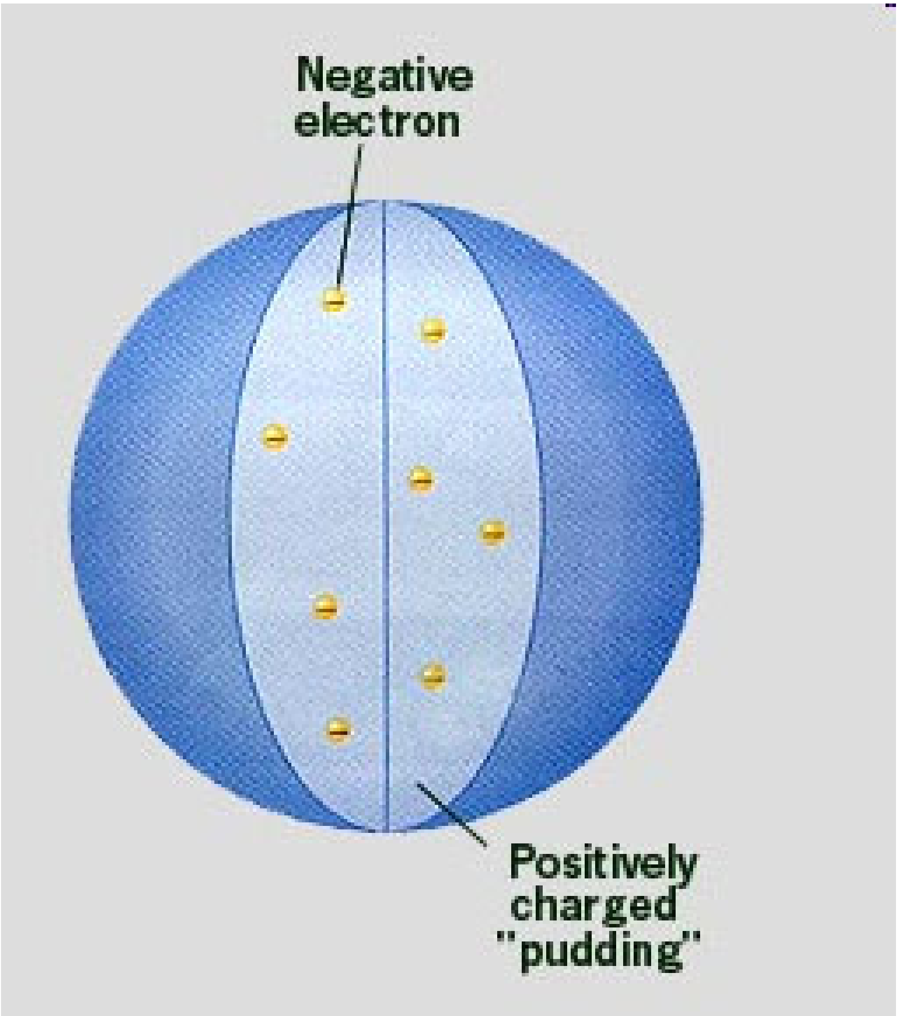
- Thomson showed that cathode rays are streams of negatively charged particles coming from inside the atoms that made up the negatively charged electrode, the cathode

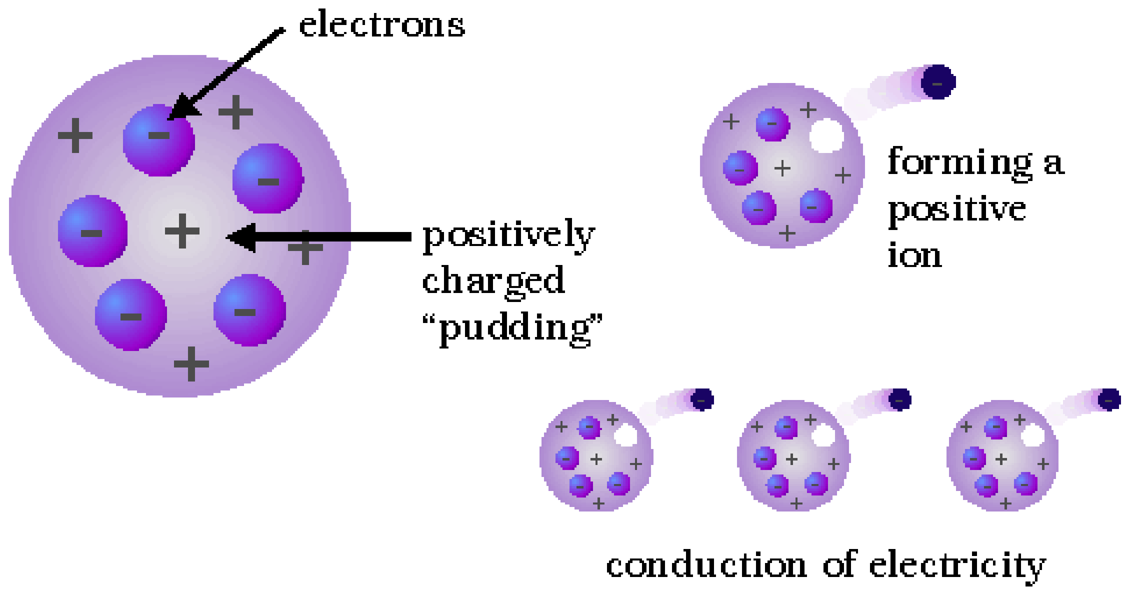
- Thomson found that the charged particles, which came to be called electrons, were the same regardless of the metal he used for the cathode

- He concluded that they are part of the makeup of all atoms

- Thomson was able to measure the value of e/m, the ratio of the magnitude of the electron's charge e to its mass m (9×10^{-31} kg^{-1})

Thompson Plum-Pudding Model

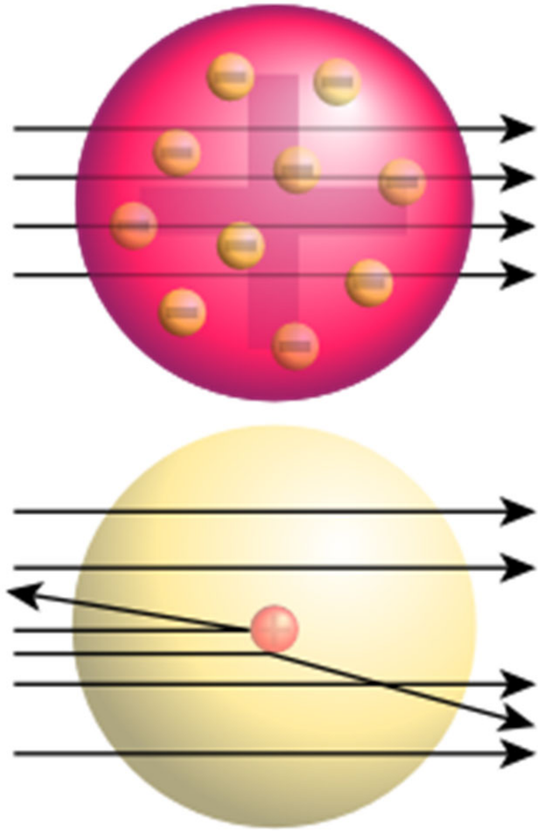


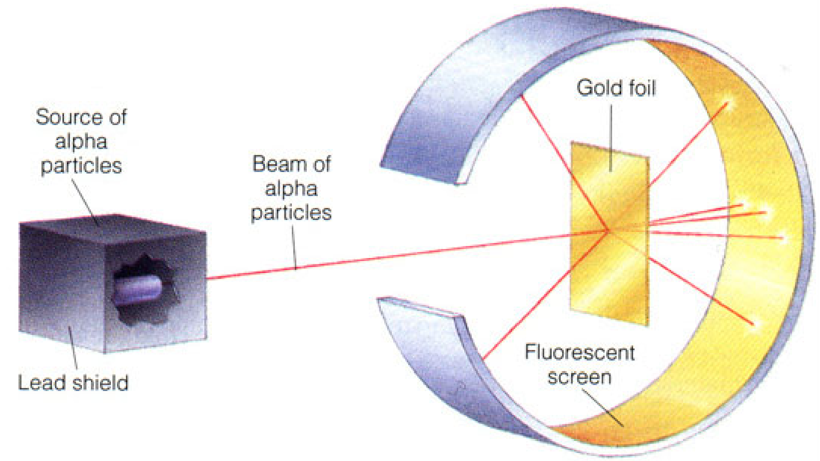


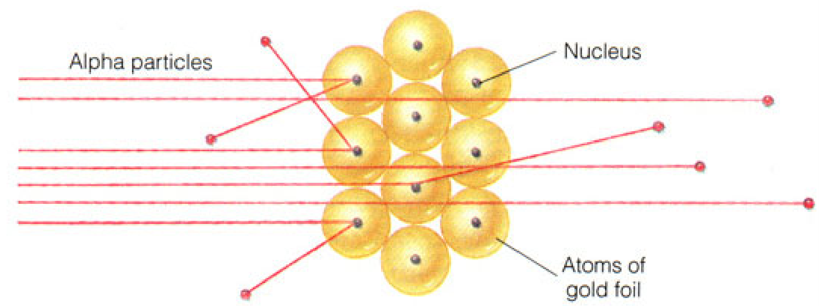
J.J. Thompson (Discovered Electrons, 1896)

Rutherford's Gold Foil Experiment

1871-1937



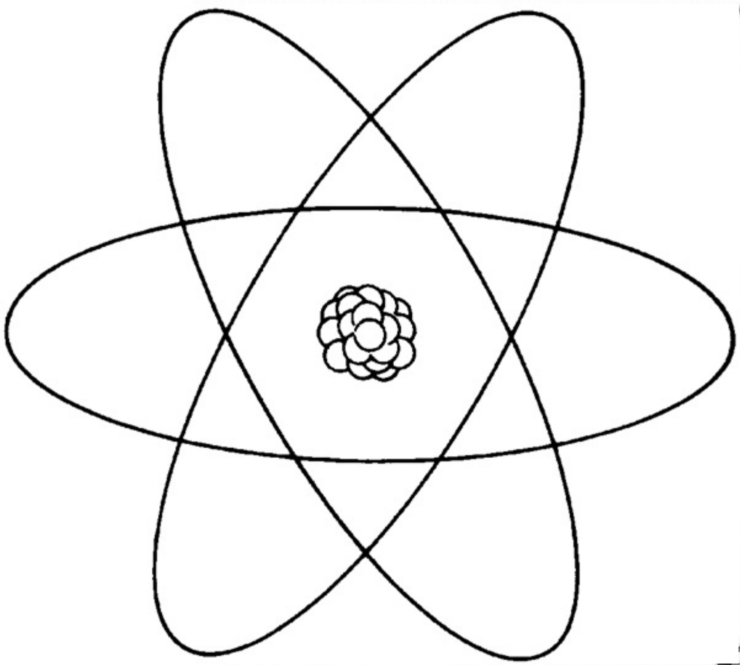


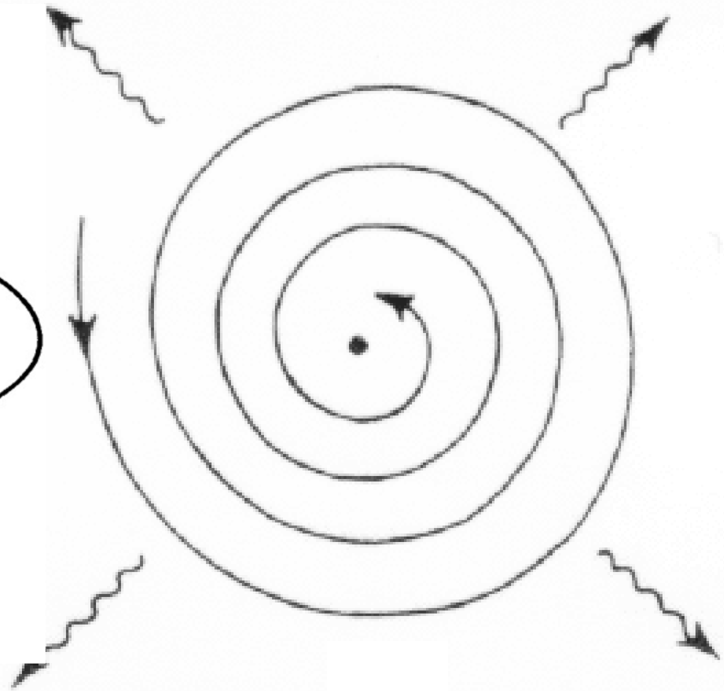


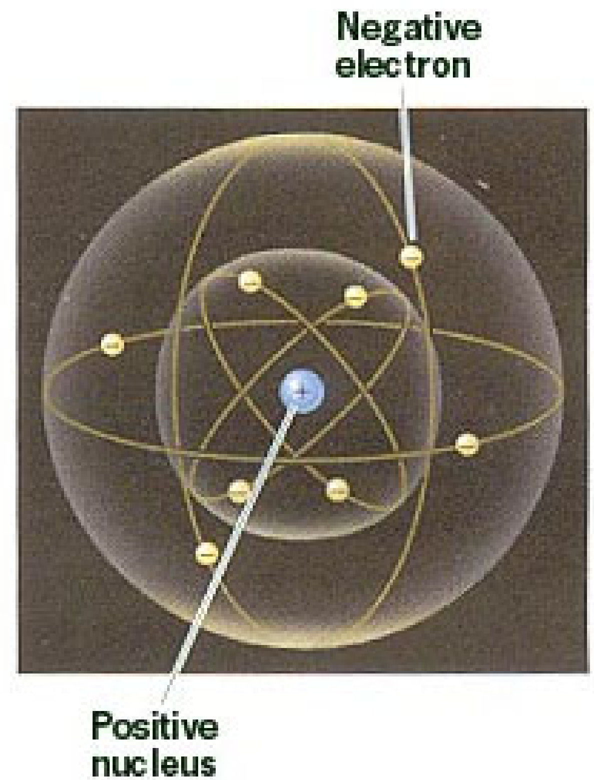
Rutherford beamed alpha particles (++) through gold foil and detected them as flashes of light on a screen. The gold foil was only 0.00004 cm thick, meaning on a few hundreds of atoms thick

Experiments performed by Hans Geiger and Ernest Marsden

Planetary model loggerheads with classical electromagnetic theory







According to classical physics, an electron in orbit around an atomic nucleus should emit electronmagnetic radiation (photons) continuously, because it is continually accelerating in a curved path. The resulting loss of energy implies that the electron should spiral into the nucleus in a very short time (i.e. atoms can not exist).

With the discovery of subatomic particles, the need for a new type of mechanics evolved (Quantum Mechanics)

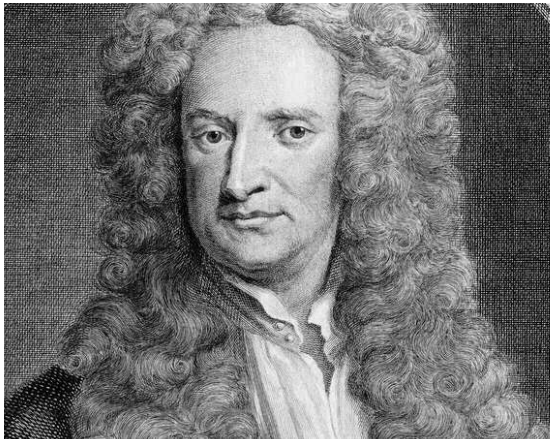
To explain the observations scientists were making, two tenets were required:

(i) Radiation and matter had both wave-like and particle like properties

(ii) Energy is quantized into discreet packets called “photons”

A Brief History of "Light"

Newton



(1643-1727)

Light is a beam of particles

Huygens

(1629-1695)

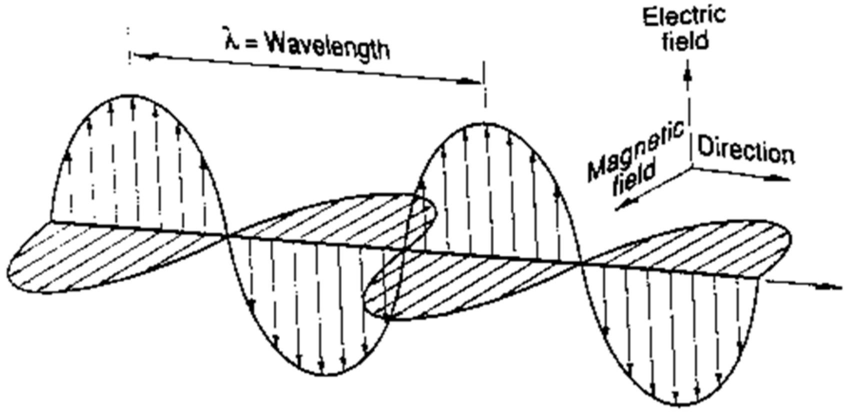
Exhibits Interference, hence waves

Maxwell

(1831-1879)

EM Theory, hence waves

Light is EM Radiation: Waves

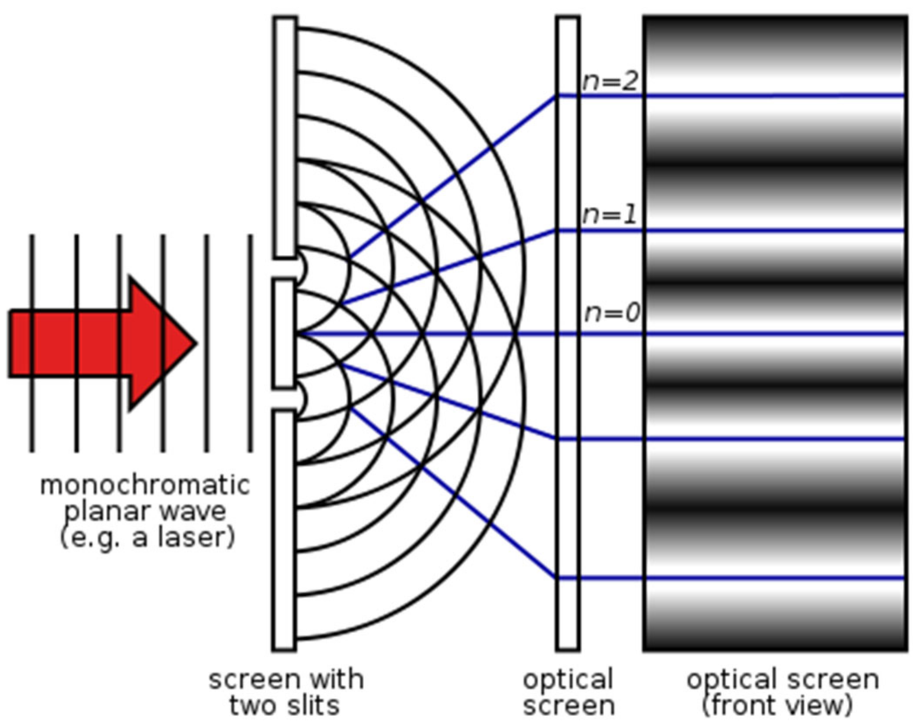


$$E = E_m Sin(kx - \omega t)$$

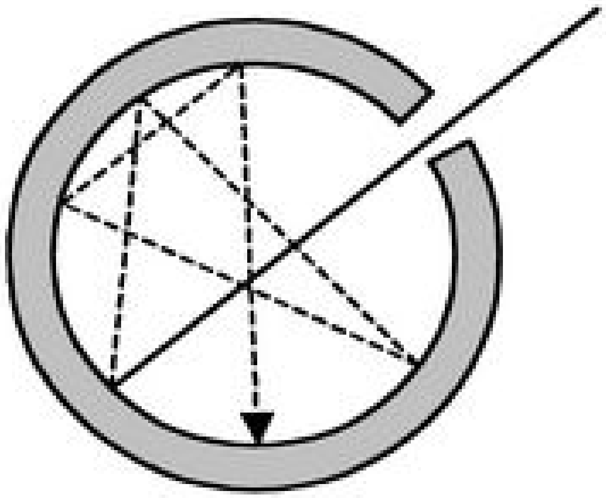
$$B = B_m Sin(kx - \omega t)$$

$$\frac{E_m}{B_m} = c \sim 3\times 10^{10}\, cm/\sec$$

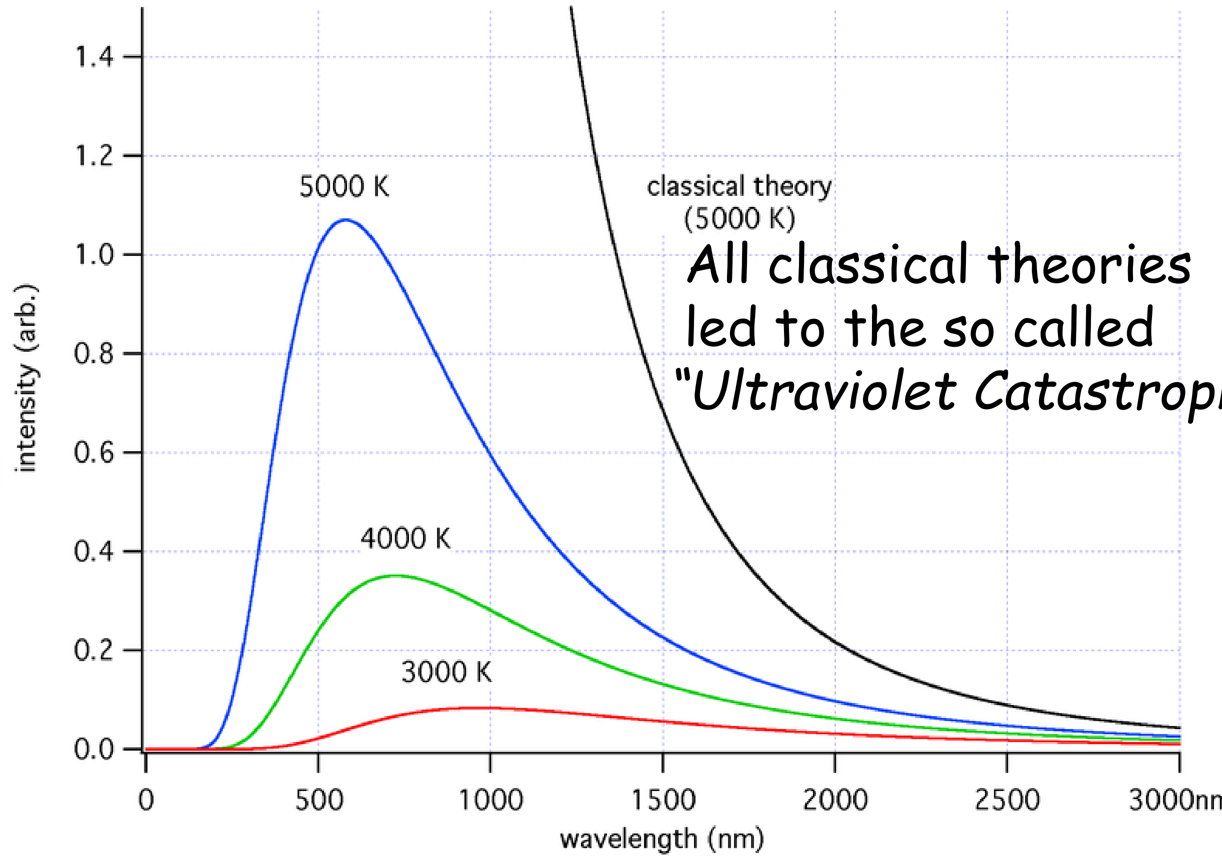
Diffraction or Interference Pattern can be possible only if light is a wave



Classical EM theory can not explain Blackbody Radiation



Sun, stars…hot iron rod



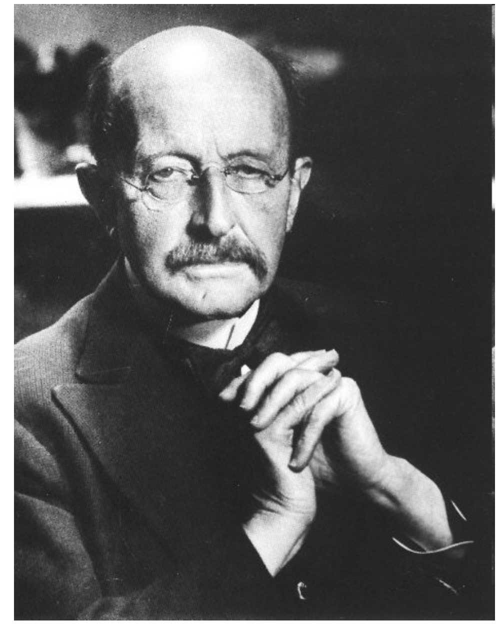
All classical theories led to the so called *"Ultraviolet Catastrophe"*

Theories based on classical physics unable to explain temperature dependence of emitted radiation (radiant energy density)

Max Planck assumed energies of oscillators are discontinuous

Assumption:

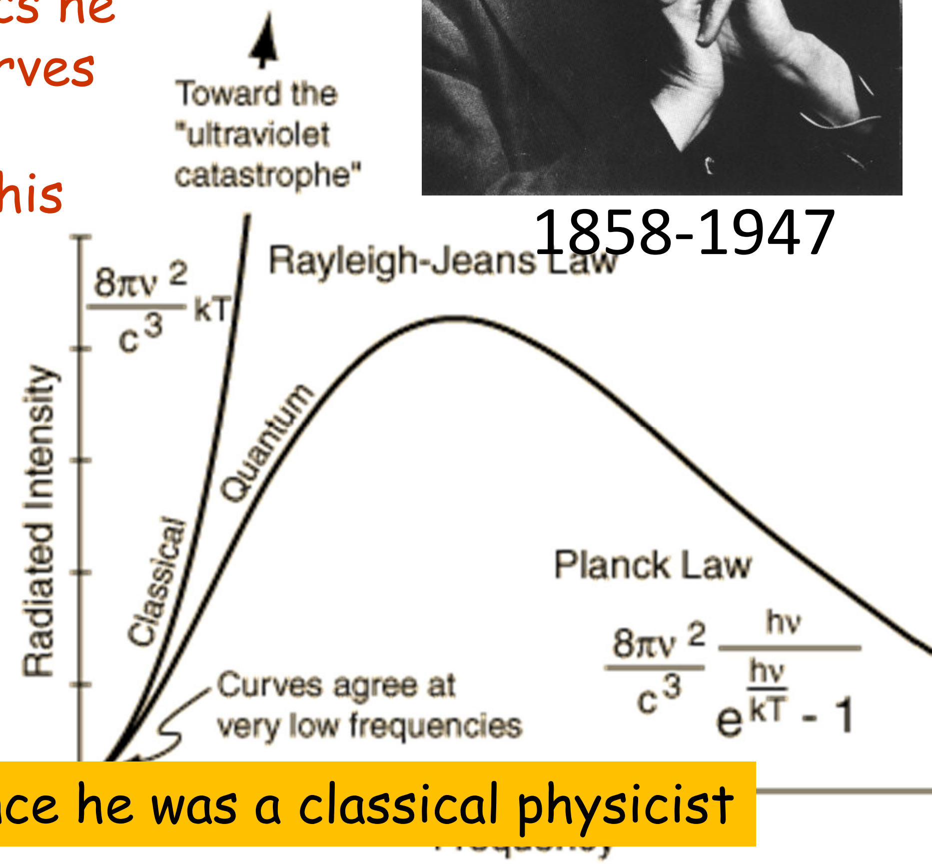
- Presence of electronic oscillators in these materials which must be giving of radiation
- *Energy of electronic oscillators were discrete; Proportional to integral multiple of frequencies*
- Proposed that this radiation was being emitted in quanta or chunks
- Using this idea and some statistical mechanics he was able to calculate the shapes of these curves
- To get the intensity correct he had to use scaling factors in front of the frequency of his oscillators -the Plank's constant.



1858-1947

E = Energy of electronic oscillators
v = frequency of electronic oscillators
h = Planck's constant = 6.626 x e^{-34} joule-sec
Note: h came in as a fitting parameter

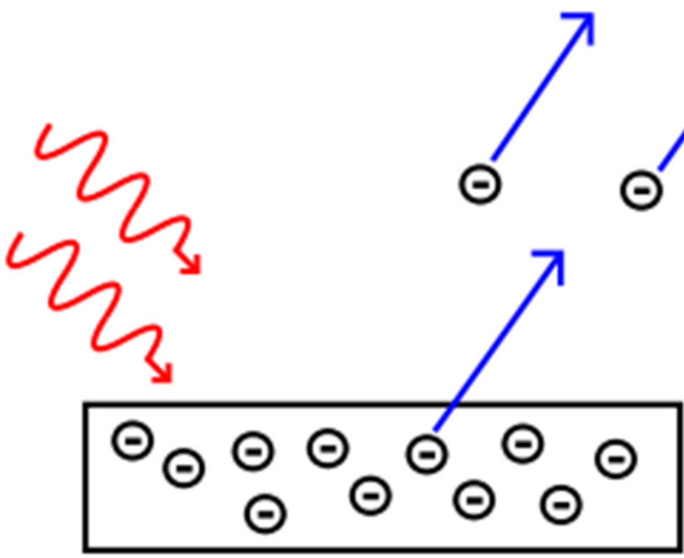
$$E_{Osc} = nh\nu$$



Planck never believed his theory was right, since he was a classical physicist

Photoelectric Effect

Photodetectors, Photovoltaics, Elevator sensor, smoke detectors



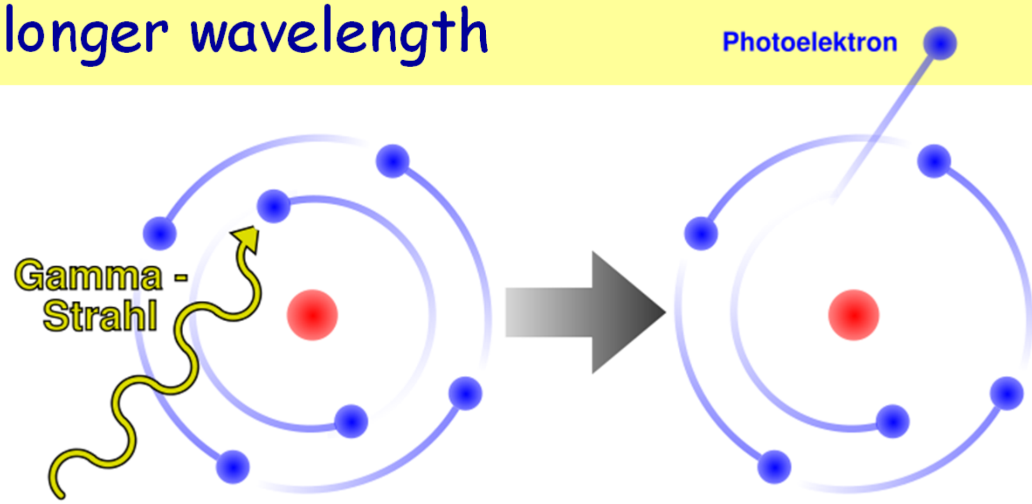
- Classical physics predicted that kinetic energy would not change with the frequency of light
- In addition it predicted that KE should be dependent on the Intensity of light.

Experimental Observations

1. Increasing intensity of light increases number of photoelectrons, but not their max. kinetic energy (KE_{MAX})!

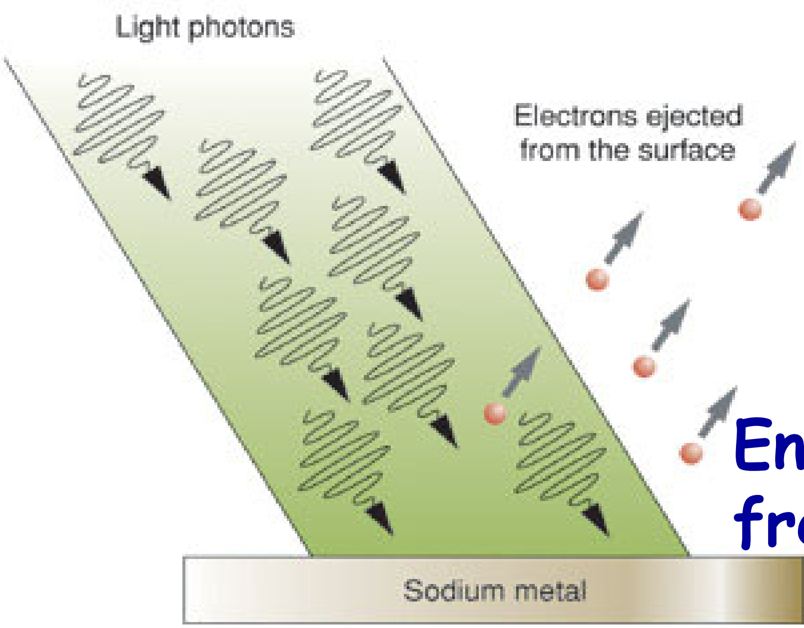
2. Light below a certain wavelength will not cause ejection of electrons, no matter how high it's intensity!

3. Extremely weak violet light ejects few electrons! But their KE_{Max} >> KE_{Max} of electrons ejected by intense light of longer wavelength



Einstein: light behaves like particles

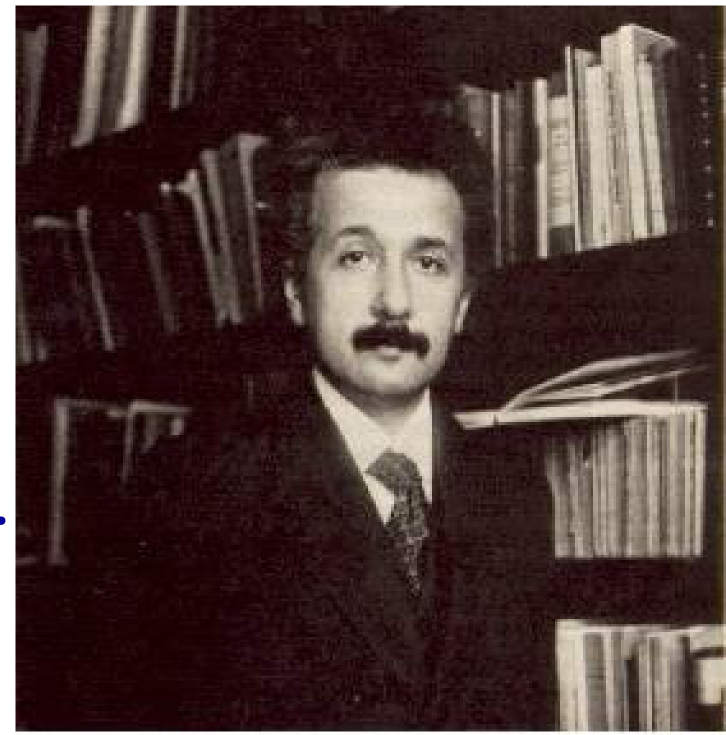
Borrowing Planck's idea that ΔE=hν, Einstein further proposed <u>radiation itself existed as small packets of energy</u> (Quanta), known as PHOTONS



$$E_P \propto \nu$$

$$E_P = h\nu$$

Energy of photon is frequency dependent



Albert Einstein

$$E_P = h\nu = KE_M + \phi = \frac{1}{2}mv^2 + \phi$$

$\phi =$ Energy to remove e' from surface

$$KE_M = h\nu - \phi_0 \geq 0$$

1879-1955; Nobel prize For explanation of Photoelectric effect

Optical Tweezers