Learning Objectives

- Who was involved?
- Which experiments were used to help us understand?
- What are atomic line spectra?
- Which models were used to represent the atom?
- Which equations are fundamental?
- Which ones are handy to know?!
- What have been the successes of quantum theory?
- What are the future applications?

Albert Einstein 1879-1955

- We believe in the possibility of a theory which is able to give a complete description of reality, the laws of which establish relations between the things themselves and not merely between their probabilities ... GOD DOES NOT PLAY DICE.

Niels Bohr 1885-1962

- Einstein, DON'T TELL GOD WHAT TO DO!
- Those who are not shocked when they first come across quantum mechanics cannot possibly have understood it.

Werner Heisenberg 1901-1976

- We have to remember that what we observe is not nature itself but nature exposed to our method of questioning.

- I, at any rate, am convinced that HE IS NOT PLAYING AT DICE.

Erwin Schroedinger 1887-1961

- I do not like it, and I am sorry I ever had anything to do with it.
- Had I known that we were not going to get rid of this damned quantum jumping, I never would have involved myself in this business!

Prince Louis de Broglie 1892-1987

- Electrons should not be considered simply as particles, but that frequency must be assigned to them also.

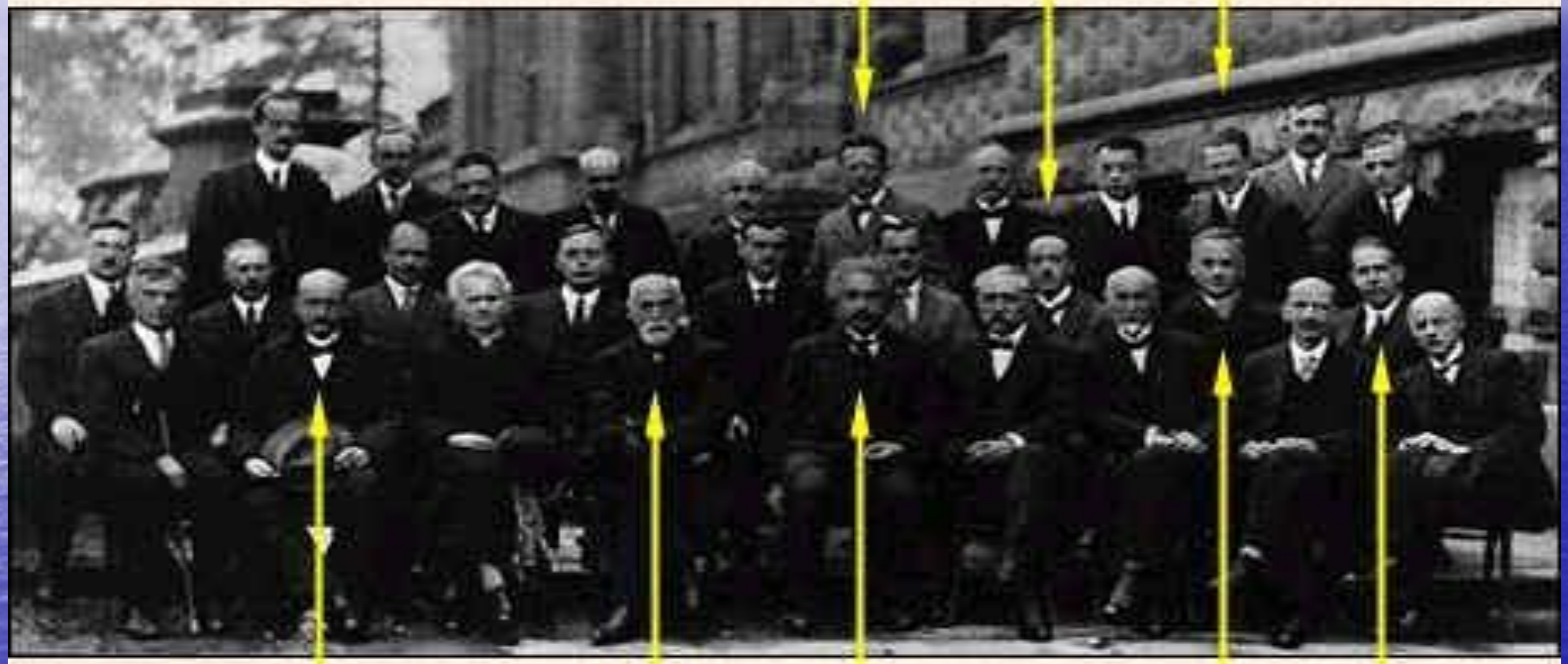
(1929, Nobel Prize Speech)

Max Planck 1858-1947

- Physics is finished, young man. It's a dead-end street.

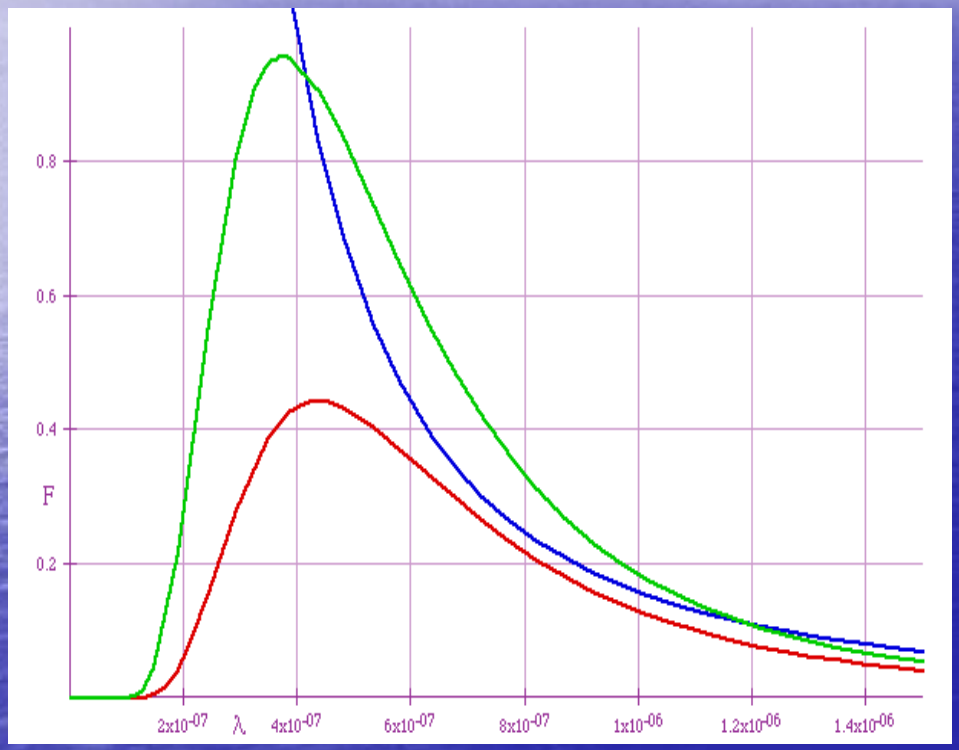
(from an unknown teacher to Planck considering Physics at the turn of the 20th century!)

The Solvay Congress of 1927



THE 'ULTRAVIOLET CATASTROPHE'

1900 - Rayleigh



This was a CLASSICAL prediction, first made in the late 19th century, that an IDEAL BLACK BODY at thermal equilibrium will emit radiation with INFINITE POWER.

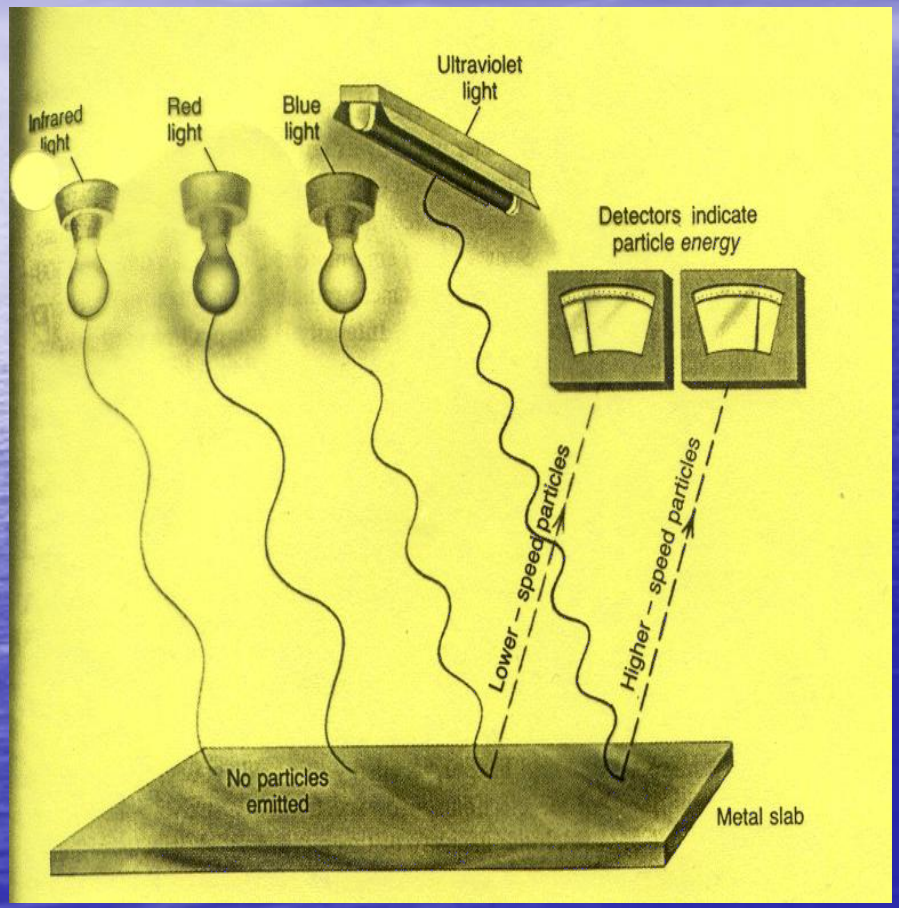
Max Planck resolved this issue by postulating that electromagnetic energy did not follow the classical description, but could only oscillate or be emitted in DISCRETE PACKETS OF ENERGY proportional to the frequency. He called these packets '**QUANTA**'.

$$E = h\upsilon$$

Note: $h = 6.626x10^{-34}\ J.s$

THE PHOTOELECTRIC EFFECT

1905 - Einstein



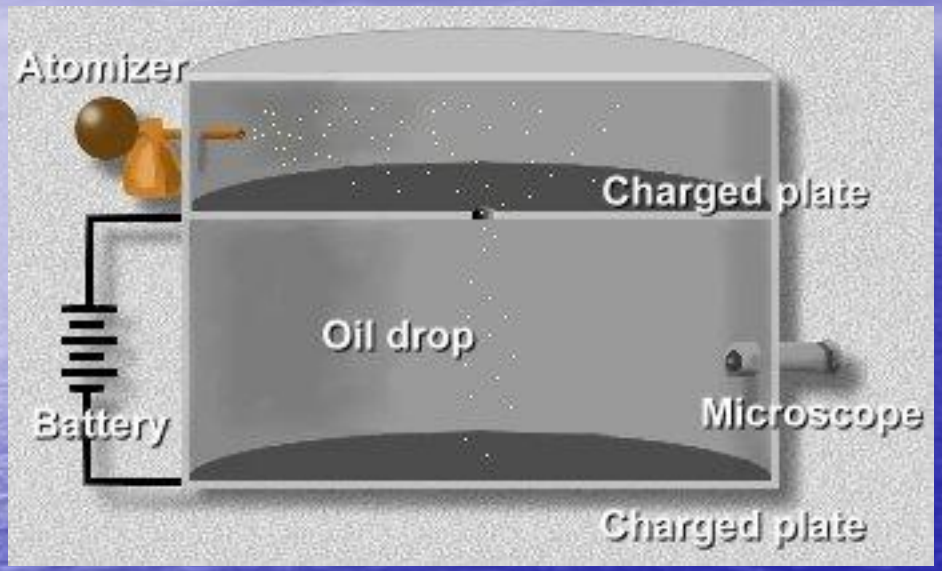
The emission of electrons from a surface (usually metallic) upon exposure to, and absorption of, electromagnetic radiation.

The photoelectric effect was explained mathematically by Einstein who extended the work on QUANTA as developed by Planck.

$$KE = h\upsilon - \phi$$

MILLIKAN'S OIL DROP EXPERIMENT

1909 - Robert Millikan



This experiment determined the magnitude of the electronic charge, and that it was QUANTISED.

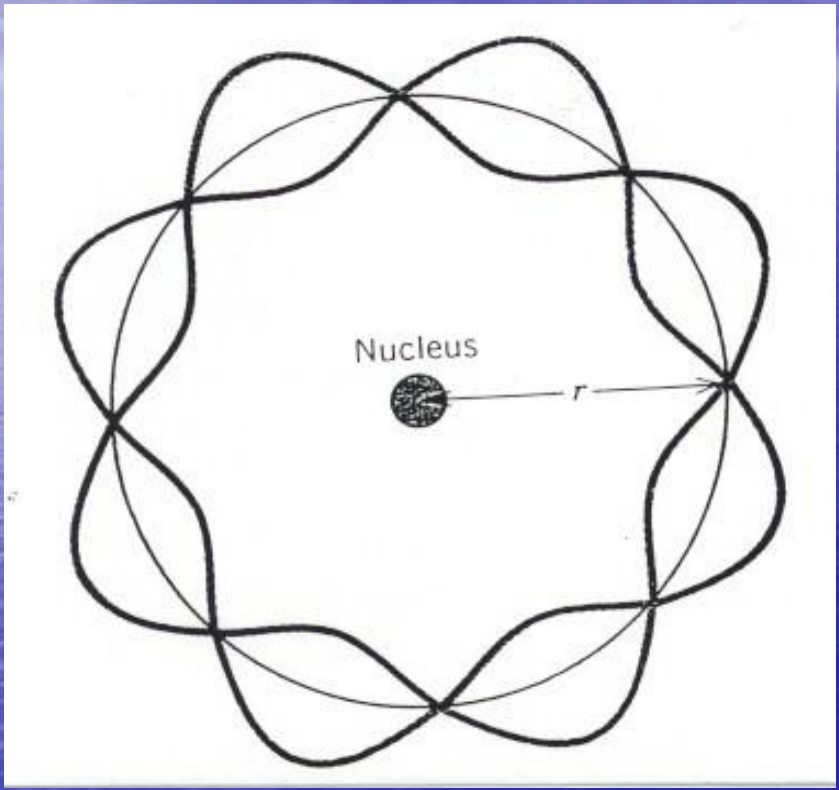
This value is approximately

$1.6x10^{-19}C$

Note: An electron volt (eV) is the amount of energy it takes to accelerate one electron through a potential of one volt.
Thus, $1\text{eV} \equiv 1.6x10^{-19}\,J$

DE BROGLIE WAVELENGTH

Prince Louis de Broglie - 1932



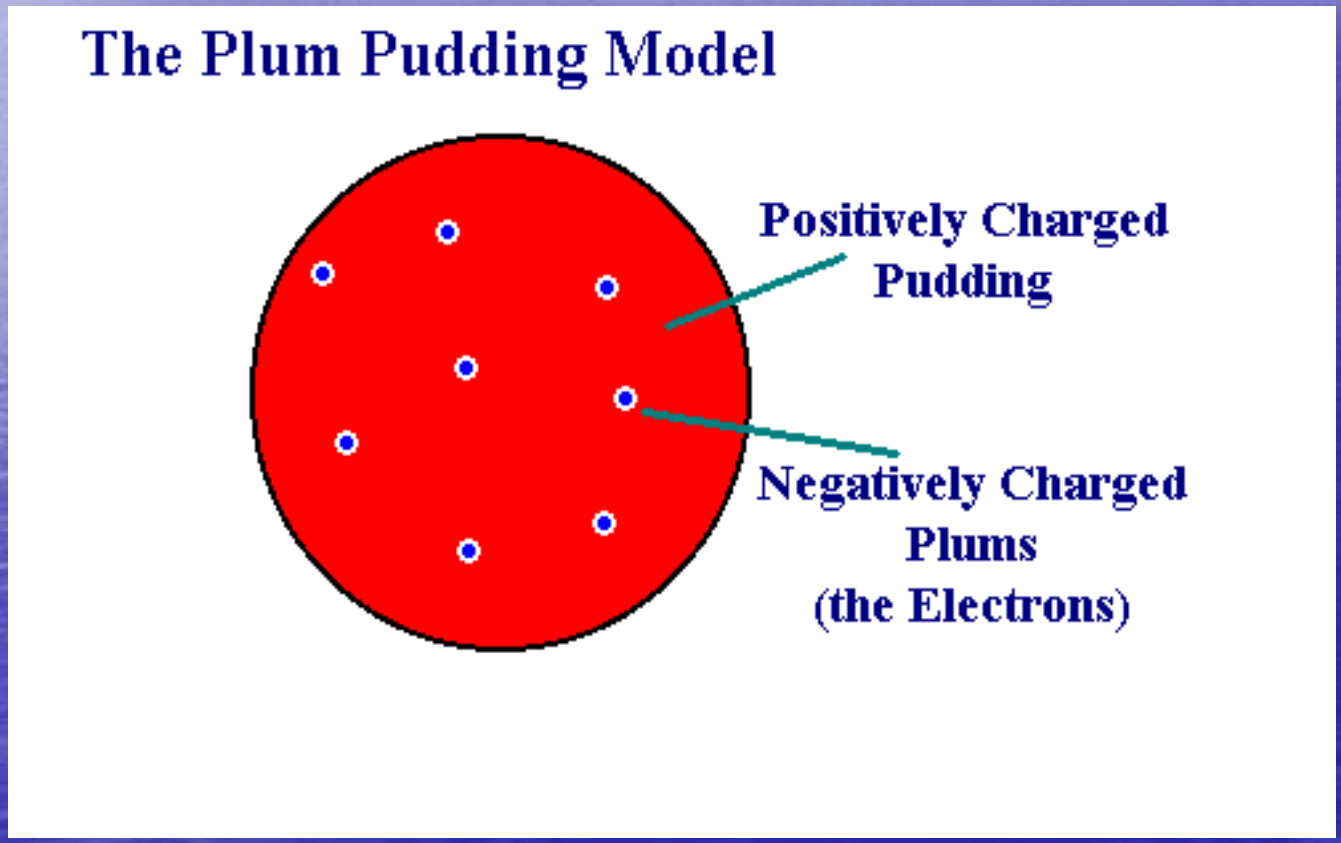
De Broglie discovered that all particles with momentum have an associated wavelength.

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

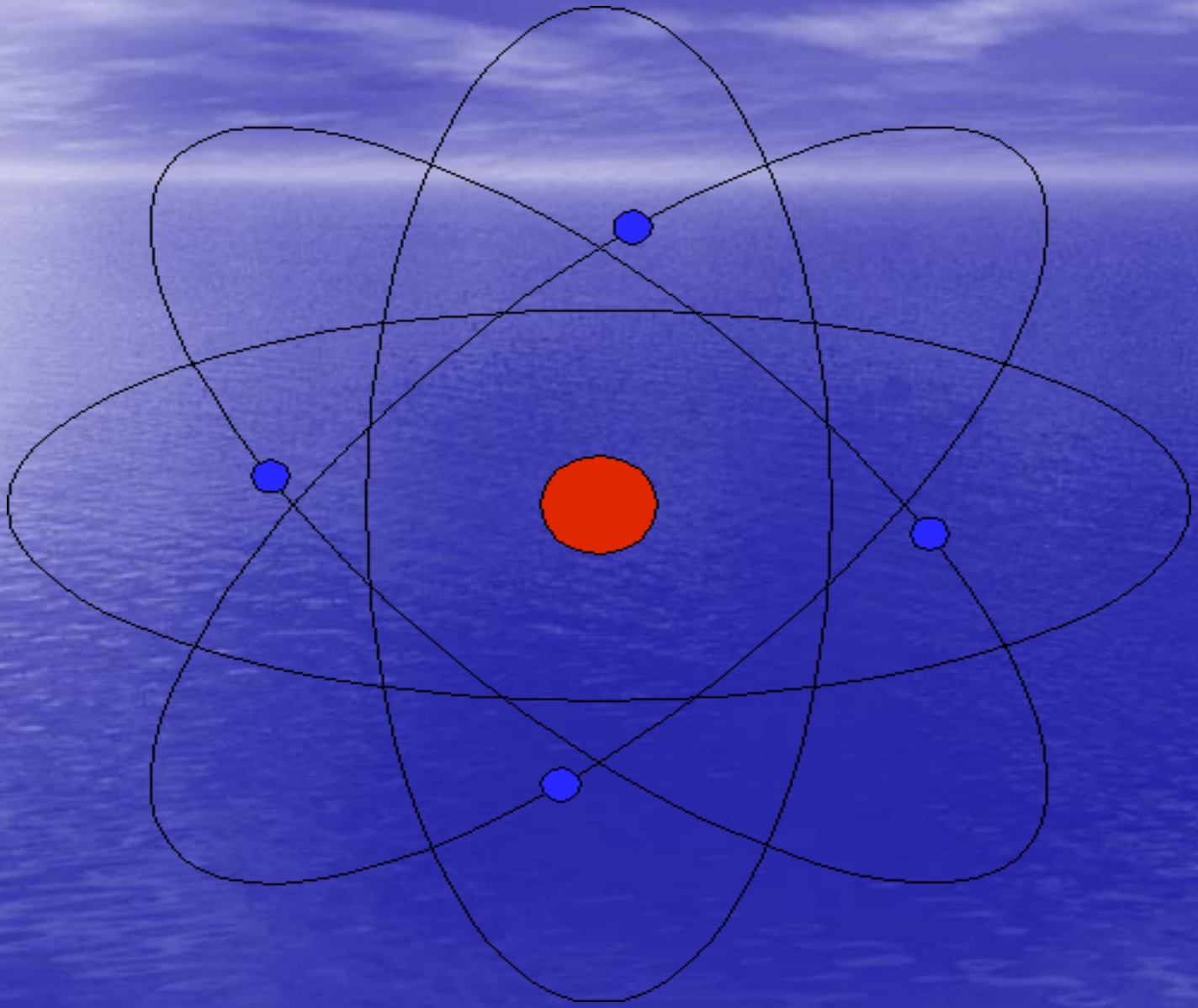
What is the wavelength of a human being, assuming he/she weighs 70 kg, and is running at 25 m/s?

NUCLEAR ATOM STRUCTURES

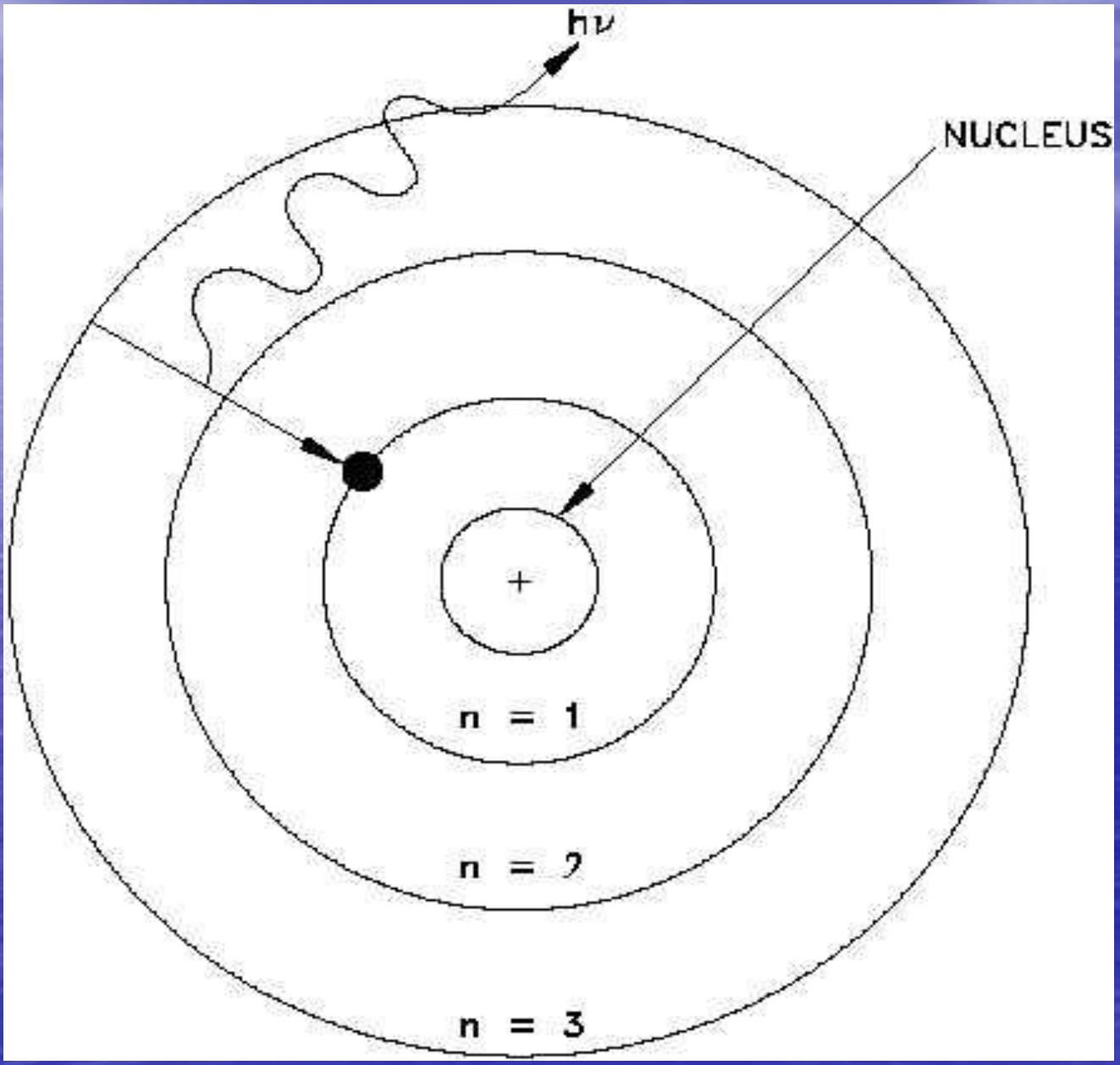
1898 - Thomson



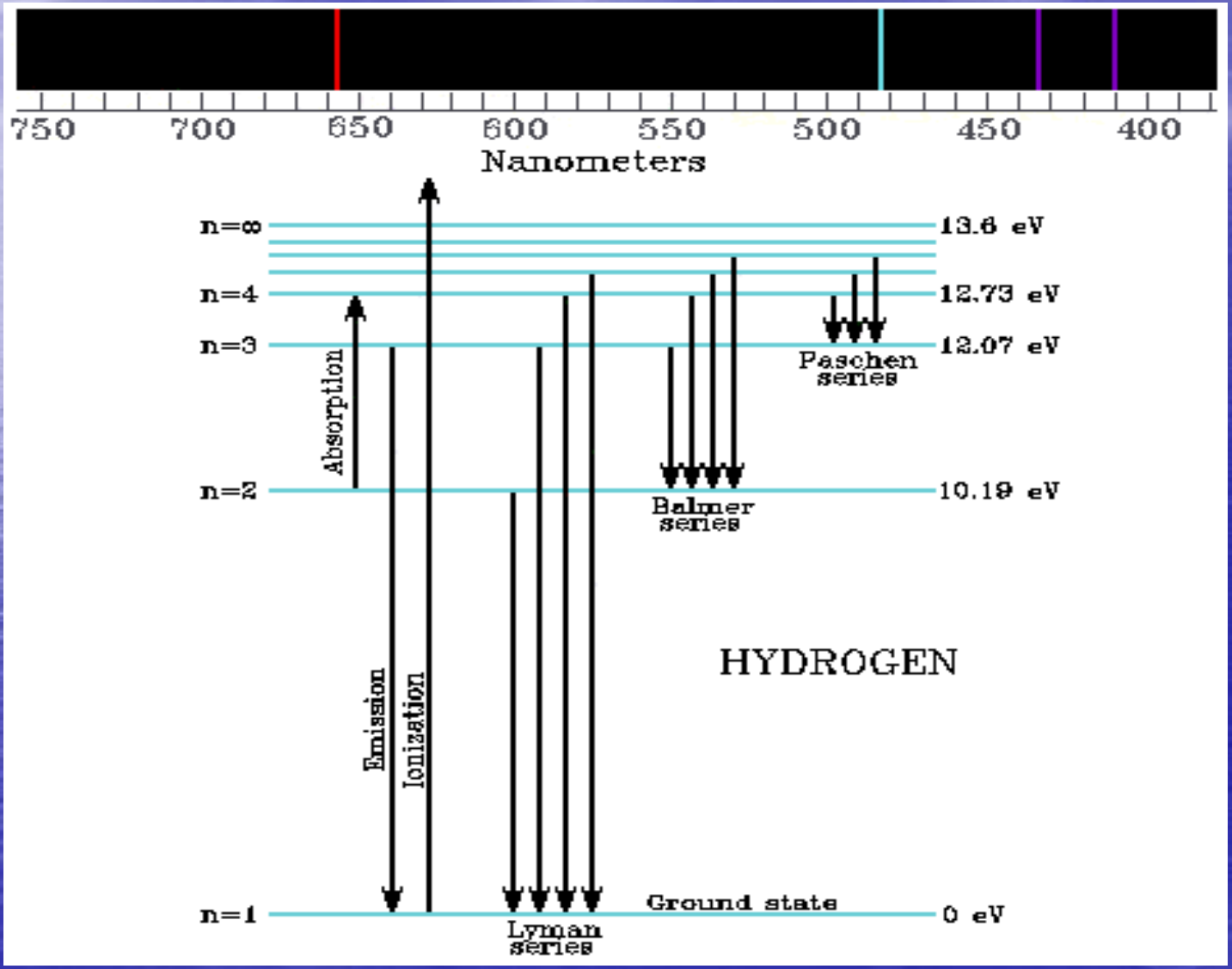
1911 -Rutherford



1913 - Rutherford/Bohr



Atomic Line Spectra



- **General expression:** $E_n = -\frac{hcR}{n^2}$
- *Lyman:* $\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$ *n>1* **(ultraviolet)**
- *Balmer:* $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$ *n>2* **(visible)**
- *Paschen:* $\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$ *n>3* **(infrared)**
- *Brackett:* $\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n^2}\right)$ *n>4* **(infrared)**
- *Pfund:* $\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{n^2}\right)$ *n>5* **(infrared)**

SUMMARY OF IMPORTANT EQUATIONS

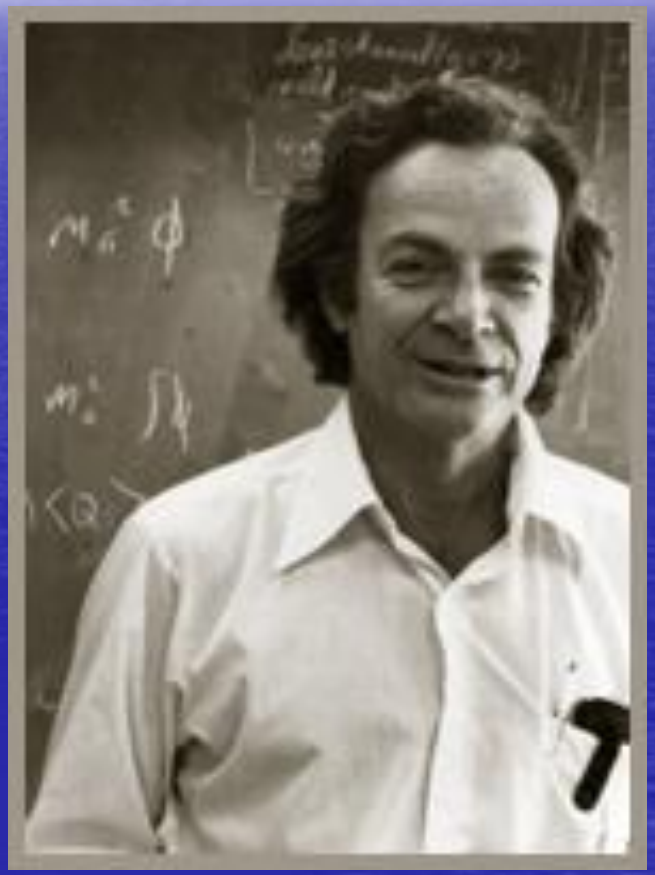
- Energy and frequency: $E = h\upsilon = \frac{hc}{\lambda}$
- The photoelectric effect: $KE = h\upsilon - \phi$
- De Broglie wavelength: $\lambda = \frac{h}{p} = \frac{h}{mv}$
- Angular frequency: $\omega = 2\pi f$

Equations of interest (non-examinable!)

- Planck's constant: $\hbar = \frac{h}{2\pi}$
- Wave vector: $k = \frac{2\pi}{\lambda}$
- Schroedinger: $i\hbar \frac{\partial \Psi}{\partial t} = -\frac{\hbar^2}{2m} \nabla^2 \Psi + V\Psi$

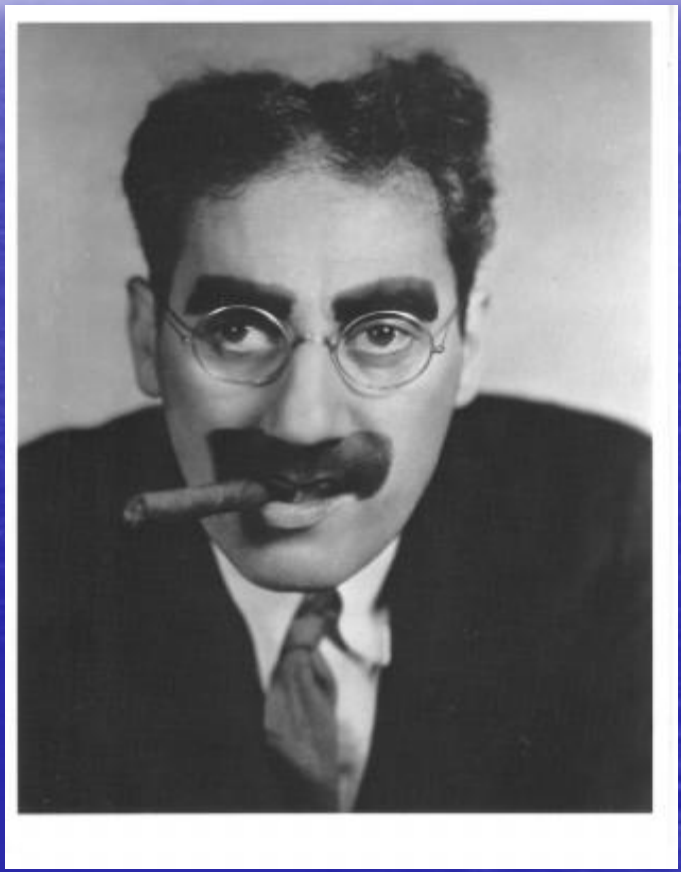
Richard Feynman 1918-1988

- Anyone who has not been shocked by quantum physics has not understood it.
- The word 'quantum' refers to this peculiar aspect of nature that goes against common sense.



Groucho Marx 1890-1977

- Very interesting theory - it makes no sense at all!



QUANTUM THEORY

Uses

- LASERs
- Semiconductors
- Transistors
- LED
- Night Vision Goggles
- CCD
- MRI / PET

Explains

- Tunnelling
- Radioactive decay
- Periodic table

(Pauli Exclusion Principle explanation to Mendeleev's chart)

THE FUTURE OF QUANTUM?

- Dot LASERs
- Logic gates
- Computing
- Cryptography / Encryption
- Cloning
- Teleportation