Our World at Small Scales

A Tourist's View of Quantum Mechanics

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University of Maryland Girls Talk Math

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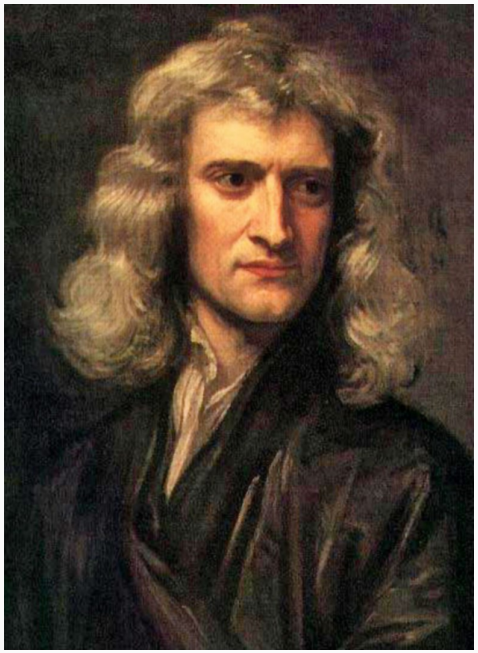
The Origin of Quantum Physics

Classical Physics

In general, the term *classical physics* refers to pre-20th century physics.



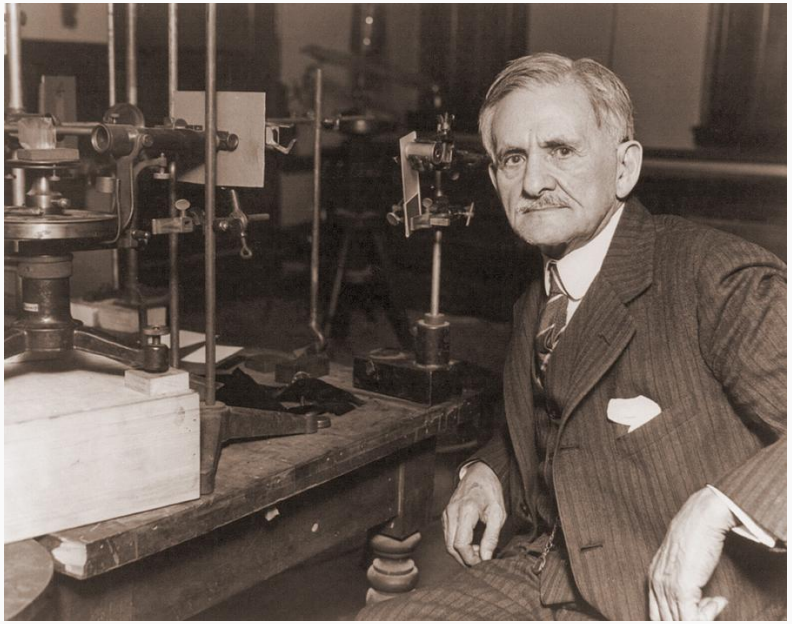
(a) Classical Mechanics

(b) Electromagnetism

(c) Thermodynamics

A lot of the rudimentary materials are covered in **AP Physics** 1, 2 and C!

Classical Physics, cont'd. Is that all?



Albert Michelson 1852-1931

The more important fundamental laws and facts of physical science have all been discovered, and these are so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote.

-Light Waves and Their Uses (1903)

Black-body Radiation

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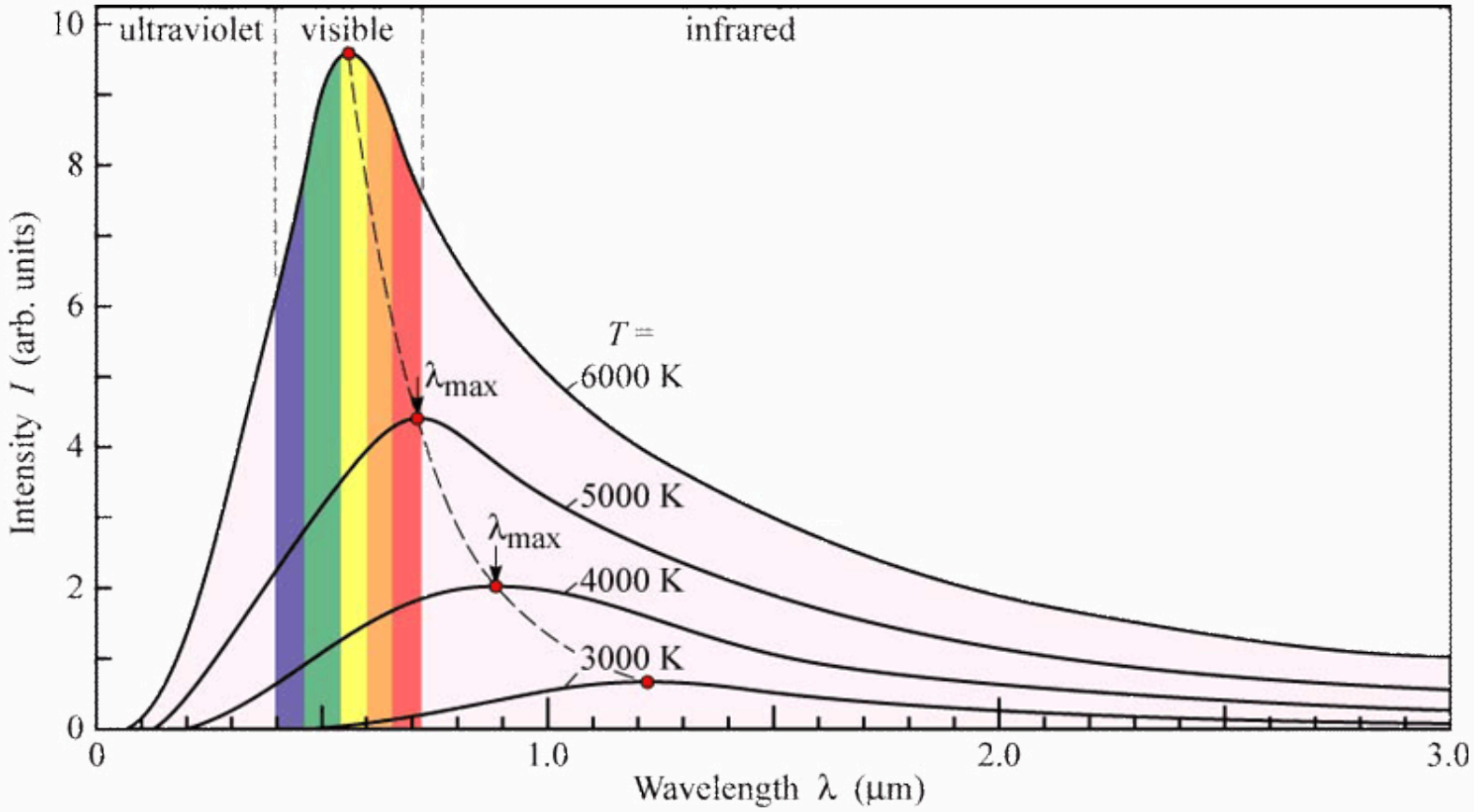
Note: Radiation refers to the emission or transmission of energy in the form of waves. (See blackboard for examples of waves)

Spectral Distribution of Electromagnetic Radiance



Planck's Discovery

- Based off the earlier works of others, Planck managed to produce a simple formula for the distribution of the spectral radiance

$$\boxed{R(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1}}$$

  which is now refers to as Planck's Law.

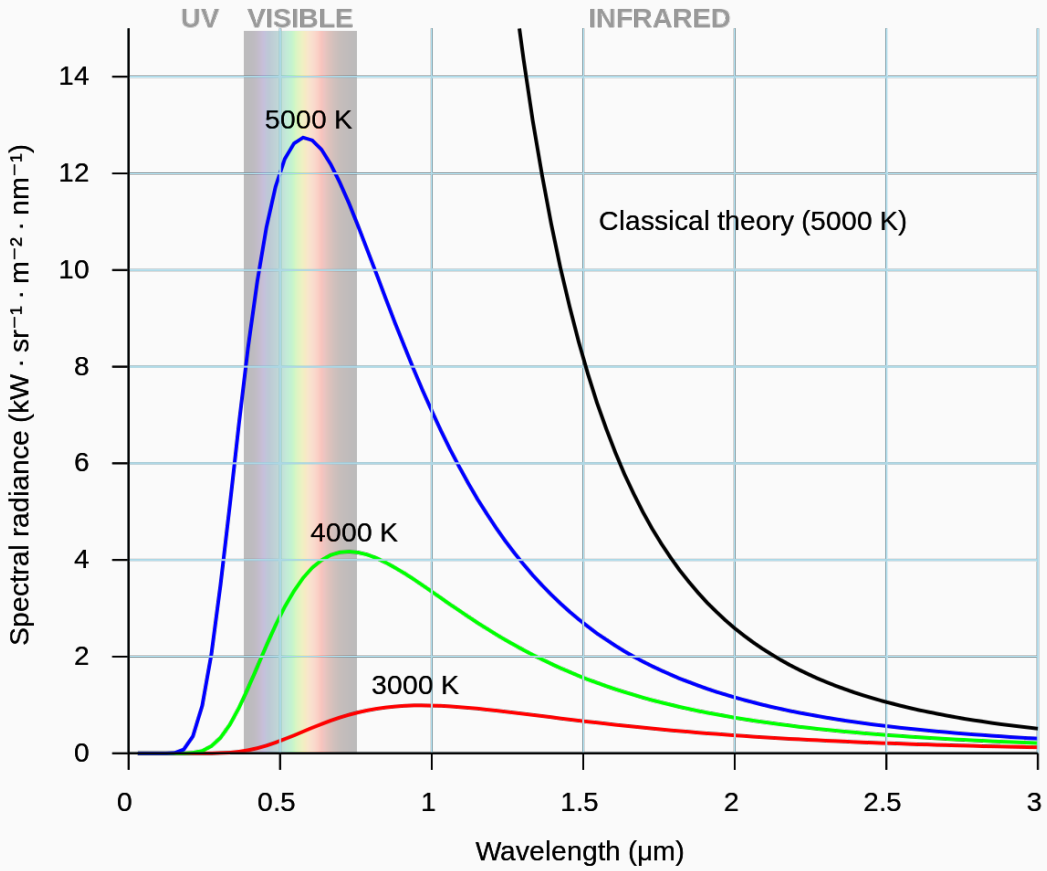
- Since his distribution matches the empirical data perfectly, Planck desperately needed a physical derivation of the distribution.

Max Planck, 1858-1947

  - Planck postulated that the energy carried by an electromagnetic wave comes in "lumps" (in fancier terms, *energy is quantized*). He wrote down the energy-frequency relation $\boxed{E = nhf}$ where h is the famous Planck's constant, $h = 6.626 \times 10^{-34}\ \text{J} \cdot \text{s}$.

Ultraviolet Catastrophe

Despite its success in deriving the radiation law, Planck's postulate was counterintuitive to many physicists (it was hard even for Planck himself to believe). Nevertheless, it provided a resolution consistent with reality which classical physics "fails" to do.



What is Light?

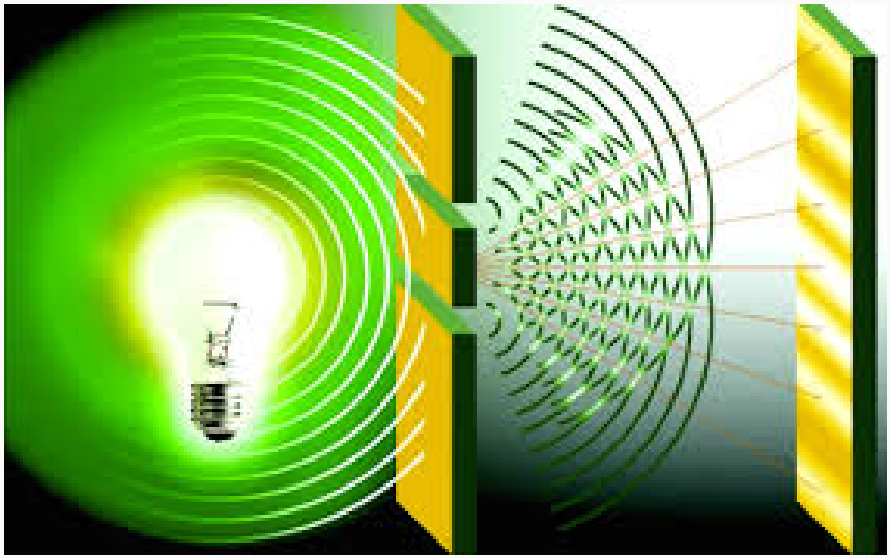
Newton's Corpuscular Theory vs. Huygens' Wave Theory

Isaac Newton, 1643-1727

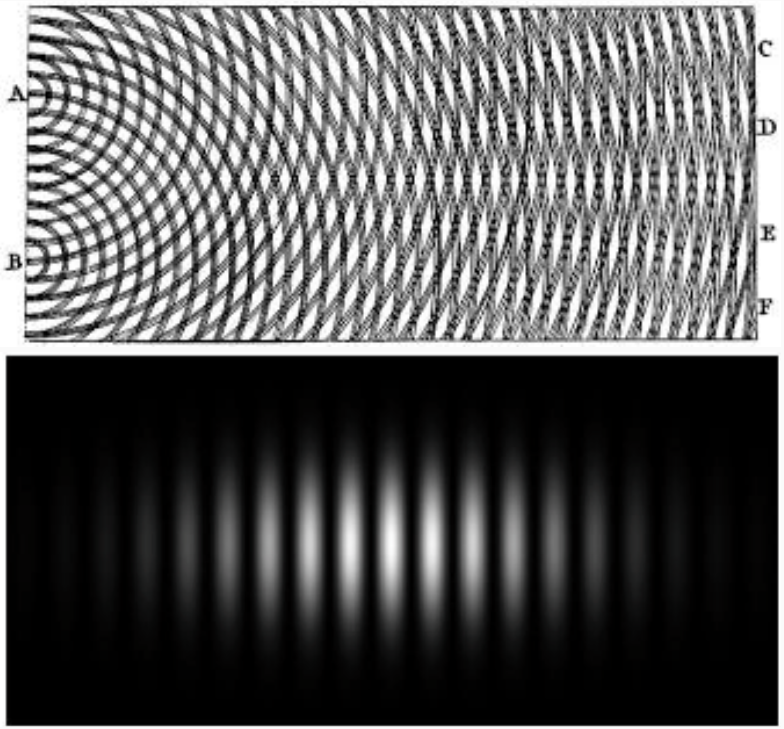
Christiaan Huygens, 1629-1695

Light is a Wave!

There is interference!

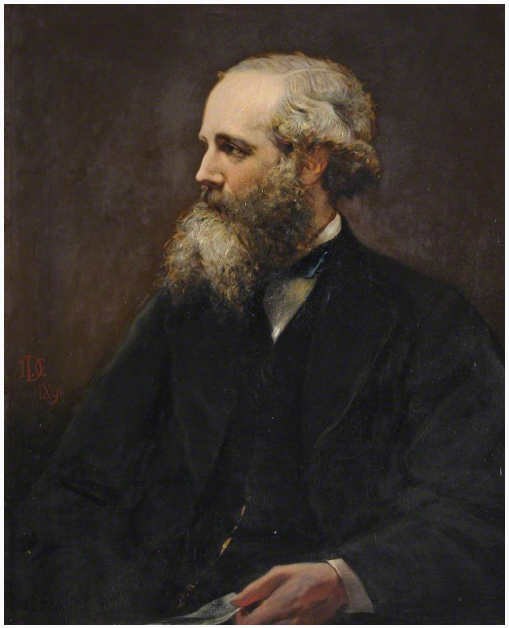


Young's Double Slit Experiment



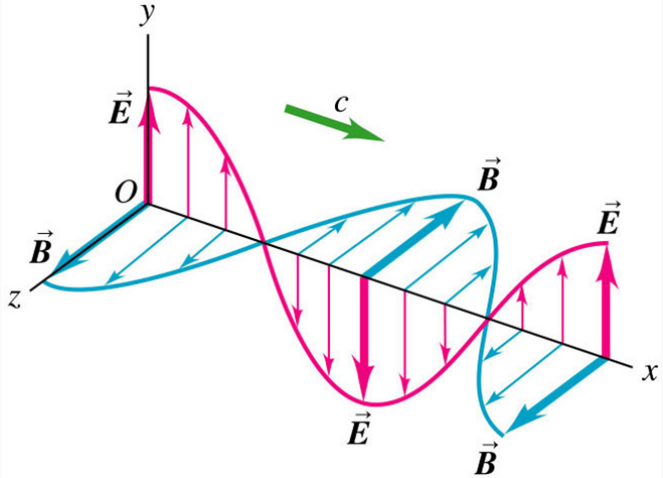
Diffraction and Interference

Light is an Electromagnetic Wave



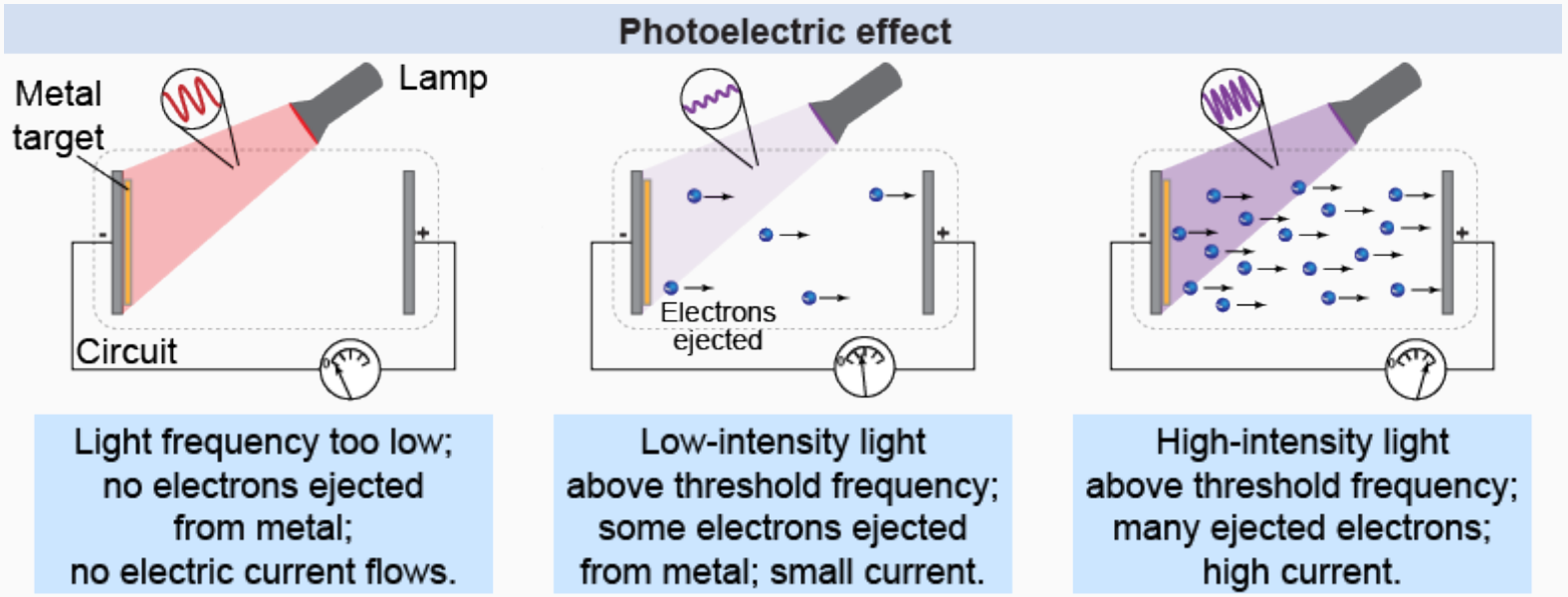
James C. Maxwell, 1831-1879

Heinrich Hertz, 1857-1894



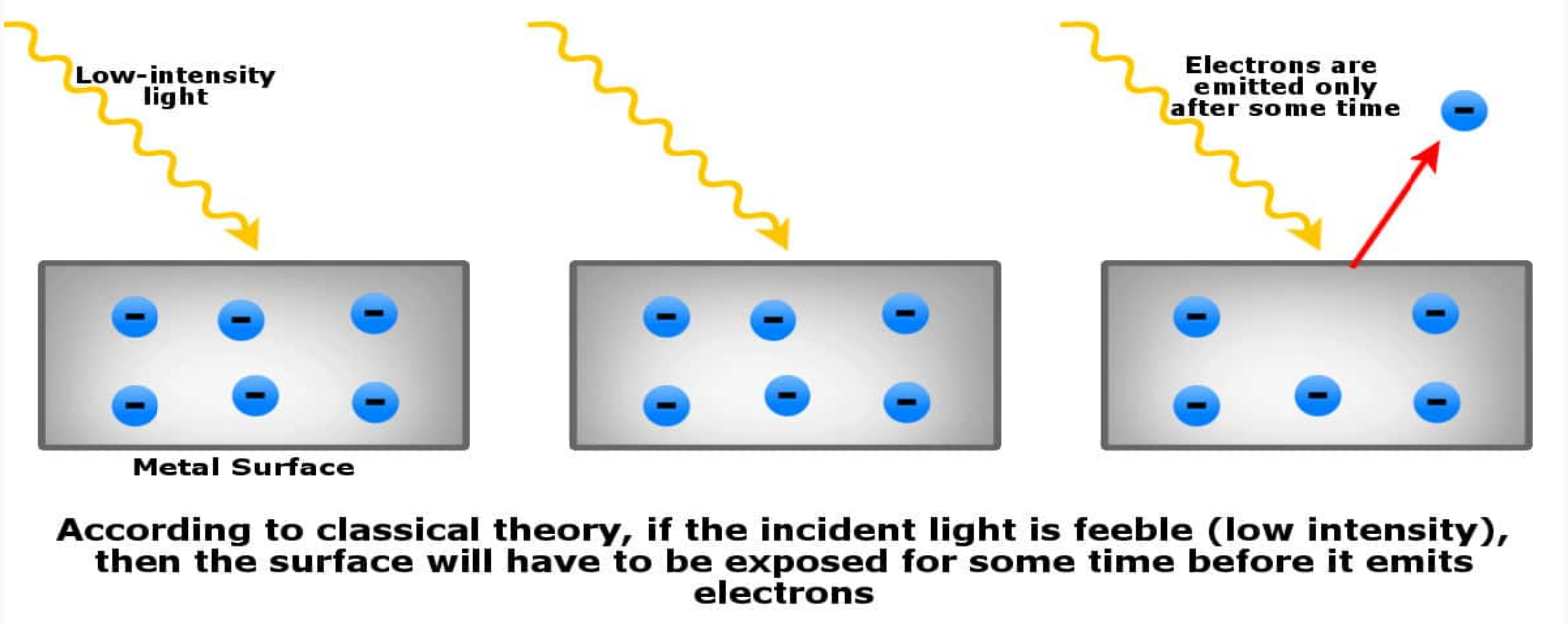
Photoelectric Effects

In 1887, Hertz initiated the study of the photoelectric effect.



Photoelectric Effect Cont'd

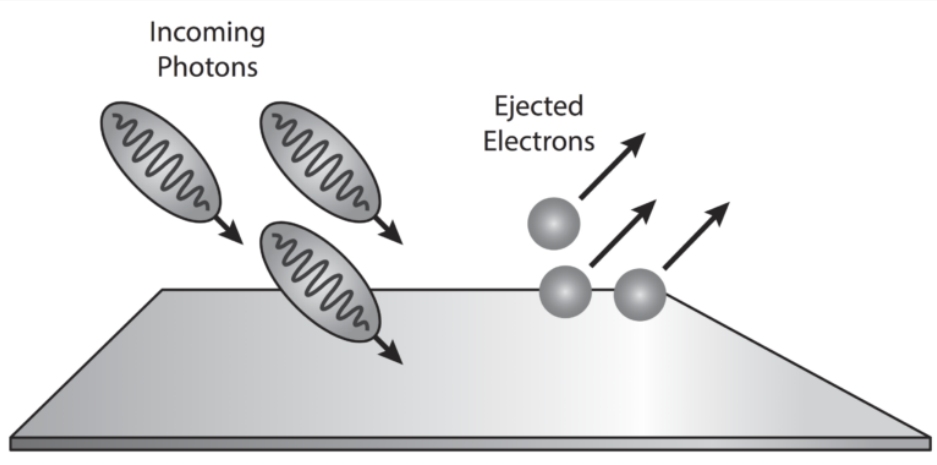
But this conflicted with the classical theory (electromagnetism)



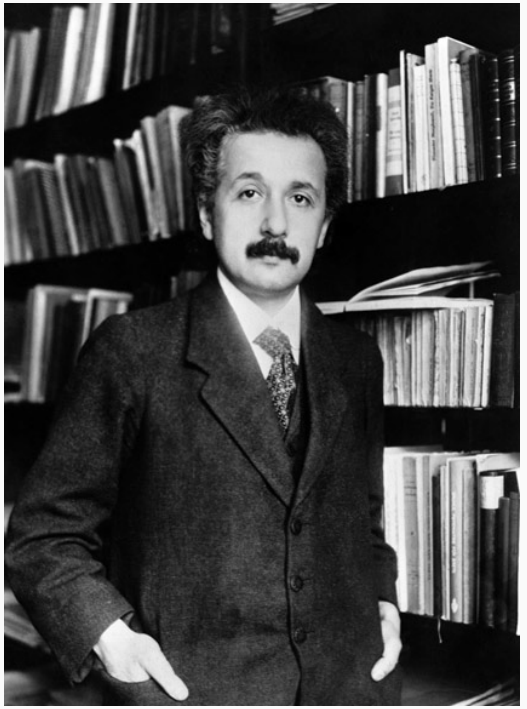
Actual observation

- The emission of electrons and their velocities depend on the frequency of the incident light ray.
- Increasing the intensity of the incident light ray results in the increase in the number of emissions.

Photon, So...Light is a stream of particles?



Photon-Electron Interaction



Albert Einstein, 1879-1955

Einstein theorized

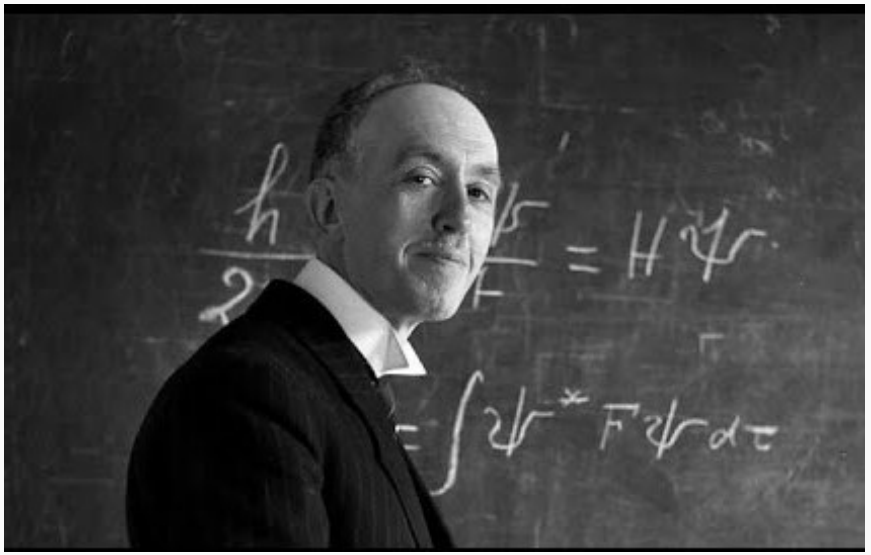
- Based on Planck's earlier idea, light is composed of finitely many discrete "energy quanta", now called a photon.
- He wrote down the formula $\boxed{\mathrm{KE}_{max} = hf - \mathrm{W}_{min}}$.

A New Era of Physics

Wave-Particle Duality

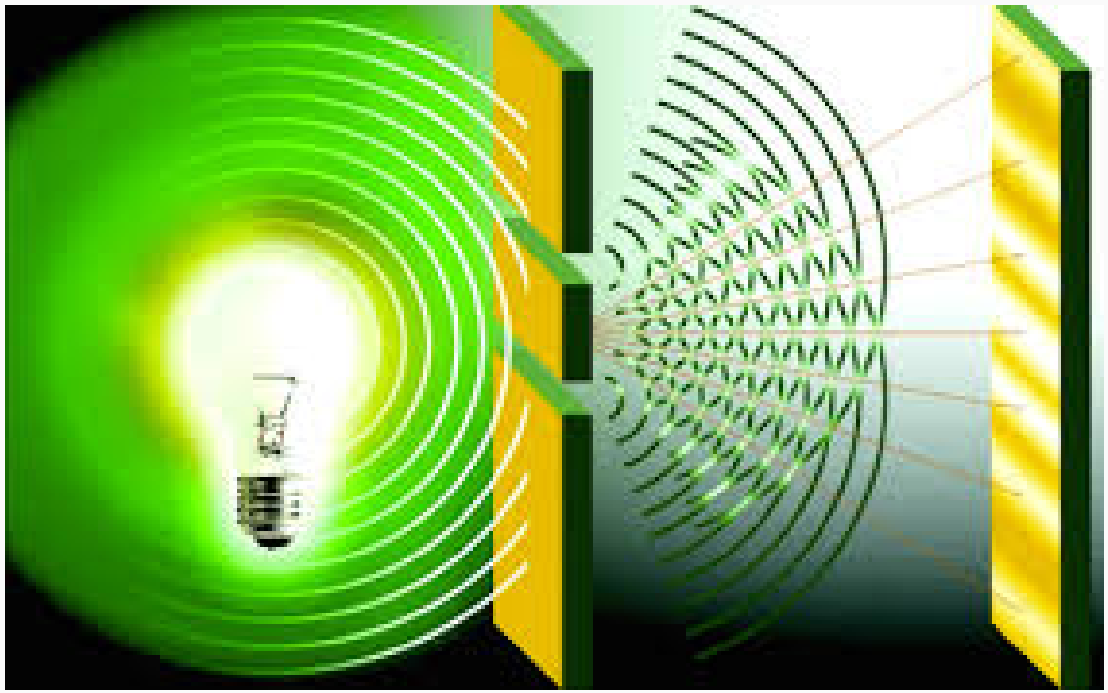
After many experiments, physicists have concluded that light has both wave-like and particle-like natures. This idea is called the *wave-particle duality of light*.

- de Broglie proposed all matter has a wave-like nature in 1924.
- He also wrote down the relationship $\lambda = \frac{h}{mv}$, which is called the *de Broglie wavelength*.
- His theory was confirmed three years later in 1927.



Louis de Broglie, 1892-1987

Wave-Particle Duality Cont'd



Fin.