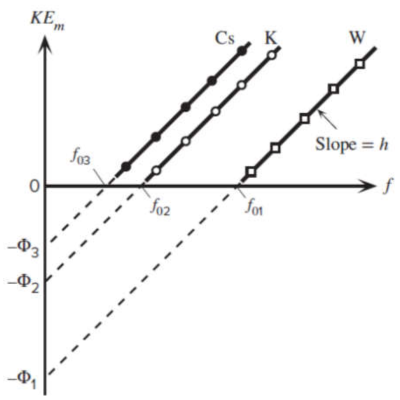
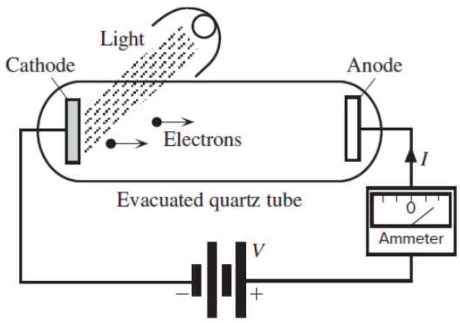
PHOTOELECTRIC EFFECT

Kinetic Energy versus Frequency

$\text{KE}_m = hf - hf_0$

- h : slope of the straight line and is independent of the type of metal; Planck's constant → 6.6×10^{-34} J s.
- f_0 : depends on the electrode material for the photocathode





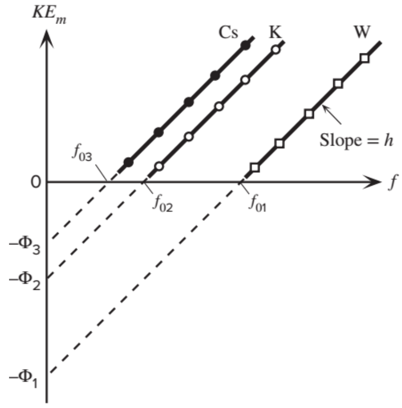
Interpretation of Photoelectric Effect

$$\text{KE}_m = hf - hf_0$$

- h : Planck's constant → 6.6×10^{-34} J s.
- f_0 : minimum frequency for emission

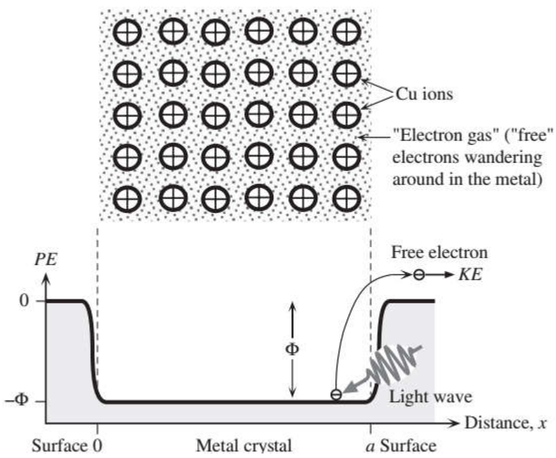
- The successful interpretation of the photoelectric effect was first given in 1905 by Einstein, who proposed that light consists of "energy packets," each of which has the magnitude hf. We can call these energy quanta **photons.**

- Einstein was awarded the Nobel Prize in 1921 for "his discovery of the law of the photoelectric effect",



Emission due to Photons

- Photoemission only occurs when hf is greater than Φ.
- Some of the photon energy hf goes toward overcoming PE barrier. The energy that is left $(hf - \Phi)$ gives the electron its KE.



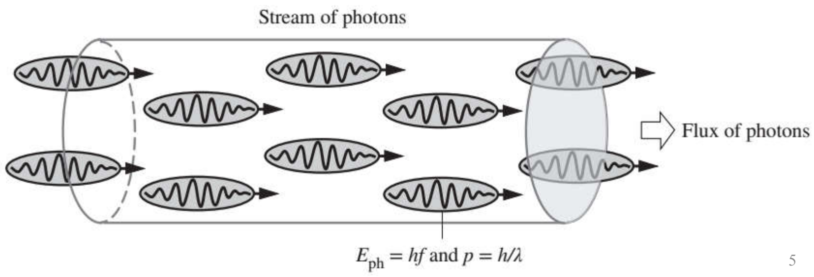
Meaning of Light Intensity

- Classically, $I = \frac{1}{2} c \epsilon_0 {E_0}^2$
- Photon flux density (Γph): Number of photons crossing a unit area per unit time.

$$\Gamma_{\mathrm{ph}} = \frac{\Delta N_{\mathrm{ph}}}{A \Delta t}$$

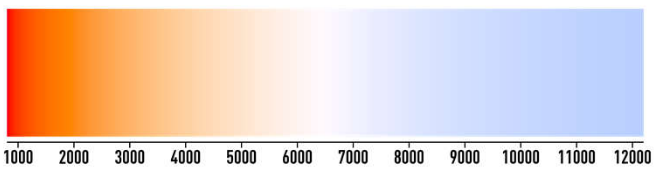
- Light intensity *(I)* : Product of photon flux density and the energy per photon,

$$I = \Gamma_{\mathrm{ph}} hf$$



Black Body Radiation

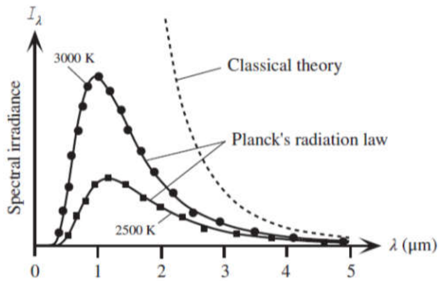
Color of a black body from 800 K to 12200 K. This range of colors approximates the range of colors of stars of different temperatures, as seen or photographed in the night sky.



Temperature of lava flow can be approximated by emitted color.

Black Body Radiation

An object that absorbs all radiation falling on it, at all wavelengths, is called a black body. When a black body is at a uniform temperature, its emission has a characteristic frequency distribution that depends on the temperature. Its emission is called black-body radiation.



Planck's black body radiation formula: $I_\lambda = \dfrac{2\pi hc^2}{\lambda^5\left[\exp\left(\dfrac{hc}{\lambda kT}\right) - 1\right]}$

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ELECTRON AS A WAVE

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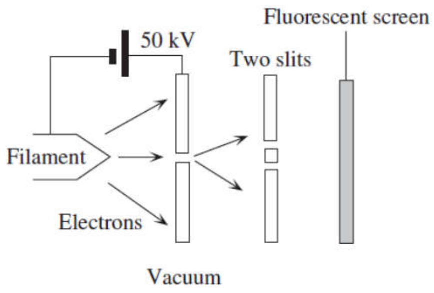
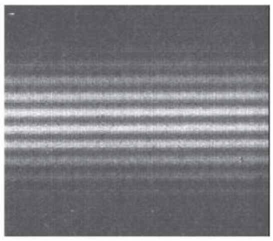
De Broglie Relationship

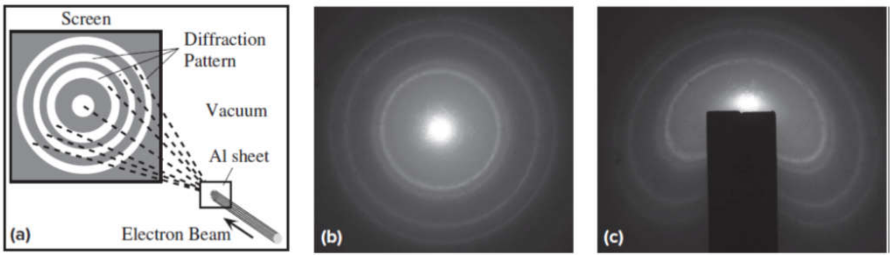
Young's double-slit experiment with an electron beam.





Electron diffraction fringes on the screen

Electron Diffraction Ring



- Electrons obey the Bragg diffraction condition $2d\ \sin\theta = n\lambda$.
- Since we know the interatomic spacing d and we can measure the angle of diffraction 2θ, we can readily evaluate the wavelength λ associated with the wave-like behavior of the electrons.
- Wavelength of an object: $\lambda = \frac{h}{p}$

Wave-Particle Duality of Nature

- Usain Bolt weighs 94 kg and he runs at a velocity of 12.42 m s^{-1}. What is his wavelength?

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{94 \times 12.42} = 56.79 \times 10^{-38}\ \text{m}$$

- Fizz throws a 160 gm cricket ball at a speed of 40 m s^{-1}. What is the wavelength of the ball?

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}\ \text{J s}}{160 \times 10^{-3} \times 40} = 1.04 \times 10^{-34}\ \text{m}$$

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Wave-Particle Duality of Nature

- Electron accelerated by 100 V. Wavelength?

$$\text{KE} = \frac{p^2}{2m_e} = eV$$

$$\lambda = \frac{h}{p} = 0.123\ \text{nm}$$

→ Since this is comparable to typical interatomic distances in solids

→ We would see a diffraction pattern when an electron beam strikes a crystal!

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