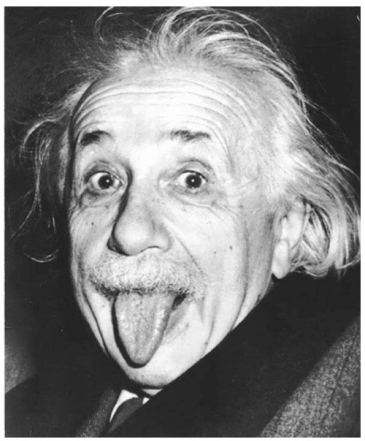
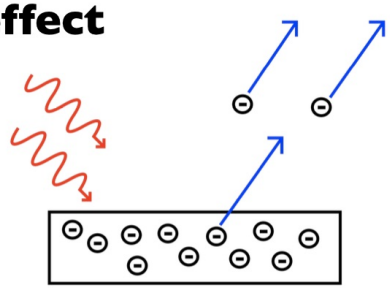
Einstein in 1905 proposed that light itself had quantized energy $E = h\nu$

The Photo-electric effect



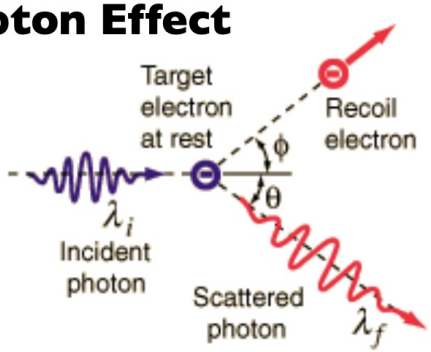


$$h\nu = \Phi + \frac{1}{2}mv^2$$

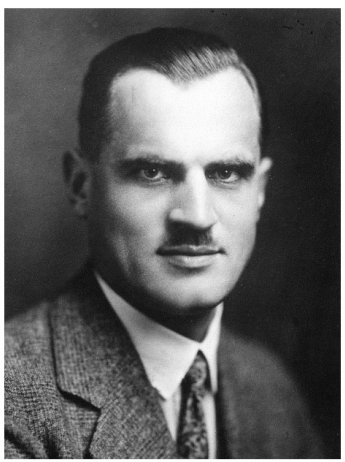
Albert Einstein

Arthur H. Compton

Compton Effect



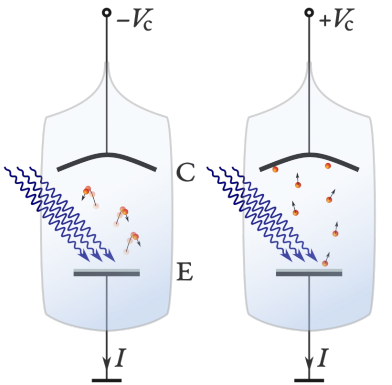
$$\lambda_f - \lambda_i = 2\lambda_C \sin^2\frac{\theta}{2}$$

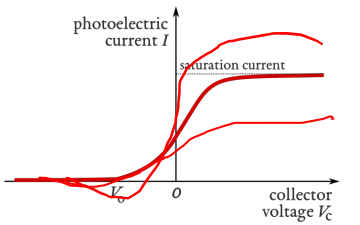


G.N. Lewis "photon"

1. There is a min. threshold ν_t of freq. of radn. used for seeing photocurrent. Below this no emission would occur no matter how long or how intense the incident radiation was.

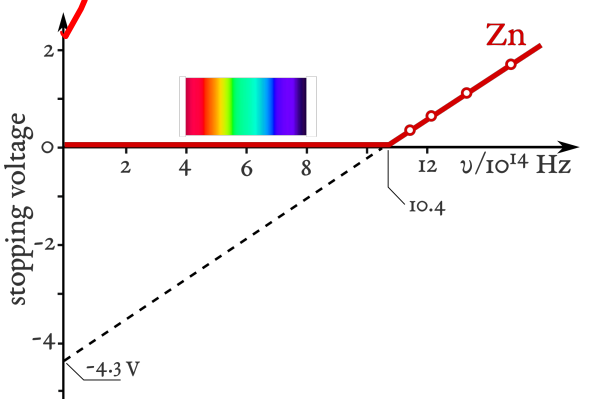
$$I \sim (E/t)/A \quad \text{(Light as wave)}$$





2. Stopping potential is independent of the intensity and instead linearly dependent on the frequency of radiation. $V_0 = c\nu + b$.

$$eV_0 = \tfrac{1}{2} m v_{max}^2$$



3. Electron emission occurred no delay.

Compton effect.

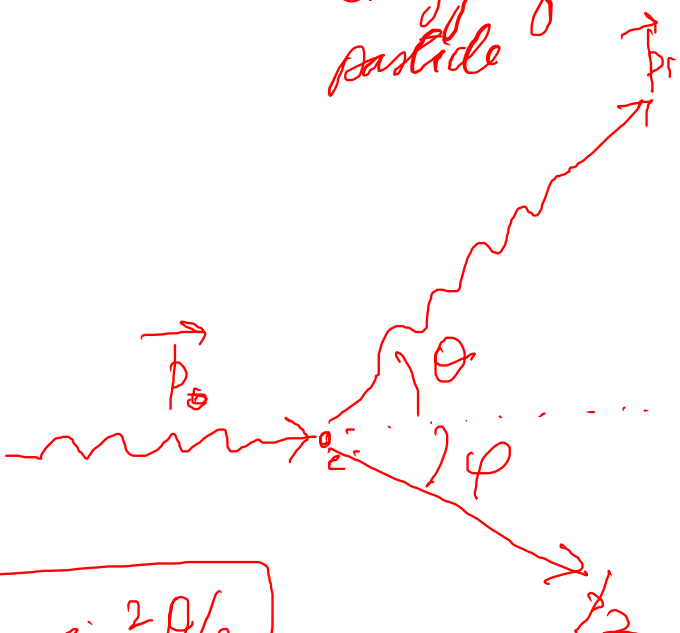
Relativistic kinematics for collision of light quanta ("photons") with loosely bound electrons in materials (atoms).

$$E^2 = m^2c^4 + p^2c^2$$

$mc^2 \rightarrow$ rest-mass energy of particle

For light, $m = 0$ (rest. mass)

$$\Rightarrow \quad p = E/c = \frac{h\nu}{c} = \frac{h}{\lambda}$$



Momentum conservation along energy conservation yields:

$$mc(p_0 - p_1) = 2p_0p_1\sin^2\left(\frac{\theta}{2}\right)$$

using defn. of $\lambda\ (= h/p)$ for light we get

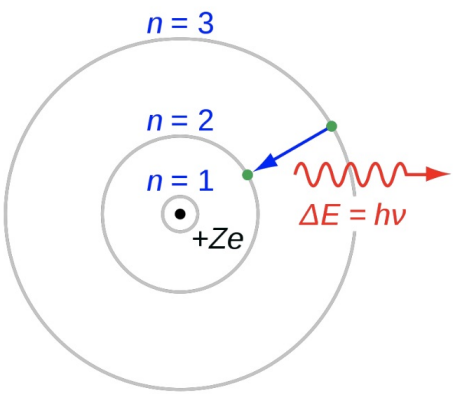
$$\boxed{\Delta\lambda = \lambda_1 - \lambda_0 = 2\lambda_C \sin^2\theta/2}$$

w/ $\lambda_C = h/mc \cong 0.024$ Å

Atomic Structure

Bohr proposed a model for the H atom to explain the Ritz combination law

Neils Bohr



$$\bar{\nu}_{ab} = R_H \left(\frac{1}{n_a^2} - \frac{1}{n_b^2} \right)$$

$$E_n = -\frac{m}{2\hbar^2} \left(\frac{Ze^2}{4\pi\epsilon_0} \right)^2 \frac{1}{n^2}$$

Atomic Structure

1914 Franck-Hertz show the shell structure of the atoms and energy quantization
1921 Stern-Gerlach show electron has an intrinsic angular momentum (spin)

1923 Louis de Broglie hypothesis
Matter waves

$$\nu = \frac{E}{h}$$

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

1923-27 G.P. Thomson and Davisson-Germer experiments show electron's wave nature

Interestingly, J.J. Thomson discovered the electron in 1897 (as a particle!!). Father and son both won Nobel prizes for their respective discoveries.