Quantum Physics
Class 4

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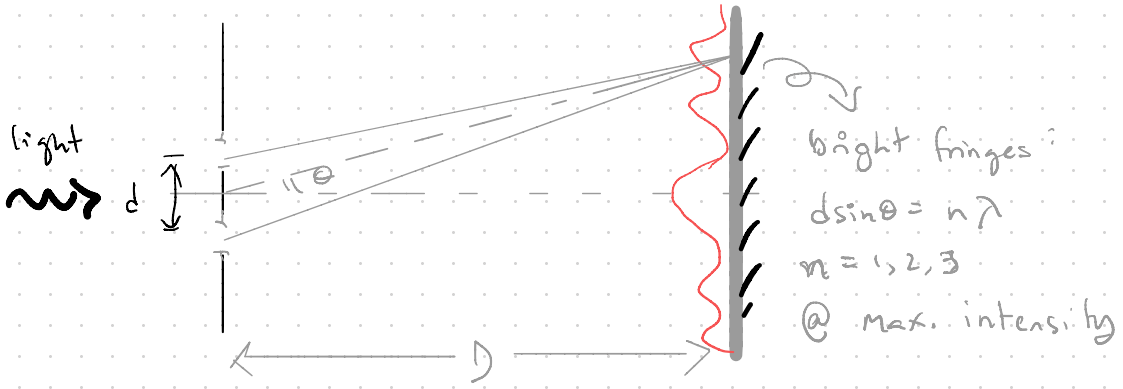
Particle Nature of Light

Review:

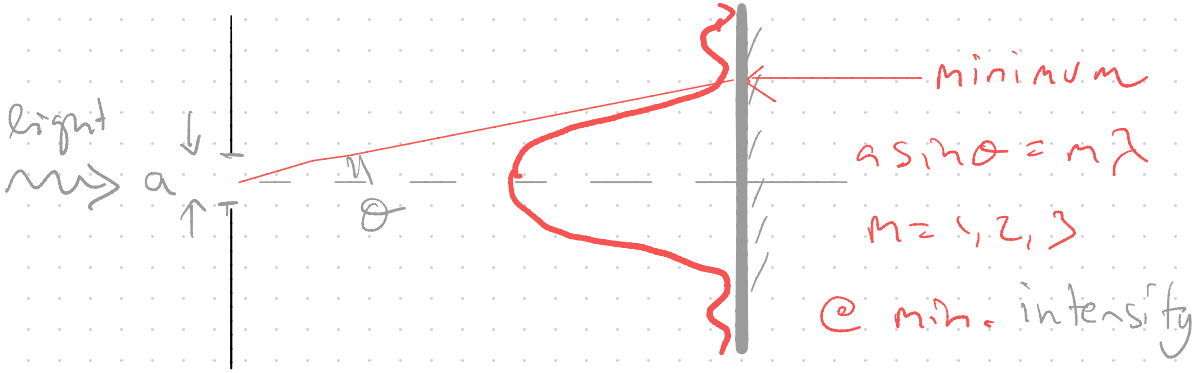
① Superposition of light waves: $\sim e^{i(kx-\omega t)}$

w/t different k

② Double-slit interference experiment:

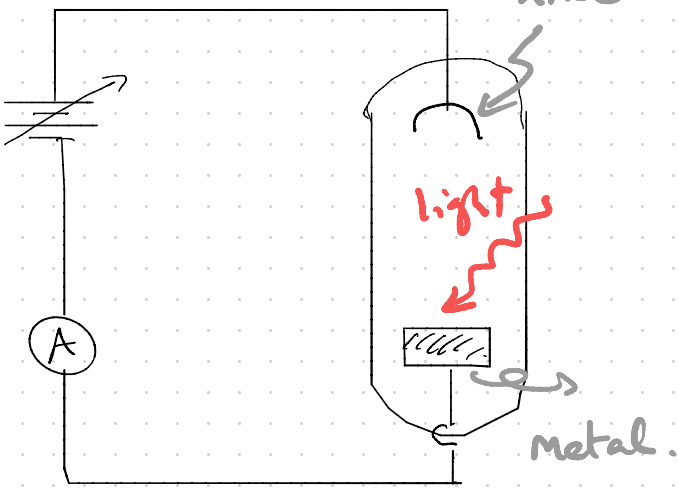


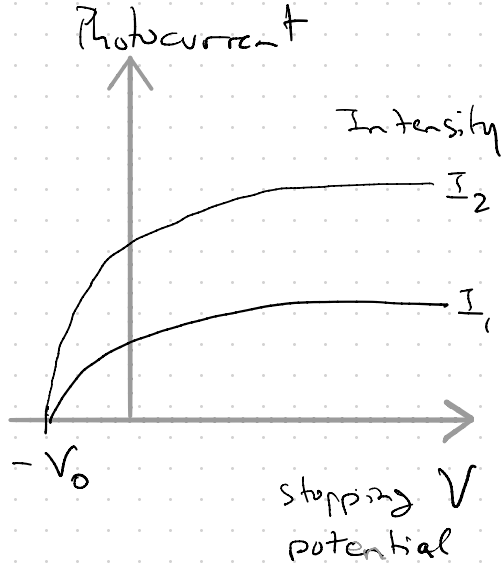
③ Singl-slit diffraction experiment:



Particle Nature of Light

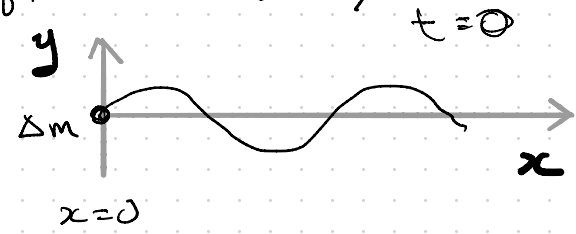
Photoelectric Effect





Consider:

① Classical Picture (light is a wave!)



$$y = y_m \sin(kx - \omega t)$$

$$\frac{dy}{dt} = -y_m \omega \cos(kx - \omega t)$$

recall. $K.E \sim \frac{1}{2}mv^2$

$$\therefore KE \sim \frac{1}{2}\Delta m \left(\frac{dy}{dt}\right)^2 \sim \frac{1}{2}\Delta m (y_m \omega)^2 \cos^2(kx - \omega t)$$

$$\therefore KE \sim (y_m \omega)^2$$

↑ the amplitude.

② Einstein's theory (particle-like nature of light):

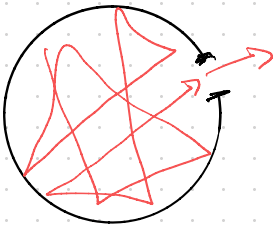
⇒ Light consists of particles or quanta

$E = h\nu$ → frequency

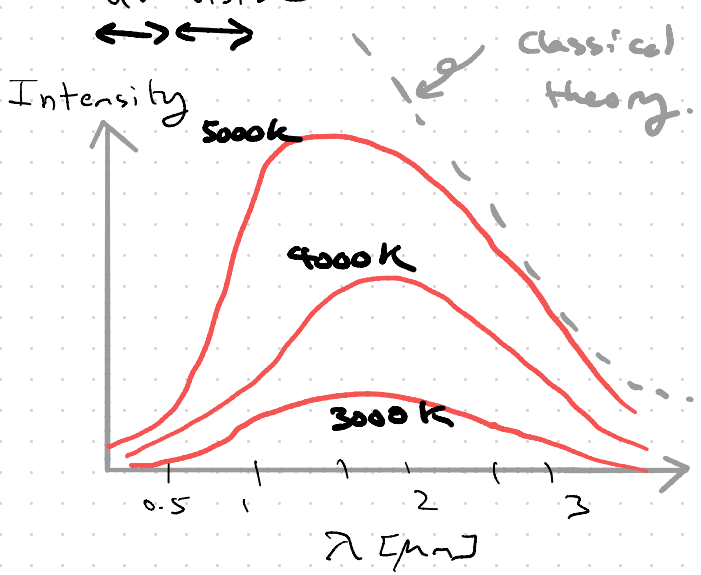
→ Planck's constant

** Intensity of light ⇒ $nh\nu$; where n is the # of photons (light particles)

This relationship was developed from research problem ~1900s with blackbody radiation. Max Planck heuristically derived the formula for observed spectra. Assumed oscillators in a cavity could change their energy by a fixed amount.



Hot cavity!



Planck: $B(\nu, T) = \frac{2h\nu^3}{c^2} \frac{1}{\exp(\frac{h\nu}{k_B T}) - 1}$

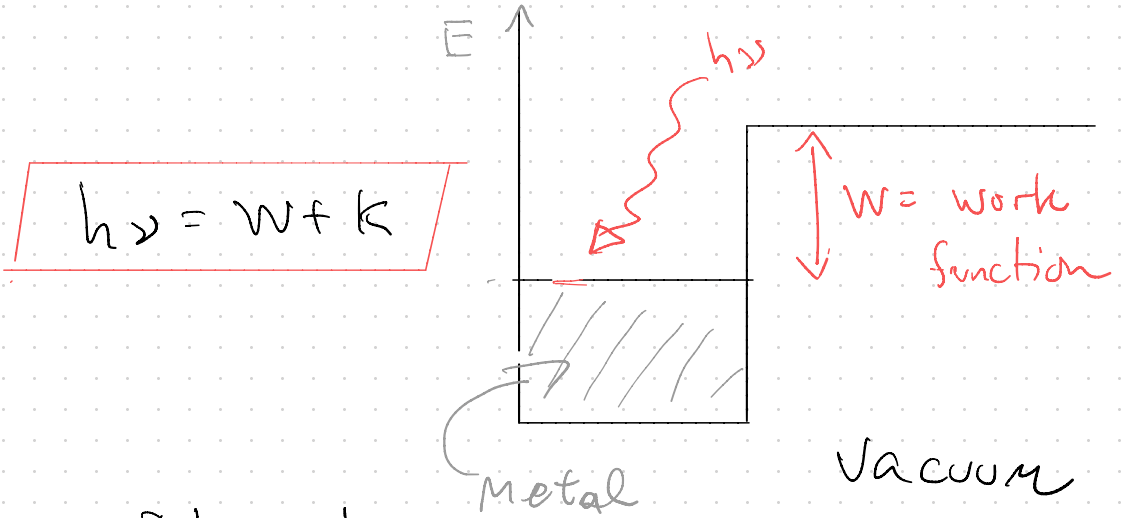
Spectral density

$\Sigma E = n h \nu$

Einstein said radiating atom: $E_1 - E_2 = h\nu$

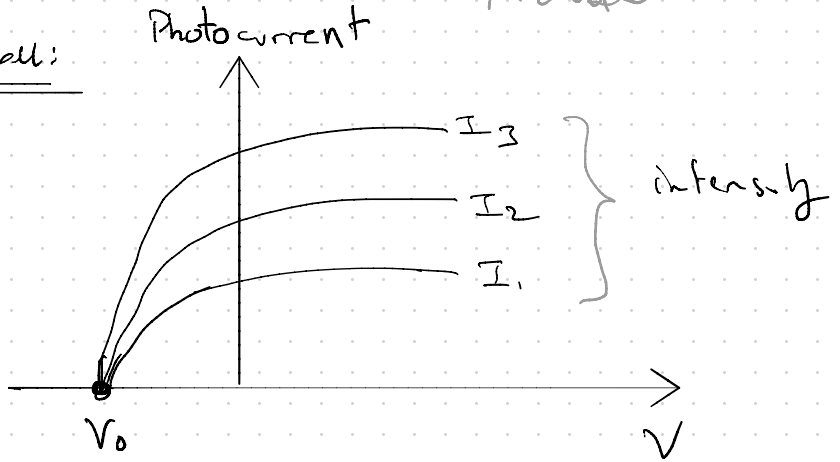
(generates single particle with energy equal to the difference of two energy levels)

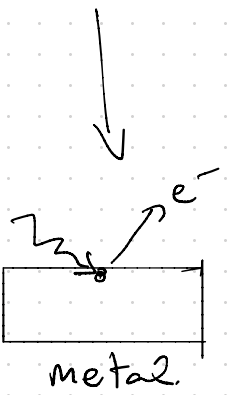
Photoelectric Effect



$h\nu = W + K$

recall:





Now, $c = \lambda \nu$

$\therefore E = h\nu = \frac{hc}{\lambda}$; Energy of the photon

$$\lambda[m] = \frac{hc}{E[J]}$$

$$\lambda[nm] \times 10^{-9} = \frac{(6.6 \times 10^{-34})(3 \times 10^{8})}{E[ev] \times (1.6 \times 10^{-19})}$$

$$\Rightarrow \lambda[nm] = \frac{1240}{E[ev]}$$

In-class 4.2, 4.3

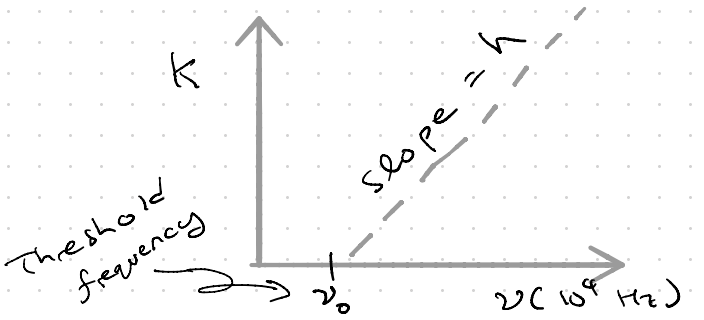
Millikan's Expt. & Einstein's Prediction:

recall : $E = K + W$

$h\nu = K + W$

$K = 0$

$h\nu_0 = W$



In-class 4.4