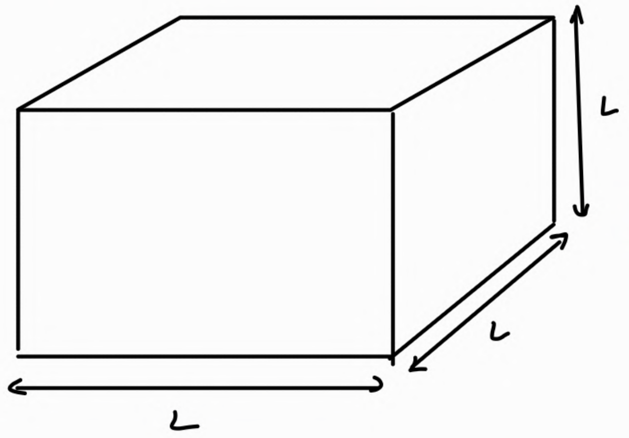
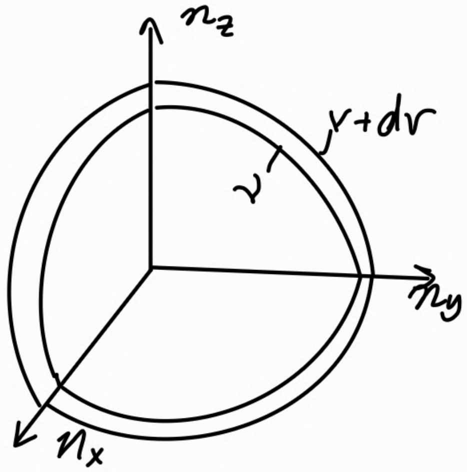


$$\vec{k} = \frac{2\pi}{L}\vec{n}$$

$$\omega = c|\vec{k}| = c\,\frac{2\pi}{L}\left(n_x^2 + n_y^2 + n_z^2\right)^{1/2}$$

Degeneracy: How many different n_x, n_y, n_z for a given ω?

$$\boxed{\begin{aligned}&\left(\frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \frac{\partial^2}{\partial x^2} - \frac{\partial^2}{\partial y^2} - \frac{\partial^2}{\partial z^2}\right) f = 0 \\ &f = A\cos(\omega t)\,\sin\left(\frac{n_x \pi x}{L}\right) \cdot \sin\left(\frac{n_y \pi y}{L}\right) \cdot \sin\left(\frac{n_z \pi z}{L}\right)\end{aligned}}$$



$$dN = \frac{4\pi V}{c^3}\nu^2 d\nu$$

$$\nu = f$$

$$\omega = 2\pi f$$

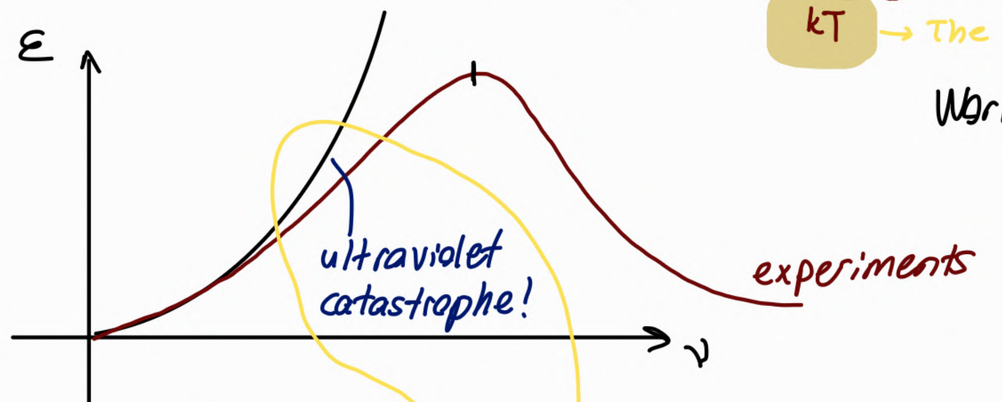
Rayleigh – Jeans

$$\varepsilon(\nu, T) = \frac{8\pi}{c^3}\nu^2 \underbrace{\bar{E}(\nu, T)}_{kT}$$

(From each polarization $\frac{kT}{2}$)

→ The problem is here!

Works in small frequencies.



$$E = \int_0^\infty d\nu\, \varepsilon(\nu, T) \rightarrow \infty$$

Some other laws:

"... kayma yasası"

"Stephan's Law about energy density"

So... The exact formula is in some books

$$\varepsilon(\nu, T)\,d\nu = \frac{8\pi h}{c^3}\frac{\nu^3 d\nu}{e^{\frac{h\nu}{kT}}-1}$$

no catastrophes!

Math Trick Used:

→ Some integrals can be manipulated to do variable change on a dimensionless parameter. (If lim isn't ∞ or there is no homogenity this trick won't work)

$$\int_0^\infty \varepsilon(\nu, T)\,d\nu = \frac{8\pi h}{c^3}\int_0^\infty \frac{\nu^3 d\nu}{e^{\frac{h\nu}{kT}}-1} \qquad z = \frac{h\nu}{kT} \qquad \nu = \frac{kT}{h}z$$

absolute temp.

$$= \frac{8\pi h}{c^3}\left(\frac{kT}{h}\right)^4 \int_0^\infty \frac{z^3 dz}{e^z - 1}$$

(pure number)

$$= aT^4 \qquad a = \frac{16\pi^8 k^4}{15\, h^3 c^3}$$

↳ stephan - Boltzmann constant.

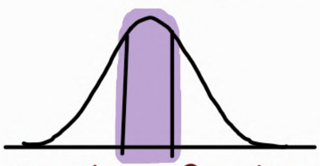
maximal ε:

$$\left(\frac{A}{B}\right)' = \frac{A'}{B} - \frac{B'A}{B^2}$$

$$\frac{(e^{\frac{h\nu}{kT}}-1)\,3\nu^2}{(e^{\frac{h\nu}{kT}}-1)^2} - \frac{\frac{h}{kT}\,e^{\frac{h\nu}{kT}}\,\nu^3}{(e^{\frac{h\nu}{kT}}-1)^2} = 0$$

$$3e^{\frac{h\nu}{kT}} - \frac{h\nu}{kT}e^{\frac{h\nu}{kT}} = 3$$

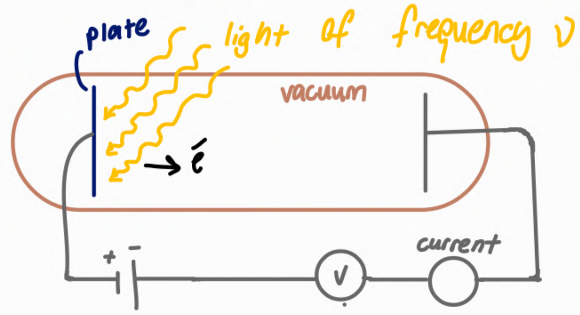
$$e^z(3-z) = 3 \rightarrow z_{max} \text{ (fix)}$$

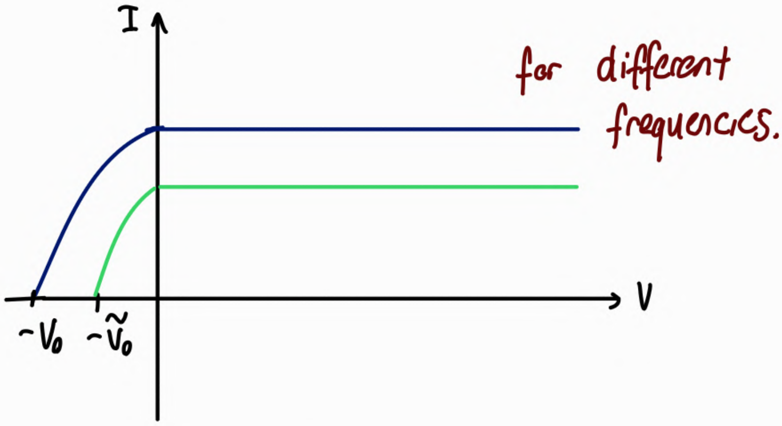


$$\nu_{max} = \frac{kT}{h} z_{max}$$

Possible Question: "Two blackbodies are in equilibrium... etc."
(so emittion from one should be equal to the other ...)

Photoelectric Effect





When light hits, electron jumps off. But what is the mechanics of this?

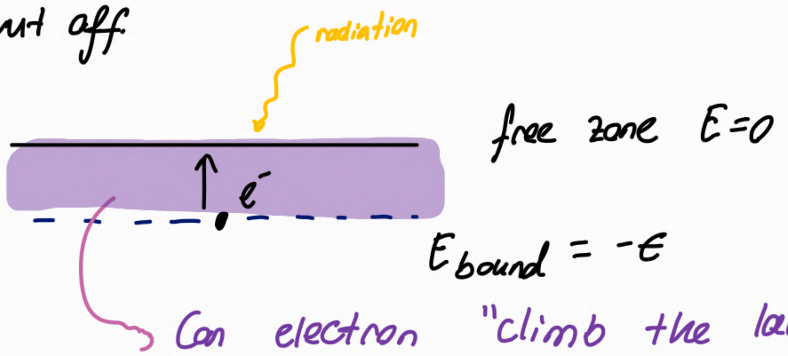
- Think like bound state → There is an energy to cut off the electron from there. (Binding energy)

→ Is there a cutoff frequency? Yes. under that, there is no effect.

→ Is there a delay? No! The moment it opens, current flows. So, electron doesn't "collect" energy. Takes the "package" and goes.

→ "More light" = More electron.

work energy of the metal: ϵ so that e^- has no K.E., but is cut off.



Can electron "climb the ladder": NO! if it did there would be time delay and no cutoff frequency.

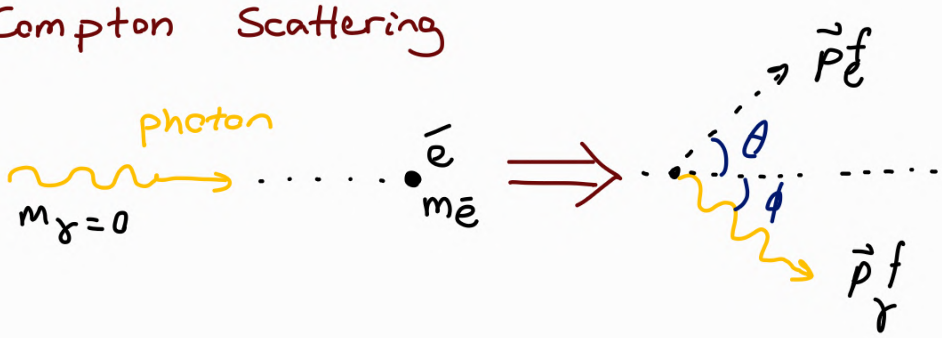
Final Energy:

$$KE_f + \epsilon = h\nu$$

stop the e^- to find ϵ. (Reverse current)

the h is the planck's constant :)

Compton Scattering



$$E^i = h\gamma + m_0 c^2 \qquad E^f = h\gamma' + E^e$$

$$\vec{P}^i = \frac{h\gamma}{c}\hat{i} \qquad p_x^f = p_e^f \cos\theta + p_\gamma^f \cos\phi$$

$$p_y^f = p_e^f \sin\theta - p_\gamma^f \sin\phi = 0$$

We want to measure the scattering.

4 - momentum conserved:

$$P_\gamma^i = P_\gamma^f + P_e^f$$

$$P_\gamma^i - P_\gamma^f = P_e^f$$

$$(P_\gamma^i - P_\gamma^f)\circ(P_\gamma^i - P_\gamma^f) = m_e^2 c^2$$

$$-2 P_\gamma^f \circ P_\gamma^i = m_e^2 c^2$$

$$P \circ P = \frac{E^2}{c^2} - P = m^2 c^2 \quad \text{Lorentz Norm}$$

$$\begin{pmatrix} E_\gamma^i/c \\ E_\gamma^i/c^2 \\ 0 \end{pmatrix} \qquad \begin{pmatrix} E_\gamma^f/c \\ \frac{E_\gamma^f}{c^2}\cos\phi \\ -\frac{E_\gamma^f}{c}\sin\phi \end{pmatrix}$$

$$-2\left(\frac{E_\gamma^i E_\gamma^f}{c^2} - \frac{E_\gamma^i E_\gamma^f}{c^2}\cos\phi\right)$$

$$E_\gamma^i E_\gamma^f(\cos\phi - 1) = \frac{m_e c^4}{2}$$

compton wavelength $\lambda = \frac{\hbar}{mc}$

$$\boxed{\nu_i \nu_f (\cos\phi - 1) = \frac{m_e c^4}{2h^2}}$$

Compton scattering Formula

"A measurable quantity is found by a constant"

De Broglie Hypothesis

$$\frac{E^2}{c^2} - p^2 = m^2c^4$$

$E = hf$

$\lambda = cT$

$\lambda = \frac{c}{f}$

$E = \frac{hc}{\lambda}$

$$\lambda = \frac{hc}{E} = \boxed{\frac{h}{p}} = \lambda$$

$$p = \sqrt{2mE} \qquad \lambda = \frac{h}{\sqrt{2mE}}$$

The same holds for massive particles too!

Note

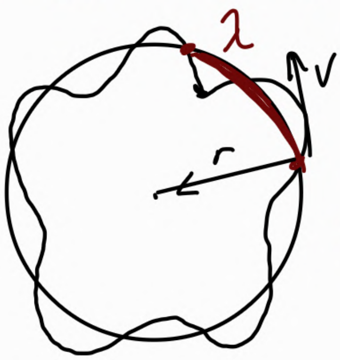
$\hbar c = 200\,\text{MeV}\,\text{Fm}$ $\quad 10^{-15}\,m$

$m_e c^2 = 0.5\,\text{MeV}$

eV: Kinetic energy of one electron in 1 Volt potential difference.

$$\lambda = \frac{\hbar c}{\sqrt{2mc^2E}} 2\pi = \frac{200\,\text{MeV Fm}}{\sqrt{10^9}} 2\pi = 20000\ 10^{-11} 2\pi\ m$$

What Bohr had in mind



① $\lambda = \frac{h}{p}$ integer λ in $2\pi r$

② $E = \frac{1}{2}mv^2 - \frac{e^2}{4\pi\varepsilon_0 r}$

$$\frac{nh}{p} = 2\pi r \Rightarrow \frac{nh}{2\pi} = rp$$

$\boxed{n\hbar = pr}$ angular momentum.