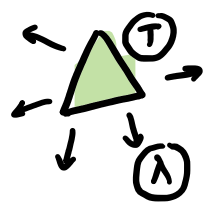
# Quantum day 2

Saturday, October 16, 2021 10:06 AM

**Thermal radiation** – obj has certain wavelength of emission @ certain temp

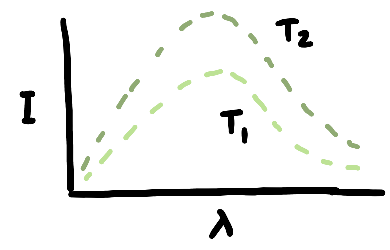
Experiment: $I = \sigma T^4$ $\sigma = 5.6\times10^{-8}\ \frac{W}{m^2K^4}$

intensity




- Stefan's Law: $\lambda_{max} \propto \frac{1}{T}$

$\lambda_{max} T = 2.89\times10^{-3}\ mK$



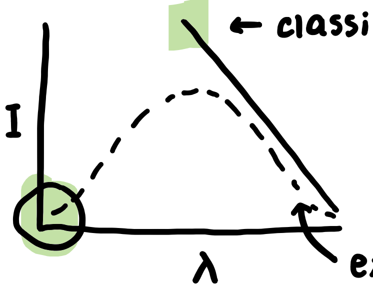

ex: obj at T=20° – what is max thermal radiation?

$\lambda_{max} = \frac{2.89\times10^{-3}}{T} = \frac{2.89\times10^{-3}}{293} = 10\mu m$

(K)

infrared range; invisible

Classical theory: $I \propto T$ ← not valid




← classical – super big intensity @ low λ

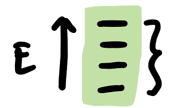
experimental – almost 0 at low λ

Quantum theory: energy is quantized; NOT continuous

$E = nE$

$E = h\times f$

Planck's



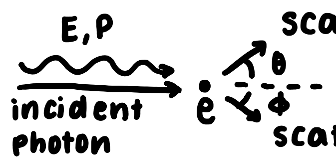

not integral b/c integrals continuous

$E_{av} = \frac{1}{N}\sum_{n=0} N_n E_n$

$I = \frac{2\pi h c^2}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1}$

**Blackbody radiation**: everything emits blackbody radiation

**Compton effect:**




scattered photon $\boxed{E', P'}$

scattered electron $\boxed{E_e, P_e}$

$E = \frac{hc}{\lambda}$ $f\times\lambda = c$

$P = \frac{E}{c} = \frac{h}{\lambda}$ ⇨

$E_i = E_f$

$P_{x_i} = P_{x_f} \rightarrow P = P_e \cos\phi + P'\cos\theta$

$P_{y_i} = P_{y_f} \rightarrow 0 = P'\sin\theta - P_e \sin\phi$

$E_e = \sqrt{c^2 P_e^2 + m^2 c^4}$

if $P_e = 0 \rightarrow E = mc^2$

so $E + mc^2 = E' + E_e$

**De Broglie's hypothesis:** generalized it for all objects

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

a) 1000 kg car $v = 100\ m/s$

$\lambda = \frac{h}{mv} = \frac{h}{(1000)(100)} = 6\times10^{-39} m$

SUPER small (that's why we don't see wave behavior in larger objects)

b) 10g bullet $v = 50\ m/s$

$\lambda = 1.3\times10^{-34} m$ still tiny

c) electron $E = 1eV$ $m = 9.1\times10^{-31}\ kg$

$E = mc^2$

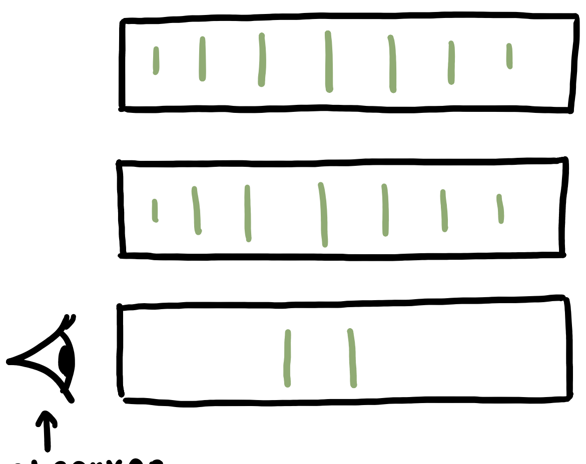
$P = \sqrt{2mK} = 5\times10^{-25}$

$\lambda = 1.2nm = 1.2\times10^{-9} m$

big asf I guess

$\boxed{\uparrow \lambda \propto \frac{1}{m\downarrow}}$

Double slit:



wave behavior
interference pattern

same for 1 electron at a time

particle behavior
wave function collapsed by observer

observer

$|\ \rangle \rightarrow$ state

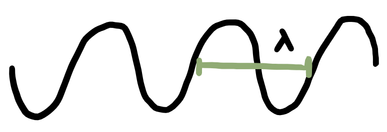
$|0\rangle \rightarrow$ state 0

$|1\rangle \rightarrow$ state 1

$\boxed{P_1|0\rangle + P_2|1\rangle}$ (probability function)

collapses when there is an observer

Uncertainty for classical waves:




$\Delta x \simeq \lambda$

uncertainty of x position (NOT the actual pos)

$\Delta\lambda \simeq \varepsilon\times\lambda$

$\Delta x \Delta\lambda \simeq \varepsilon\lambda^2$ ①

$P = \frac{h}{\lambda}$ $\Delta P = ?$

$dP = -\frac{h}{\lambda^2} d\lambda \rightarrow \Delta P = -\frac{h}{\lambda^2}\Delta\lambda$ ②

① & ②: $\frac{\Delta x \Delta P \lambda^2}{-h} = \varepsilon\lambda^2$

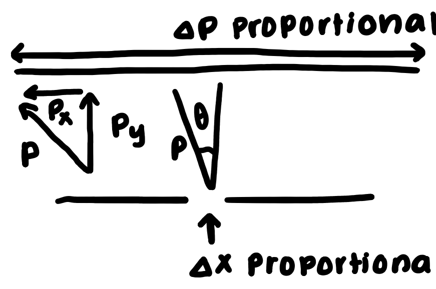
$\therefore \Delta x \Delta P \sim \varepsilon h$

equivalent

Heisenburg uncertainty principle → $\Delta x \Delta P \geq \frac{\hbar^2}{2}$ $\hbar = \frac{h}{2\pi}$

if Δx or ΔP is 0, it's not possible so there is never an exact position / momentum

Single slit diffraction: verify uncertainty principle




slit width↓ spread↑

$\sin\theta \sim \frac{\theta}{\varepsilon} \sim \frac{\lambda}{w}$

$\theta \sim \frac{\Delta P_x}{P_y}$

spread ~ width ~ constant