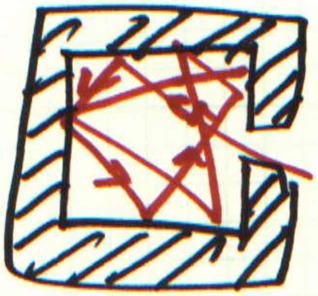
Chapter 28

Blackbody: an ideal sys. that absorbs all radiation incident on it

⇒ EM wave emitted by a b.b. is called b.b. radiation

- continuous dist. of λs radiation
-



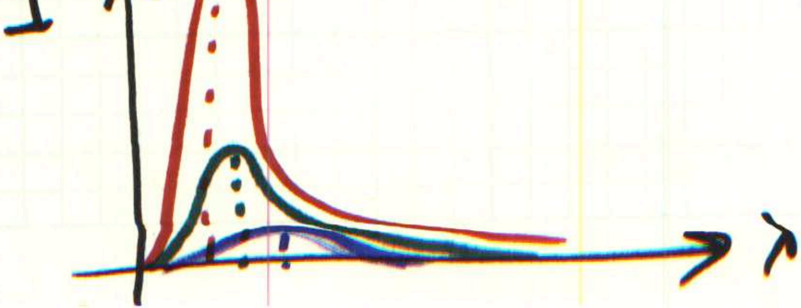
radiation only depends on T.

total power → $\boxed{P = \sigma A e T^4}$ Stefan's law

stefan-Boltzman const.

e=1 for b.b.

$$\boxed{\lambda_{max} T = 2.898 \times 10^{-3} \text{ m} \cdot \text{K}}$$ Wien's law

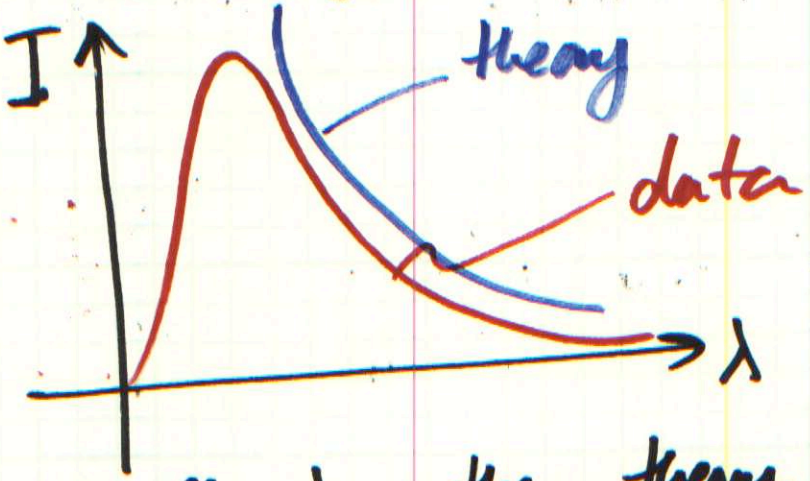


$P = \sigma A T^4$ $\lambda_{max} = \frac{2.898 \times 10^{-3}}{T}$

As T↑ then P↑

As T↑ then λ_{max}↓

Classical theory of radiation:



At small λ the theory & data did not match. ⇒ a.k.a
Ultraviolet catastrophe

Max Planck: (1918 Nobel Prize)

Introduced "quantum action"

Planck's theory:

- radiation of b.b. came from atomic osc.
- the E of osc. can only have certain values (quantized):

$$\boxed{E_n = n \cdot h \cdot f}$$

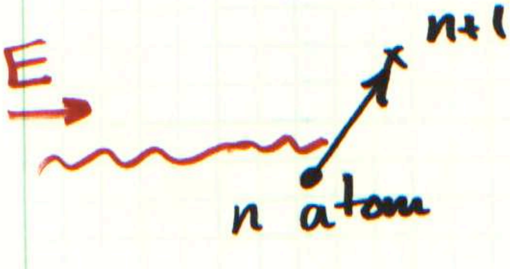
frequency

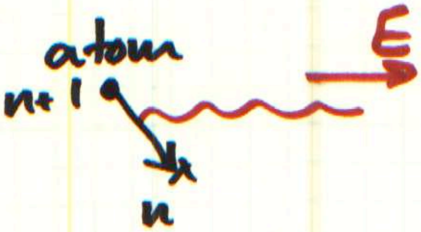
quantum #

Planck's const.

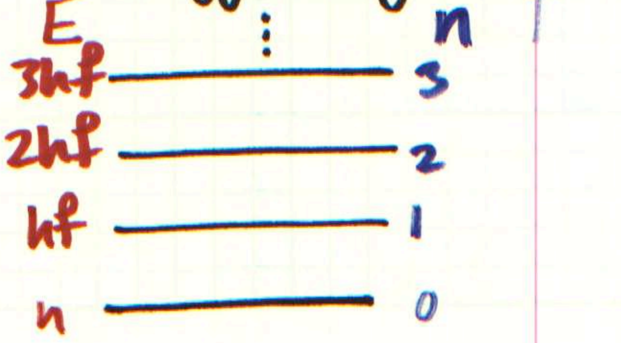
⇒ E is quantized

⇒ diff. n's corr. to diff quantum states





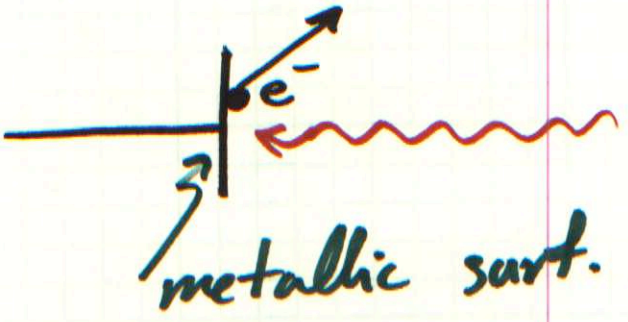
Energy diagrams:



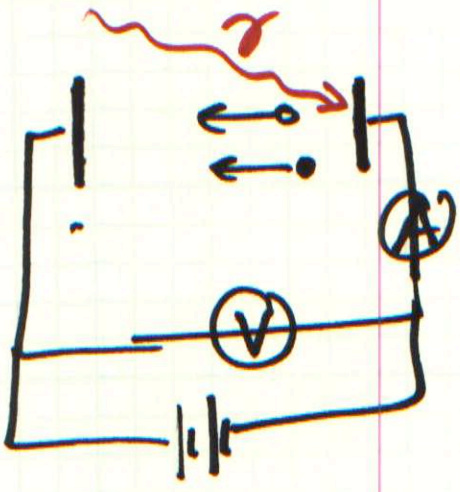
* As $n \to \infty$ we are back to classial limit. (Evryday life)

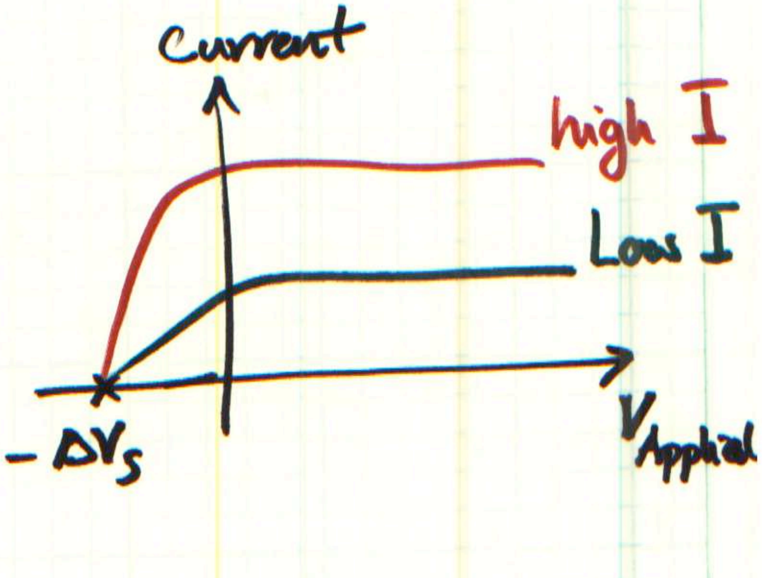
* Q. eff. are only important for submicroscapic level

Photoelectric Eff.



(eff. discovered by Hertz)





* I_{max} dep. on I
* $\Delta V < 0$ current drops
* $\Delta V = \Delta V_s$ or $\Delta V < \Delta V_s$ ⇒ no current

Classical Theo.

* e^- should absorb E cont.
* As I increases e^- should eject w/ more K.E.

Exp. Results:

* $K.E_{max}$ is ind. of I
* ΔV_s is the same for all ~~[illegible]~~ I's
* no delay for e^- emission
* No e^- emitted below a certain f.
  $f_c \equiv$ cuttoff freq.
* f_c dep. on material used
* $K.E._{max}$ increases w/ f

Einstein generalized Planck's theory to EM waves.

EM waves ⟶ stream of quanta

⟶ photo (γ)

Work Func.

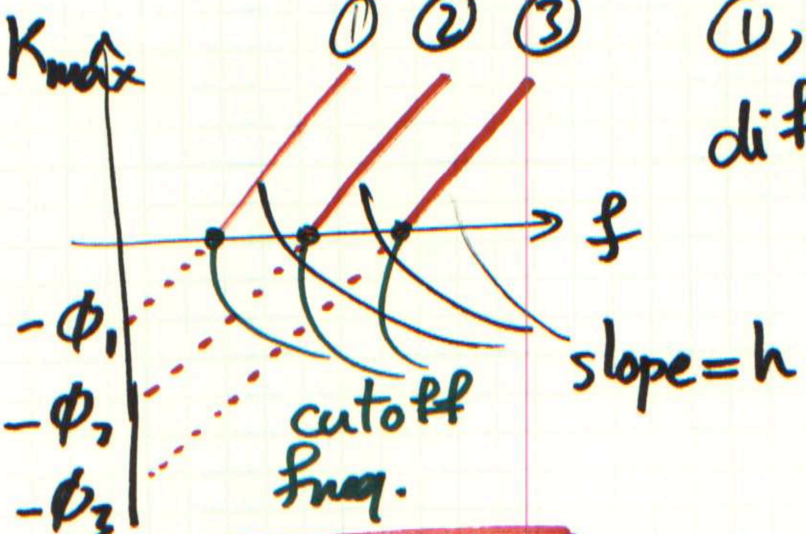
$$\boxed{K_{max} = hf - \phi}$$

work func.

ϕ is diff for diff. material

⟹ * K_{max} ind. of I

* K_{max} dep. on f
* I change the # e^- emitted & not the E
* γ has enough E to eject an e^- immidiatly
* e^- need a certain $E > \phi$ to be ejected



①, ②, ③ are diff. metals

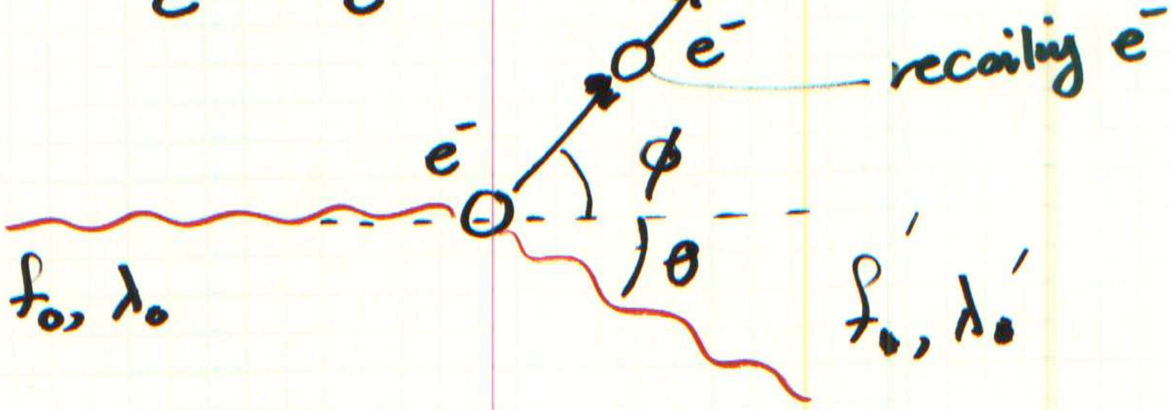
$$\boxed{f_c = \phi/h}$$

$$\boxed{\lambda_c = \frac{c}{f_c} = \frac{hc}{\phi}}$$

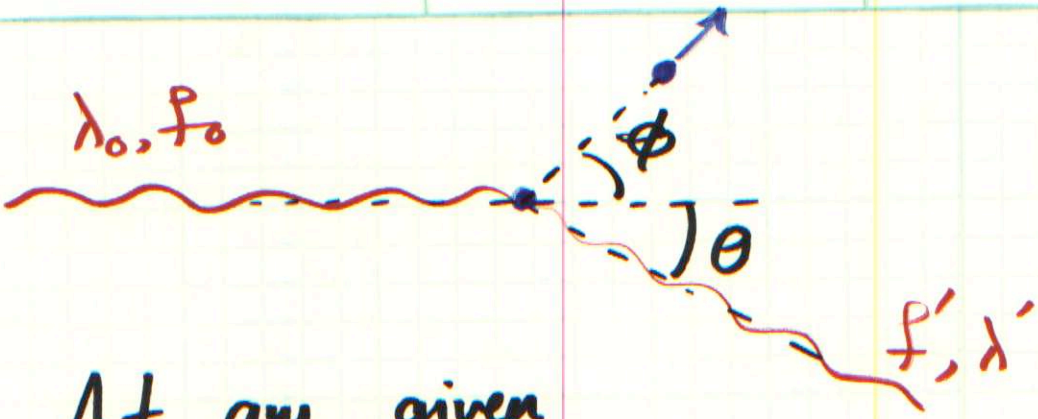
Compton Eff.

γ w/ Energy E. (Einstein)

$$\frac{E}{c} = \frac{hf}{c}$$ ← momentum of a γ



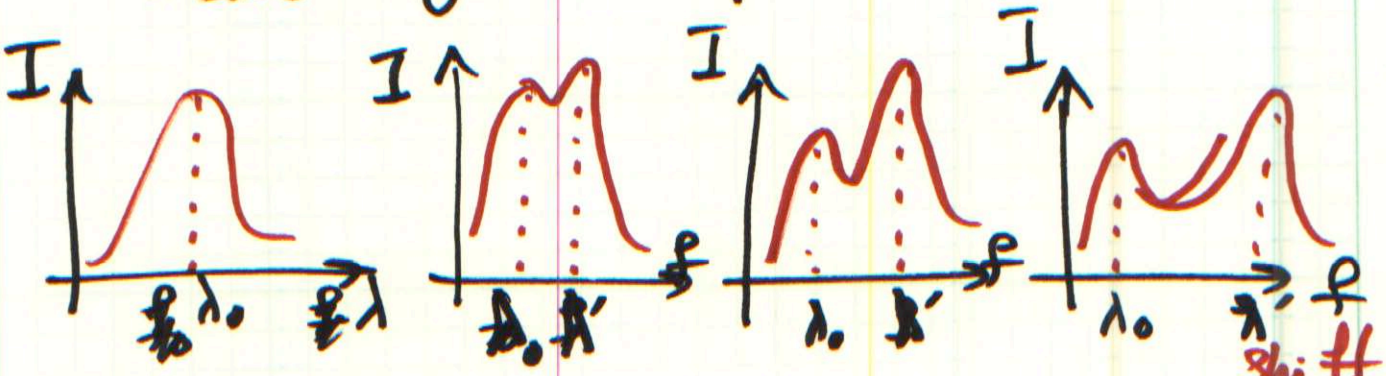
Classical theo. ~~[illegible]~~ cannot exp.
scattering of x-ray from e^-



At any given angle only one freq. is observed.

Explanation:

- treat γ as point-like particles of momentum $E/c = hf/c$
- cons. of E & p



$$\boxed{\lambda' - \lambda_0 = \frac{h}{m_e c}(1 - \cos\theta)}$$

Compton Shift eqn.

$\lambda_0 \rightarrow$ from e^- tightly bound

$\lambda' \rightarrow$ from free e^-

compton wavelength $\rightarrow \frac{h}{m_e c} = 0.00243$ nm

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Some exp. explained best by photon model, some by wave model.

$\Rightarrow$ dual nature of light.

Particles as waves

Louis de Broglie:

Matter also has dual nature.

$$\boxed{\lambda = \frac{h}{P} = \frac{h}{mv}}$$

de Broglie wavelength

$$\Rightarrow f = \frac{E}{h}$$

Davisson-Germer Exp.

Measurement of wavelength of e^-

⇒ exp. confirmation for de Broglie's theory.

e^- has a much smaller λ than visible light ⇒ Electron microscopes

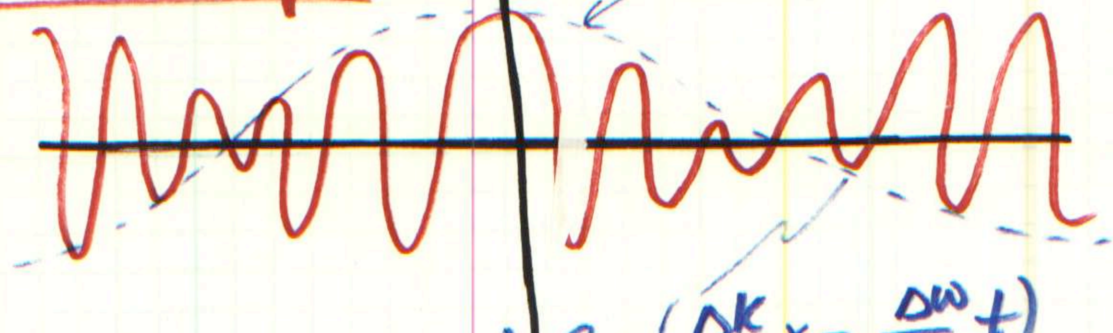
Quantum Particle

Due to dual nature of light & matter

Ideal particle:
× zero size
(localized)

Ideal Wave:
× single f
(unlocalized)

Wave Envelope

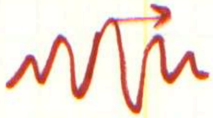


Envelople func.

$2A \cos\left(\frac{\Delta k}{2} x - \frac{\Delta \omega}{2} t\right)$

Phase speed: $V_{ph} = \omega/k$

(Advance of a crest on a single wave)



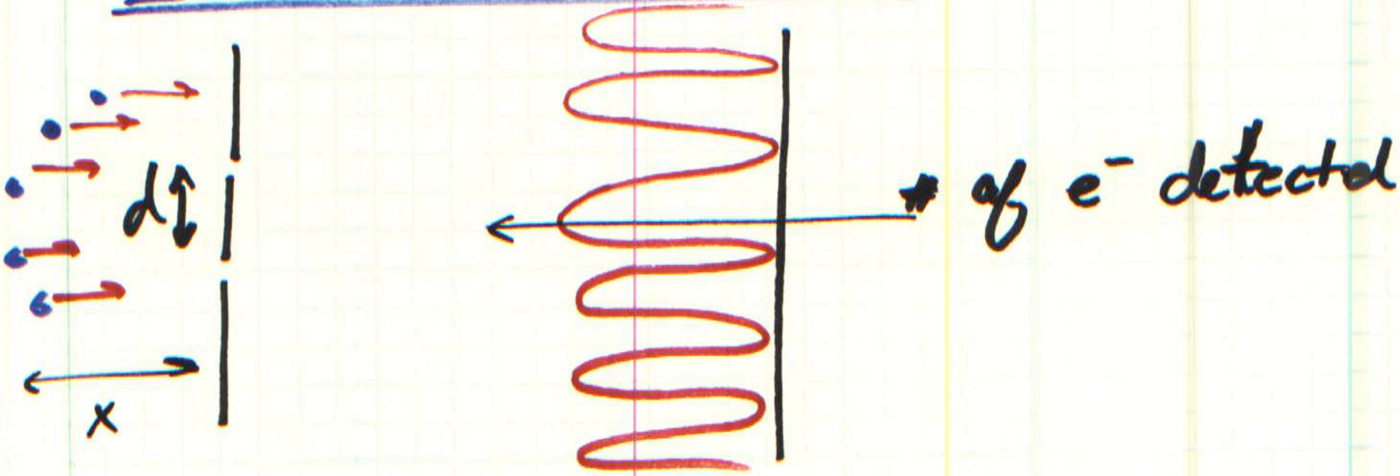
Group speed: $V_g = \frac{d\omega}{dk}$

speed of the wave packet

$$V_g = \frac{dE}{dp} = \frac{d}{dp}\left(\frac{p^2}{2m}\right) = \frac{1}{2m} \cdot 2p = u$$

$\Rightarrow$ $\underline{V_g}$ is the same as the speed of the particle $\underline{u}$

Electron Diffraction



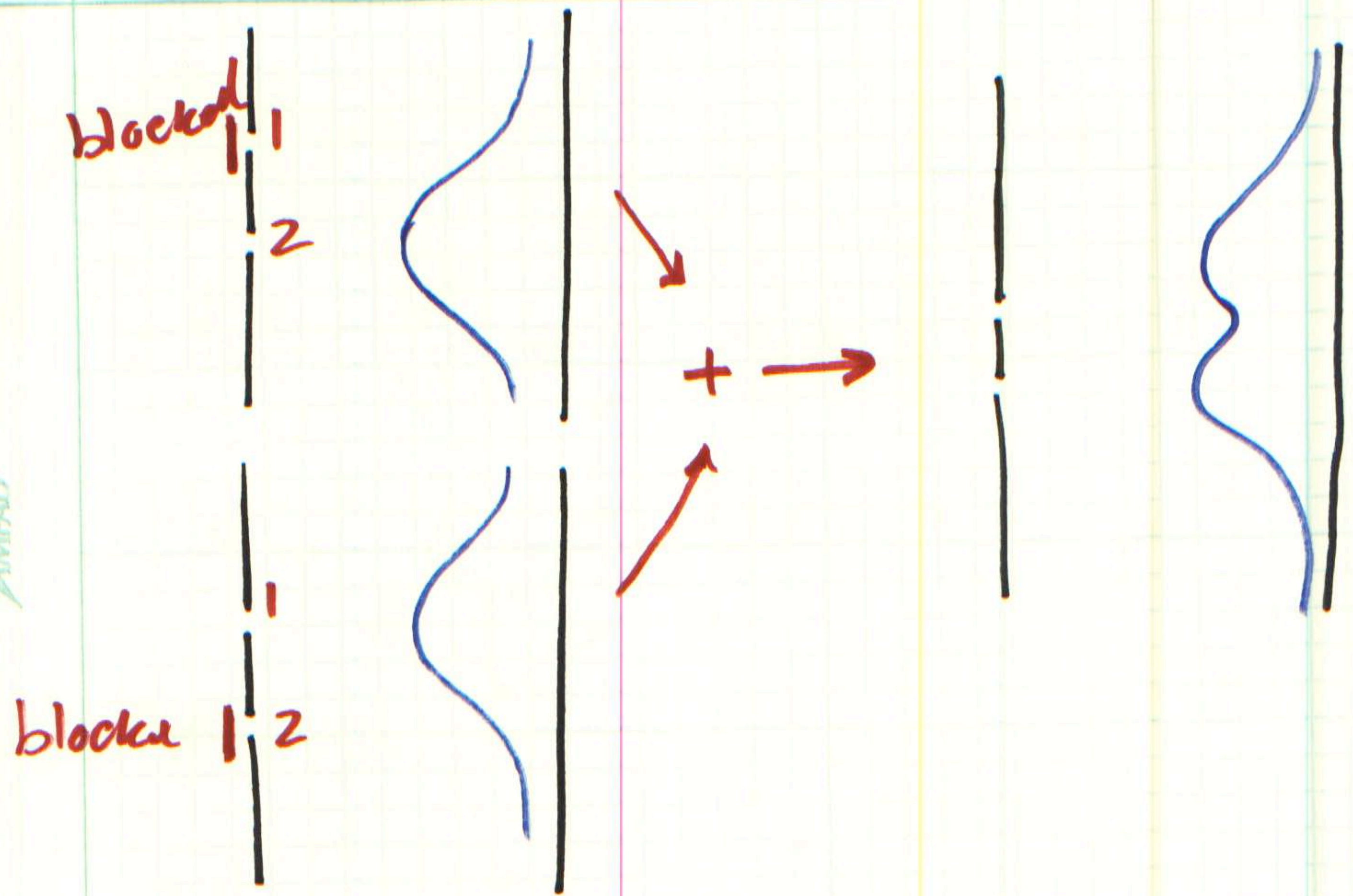
- All e^- have the same E
- Width of slits small campared to λ_{e^-}
- $x \gg d$

$\Rightarrow$ Exp. results:

e^- interfere w/ each other

minima @:

$$d \sin\theta = \frac{\lambda}{2} \qquad \sin\theta \simeq \theta = \frac{h}{2 \cdot P_x \cdot d}$$



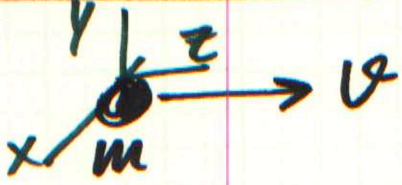
This doesn't recreate the double slit exp. results

$\Longrightarrow$ * e^- are not localized & doesn't goes only through one slit.

- * e^- interacts w/ both slits
- * Measuring the location of the e^- destroys the interference pattern

The Uncertainty Principle

Classical mechanics:



P & X can be measured accurately simultaneously.

QM:

It is impossible to measure position & momentum w/ infinite accuracy.

Heisenberg Uncertainty Principle:

$$\boxed{\Delta X \cdot \Delta P \geq \hbar/2}$$

unc. in measurement of ΔX.

Unc. in measurement of x comp. of P

$$\boxed{\Delta E \cdot \Delta t \geq \hbar/2}$$