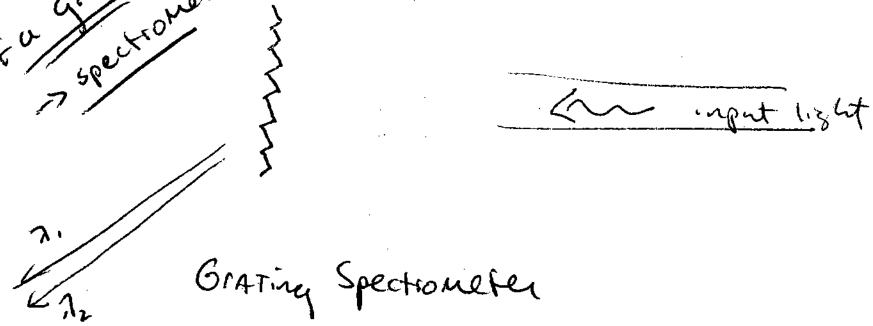
Resolving Power

of a grating → spectrometry



Grating Spectrometer

Chromatic Resolving Power

$\lambda \sim \lambda_1 \sim \lambda_2 \sim \frac{\lambda_1 + \lambda_2}{2}$

$\Delta\lambda = \lambda_2 - \lambda_1$

$$R = \frac{\lambda}{\Delta\lambda} = Nm$$

Resolution limit comes when Angular separation of 2 wavelengths = distance between Maximum and 1st minimum for the wavelengths

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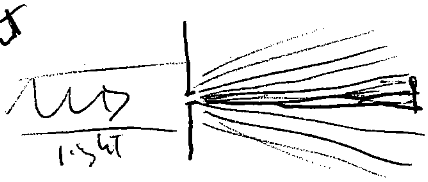
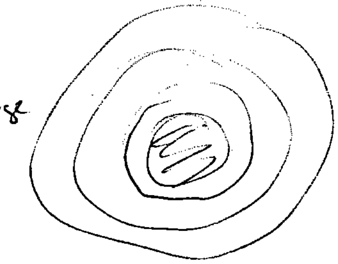
Resolution of point objects – Rayleigh's criterion

of an optical instrument



Diffraction

image



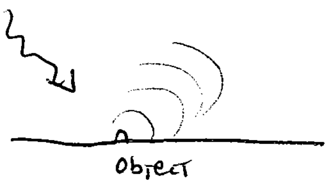


image of small object ~~on~~ is "diffraction limited" when size $\sim O(\lambda)$

If the Angular separation of two point sources is ~~just reso~~ such that the Maximum for one diffraction pattern falls on the 1st minimum of the other – The two point sources are at the threshold for resolvability

$$\theta_R = 1.22\ \lambda/d \qquad \text{Rayleigh's Criterion}$$

=> Do Young's Double Slot Demos

Easter Egg candy to whoever can answer

=> Why do cameras lenses look dark ?

=> Do Soap film Demo

↑ How does this work ?

$c = \lambda \nu$

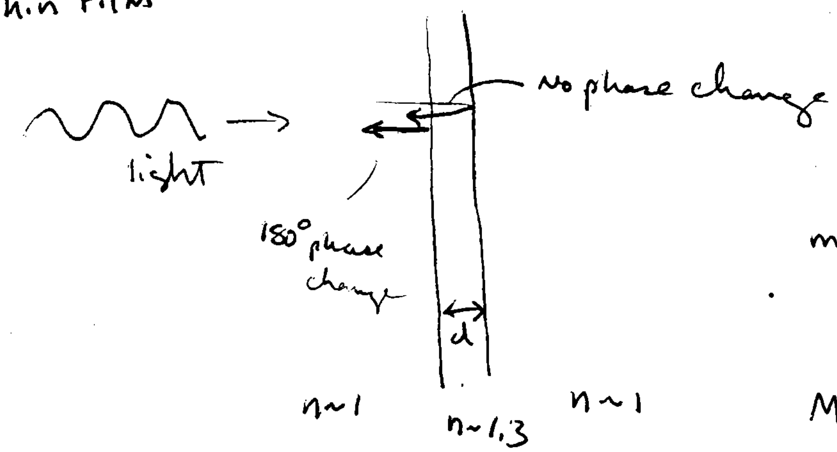
$v = \lambda_n \nu$

$v\,n = c \quad \frac{c}{n} = \lambda_n \nu$

$\lambda_n = \frac{c}{n}\frac{1}{\nu} = \lambda / n$

λ in medium

Thin Film



minimum in reflection if

$2d = m\lambda_n$

($m = 1, 2, 3 \ldots$

Maximum if

$2d = (m + 1/2)\lambda_n$

($m = 0, 1, 2 \ldots$

=> light ~~reflected~~ going from low n to high n

=> 180° phase change upon reflection at surface

=> light going from high n to low n

=> No phasechange upon reflection at surface

No phase change in transmitted wave in either case.

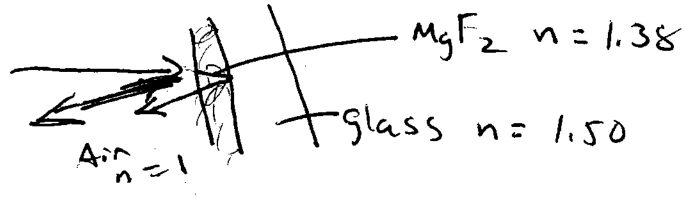
example

Lenses often coated w/ MgF_2 magnesium Flouride

To reduce the reflection in the visible spectrum

(central λ = 550 nm)

How Thick should the coating be to minimize reflection at 550 nm



(WANT Minimum Thickness)

at both interfaces there is a 180° phase change upon reflection.

∴ interference determined solely by path difference

Minimum if $2d = (m + \tfrac{1}{2})\lambda_n$
($m = 0, 1, 2, \ldots$

$$\lambda_n = \lambda / n$$

Thickness of thinnest possible film

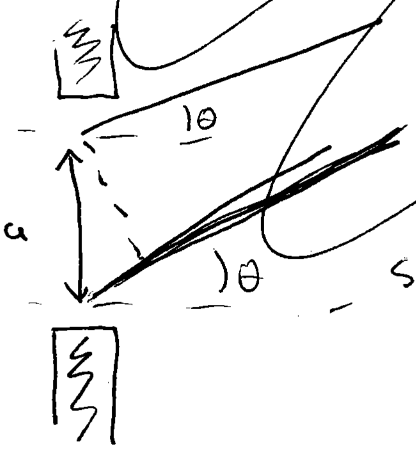
$$2d = (m + \tfrac{1}{2})\lambda / n$$

$$d = \frac{\lambda}{4n} = \frac{550 \text{ nm}}{(4)(1.38)} = 100 \text{ nm}$$

Diffraction Pattern

double slit interference discussion

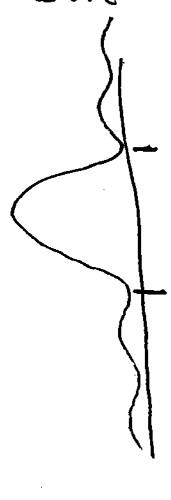
Assumed slits were thin, i.e. all light coming from slit had same path length to screen



Not so if a is larger

get pattern

Single Slit diffraction pattern



Positions of zeros in intensity given by $\sin\theta = \lambda / a$

at both interfaces there is a 180° phase change upon reflection.

∴ interference determined solely by path difference

Minimum if $2d = (m+\tfrac{1}{2})\lambda_n$
$(m = 0, 1, 2, \ldots)$

$$\lambda_n = \lambda/n$$

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Diffraction Pattern

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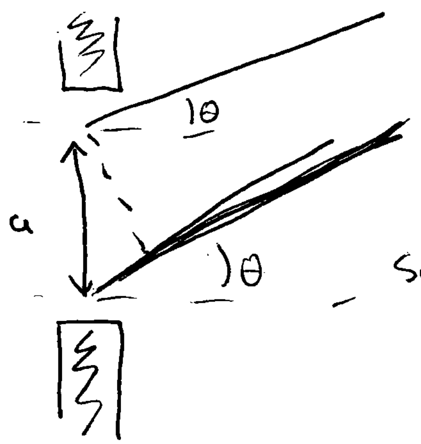
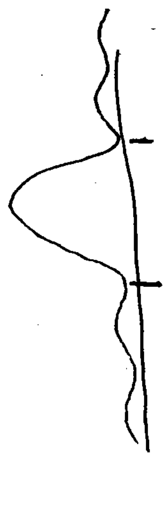


Not so if a is larger

get pattern

single slit diffraction pattern



Positions of zeros in intensity given by $\sin\theta = \lambda/a$

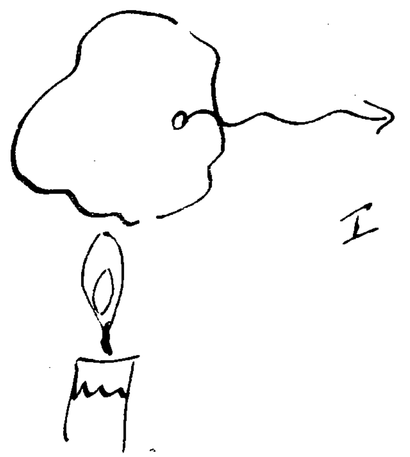
I will Not be working from Tipler w/ quite the closeness I have earlier — will be using a different text next year

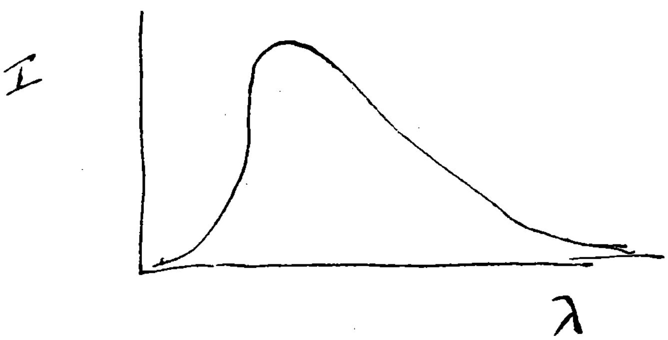
3 things really led to rise of Quantum Mechanics:

(I)

Blackbody Radiation

Spectrum of Radiation emitted by an object due solely to its temperature





Classical Treatments failed end of 1800's

In 1900 Max Plank

Worked exactly

$$R(\lambda) \approx I = \frac{c}{4}\left(\frac{8\pi}{\lambda^4}\right)\left[\frac{hc}{\lambda}\,\frac{1}{e^{hc/\lambda kT}-1}\right]$$

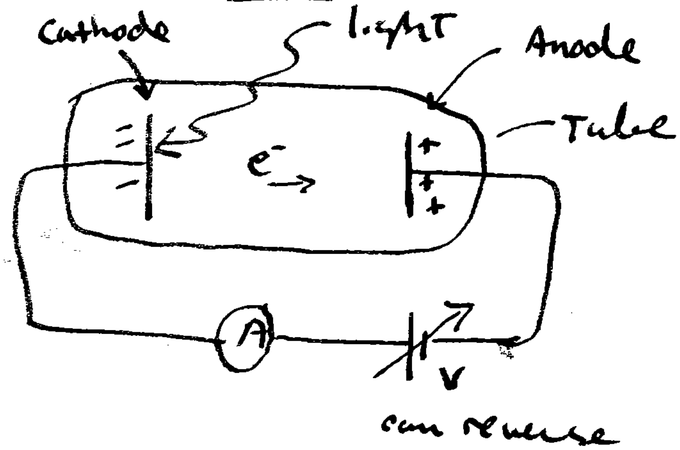
To derive ... Must Assume light comes in little bundles called quanta $E = h\nu$

Energy of quanta $\propto \nu$

Proportionality constant h (plank's constant)

This was viewed as a Curiosity at the time.

II Photo electric effect (ν)



e^- ejected from metal as light shines

can vary I, ν of light

can vary V to meas KE of e^-

Can measure i (current) (# e^- ejected)

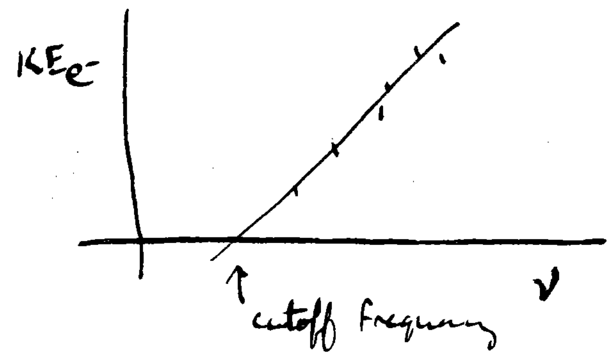
KE of e^-

Classical physics predicted

Some e^- ejected w/ any ν

double intensity → ~~double~~ ½ time for ejection

Found



1905 Einstein

light $E = h\nu$

$$KE_{e^-} = h\nu - W$$

← work function

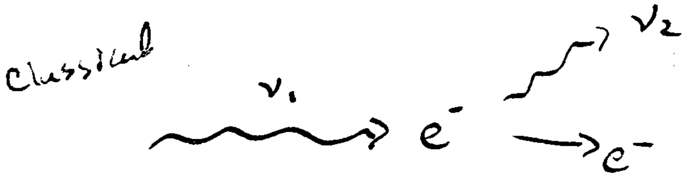
Assumes/uses Planck's quanta

Note h ~~could~~ photoelectric effect
could be different from
h in black body radiation

Measure h experimentally → It is the same !!
$h = 6.62 \times 10^{-34}$ J·s

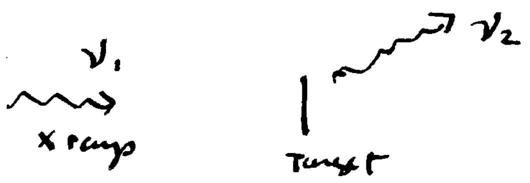
These 2 Things started us on the road to quantum Theory

III one more Thing
Compton scattering



some energy given to e^-
$\nu_1 = \nu_2$
~~[illegible]~~ $I_2 < I_1$

1923 Arthur Compton



Measured ν_2, θ_2
Could only be explained
Thinking of light as a Particle
Treat as more of a billiard ball collision

⇒ There you have it

interference diffraction	blackbody rad Photoelectric effect Compton Scattering	Which is it?

Wave Particle duality of light

Things got much STRANGER:

if light waves are particles

Suppose particles are waves

Louis de Broglie ~ 1925 proposed

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

h is very small

→ λ of 1000 kg Auto travelling at 100 m/s $\Rightarrow \lambda = 6.6 \times 10^{-39}$ m

→ λ of e^- w/ KE of 1 electron volt → $\lambda = 1.2$ nm

↑ Small but NOT crazy!

1926 Davisson Germer

observed diffraction of e^- beam off Nickel!

x ray diffraction
e^- diffraction
neutron diffraction
} crystallography!!

diffraction pattern yields details about crystal lattice waves are reflecting from!

So matter also has wave-particle duality!

Particle is a wave ... Should be able to write down a Classical wave eqn.

No: We've worked w/ "free" waves
Now we need them to operate in "Potentials"
Particles have Mass
Must come in quanta $E = h\nu$, $p = h/\lambda$
Have NOT done that w/ light either