UNIT 1: WAVE-PARTICLE DUALITY

Matter Waves & Davission-Germer Experiment

THE WAVE NATURE OF MATTER

- Subatomic particles
- De Broglie
- Electron beam
- Davisson-Germer Experiment
- Electron Interference
- Matter Waves

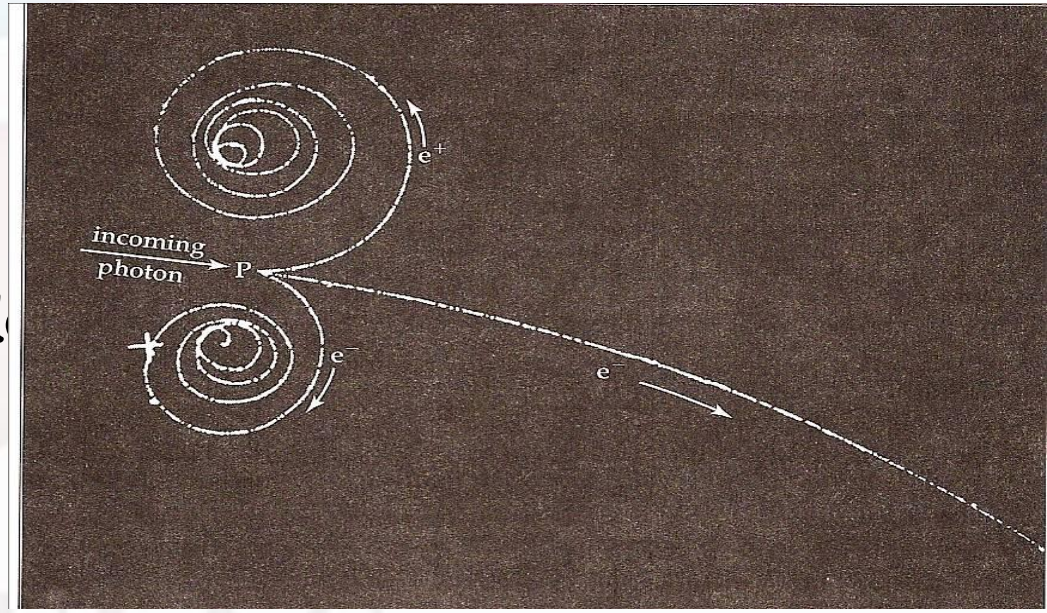
SUBATOMIC PARTICLES

- We can see the electron tracks

- There is evidence of light as a particl

the collision of light with

the electrons at point P



DE BROGLIE HYPOTHESIS

- Linking momentum and wavelength
- Based on the photoelectric effect, de Broglie surmised that particles should behave by photons and their wavelength should be related to their momentum

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

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

PROBLEM

- **What is the de Broglie wavelength of a 50 kg person traveling at 15 m/s?**

  (h = 6.6 x 10^{-34} J s) comparable to spacing

THE ELECTRIC BEAM

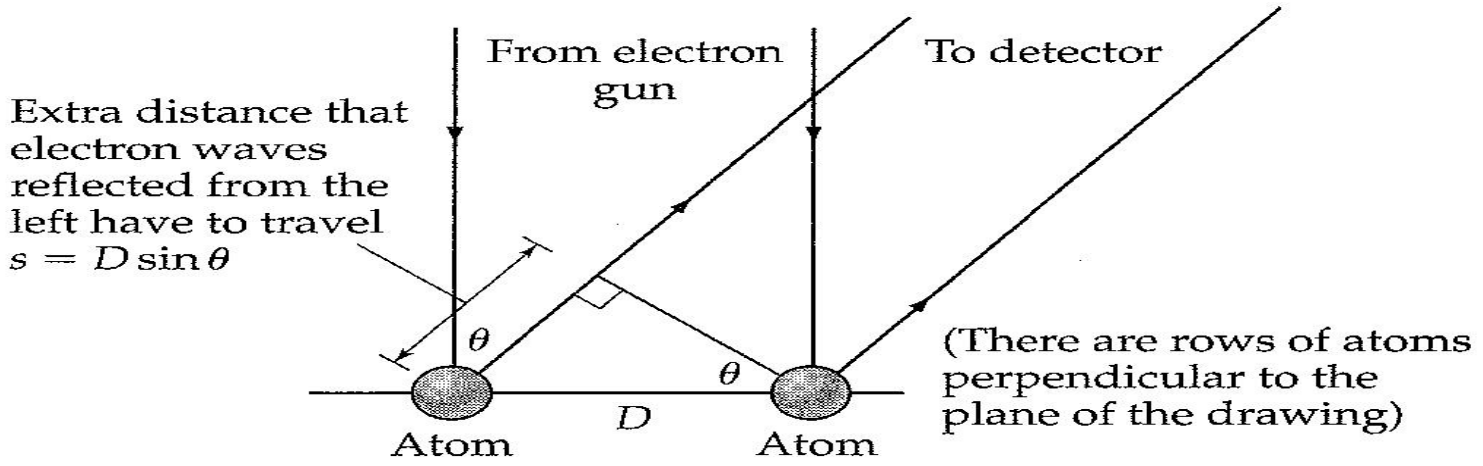
- To create a beam of electrons for a double slit experiment, the electrons must have the same wavelength
- To have the same wavelength, the electrons must have the same momentum or equivalently, energy

$$K = \frac{1}{2}mv^2 = \frac{p^2}{2m} \qquad p = \sqrt{2Km}$$

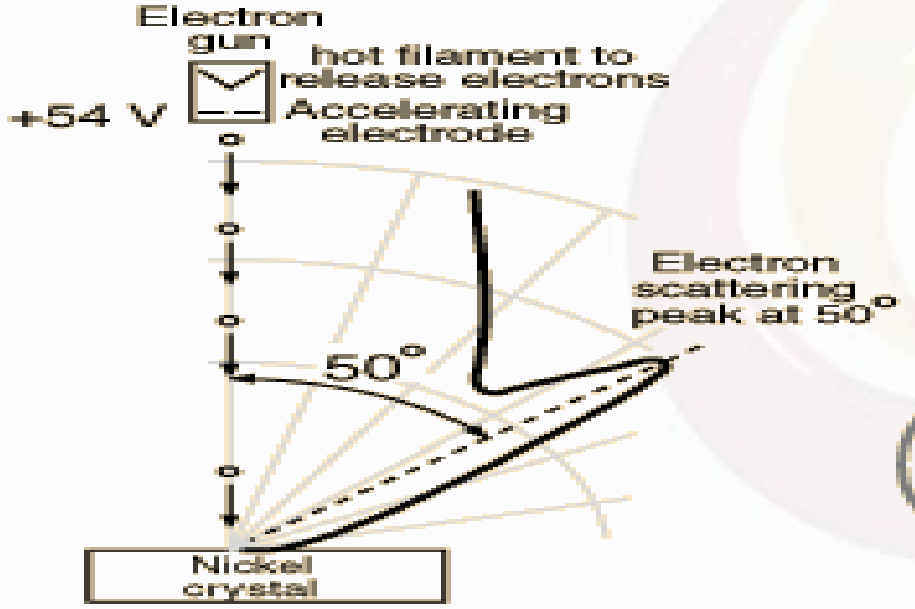
$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2Km}} = \frac{hc}{\sqrt{2Kmc^2}}$$

DAVISSON-GERMER EXPERIMENT

- By accident, Davisson and Germer found that electrons were diffracted by large nickel crystals, similar to diffraction of light by crystals



DAVISSON-GERMER EXPERIMENT



Theory

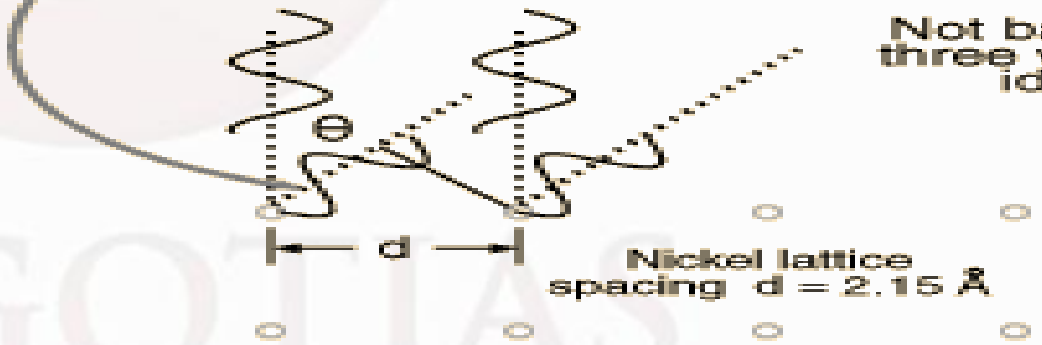
$\lambda = \frac{h}{mv}$ = 1.67 Å for 54 V

Experiment

Pathlength difference

d sin Θ = 2.15 sin 50° = λ = 1.65 Å

for constructive interference



1924 de Broglie's hypothesis

1927 Davisson-Germer experiment

1929 Nobel Prize for de Broglie

- **Application of diffraction to measure atomic spacing**
- **Single crystal Ni target**
- **Proved deBroglie hypothesis that λ=h/p**

PROOF THAT $\lambda=h/P$

Accelerated electrons have energy eV:

$eV = \frac{1}{2} mv^2 \Rightarrow v = (2Ve/m)^{1/2}$

de Broglie said:

$\lambda=h/p=h/(mv)=h/(2mVe)^{1/2}=1.67$ Å

Davisson-Germer found lattice spacing: $\lambda=d\sin\theta=1.65$ Å

Excellent agreement between theory and experiment!

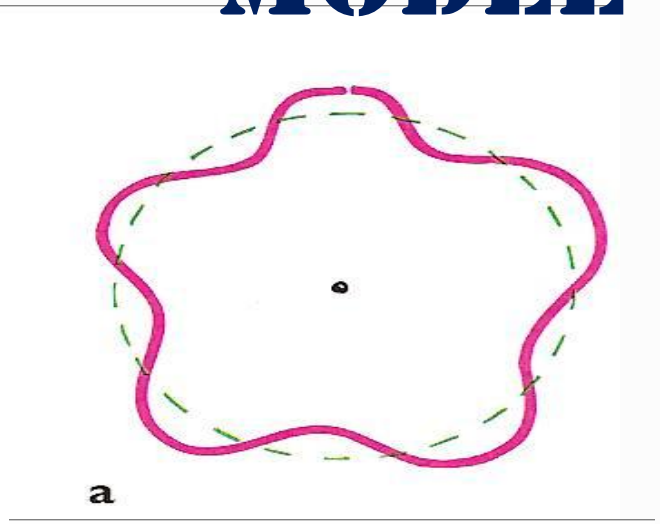
MATTER WAVES

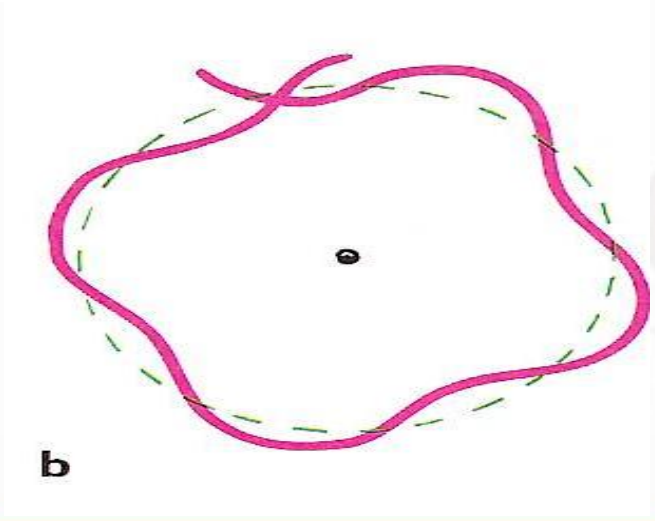
- Like photons and electrons, protons, neutrons, atoms, and even molecules have wave properties

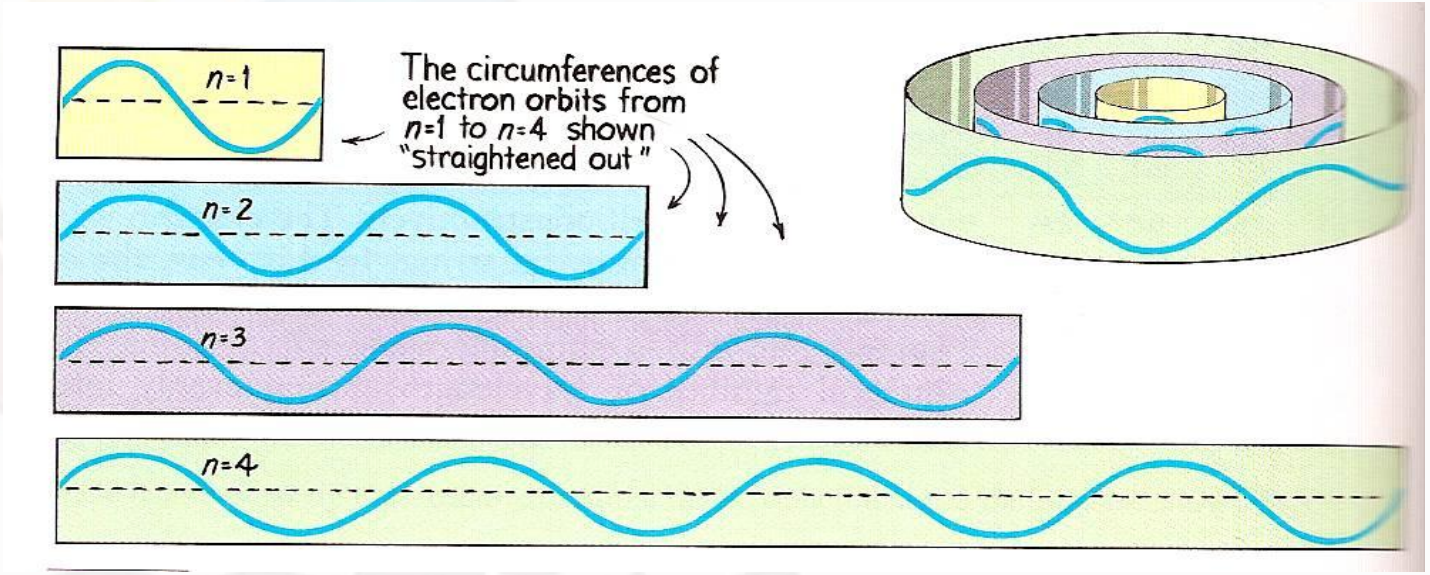
$$\lambda = \frac{hc}{\sqrt{2Kmc^2}}$$

- Electrons have lowest mass
- As mass increases, wavelength decreases
- For macroscopic molecules, the wavelength is smaller than any known particles.
- it's impossible to make the slit separation small enough
- The screen must be placed much to far away to resolve the interference pattern

MODEL OF THE ATOM - ELECTRONS







COMPLEMENTARITY

- Light waves that interfere and diffract deliver their energy in particle package of quanta
- Electrons that move through space in straight lines and experience collisions as if they were particles, distribute themselves spatially in interference patterns as if they were waves
- What you see depends on what facet you look at
- When Niels Bohr was knighted for his contributions to physics, he chose the yin-yang symbol for his coat of arms

REFERENCES

•CONCEPTS OF MODERN PHYSICS, ARTHUR BEISER, MCGRAW-HILL.
•INTRODUCTION TO MODERN PHYSICS, RICH MEYER, KENNARD, COOP, TATA MCGRAW HILL
•INTRODUCTION TO QUANTUM MECHANICS, DAVID J. GRIFFITH, PEARSON EDUCATION.