Learning Objectives

- Photons can transfer energy to beam of electrons.

- Significance of h in daily life and quantum world

- Davison Germer experiment

$$\boxed{\lambda_2 - \lambda_1 = \frac{h}{m_0 c}(1 - \cos\theta)}$$

Compton shift

Compton wavelength
0.0243 angstrom

Quantum Mechanics: Compton Scattering

mom. cons.

$$\vec{p_1} = \vec{p_2} + \vec{p_e}$$

$$\vec{p_e} = \vec{p_1} - \vec{p_2}\,, \quad p_e^2 = p_1^2 + p_2^2 - 2p_1p_2\cos\theta \quad \text{—(1)}$$

energy cons.

$$p_1c + E_0 = p_2c + (E_0^2 + p_e^2c^2)^{1/2} \quad \text{—(2)}$$

$$E_0 + c(p_1 - p_2) = (E_0^2 + p_e^2c^2)^{1/2}$$

$$\cancel{E_0^2} + c^2(p_1 - p_2)^2 + 2E_0c(p_1 - p_2) = \cancel{E_0^2} + p_e^2c^2$$

$$p_e^2 = p_1^2 + p_2^2 - 2p_1p_2 + \frac{2E_0}{c}(p_1 - p_2) \quad \text{—(3)}$$

(1) and (3) $\cancel{p_1^2} + \cancel{p_2^2} - 2p_1p_2\cos\theta = \cancel{p_1^2} + \cancel{p_2^2} - 2p_1p_2 + \frac{2E_0}{c}(p_1 - p_2)$

$$\frac{E_0}{c}(p_1 - p_2) = p_1p_2(1 - \cos\theta)$$

multiply by $\frac{hc}{p_1p_2E_0}$

$$\frac{h}{p_1p_2}(p_1 - p_2) = \frac{hc}{E_0}(1 - \cos\theta)$$

$$p_1 = \frac{h}{\lambda_1} \qquad p_2 = \frac{h}{\lambda_2}$$

$$E_0 = m_0c^2$$

$$\boxed{\lambda_2 - \lambda_1 = \frac{h}{m_0c}(1 - \cos\theta)}$$

compton wavelength

Quantum Mechanics: Photoelectric effect

Energy of one photon (E) =hv

Intensity of light (I) = no. of photons X energy of one photon
= n X hv

Power of photon (P) = $\frac{E}{t}$

A red and green laser produce light at a power level of 2.5mW. Which one produces more photons/second?

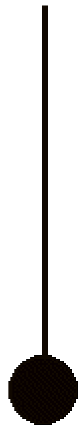
(a) Red
(b) Green
(c) Same

$$\lambda\, green = 550\, nm$$
$$\lambda\, red \quad = 700\, nm$$

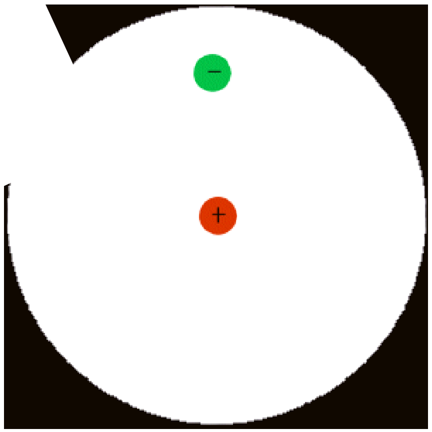
Quantum Mechanics: What have we learnt so far??

Planck's quantum is small for "ordinary-sized" objects but large for atoms etc

"ordinary" pendulum
$f = 1$ Hz



Hydrogen atom
$f \approx 2 \times 10^{14}$ Hz



$E_{quant} = hf$

about the same as the electron's KE

$E_{quant} = hf$ $= 6.6 \times 10^{-34}$ Js $\times 1$ Hz

$= 6.6 \times 10^{-34}$ J

very tiny

$= (6.6 \times 10^{-34}$ Js$) \times (2 \times 10^{14}$ Hz$)$

$= (6.6 \times 2) \times 10^{-34+14}$ J

$= 1.3 \times 10^{-19}$ J

Quantum Mechanics: so far

1. Heisenberg uncertainty principle:

2. Wave particle duality:

3. Schrodinger’s equation:

4. Compton Scattering:

5. Photoelectric effect:

6. Davisson-Germer experiment:

Quantum Mechanics

1. Heisenberg uncertainty principle: Real and quantum world
2. Wave particle duality: Real and quantum world
3. Schrodinger’s equation: Mathematical formulation of quantum mechanics
4. Compton Scattering: collision of wave with electron
5. Photoelectric effect: evidence of wave behaving like particle
6. Davisson-Germer experiment: experiment confirms the existence of de Broglie waves.

Quantum Mechanics: Dual behaviour of particle

Davisson-Germer experiment: An experiment that confirms the presence of de Broglie waves

- In 1927, Clinton Davisson and Lester Germer in the Unites States (Bell Labs) and G.P. Thomson in England independently confirmed de Broglie's hypothesis by demonstrating that electron beams are diffracted when they scattered by the regular arrays of crystals.
- Diffraction of electron from Nickel crystal
- Nickel behaves as a grating for incident electrons

Ref. Concepts of Modern Physics by Arthur Beiser

Quantum Mechanics: Learning Objectives

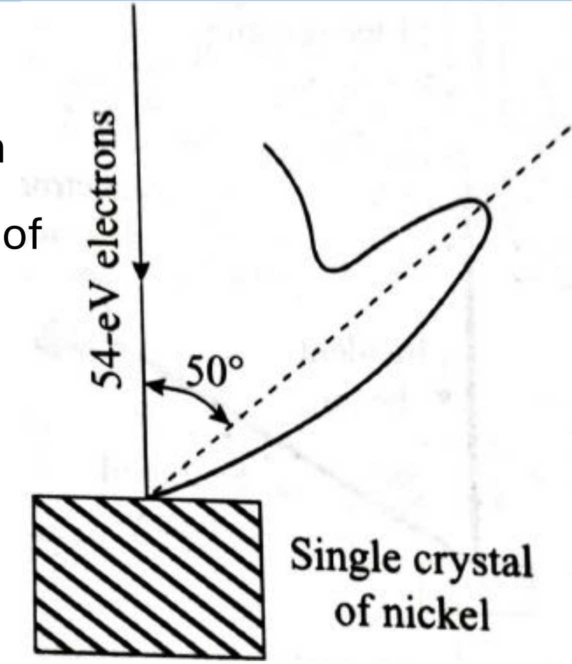
- A beam of 54 eV electrons was directed perpendicularly at the nickel target and a sharp maximum in the electron distribution occurred at an angle of 50° with the original beam. The angles of incidence and scattering relative to the family of Bragg planes are both (θ) 65 °.
- Spacing of these planes (d) is 0.091 nm.
- Bragg equation for maxima in diffraction pattern is

$2d\sin\theta = n\lambda$, n=1

$\lambda = 0.165$ nm

De Broglie's wavelength of electron

$\lambda = \frac{h}{p}$, p= $\sqrt{2mE_{kinetic}}$



Quantum Mechanics: What have we learnt so far??

1. Photoelectric effect

2. Einstein explained the observation of photoelectric effect and awarded with Nobel prize in Physics for the same

3. Photoelectric effect- evidence of particle nature of wave (light/ em radiation)

4. Davisson-Germer experiment: evidence of wave nature of particle (electron).

5. Davisson,Lester Germer, G.P. Thomson got Nobel prize.

Always be happy and grateful