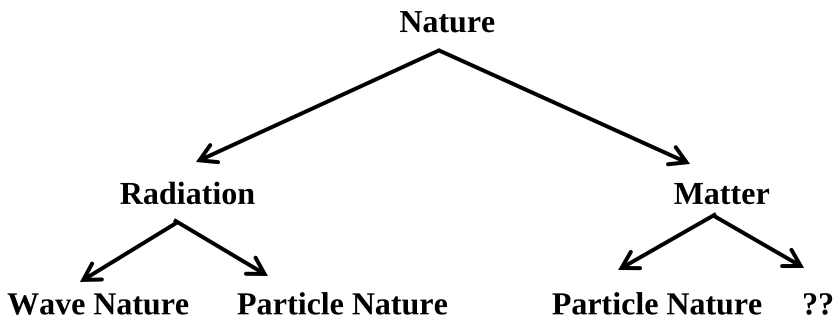
Wave properties of Particles
Part-1
de Broglie waves



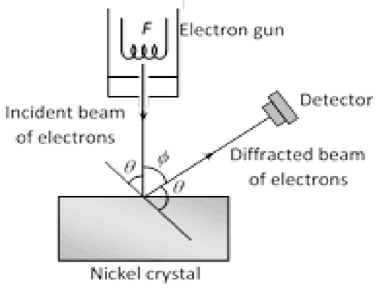
de Broglie Waves

- In 1923 de Broglie suggested that the wave - particle duality is not restricted to radiation alone, but must be universal: all material particle should also display a dual wave- particle behaviour.
- That is, the wave particle duality is present in light must also occur in matter.
- Each material particle of momentum p behaves as a group of waves called matter waves or de-Brogile waves.
- Their wavelength λ and wave vector k are governed by the speed and mass of the particle.
- If a particle have momentum p then the de Brogile wavelength associated with the particle is

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

Wave vector, $\vec{k} = \frac{\vec{p}}{\hbar}$ where $\hbar = {}^{h}/_{2\pi}$

Davisson - Germer Experiment



- The Davisson - Germer experiment demonstrated the wave nature of electron, conforming the earlier hypothesis of de Broglie
- The Bragg law for diffraction has been applied to X-ray diffraction. But this was the first application to particle wave.

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

Calculation of de Broglie Wavelength

Velocity given

i) Non - Relativistic (v <<< C)

$$\text{Then } \lambda = \frac{h}{p} = \frac{h}{mv}$$

ii) Relativistic (v≈ C)

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

But according to relativity m = $m_0\gamma$, where $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

$$\lambda = \frac{h}{m_0\gamma v} = \frac{h}{m_0 v}\sqrt{1-\frac{v^2}{c^2}}$$

Kinetic Energy Given

i) Non-Relativistic (k < E_o)

$$E_0 = m_0 C^2$$

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

$$K = \frac{P^2}{2m}$$

$$p^2 = 2mk$$

$$P = \sqrt{2mk}$$

$$\lambda = \frac{h}{\sqrt{2mk}}$$

ii) Relativistic (K >> E_0)

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

$E^2 = p^2C^2 + m_0{}^2C^4$ [$E_0{}^2 = m_0{}^2C^4$]

$E^2 = p^2C^2 + E_0{}^2$

$E = k + E_0$

$(k + E_0)^2 = p^2C^2 + E_0{}^2$

$k^2 + E_0{}^2 + 2kE_0 = E_0{}^2 + p^2C^2$

$p^2C^2 = k^2 + 2kE_0$

$Pc = \sqrt{k^2 + 2kE_0}$

$$\lambda = \frac{hc}{pc}$$

$$\lambda = \frac{hc}{\sqrt{k^2 + 2kE_0}}$$

Problems

1. Find the de Broglie wavelengths of

A) A 46-g golf ball with a velocity of 30 m/s and

B) An electron with velocity of 10^7 m/s

Solution :

Given, $m = 46\times10^{-3}$kg

A) V= 30 m/s

So this is non-relativistic case, then $\lambda = \frac{h}{mv}$

$$\lambda = \frac{6.626\times10^{-34}}{46\times10^{-3}\times30} = 4.8\times 10^{-34} \text{ m}$$

B) V= 10^7m/s

$m = 9.1\times 10^{-31}$kg

$$\lambda = \frac{h}{mv} = \frac{6.626\times10^{-34}}{9.1\times10^{-31}\times10^{7}} = 0.67\times10^{-10}\text{m}$$