Wave Properties of Matter and Quantum Mechanics I

https://www.youtube.com/watch?v=M4_0obIwQ_U

- In 1924, a French graduate student, Louis de Broglie,1 proposed in his doctoral dissertation that the dual—that is, wave-particle—behavior that was by then known to exist for radiation was also a characteristic of matter, in particular, electrons.
- De Broglie described it with these words:
- After the end of World War I, I gave a great deal of thought to the theory of quanta and to the wave-particle dualism. . . . It was then that I had a sudden inspiration. Einstein’s wave-particle dualism was an absolutely general phenomenon extending to all physical nature.

The de Broglie Hypothesis

- de Broglie relations :
- $f = \frac{E}{h}$
- $\lambda = \frac{h}{p}$

where E is the total energy, p is the momentum, and λ is called the de Broglie wavelength of the particle.

- For photons, these same equations result directly from Einstein's quantization of radiation
- $E = hf$
- E=pc

- In 1927, C. J. Davisson and L. H. Germer verified the de Broglie hypothesis directly by observing interference patterns, a characteristic of waves, with electron beams.
- Why wavelike behavior of matter had not been observed before de Broglie’s work?
- Recall, that the wave properties of light were not noticed, either, until apertures or slits with dimensions of the order of the wavelength of light could be obtained.
- Because Planck’s constant is so small, the de Broglie wavelength is extremely small for any macroscopic object.

Measurements of Particle Wavelengths

- What is the de Broglie wavelength of a Ping-Pong ball of mass 2.0 g after it is slammed across the table with speed 5 m/s?

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}\,\mathrm{J \cdot s}}{(2.0 \times 10^{-3}\,\mathrm{kg})(5\,\mathrm{m/s})}$$
$$= 6.6 \times 10^{-32}\,\mathrm{m} = 6.6 \times 10^{-23}\,\mathrm{nm}$$

- This is 17 orders of magnitude smaller than typical nuclear dimensions, far below the dimensions of any possible aperture.

- Consider an electron that has been accelerated through V_0 volts. Its kinetic energy (nonrelativistic) is then

$$E = \frac{p^2}{2m} = eV_0$$

$$\lambda = \frac{h}{p} = \frac{hc}{pc} = \frac{hc}{(2mc^2 eV_0)^{1/2}}$$

Using $hc = 1.24 \times 10^3$ eV · nm and $mc^2 = 0.511 \times 10^6$ eV, we obtain

$$\lambda = \frac{1.226}{V_0^{1/2}} \text{ nm} \qquad \text{for} \qquad eV_0 \ll mc^2$$

- Compute the de Broglie wavelength of an electron whose kinetic energy is 10 eV.
- The de Broglie wavelength is

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

$$\lambda = \frac{6.63 \times 10^{-34}\,\mathrm{J \cdot s}}{1.71 \times 10^{-24}\,\mathrm{kg \cdot m/s}}$$
$$= 3.88 \times 10^{-10}\,\mathrm{m} = 0.39\,\mathrm{nm}$$

- https://www.youtube.com/watch?v=a8FTr2qMutA