Chapter 1. Particles and Waves

Particles vs. Waves

▷ Particle

Smaller scale

Atoms, electrons, …

Stones, baseballs,
billiard balls

Larger scale

In a space, planets, …

We can naturally think that all the things in our word are particles! It's from everyday experience.

▷ Waves

Ex) Ocean waves – But, not real stuff. It's motion.

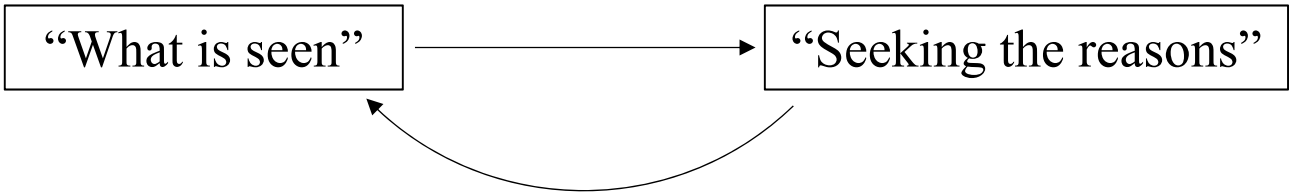
Q. Is the electron a particle or a wave?

A. It is neither. An electron is an electron. No more or no less.

“particle” and “wave” are useful words to describe different aspects of the properties of electron.

Understanding of “electrons” is important since the electrons in materials determine the electrical, optical, and magnetic properties.

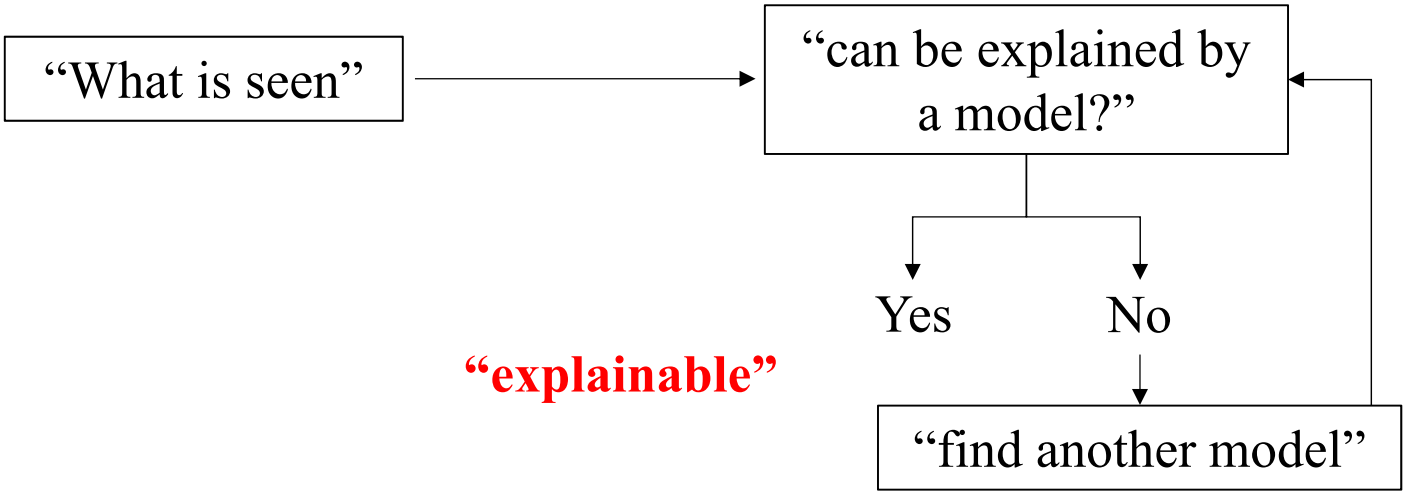
▷ Classical Science



Now, what is seen can be explained by reasons.

“reasonable”

▷ Modern Science



“explainable”

What you have to is

1) Open-minded
2) Accept without reasoning
3) Break the stereotype and the boundary

Particle-like and wave-like electrons

Classical View

- Electrons are small particles with charge (q), mass (m), and spin.

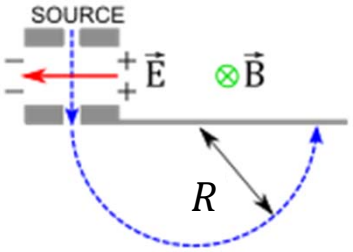
[Measurement of q/m]

Passing electrons through a potential difference (ϕ)

$$E_{kinetic} = \frac{1}{2}mv^2 = q\phi$$

Deflection of electrons by magnetic field

$F = qv \times B$



$$\frac{mv^2}{R} = qvB$$

Centripetal force

$$\frac{q}{m} = \frac{2\phi}{R^2B^2}$$

Quantum View

- Electrons show wavelike properties.

Diffraction of electrons in solids

$n\lambda = 2d\sin\theta$ (Bragg condition)

How can we define λ? It is related to the energy of electrons.

for free electrons

$$\lambda = \frac{h}{mv} = \frac{h}{p}$$ (de Broglie Wavelength)

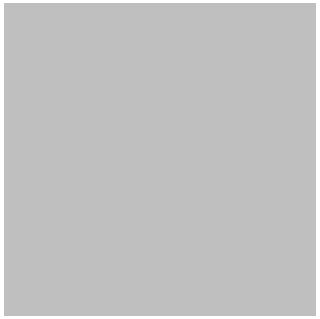
Particle-like and wave-like electrons

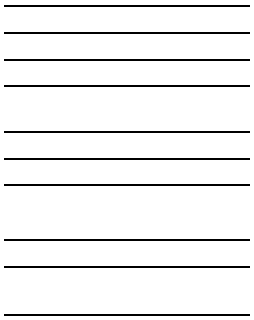
Classical View

- Electrons are free.
- Not confined (free)
- Energy is continuous and takes all values.
- Not quantized (continuous energy)

Quantum View

- Electrons in solids (crystals) are confined (fixed).
- Energy of electrons is quantized with discrete energy.
- ex) atomic emission spectra from atoms suitably excited
- ex) spectral emission lines from hydrogen





Need to describe the wavelike properties of electrons!