lecture (4)

Nature of light

❑Light is both a wave and a particle

- **All electromagnetic waves consist of photons, particle like pulses that have energy and momentum.**

The energy of a photon , E = hf

- **Some experiments can be explained by the photon concept, whereas others require a wave model.**

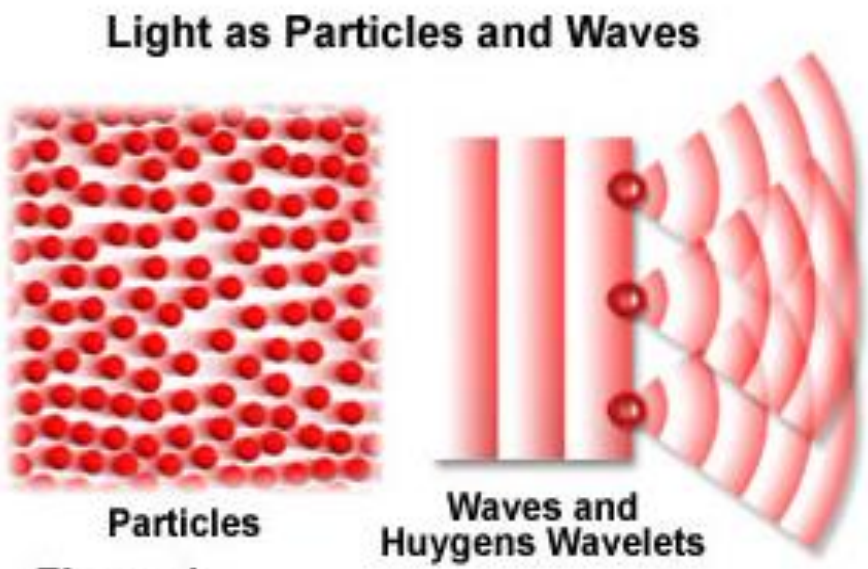


Figure 1

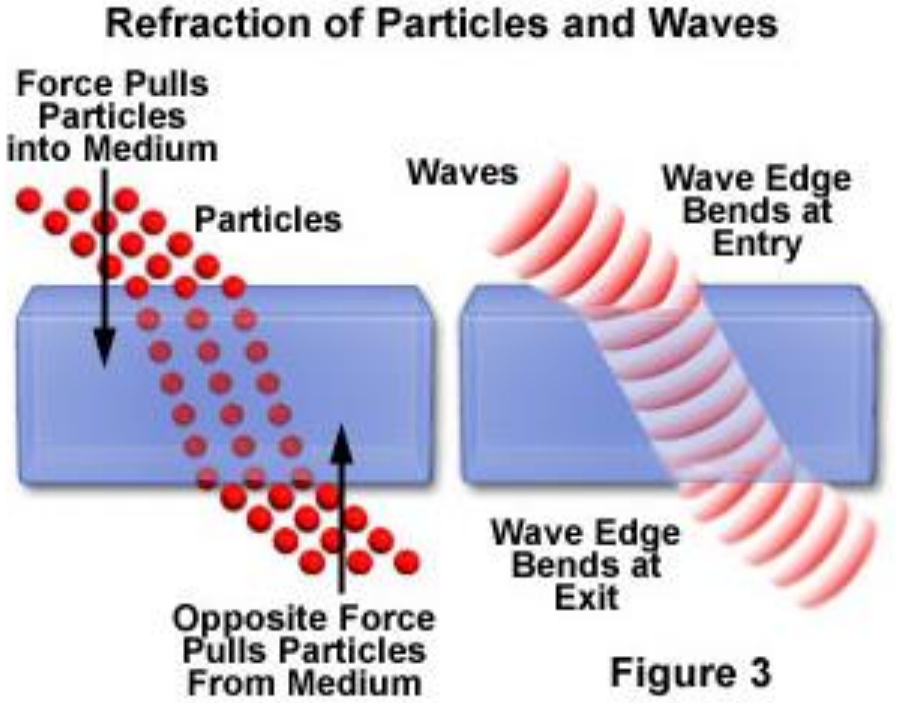


Figure 3

- **In the visible region, it is possible to observe both the photon and the wave characteristics of light. As we mentioned earlier, a light beam can show interference phenomena and produce photoelectrons. The interference phenomena are best explained by the wave model of light, while the photoelectrons are best explained by the particle theory of light**

❖**Thus, all forms of electromagnetic radiation can be described from two points of view.**

1. **At one extreme, the electromagnetic wave description suits the overall interference pattern formed by a large number of photons.**
2. **At the other extreme, the particle description is more suitable for dealing with highly energetic photons of very short wavelengths.**

❑ Matter waves

Louis de Broglie law

❑ **De Broglie proposed that all forms of matter may have both wave properties and particle properties.**

WAVELENGTH OF MATTER WAVES

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

$$\text{de Broglie wavelength} = \frac{\text{Planck's constant}}{\text{momentum}}$$

❖ **In an analogy with photons, de Broglie postulated that the frequency of a matter wave can be found with Planck's equation as illustrated below:**

FREQUENCY OF MATTER WAVES

$$f = \frac{E}{h}$$

$$\text{de Broglie frequency} = \frac{\text{energy}}{\text{Planck's constant}}$$

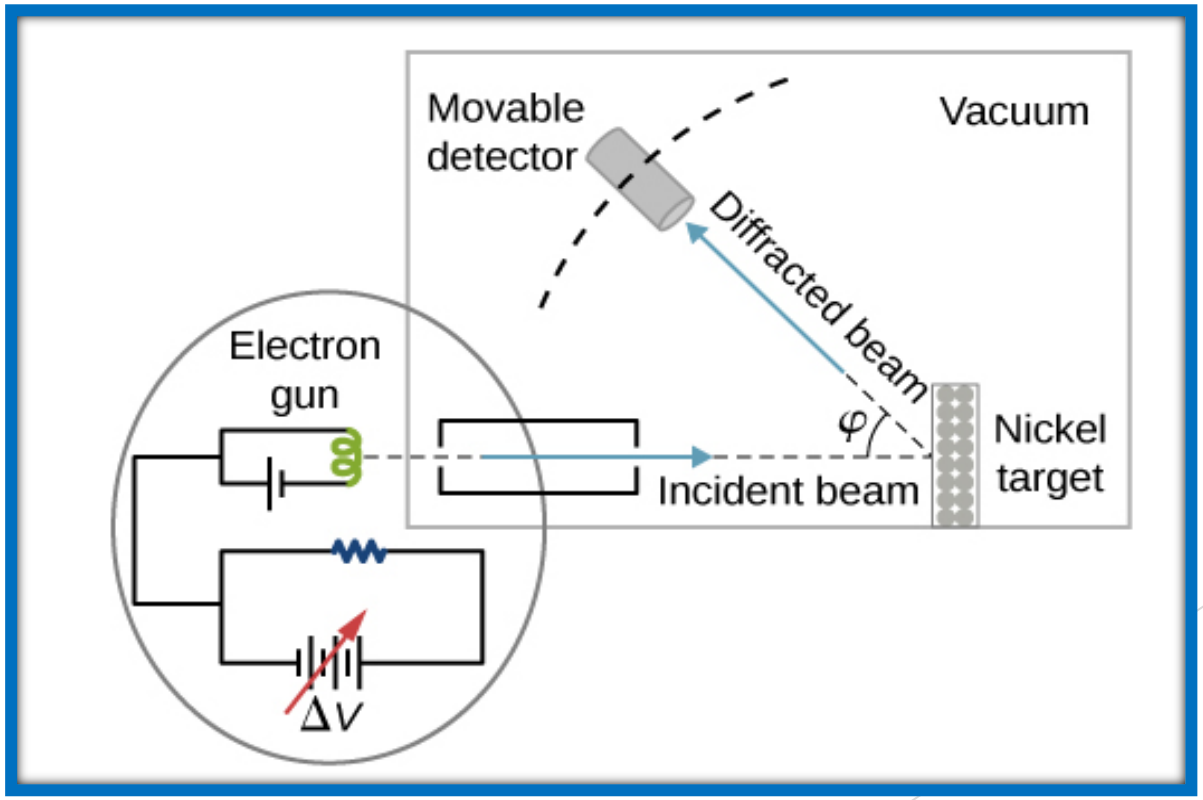
❖ **Because the velocity of the electrons is determined by the accelerating voltage, or electron potential where**

$$eV = \frac{1}{2}mv^2$$

The velocity of electrons can be calculated by

$$v = \sqrt{\frac{2eV}{m}}$$

- **If particles such as electrons had wave properties, then under certain conditions they should exhibit interference phenomena.**
- **Three years after de Broglie's proposal, C. J. Davisson and L. Germer, discovered that electrons can be diffracted by a single crystal of nickel.**



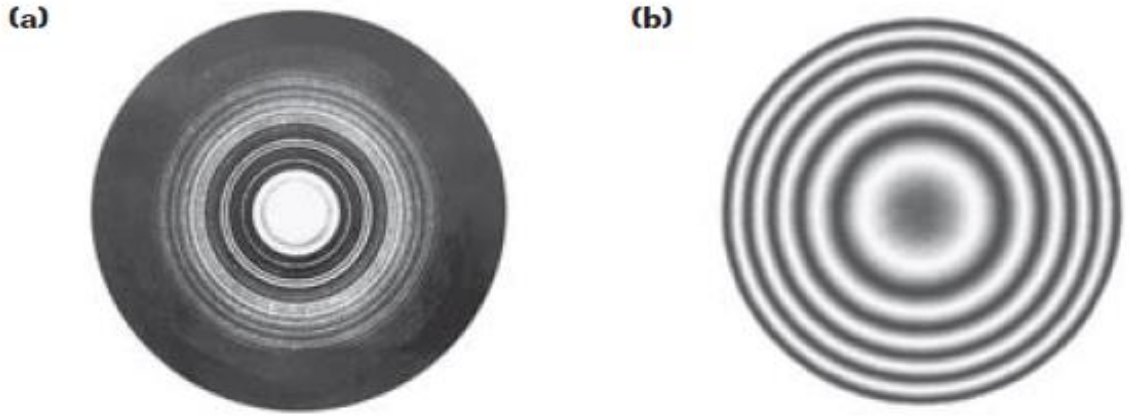
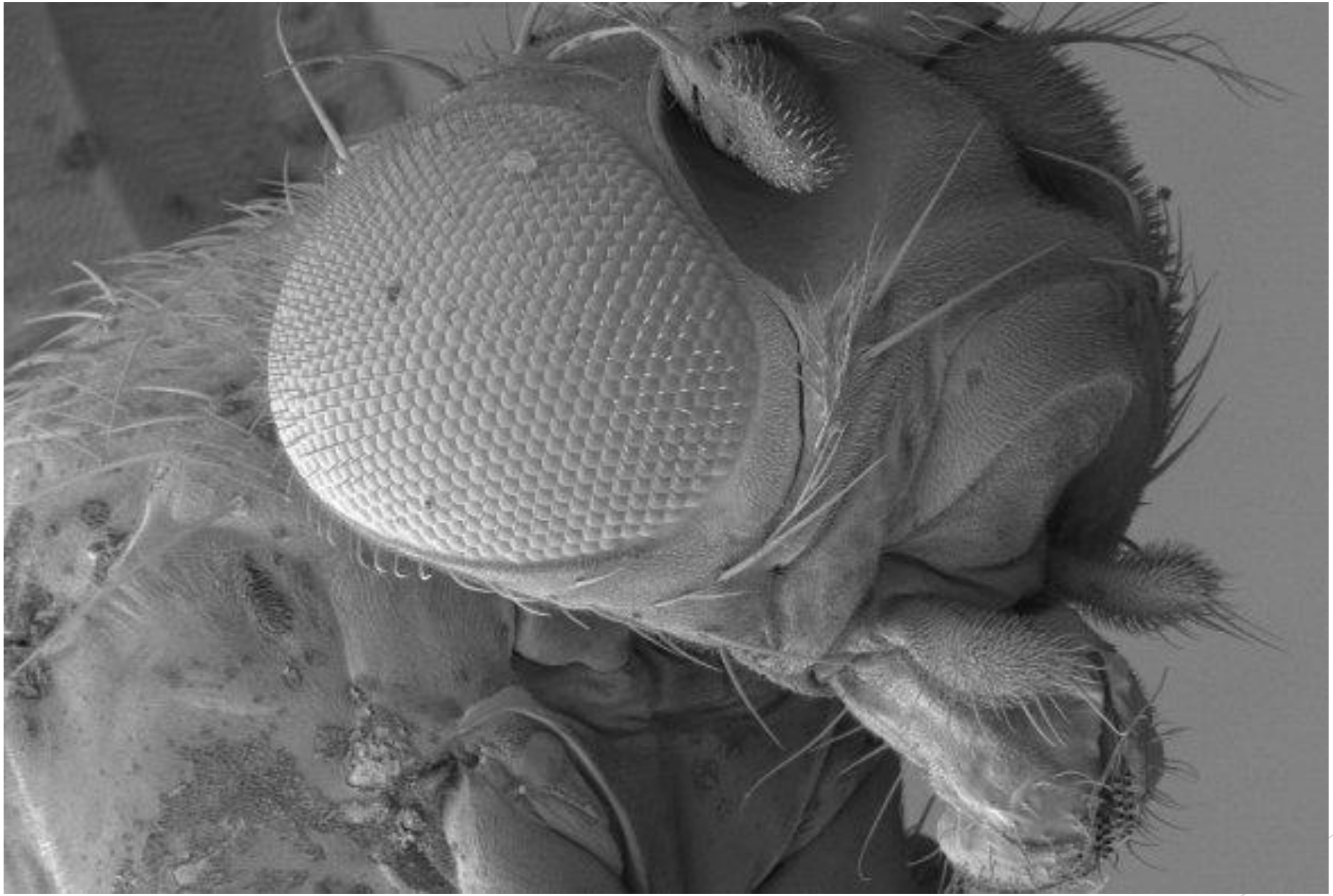


Figure: (a) Electrons show interference patterns (b) light waves.



Example

With what speed would an electron with a mass of 9.109×10^{-31} kg have to move if it had a de Broglie wavelength of 7.28×10^{-11} m?

Given: $m = 9.109 \times 10^{-31}$ kg $\quad \lambda = 7.28 \times 10^{-11}$ m

$h = 6.63 \times 10^{-34}$ J•s

Unknown: $v = ?$

Use the equation for the de Broglie wavelength, and isolate v.

$$\lambda = \frac{h}{mv} \quad \text{or} \quad v = \frac{h}{\lambda m}$$

$$v = \frac{6.63 \times 10^{-34}\ \text{J•s}}{(7.28 \times 10^{-11}\ \text{m})(9.109 \times 10^{-31}\ \text{kg})} = 1.00 \times 10^{7}\ \text{m/s}$$

$$\boxed{v = 1.00 \times 10^{7}\ \text{m/s}}$$

Problems

1-At what velocity will an electron have a wavelength of 1.00 m?

2-What is the de Broglie wavelength of an electron travelling at a speed of 5×10^6 m/s

3-What is the de Broglie wavelength of an electron that is accelerated from rest through a potential difference of 20 keV?

4-What is the de Broglie wavelength of a proton whose kinetic energy is 2.0 MeV? 10.0 MeV?

5-What is the de Broglie wavelength of a 10-kg football player running at a speed of 8.0 m/s?(a) What is the energy of an electron whose de Broglie wavelength is that of a photon of yellow light with wavelength 590 nm? (b) What is the de Broglie wavelength of an electron whose energy is that of the photon of yellow light?

6-The de Broglie wavelength of a neutron is 0.01 nm. What is the speed and energy of this neutron?

7-What is the wavelength of an electron that is moving at a 3% of the speed of light?

8-At what velocity does a proton have a 6.0-fm wavelength (about the size of a nucleus)? Give your answer in units of c.

9-What is the velocity of a 0.400-kg billiard ball if its wavelength is 7.50 fm?

10- Find the wavelength of a proton that is moving at 1.00% of the speed of light.

Finish …

Thank you