Course: Engineering Physics
PHY 1701

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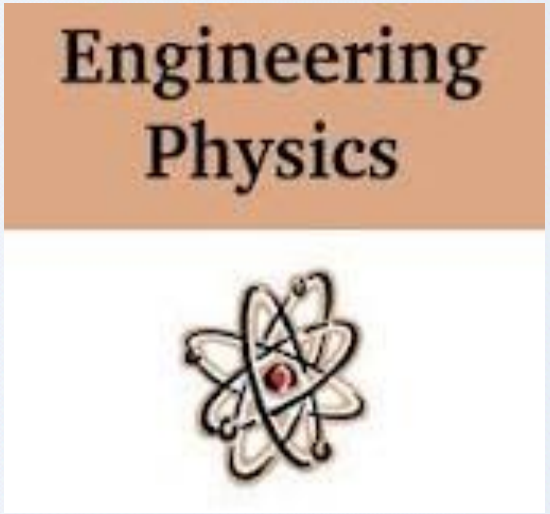
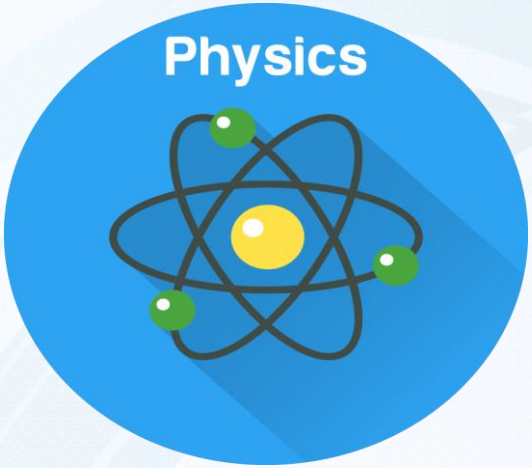
Outline

- **de Broglie Waves**



Resources:

Concepts of Modern Physics (Arthur Beiser)
Pages: 104 – 108



Dual Nature of EM Waves

WAVE-PARTICLE DUALITY

Dual Nature of EM Waves

- **If light can behave as a particle, particles should be able to behave as waves**

- Light is a member of a general family all with wave and particle properties.

Matter Waves

De-Broglie Matter Waves

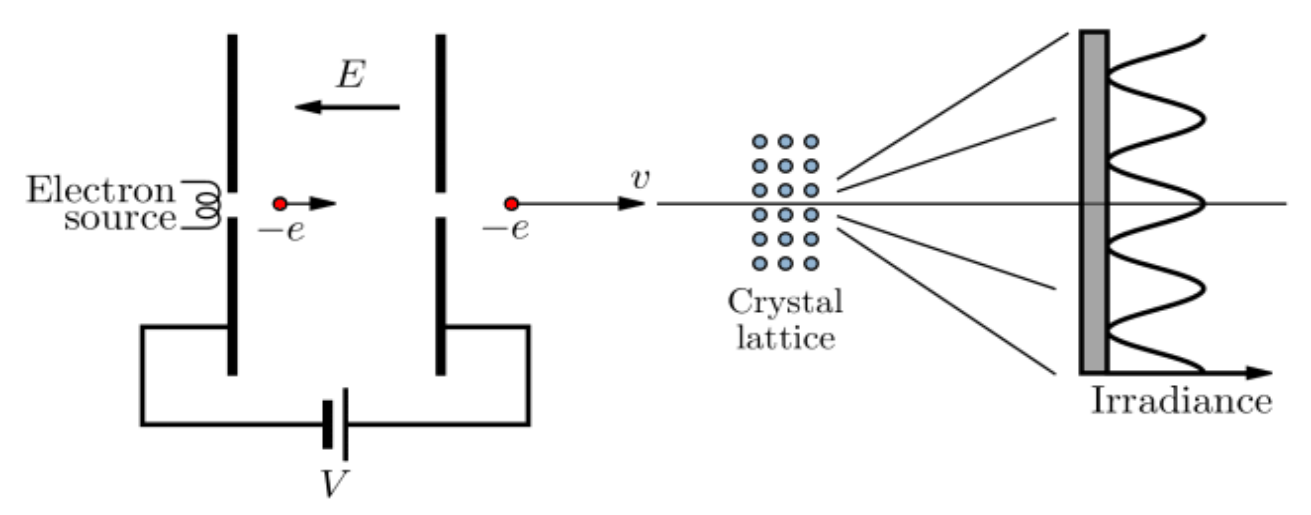
What is wave particle duality? Explain the De-broglie concept of matterwave. Derive an expression for De-Broglie wavelength.

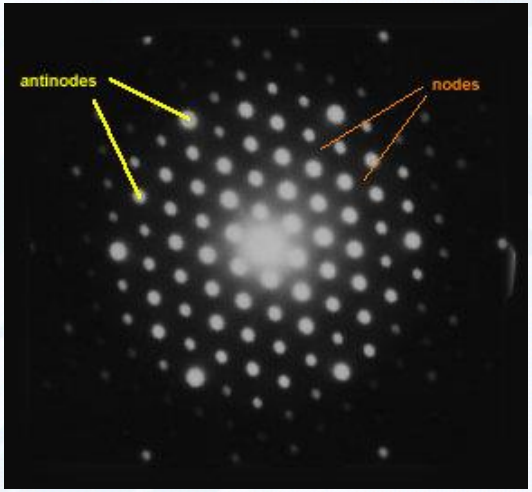
Phenomena such as interference, diffraction and polarisation can be explained by wave theory of light, however, phenomena such as photo electric effect and compton effect can be explained by particle theory of light.

According to plank quantum theory emission and absorption of light is not continuous but it is descrets and light is in form of small bundles or packets of energy which is called photons. Hence light behaves as a wave on one hand and as particle on the other hand. This nature of light is known as dual nature. While this property of light is known as wave-particle duality.

On the basis of this dual nature of light, De-Broglie suggested that dual nature is not only of light but each moving material particle has dual nature. He assumed a wave to be associated with each moving material particle which is called the "matter wave".

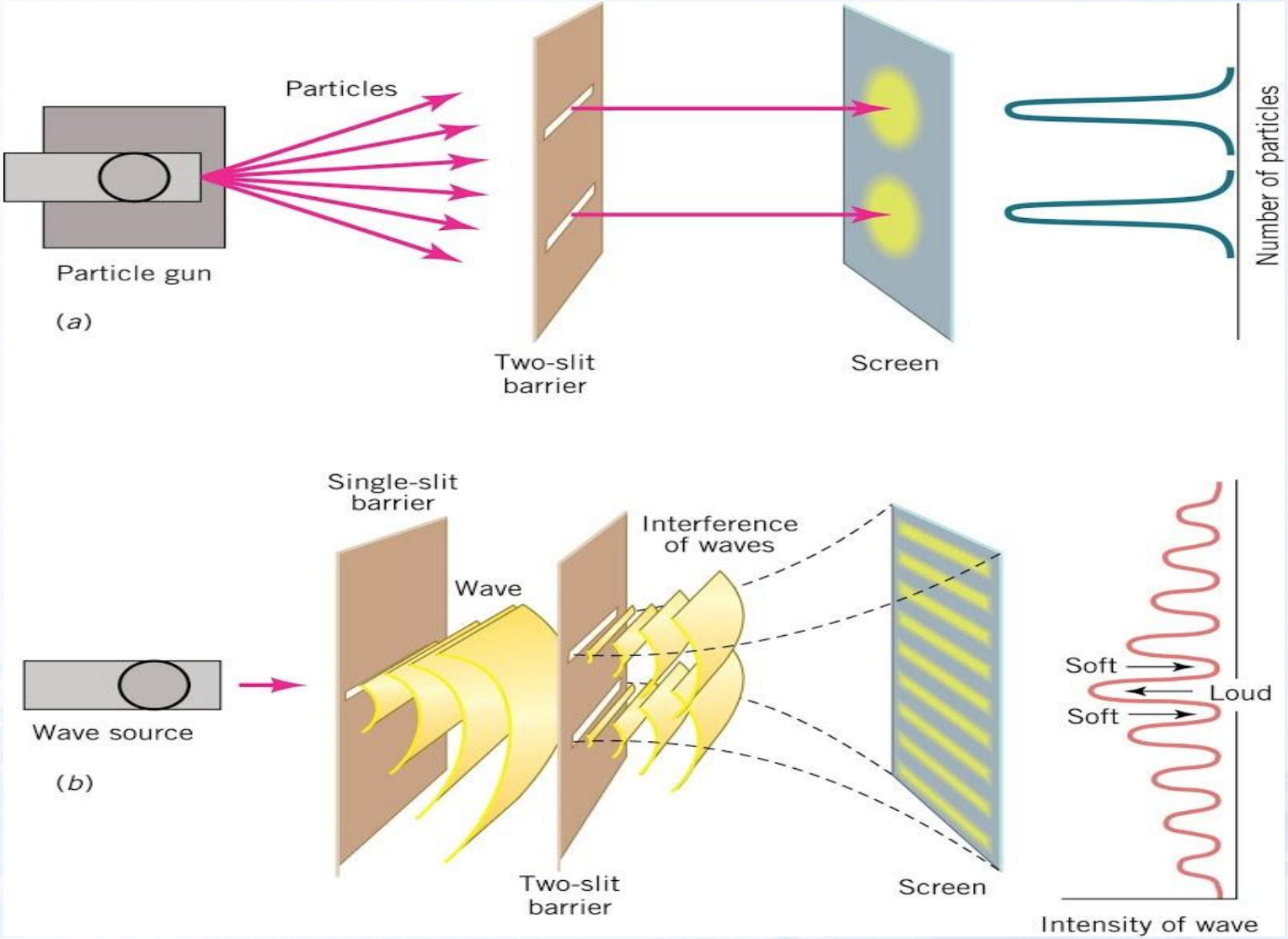
Dual Nature of EM Waves





The above pattern is of electrons passing through a single crystal . Bright spots are antinodal, dark spaces are nodal.

Dual Nature of EM Waves



de Broglie Wavelength

In 1924, de Broglie, speculated that particle might show wave behavior which exhibits a wave-particle duality.

He proposed that ordinary ``particles'' such as electrons, protons, or bowling balls could also exhibit wave characteristics in certain circumstances. Quantitatively, he associated a wavelength to a particle of mass *m* moving at speed *v* :

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

de Broglie Wavelength

If p is the momentum of the particle, the wavelength of the wave associated with it is given as

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

Proof: We know that energy of photon of frequency v (or wavelength λ) is $E = hv$

But from mass-energy equivalence energy of photon $E = mc^2$

$\therefore$ $E = hv$ and $E = mc^2$

$$hv = mc^2$$

$$m = hv/c^2$$

therefore momentum of photon

$$p = mc = \frac{hv}{c^2} \cdot c$$

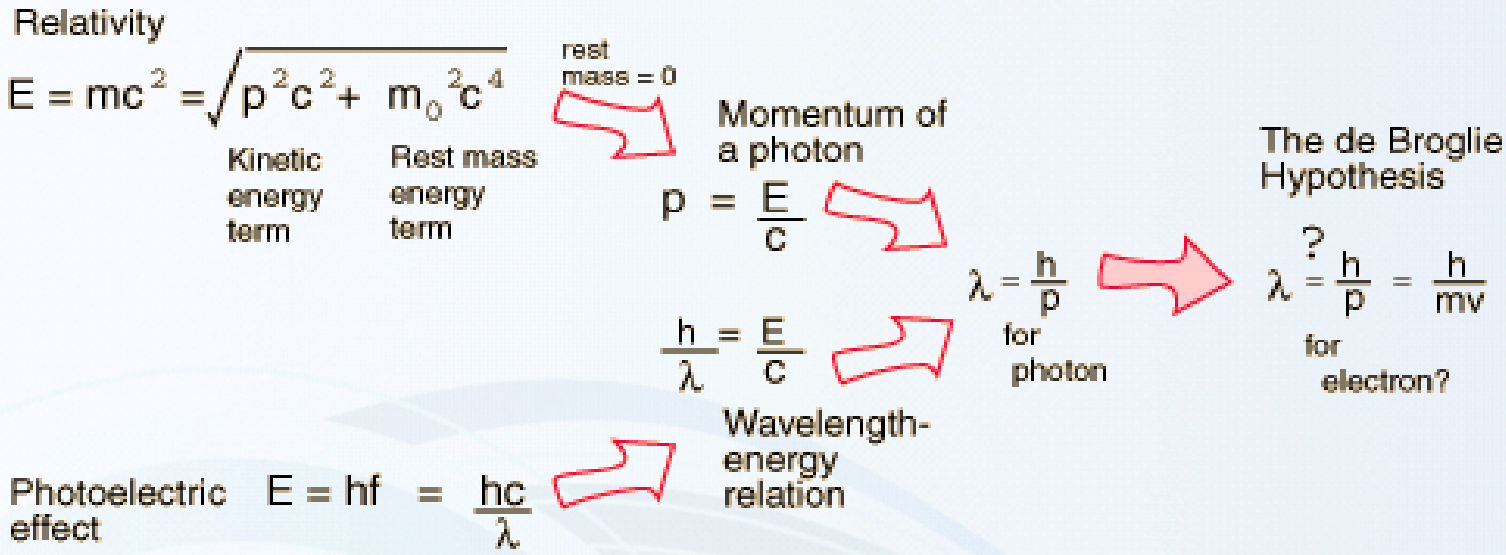
$$p = \frac{hv}{c} = \frac{h}{\lambda} \qquad [\because \quad c = v\lambda]$$

or wavelength of light

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

This wavelength is called De-Broglie wavelength

de Broglie Wavelength



DeBroglie Wavelength

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

Properties of Matter Waves

properties of matter waves?

Matter waves possess the following important properties:

i. Lighter is the particle, greater is the wavelength associated with it.

ii. Smaller is the velocity of the particle, greater is the wavelength associated with it.

iii. when $v = 0$ then $\lambda = \infty$ and if $v = \infty$ then $\lambda = 0$. This shows that matter waves are generated only when material particle are in motion.

iv. The velocity v of the matter wave is greater then the velocity of electromagnetic wave, i.e. velocity of light.

$$V_p = c^2/v$$

v. The velocity of matter wave is not constant. Wave depend on the velocity of material particle.

Numerical

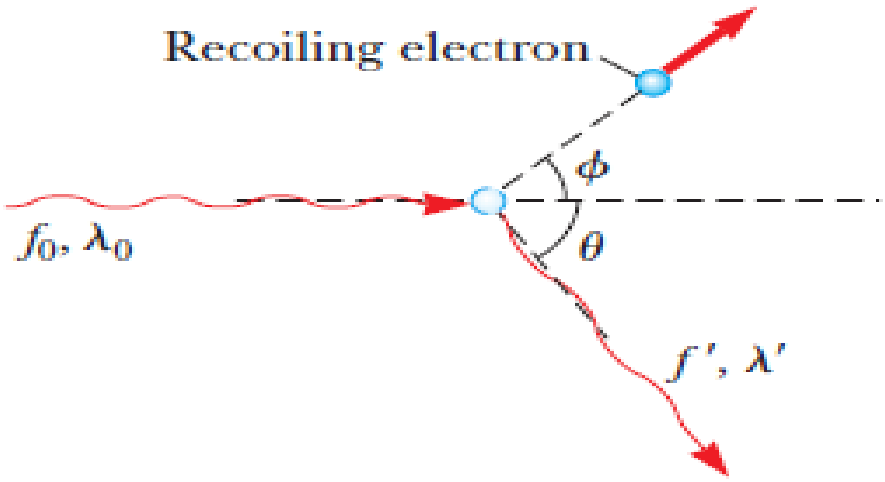
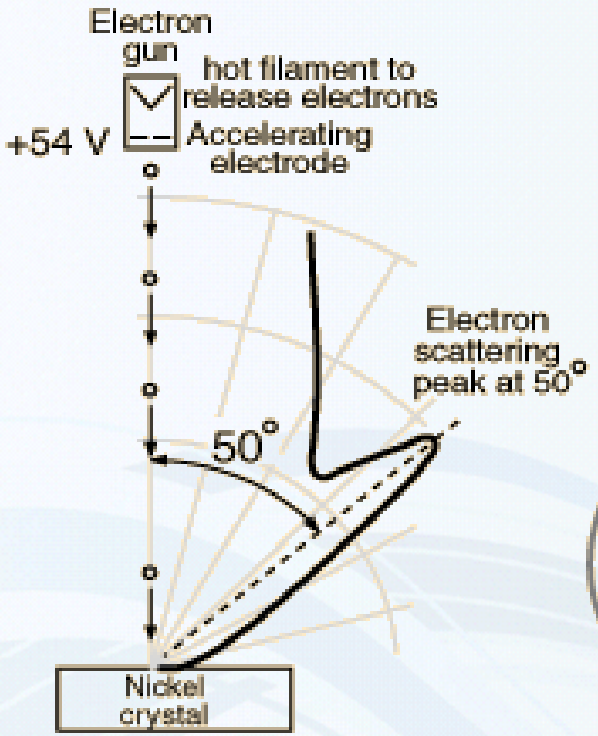


Figure 40.13 The quantum model for x-ray scattering from an electron. The collision of the photon with the electron displays the particle-like nature of the photon.

Davison-Germer Experiment



Theory

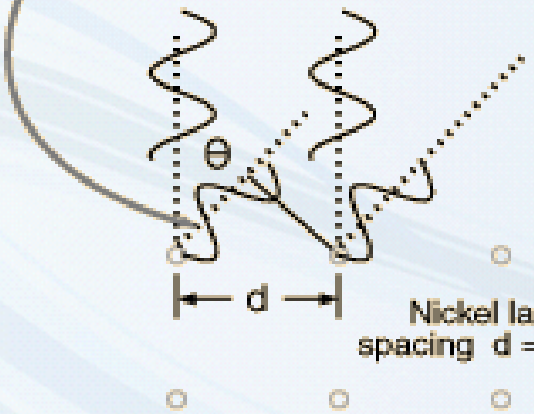
$$\lambda = \frac{h}{mv} = 1.67 \text{ Å for 54 V}$$

Experiment

Pathlength difference

$d \sin\theta = 2.15 \sin 50^\circ = \lambda = 1.65$ Å

for constructive interference



Not bad for a three year old idea!

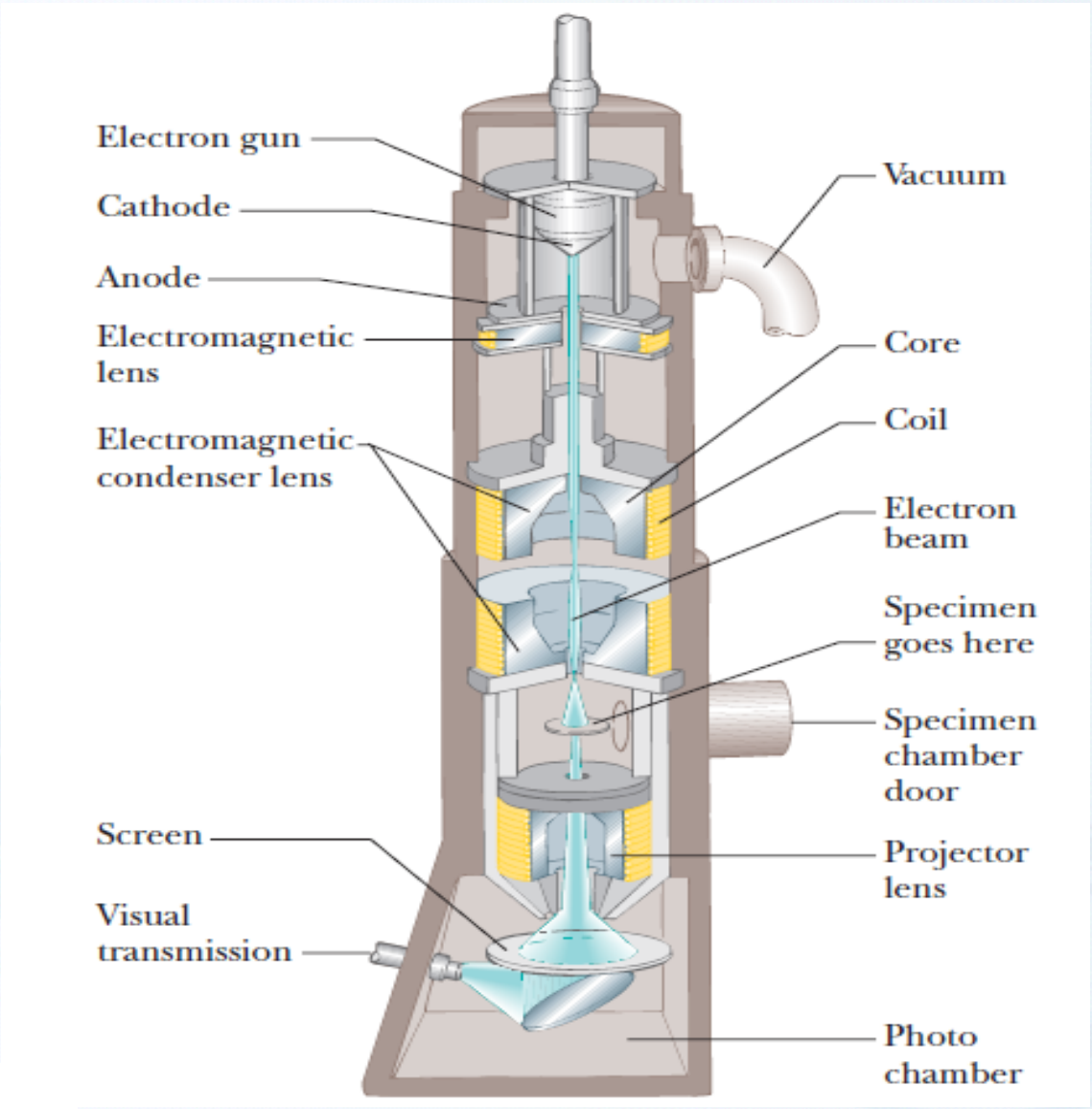
Nickel lattice spacing d = 2.15 Å

1924 de Broglie's hypothesis

1927 Davisson-Germer experiment

1929 Nobel Prize for de Broglie

Scanning Tunneling Microscope



Scanning Tunneling Microscope