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ENGINEERING PHYSICS

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Unit I : Review of concepts leading to Quantum Mechanics

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Week #2 Class #5

- Atomic Spectra
- Photo Electric effect
- Compton effect
- Compton shift
- Dual nature of radiation

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Unit I : Review of concepts leading to Quantum Mechanics

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➢ *Suggested Reading*

1. *Concepts of Modern Physics, Arthur Beiser, Chapter 2*
2. *Learning Material prepared by the Department of Physics*

➢ *Reference Videos*

1. *drPhysicsA youtube channel*

Atomic Spectra

- Atomic absorption lines are observed in the solar spectrum and referred to as Fraunhofer lines
- Robert Bunsen and Gustav Kirchhoff discovered new elements by observing their emission spectra.
- The existence of discrete line emission spectra or the absence of discrete lines in an absorption spectra

Atomic spectra

- *Continuous spectra from a source of white light*
- *Discrete emission lines*
- *Absence of lines from a continuous spectrum*

<- Continuous spectrum

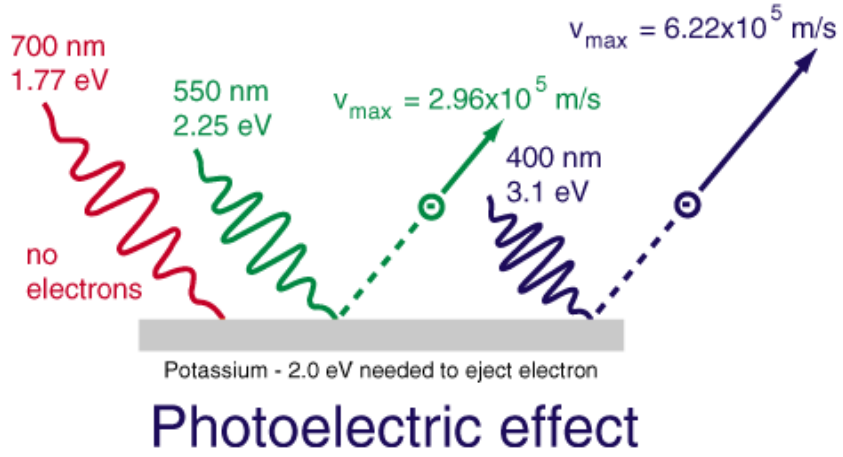
<- discrete emission line spectrum

<- absorption line spectrum

Image courtesy **Hyperphysics, Wikipedia**

Photo electric effect

- *Electron emission from metals under irradiation - Photo electric effect*
- *Instantaneous emission of electrons with kinetic energy dependent on wavelength of radiation*
- *Energy of photo electrons independent of intensity of radiation*
- *Failure of EM wave theory to explain observed results*



Photoelectric effect

Image courtesy **Hyperphysics,**

Photo Electric effect

- Einstein's concepts of photons
- Low energy electron – photon interaction
- Transfer of energy and momentum to the photo electron
- $h\nu = W + KE_e$
- Waves can have dual nature – depending on the nature of interaction with matter !

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Scattering of X Rays by target materials

- X Ray scattering experiments with different targets
- Scattered X rays have a higher wavelength than the incident X rays
- Wavelength of scattered X rays depend on the angle of scattering
- Scattering of EM waves as interaction of the electric fields with the electrons do not explain the change in the wavelength

Compton effect

- Arthur H Compton proposed a high energy photon -electron interaction
- X ray energies are in the range of 100KeV
- Electrons can gain energy and can be emitted with relativistic velocities

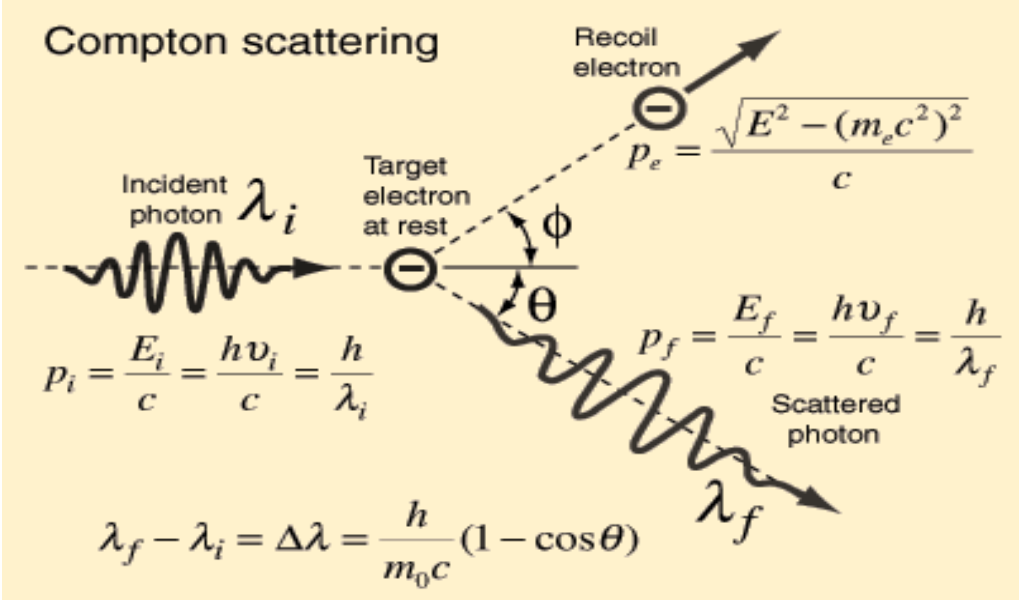

Image courtesy **Hyperphysics,**

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Relativistic concepts of momentum and energy

- *Rest mass energy of a particle given by*

  $E = m_o c^2$.

- *the kinetic energy of a particle with momentum p is given by pc*

- *The total energy of the particle is given by*

$$E = \sqrt{p^2 c^2 + {m_o}^2 c^4}$$

Conservation of momentum in X ray scattering

- **Momentum conservation along the incident direction -**

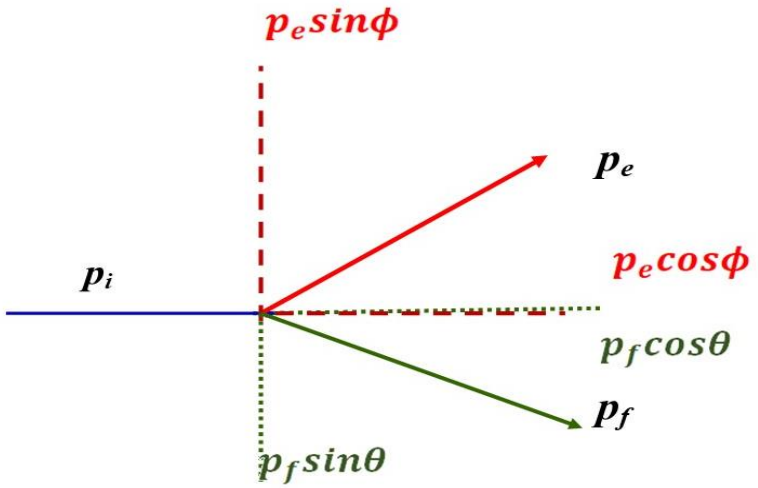
$$p_i + 0 = p_f cos\theta + p_e cos\phi.$$

- **Momentum conservation in a perpendicular direction -**

$$0 = p_f sin\theta - p_e sin\phi$$

- ***Conservation of momentum before and after collision***

$$p_e{}^2 = p_i{}^2 + p_f{}^2 - 2p_i\, p_f cos\theta \qquad \text{... 1.}$$



Conservation of energy

- ***Conservation of energy before and after collision***

$$p_i c + m_o c^2 = p_f c + \sqrt{p_e{}^2 c^2 + m_o{}^2 c^4}$$

$$p_e{}^2 = p_i{}^2 + p_f{}^2 - 2p_i\, p_f + 2m_o c(p_i - p_f) \quad \text{--- 2}$$

- **Comparing equations 1 & 2**

$$-2p_i\, p_f + 2m_o c(p_i - p_f) = -2p_i\, p_f cos\theta \quad \text{---- 3.}$$

Compton Shift

- *With* $p_i = \frac{h}{\lambda_i}$ *and* $p_f = \frac{h}{\lambda_f}$ *equation 3. simplifies to*

$$\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

- $\Delta\lambda$ *is termed as the Compton shift*
- $\Delta\lambda$ *is independent of the incident wavelength*
- $\Delta\lambda$ *dependents only on the angle of scattering*
- $\frac{h}{m_e c} = \lambda_c$ **is termed as the Compton wave length**
- *For electrons* λ_c **=2.42 x 10^{-12} m**

Compton effect

- **Experimental values of measurements of the scattered wavelengths along different directions**

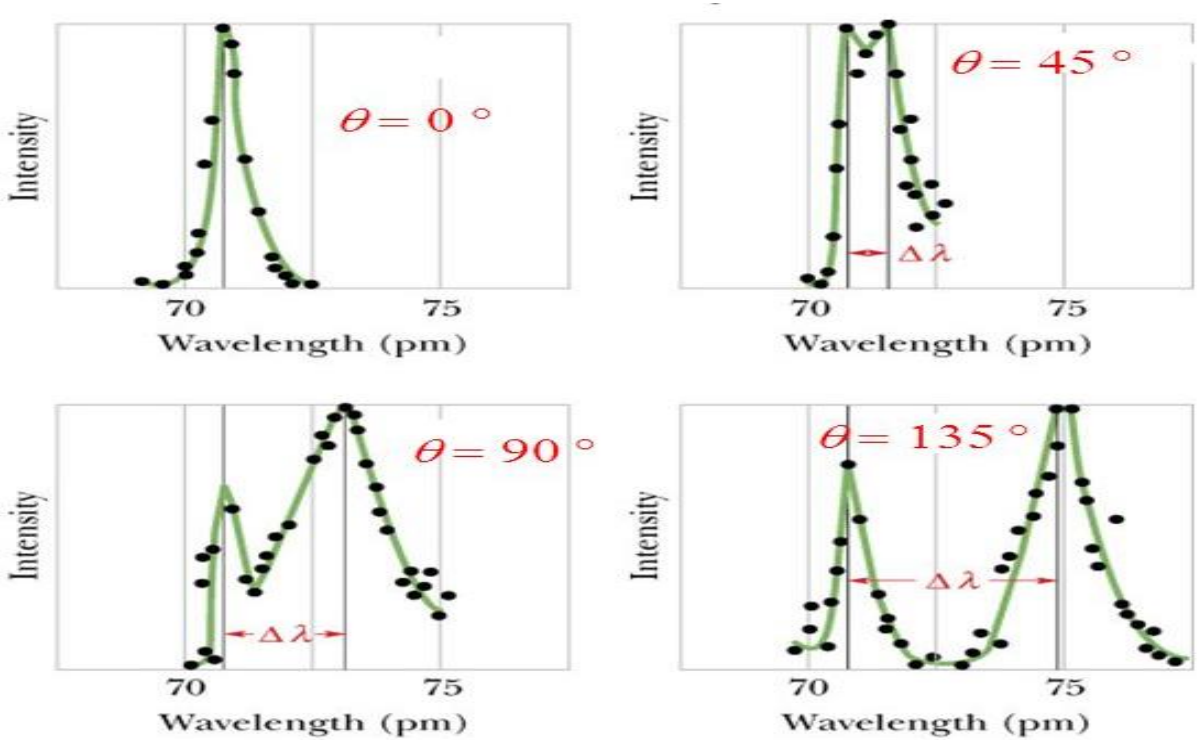


Image courtesy **Hyperphysics**

Compton effect

- *X rays – part of the EM wave spectrum*
- *Interaction of radiation with matter at sub-atomic matter requires radiation to be treated as particles - photons*
- *High energy photon – particle interaction explains the scattering phenomena*
- *Wave particle duality is a reality…*

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Class #5 …….. Quiz….

The concepts which are **incorrect** ….

1. EM waves can explain discrete spectral lines
2. Photo electric effect is the first proof for wave particle duality
3. Compton effect cannot be observed in the visible region
4. Compton shift for protons are higher than that for electrons
5. The maximum shift in the wavelength is 4.84 pm
6. Maximum momentum transfer to electron happens when the angle of scattering is 180°

THANK YOU

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