General Physics (PHY 2140)

Lecture 28

- Modern Physics
  - Quantum Physics
  - Photons. Wave properties of particles

http://www.physics.wayne.edu/~apetrov/PHY2140/

Chapter 27
If you want to know your progress so far, please send me an email request at

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Exam III review (transparences)
Lightning Review

Last lecture:

1. Quantum physics
   ✓ X-rays
   ✓ Compton scattering

\[ \lambda_{\text{min}} = \frac{hc}{e(\Delta V)} \]
\[ \Delta \lambda = \frac{h}{m_e c} (1 - \cos \theta) \]

**Review Problem:** The best color to paint a radiator, as far as heating efficiency is concerned, is

1. black.
2. white.
3. metallic.
4. some other color.
5. It doesn’t really matter.
An x-ray photon is scattered by an electron. The frequency of the scattered photon relative to that of the incident photon (a) increases, (b) decreases, or (c) remains the same.

(b). Some energy is transferred to the electron in the scattering process. Therefore, the scattered photon must have less energy (and hence, lower frequency) than the incident photon.
A photon of energy $E_0$ strikes a free electron, with the scattered photon of energy $E$ moving in the direction opposite that of the incident photon. In this Compton effect interaction, the resulting kinetic energy of the electron is (a) $E_0$, (b) $E$, (c) $E_0 - E$, (d) $E_0 + E$, (e) none of the above.

(c). Conservation of energy requires the kinetic energy given to the electron be equal to the difference between the energy of the incident photon and that of the scattered photon.
27.8 Photons and Electromagnetic Waves

- **Light has a dual nature. It exhibits both wave and particle characteristics**
  - Applies to all electromagnetic radiation

- The **photoelectric effect** and **Compton scattering** offer evidence for the **particle nature of light**
  - When light and matter interact, light behaves as if it were composed of particles

- **Interference and diffraction** offer evidence of the **wave nature of light**
In 1924, Louis de Broglie postulated that because photons have wave and particle characteristics, perhaps all forms of matter have both properties.

Furthermore, the frequency and wavelength of matter waves can be determined.

The de Broglie wavelength of a particle is

\[ \lambda = \frac{h}{mv} \]

The frequency of matter waves is

\[ f = \frac{E}{h} \]
The Davisson-Germer Experiment

- They scattered low-energy electrons from a nickel target.
- They followed this with extensive diffraction measurements from various materials.
- The wavelength of the electrons calculated from the diffraction data agreed with the expected de Broglie wavelength.
- This confirmed the wave nature of electrons.
- Other experimenters have confirmed the wave nature of other particles.
Review problem: the wavelength of a proton

Calculate the de Broglie wavelength for a proton \( (m_p=1.67 \times 10^{-27} \text{ kg}) \) moving with a speed of \( 1.00 \times 10^7 \text{ m/s} \).
Calculate the de Broglie wavelength for a proton \((m_p=1.67\times10^{-27} \text{ kg})\) moving with a speed of \(1.00 \times 10^7 \text{ m/s}\).

**Given:**

\[ v = 1.0 \times 10^7 \text{ m/s} \]

**Find:**

\[ \lambda_p = ? \]

Given the velocity and a mass of the proton we can compute its wavelength

\[ \lambda_p = \frac{h}{m_p v} \]

Or numerically,

\[ \lambda_{ps} = \frac{(6.63 \times 10^{-34} \text{ J} \cdot \text{s})}{(1.67 \times 10^{-31} \text{ kg})(1.00 \times 10^7 \text{ m/s})} = 3.97 \times 10^{-14} \text{ m} \]
A non-relativistic electron and a non-relativistic proton are moving and have the same de Broglie wavelength. Which of the following are also the same for the two particles: (a) speed, (b) kinetic energy, (c) momentum, (d) frequency?

(c). Two particles with the same de Broglie wavelength will have the same momentum $p = mv$. If the electron and proton have the same momentum, they cannot have the same speed because of the difference in their masses. For the same reason, remembering that $KE = p^2/2m$, they cannot have the same kinetic energy. Because the kinetic energy is the only type of energy an isolated particle can have, and we have argued that the particles have different energies, Equation 27.15 tells us that the particles do not have the same frequency.
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