AP Phys 2 Unit 6.4 Notes - Wave-Particle Duality

6.4 Wave-Particle Duality

Duality

Light behaves as waves in diffraction and interference.

It behaves as particles too, in the photoelectric effect, Compton scattering, and emission spectra.

This leads to **wave-particle duality:** both theories are necessary to adequately describe the observed phenomena of light.

1. Momentum Review

The momentum (p) of a material object is:

$p = m \cdot v$ AP Equation	p = momentum (kg m/s) m = mass (kg) v = velocity (m/s)

What's the momentum of a 160 kg runner going 8.8 m/s?

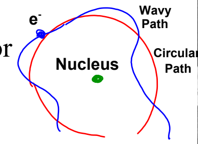
$$p = m \cdot v = 160 kg \cdot 8.8 m/s = 1400 kg \cdot m/s$$

de Broglie's Hypothesis

Louis de Broglie hypothesized that matter behaved as waves (as well as particles), just like light has wave-particle duality. Matter waves!

$\lambda = \frac{h}{p}$ AP Equation	$= \frac{h}{mv}$	λ = De Broglie wavelength (m) h = 6.63 E -34 Js p = momentum (kg m/s) m = mass (kg) v = velocity (m/s)

This applies to material objects, and accounts for the funky shapes of electronic orbitals.



Baseball Examples

A ball player hits a 145 g baseball 55 m/s.

2. What is the ball's momentum?

$$p = m \bullet v = 0.145 kg \bullet 55 m/s = 7.98 kg \cdot m/s$$

3. What's its De Broglie wavelength?

$$\lambda = \frac{h}{p} = \frac{6.626E-34 J \bullet s}{7.98 kg \cdot m/s} = 8.3E-35 m$$

Photon Momentum

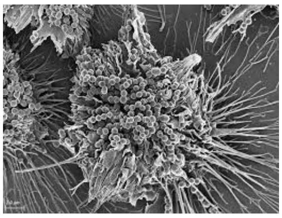
Photons (traveling light speed) have momentum (despite having no mass).
These equations apply to photons - don't try calculating a photon's mass!

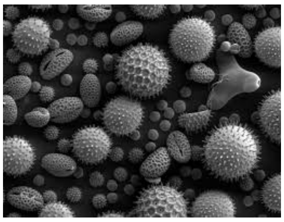
Relations: $p = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$

p = momentum (kg m/s)	h = 6.63 E -34 Js
E = energy (J)	f = frequency (Hz or 1/s)
c = 3.00 E 8 m/s	λ = wavelength (m)

Applications of Matter Waves

Energy factors in when electrons are used in such applications as electron microscopes.
Their wavelengths can be used for making images!





Electron Examples

An electron accelerates across 225 V.
4. How much energy does it gain?

$$E = e \bullet V = 1e^{-} \bullet 225V = 225eV$$

5. What's its wavelength?

$$\frac{E}{c} = \frac{h}{\lambda}$$

$$\lambda = \frac{hc}{E} = \frac{4.14E-15eV \bullet s \bullet 3.0E8\,m/s}{225eV} = 5.53E-9\,m$$

6. Photonic Example

What is the frequency of a photon with a momentum of 1.54 E -27 kg m/s?

$$p = \frac{hf}{c}$$

$$f = \frac{pc}{h} = \frac{1.55E-27kg\,m/s \bullet 3.0E8\,m/s}{6.63E-34J \bullet s} = \boxed{7.0E14Hz}$$

Homework 6.4

Problems 6.4 in your Booklet
Due: Next Class