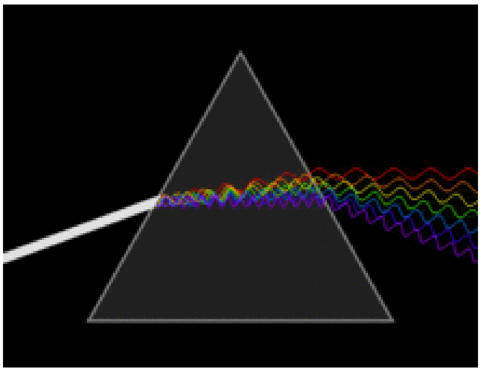
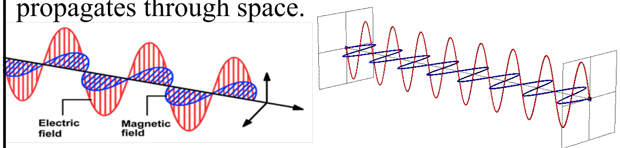
7.1 - 7.2 Electromagnetic Radiation and Photons



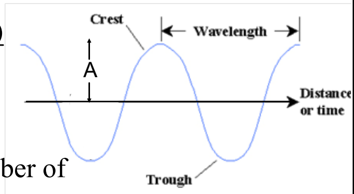
Electromagnetic (EM) Radiation

Def: Energy having perpendicular electric AND magnetic-field components changing polarity as it propagates through space.



Note: often EM radiation is drawn as a sinusoidal wave, but that represents fluctuating fields, NOT the radiation's true path.

EM Wave Characteristics



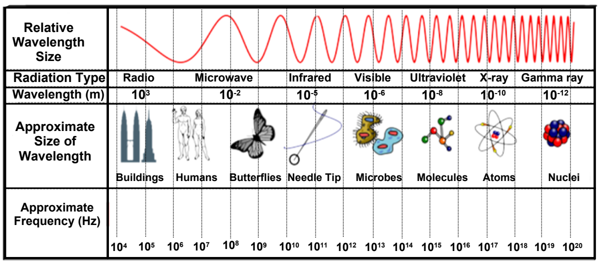
Wavelength(λ: lambda) distance between equivalent points of a wave.

Frequency (ν: nu): number of waves passing a point every second. Units: cycles/second (s^{-1}) or Hertz (Hz).

Amplitude (A): height from axis to crest OR trough.

EM Spectrum

Covers a wide range of frequencies.



Wave Equation

Frequency and wavelength are unified through the speed of light:

$c = \lambda \nu$	c = vacuum speed of light (3.00 E 8 m/s) λ = wavelength (m) ν = frequency (Hz or s^{-1})
AP Equation	

Terrible Chemistry Joke:
Asked one chemist to another: "What's new?"
To which the second chemist repies "C over lambda."
(What's ***nu***?) Get it?

EM Example:

1. What frequency is radiation of λ = 8.72 E – 2 m?

$$\lambda = \frac{c}{\nu}$$

$$\nu = \frac{c}{\lambda} = \frac{3.00E8\,m/s}{8.72E-2\,m} = \boxed{3.44E9\,Hz}$$

2. What type of radiation is it? (Use your Table)

Between microwave and infrared radiation.

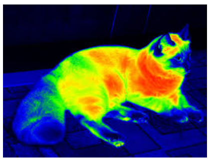
Radiation Types

Radio Waves – Long wavelength carriers for TV and radio stations. Also generated by lightning, stars, quasars, and galaxies.

Microwaves – Produced by special vacuum tubes – used for communication, heating food, and speed guns used to time baseball pitches and speeding motorists.

Infrared (IR) – Associated with heat emissions. Water absorbs IR waves and warms up. Also keeps Earth warm by the Greenhouse Effect.

Warm Kitty



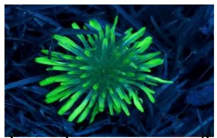
Radiation Types

Visible Light – A narrow range of wavelength (390 – 700 nm) allows us to see colors.

What would it look like if we could see beyond this?

Some snakes "see" in IR (they have organs that detect warm objects (food species) up to a meter away). We have receptors that feel IR radiation.

Some insects can see in the ultraviolet range (which many flowers give off).



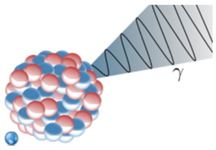
Human eye sensitivity conforms closely to the spectrum of wavelengths emitted by the sun.

Radiation Types

Ultraviolet (UV) – Just beyond the visible spectrum – higher energy. Sun emits UV; ozone in atmosphere absorbs it. Welding produces lots of UV – wear a mask.

X-Rays – Discovered when a fluorescent material illuminated in a lab for no apparent reason.
High energy – used for imaging bones.
Produced by high-energy electron bombardment of atoms.
Old-school televisions made X-Rays: "Don't sit too close!"

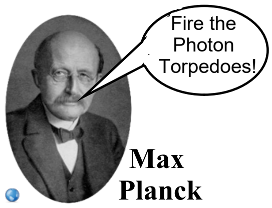
Gamma Rays – High energy, short frequency radiation. Generated during radioactive decay of unstable nuclei. Symbol = γ.



Quantum Cannonballs

Light can be thought of as particles that carry a frequency-dependant quantity (a quantum) of energy. Max Planck predicted that photons carry a discrete amount of energy, dependant on frequency:

$E = h\nu$ AP Equation	E = Energy (J) h = Planck's Constant (6.63 E -34 J s) ν = frequency (Hz)



Max Planck

Photoelectric Effect

Einstein used photon concept to explain the photoelectric effect - ejection of electrons from a metal's surface when bombarded by light.

Photoelectric Characteristics

1. Photocurrent is proportional to light intensity (how many photons).
2. Maximum kinetic energy depends on frequency not intensity.
3. Below cutoff frequency, no photocurrent occurs, regardless of light intensity.
4. Photocurrent occurs as soon as cutoff frequency is reached, regardless of intensity.

Duality

Light behaves as waves in diffraction and interference.

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

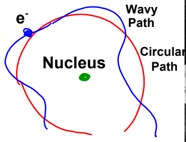
This leads to **wave-particle duality:** both theories are necessary to adequately describe the observed phenomena of light.

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!

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

This applies to material objects, and accounts for the funky shapes of electronic orbitals (to be seen later).



Baseball Examples

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

3. What is the ball's De Broglie wavelength?

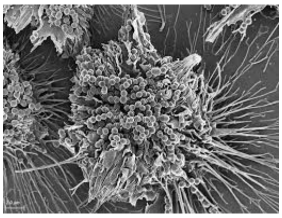
$$\lambda = \frac{h}{mv} = \frac{6.63E-34 J \bullet s}{0.145 kg \cdot 55 m/s} = 8.3E-35 m$$

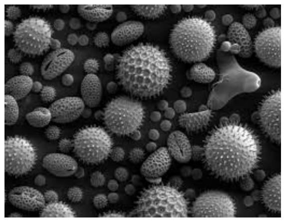
4. What is the wavelength of an electron (mass = 9.11 E -31 kg) traveling the same speed?

$$\lambda = \frac{h}{mv} = \frac{6.63E-34 J \bullet s}{9.11E-31 kg \cdot 55 m/s} = 1.3E-5 m$$

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!





Homework

Preview 7.3 - 7.9

7.1-7.2 Problems in your Booklet
Due: Next Class