Review of Radiation Physics

RTT4220 – Lecture #1

Kedree Proffitt

WSU

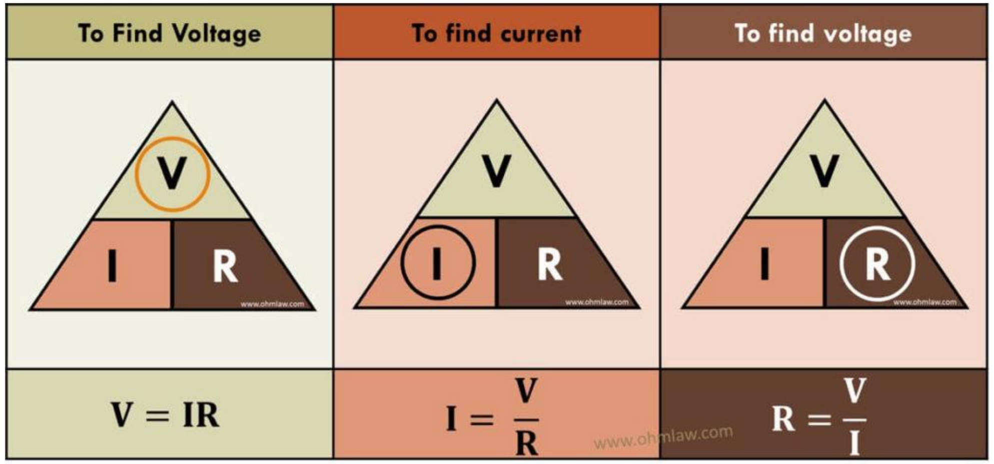
09/02/2025

Review of Electricity and Magnetism

The old stuff

Electricity and Magnetism

- Energy (Many Symbols) [J or eV]
- Charge (q) [C or A×s]
- Current (I) [A]
- Electric Potential (Voltage) (ε) [V or J/C]
- Power (P) [W or J/s]
- Resistance (R) [Ω]



$$\boxed{P = I \times V}$$

$$\boxed{\text{KE} = q \times \varepsilon = \frac{mv^2}{2}}$$

$$\boxed{V = I \times R}$$

Moving Electrons

When electrons accelerate → photons are generated

Acceleration can occur two ways; SPEED or DIRECTION

High speed accelerating electrons are awesome and dangerous: X-rays

We often want fast electrons, easiest way to get them is VOLTAGE

VOLTAGE gives electrons energy, makes them accelerate (charged particles)

Electron Energy and Speed Practice

An electron travels a 300 V electric potential ($\varepsilon = 300$ V) has a typical mass ($m = 9.1 \times 10^{-31}$ kg) and a typical charge ($q = 1.6 \times 10^{-19}$); find the kinetic energy assuming it started at rest.

$$\mathrm{KE} = q \times \varepsilon$$

$$\mathrm{KE} = (1.6 \times 10^{-19}) \times (300) = 4.87 \times 10^{-17}\ \mathrm{J}$$

$$(2.73 \times 10^{-28}\ \mathrm{J}) \times \left(\frac{1\ \mathrm{eV}}{1.6 \times 10^{-19}}\right) = 300\ \mathrm{eV}$$

Now find the velocity it had as it left the potential (ignore relativity).

$$\mathrm{KE} = \frac{mv^2}{2} \rightarrow v = \sqrt{\frac{2\mathrm{KE}}{m}} \rightarrow v = \sqrt{\frac{2 \times (4.87 \times 10^{-17})}{9.1 \times 10^{-19}}} = 10.3\,\frac{\mathrm{m}}{\mathrm{s}}$$

Atomic Mass Units

An atomic mass unit (amu) is 1/12th of the mass of a carbon-12 **nucleus**.

Carbon-12 has 6 protons and 6 neutrons and weighs 12 amu (by definition).

Protons and neutrons weigh ~ the same, each is about 1 amu

1 amu = 1.66E-27 kg

Radiation Physics

The good stuff

What is Radiation?

When energy **radiates** away from something (energy or mass)

Lots of misconceptions!

Many types of radiation and the uses/danger are just as variable

Light, Microwave, infrared, alpha, beta, gamma, the list goes on

Types of Radiation

ELECTROMAGNETIC

- Photons (that's it!)
- The name depends on energy and/or source (i.e. **Gamma/X-ray/Light**)

PARTICULATE

- Helium (**Alpha**)
- Electrons (**Beta**)
- Protons

What is a Photon?

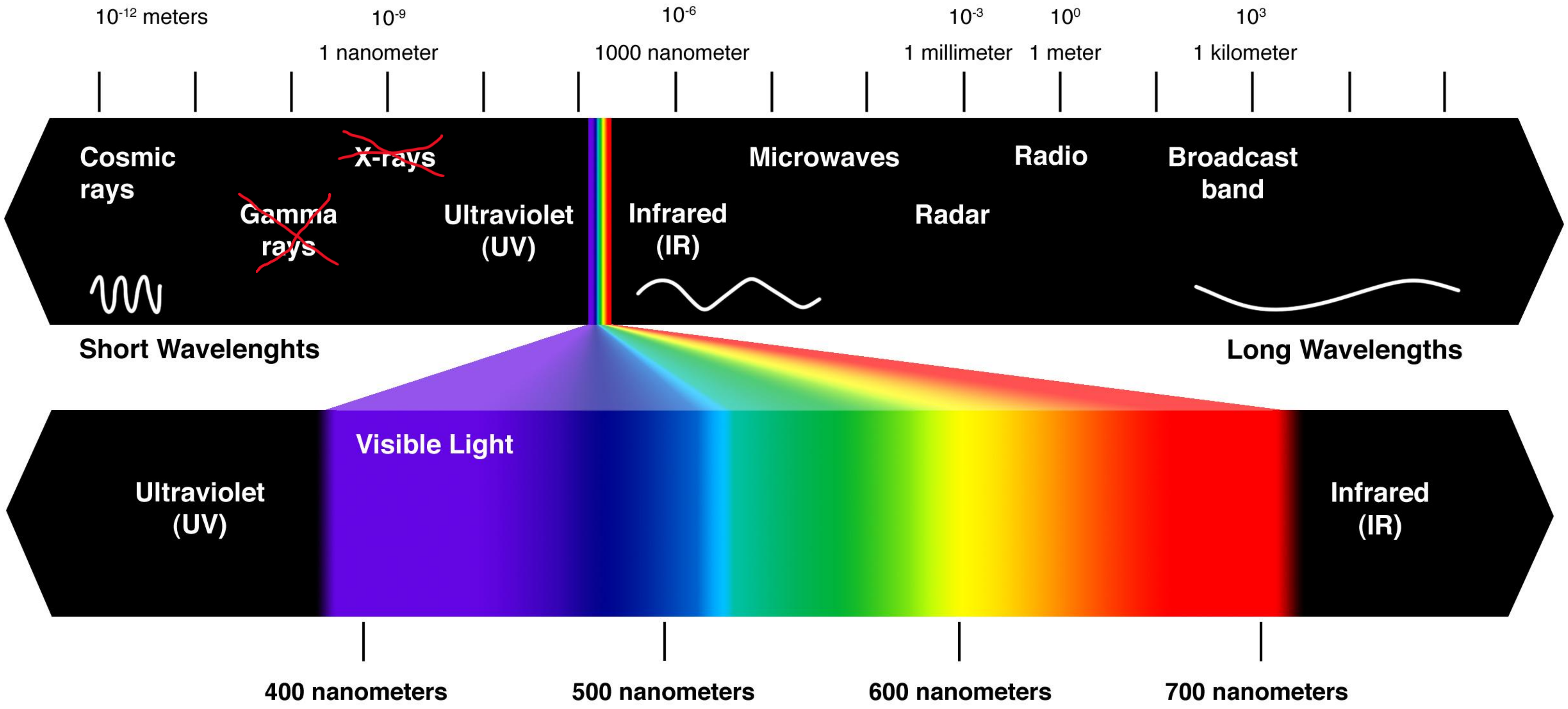
- All EM radiation is comprised of photons (γ)
- Because of dumb history photons were “discovered” many times before we unified them thus some names stuck
- This yields the ELECTROMAGNETIC SPECTRUM

If it came from an atom*:
ITS GAMMA RADIATION*

If it came from anything else*:
WE DON’T HAVE A WORD*

But no matter what, it’s on the spectrum!

Electromagnetic Spectrum



Wave-Particle Duality

- EM Radiation behaves in ways that determine it MUST BE particles, and it MUST BE waves at the same time.
- ?????
- Its both due to quantum mechanics.

Wave-like Behavior:

- Particles CANNOT diffract
- We see EM rad. diffract!

Therefore, its wave-like!

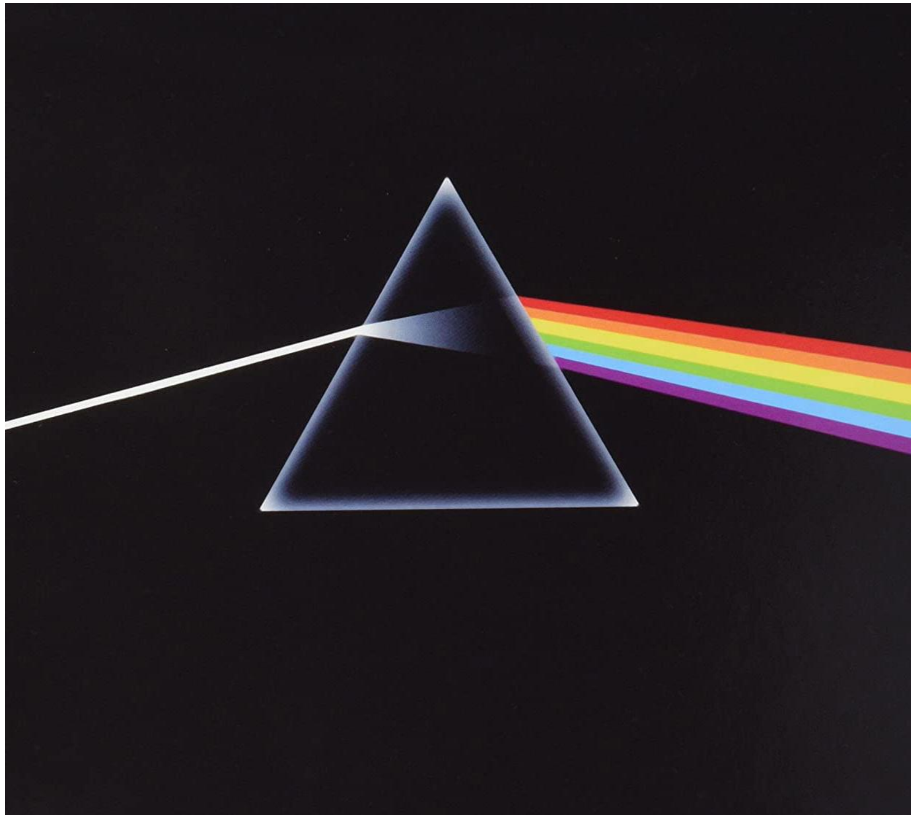
Particle-like Behavior:

- Waves CANNOT deposit energy in "batches"
- EM rad. does so: photoelectric effect

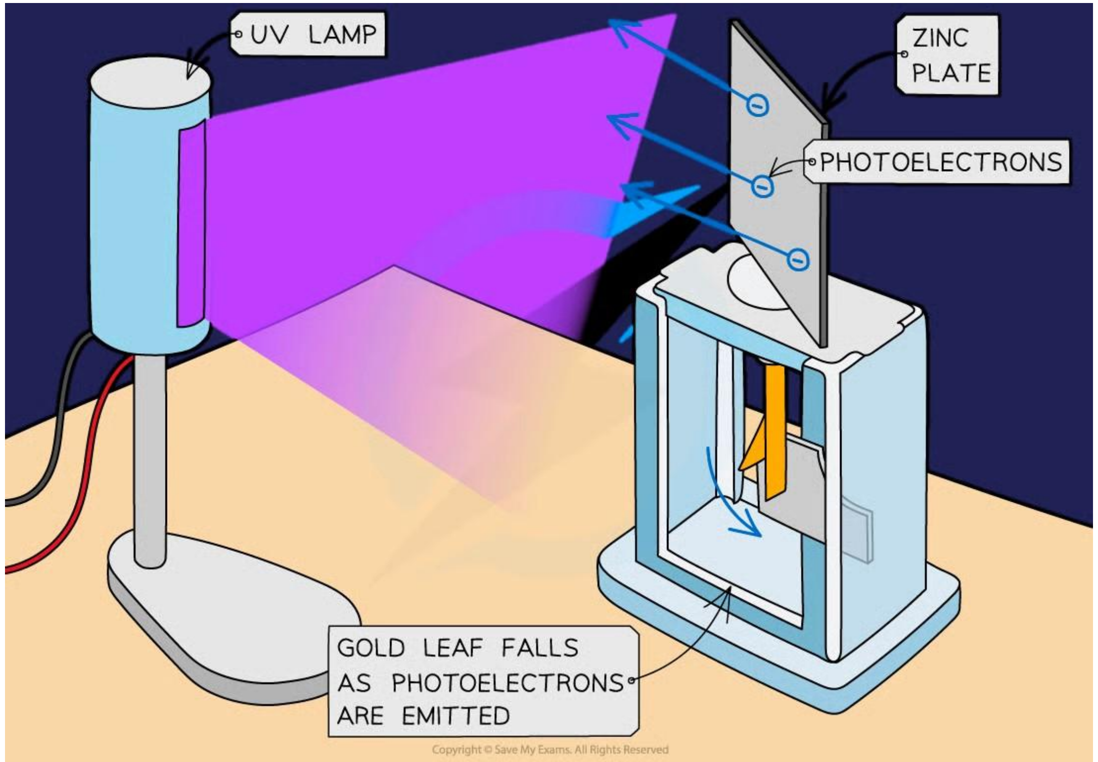
Therefore, its particle-like!

Wave-Particle Duality

Wave-Like



Particle-Like



Photon Physics

- Photons are the representation of the particle-like behavior
- Photons travel at the speed of *massless things**
- Photon energy is directly related to its wave-like behavior frequency
- EM frequency is inversely related to its wavelength
- ($h = 6.63 \times 10^{-34}$ [Js] is Planck's constant)

$$\boxed{E = h \times \nu}$$

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

$$\boxed{E[\mathrm{kev}] = \frac{1.24}{\lambda[\mathrm{nm}]}}$$

Photon Energy Practice

An x-ray with a wavelength of 4.20E-9 m is ATTENUATED by a detector. How much energy would be deposited? What is the frequency of that radiation?

$$E = \frac{1.24}{4.2} = 0.295 \text{ keV OR}$$

$$E = \frac{h \times c}{\lambda} \rightarrow E = \frac{(6.63 \times 10^{-34}) \times (3 \times 10^{8})}{4.20 \times 10^{-9}} \times \frac{1 \text{ eV}}{1.6 \times 10^{-19}} = 296 \text{ eV}$$

How much energy would be deposited by 1 MILLION of these x-rays?

$$296 \times 10^{6} = 2.96 \times 10^{8} \text{ eV or } 296 \text{ MeV}$$