What is Radiation?

- Transfer of kinetic energy that passes from one location to another.
    - Varying types and sources
    - Matter that intercepts or absorbs radiation is said to be irradiated.

Wave Theory

- All waves have an associated
  - Wavelength
  - Frequency
  - Amplitude
  - Period

Wave Theory

- Wavelength
  - Distance between any two successive points on a wave
  - Measured crest-crest or trough-trough
  - Represented by Greek letter lambda (λ)
- Frequency
  - Number of wavelengths in a given time
  - Unit is a Hertz (Hz)
  - One Hz= 1 cycle/second
- Amplitude
  - Intensity of wave defined by its maximum height
- Period
  - Time required to complete one cycle

Wave Equation

- Relationship between the frequency, wavelength and velocity of a wave is expressed in a formula.

The Wave Equation

- Velocity = frequency (f) x wavelength (λ)
- $v = f\lambda$

Electromagnetic Waves

- **Electromagnetic waves** travel at the speed of light in a vacuum and <u>do not</u> require a medium

Electromagnetic Wave Equation

$$c = f\lambda$$

*reference from BushonG

- C - constant (velocity or speed of light)
- *f - frequency
- λ – wavelength

Particle Theory

- High-frequency radiation interacts with matter more like a particle than a wave.
- Radiation acts like a discrete bundle of photon energy.
- Photons carry a specific amount of energy depending on frequency.
- Photon energy and frequency are directly proportional.
- Relationship was first described by a physicist named Max Planck.

Particle Theory - Formula

- The relationship between photon energy & frequency is described in this formula:

Planck's Quantum Equation

$$E = hf$$

  - E = photon energy (eV)
  - h = Planck's constant (4.15×10^{-15} eV-sec)
  - f = photon frequency (Hz)

- This equation is used to calculate the frequency of an x-ray when given the x-ray photon's energy.

Wave-Particle Duality

Wave-Particle Duality

- X-ray photons can be described as both waves or particles
- Can travel through space in form of a wave
- Can interact with matter as a particle of energy

Electromagnetic Spectrum

- Low frequencies, long wavelengths are at the bottom of the spectrum:
  - Radiowaves
  - Microwaves
  - Light
  - Ultraviolet
- High frequencies, short wavelengths are at the top of the spectrum:
  - X-rays
  - Gamma rays

Electromagnetic Spectrum

- Each frequency has a characteristic wavelength and energy.
  - Higher frequencies are associated with shorter wavelengths.
- Wavelengths range from largest to smallest.
- Frequencies and energy range from smallest to largest.
- Lower frequencies and energy at lower end of the spectrum.
- Higher frequencies and energy at the top of the spectrum.

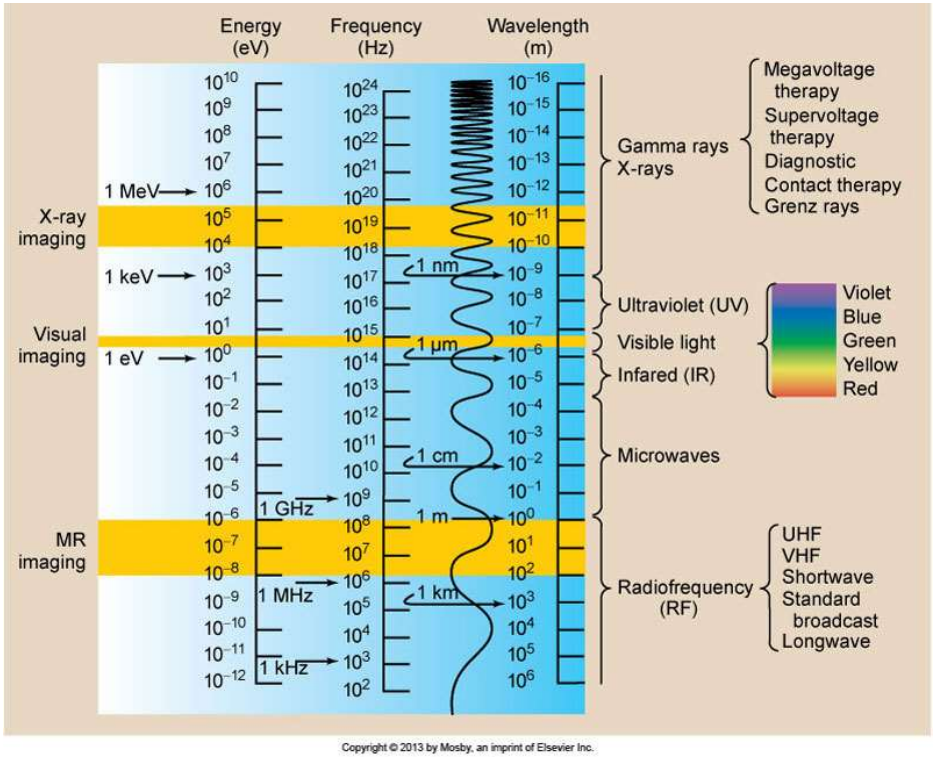
Electromagnetic Spectrum

Top of the spectrum

- Higher energy
- Higher frequency
- Shorter wavelength

Bottom of spectrum

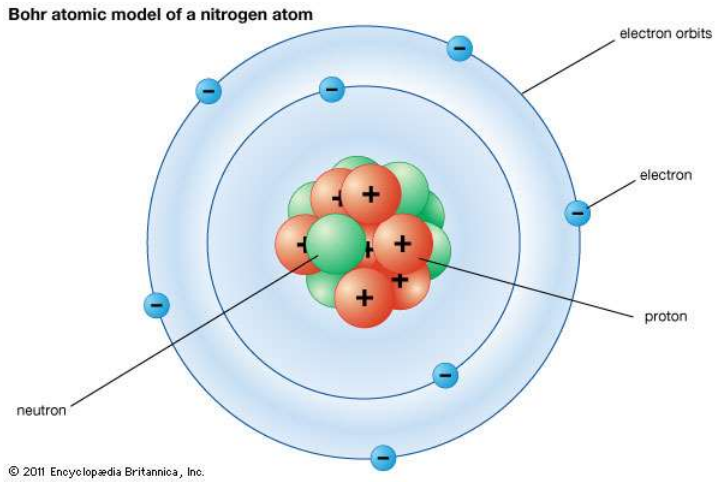
- Lower energy
- Lower frequency
- Longer wavelength



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Atoms

- Atoms in a normal state are electrically neutral.
- Total number of electrons in orbital shell is equal to the number of protons in nucleus.



Excitation of an Atom

- Occurs with both ionizing and non-ionizing radiation.
    - Electrons are infused with energy
    - Jump to a higher energy shell
    - Electron will return to its original location
    - Excess energy is released as non-ionizing radiation

Ionizing Radiation

- Ionizing radiation causes ionization of atoms
  - Causes electrons to be ejected from an atom
  - This is the foundation of interactions in human tissue
  - An atom that has an extra electron or loses one becomes ionized.
  - Ionized atom will then carry a charge equal to the difference between number of protons and electrons.
- Ion
  - Electrically charged atoms (positive or negative)
  - Caused by loss or gain of one or more electrons
- Free electron and the atom are called an **ion pair.**

Electromagnetic Radiation

- Ionizing Radiation
  - X-rays
  - Gamma rays
  - High-energy ultraviolet radiation
- Non-Ionizing Radiation
  - Low-energy ultraviolet
  - Visible light
  - Infrared rays
  - Microwaves
  - Radiowaves

Particulate Radiation

- Alpha and Beta particles
  - Associated with radioactive decay

Alpha Rays

- Highly ionizing, short range in tissue
- Less penetrating than beta particles
- Emitted from nuclei of heavy elements during radioactive decay (uranium and radium)
- Contains **two protons** and **two neutrons**
  - Helium atom without electrons
- Large mass and **positive** charge
- Could be absorbed by piece of paper

Particulate Radiation

- Beta Rays
  - Light particles emitted from nucleus of radioactive atom
  - Very high energy ejected at high speed
  - 8000 times lighter than alpha particle
  - Penetrates matter to a greater depth than alpha with less ionization (1-2 cm of soft tissue)

Sources of Radiation (natural)

- Terrestrial
  - Uranium and radium present in the earths crust
  - Radon
    - Largest contributor of background radiation
    - Arises from the decay of uranium-238
    - Colourless, odourless and chemically non-reactive
    - Always present in the air
    - Comes up through soil, permeates buildings
    - Bricks, concrete, gypsum all contain radon

Sources of Radiation (cont'd)

- Cosmic
  - From nuclear interactions that have taken place in the sun and other stars
  - Protected by the atmosphere and earth's magnetic field
  - Greatest intensity at high altitudes and lowest at sea level
  - Air travel: 10 hours in the air = 1 chest x-ray
- Internal
  - Human tissue has naturally existing radionuclides that are inhaled or ingested in tiny quantities

Sources of radiation (artificial)

- Manmade
  - Industrial
    - Nuclear accidents
    - Mining
  - Research
    - Electron microscopes
    - Particle accelerators
  - Consumer products
    - Watches
    - Smoke detectors
    - Exit signs
  - Medical Radiation