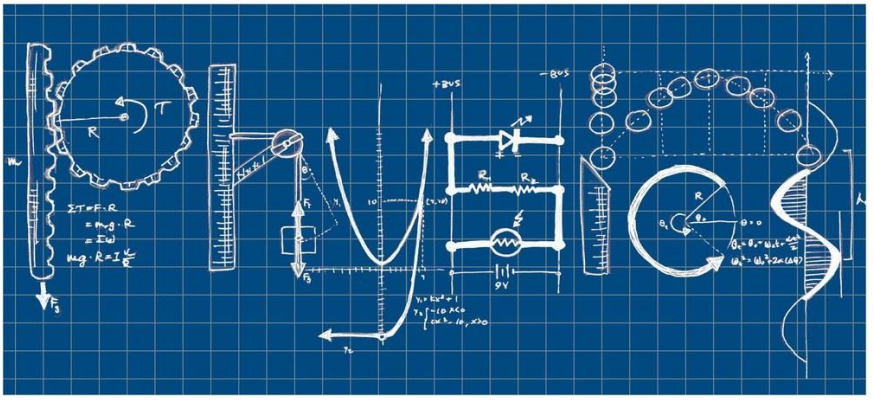
Hazards Ignored: Non Ionizing Radiation

An overview of commonly ignored and misunderstood hazards

First: a Little Physics



Electromagnetic Radiation

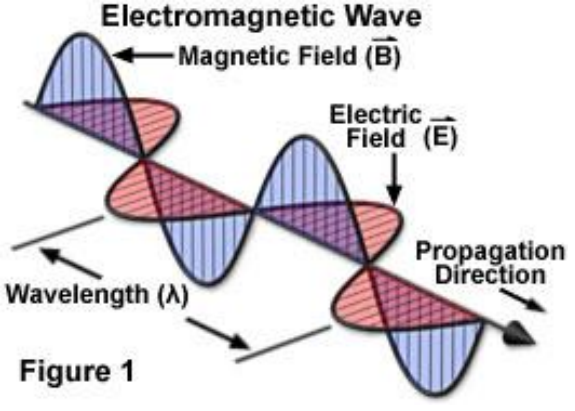
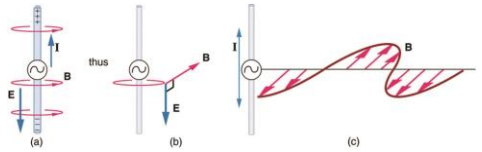


Figure 1

Wavelength = Frequency X Speed
EMR propagates at the speed of light = 299,792,458 m/sec

Sources of EMR

Electrical oscillation in a conductor ("antenna")



- Alternating current induces magnetic field at right angle.
- Magnetic field induces electrical field
- Electromagnetic field propagates away from antenna

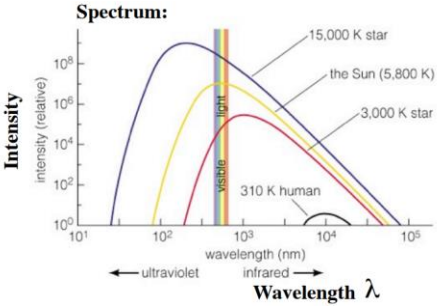
Properties

- Typically a single frequency depending on AC frequency
- EMR is "polarized" based on antenna orientation
- Antenna is most efficient for a wavelength = antenna size

Sources of EMR

Spectral absorption and emission (black body)

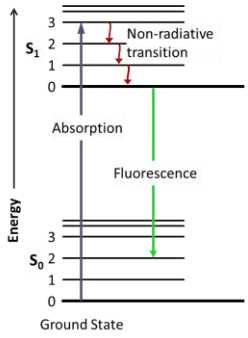
- Every object emits electromagnetic radiation, at a rate proportional to its ability to absorb the same frequency
- Emissions are in continuous broad spectrum (think rainbow), dependent on temperature (Plancks Curve)
- EMR is non-polarized
- Wien's Law: Max emissions are at a wavelength of .0029m/temp(Kelvin)
- Your body at 98.6˚F (310K) has maximum EMR emissions at 9.355µm – 32 terra Hz, in the middle of the infrared spectrum.



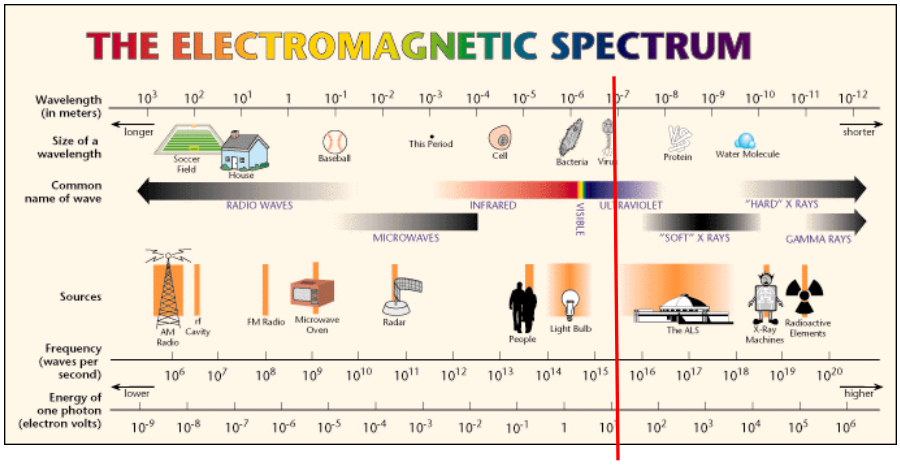
Sources of EMR

Electron energy state drop (fluorescence)

- Energy added (by radiation or electricity)
- Excites electrons to higher energy level
- Some energy lost
- Electrons drop back emitting precise frequency
- Emissions produce a "bright line" spectrum, dependent on the outer electron orbits of the elements present.
- EMR is non-polarized



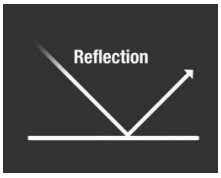
Electromagnetic Wave Spectrum



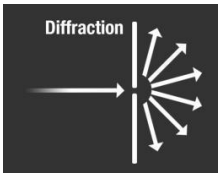
Non-ionizing | 124 nm / 2.4 peta Hz (by US FCC definition) | **Ionizing**

Properties of EMR

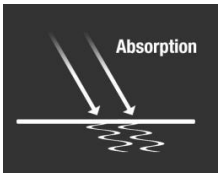
Reflection



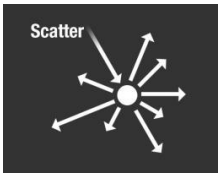
Diffraction



Absorption



Scattering



Refraction

Frequency Influences Properties

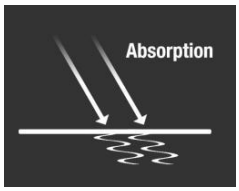
In general…

- **Higher frequency:**
  - Higher energy,
  - Lower penetration (easier to block)
- **Lower frequency:**
  - More penetrating,
  - Propagates further
- **Frequency resonance:** Wavelength/size of body.
- **Absorptivity/Emissivity:** Different materials absorb differentially

General Classes of Human Exposure

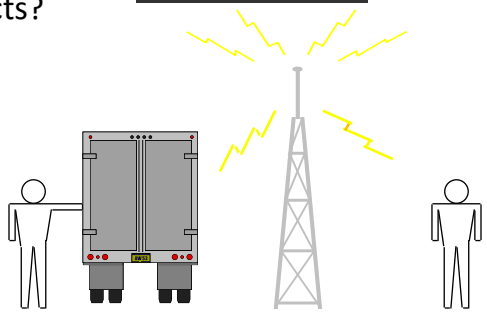
Energy absorption

- Heating
- Burns
- Photochemical or thermochemical effects?



Induced current

- Electrical shock
- RF burns
- Impressed current on a body



General Protections

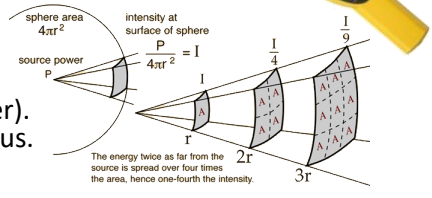
Awareness/Detection

- Know the sources
- Measure the presence

Distance/Time

- Unfocussed EMR, power decreases by distance^2

  Be aware of focused sources (e.g., microwave antenna/laser). Stay out of the beam or unfocus.
- Minimize exposure time
  Total energy = Intensity x time



Blocking/Absorbing

- Shield the source (Intrinsically Safe Equipment)
- Shield the exposure (PPE)

Classes of Non-Ionizing Radiation

	Wavelength (m)	Frequency (Hz)
Ultraviolet (UV)	0.000 000 1	1 quadrillion (1 petahertz)
Visible Light	0.000 001	100 trillion (100 terahertz)
Infrared (IR)	0.000 01	1-10 trillion (1-10 terahertz)
Cellular Radiofrequency (UHF)	0.01	1-10 billion (1-10 GHz)
Microwave (MW)	1	300 million (300 MHz)
High Radiofrequency (FM/VHF)	.1	100 million (100 Mhz)
Low Radiofrequency (AM)	300	1 million (1000 kHz)
Extremely Low Frequency (ELF)	5,000,000	60 (60 Hz)

Measurements in order of magnitude, not precise.

UV Radiation

10 nm – 400 nm / 780 TeraHz – 30 PetaHz

Sources

- Sunlight
- Intentional UV sources (UV bulbs, UV curing, tanning beds, etc.)
- "Leaking" from gas discharge bulbs
- Extremely high temperature operations (e.g., Arc or MIG welding)

Hazards/Risks

- High energy-near ionizing. Not very penetrating.
- Primary effects are on eyes and skin.
  - Short term: Sunburn, corneal inflamation
  - Long term: Cataracts, premature skin aging, skin cancer
- The only "non-ionizing" radiation known to cause cancer

UV Radiation

Protections

- Awareness
  - Know the sources
  - Signage/access control/training
- Shielding
  - Maintain equipment
  - Use in controlled areas
  - Restrict access.
- Blocking
  - UV blocking clothing
  - UV filtering glasses and face shields
  - UV creams / “sunscreen”
  - Know the ratings – frequency and attenuation factors

Visible Light

380 nm – 780 nm / 430-770 TeraHz

Sources

- Sun
- Lighting
- Lasers
- Hot work
- Magnification

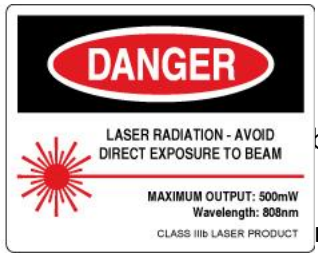
Hazards/Risks

- Vision (retinal damage)
- Burns/Fire

Visible Light

Laser Safety Classification

Four numbered classes:



beam)

1M n

"Don't be stupid"
Examples: Class 2 and some Class 1
"CAUTION"
Black & white / yellow & white

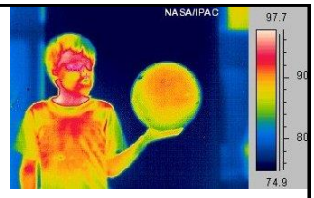
"Significant Hazard"
Examples: Class 3 and 4
"DANGER"
Red laser starburst

Visible Light

Laser Safety Precautions

- Appropriate use:
  - Trained users
  - Use in controlled areas
  - Restrict access
- Shielding:
  - Contain the beam
  - Maintain equipment
  - Diffuse/defocus the beam
- Blocking
  - Safety Glasses: Know the frequency & attenuation factors

Infrared Light



780 nm – 1 mm / 300 GigaHz 430 TeraHz

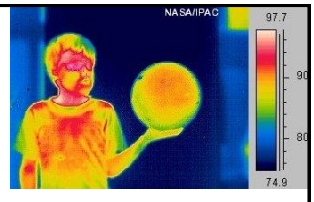
Sources

- Bodies at or near room temperature
- Heat guns
- Fiberoptic communications

Hazards/Risks

- Heat
- Vision (retinal damage)
- Burns/Fire
- (It's Invisible!)

Infrared Light

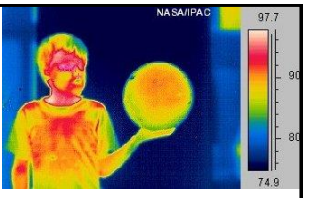


Laser Safety Classification

Class 3B:

1. Relatively low power, but "hazardous to eyes" because you can't see it. Eliminates the blink reflex.
2. Typical in fiberoptic data
3. Can be made intrinsically safe by equipment design (Class 1M)
   - Auto-closing connections
   - "lens" at connections

Infrared Light



Laser Safety Precautions

- Appropriate use:
- Awareness:
  - Know the sources
  - Measure the presence (instruments or phosphor cards)
  - Signage/access control/training
- Shielding:
  - Contain the beam
  - Maintain equipment: Don't defeat Class 1M protections
  - Diffuse/defocus the beam
- Blocking
  - Safety Glasses: Know the frequency & attenuation factors

HF Radio Waves (VHF/UHF)

1 mm – 10 m / 30 MHz - 300 GigaHz

Sources

- Wireless telecommunication
- FM Radio
- Public Safety

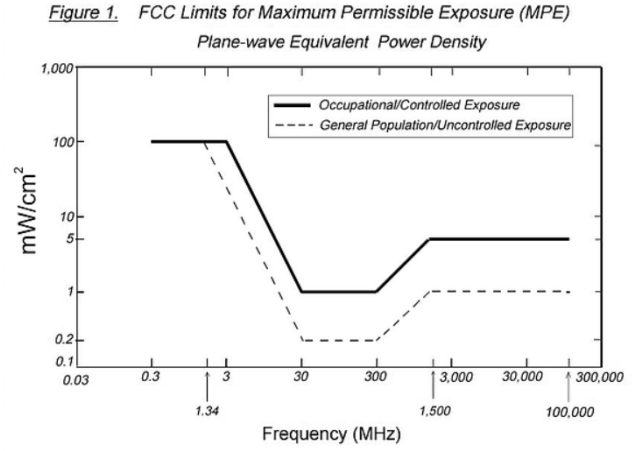
Hazards/Risks

- Tissue warming
  - Acute exposures
  - Whole body symptoms similar to mild fever
  - Increased impact on eyes
- Medical device interference
- RF Burns
- Cancer?
  - Some studies suggest weak correlation, others none.
  - IARC recently classified as possible (Group 2B).
- Increased neural activity—Not linked to injury but possible mechanism

HF Radio Waves (VHF/UHF)

FCC Exposure Limits

Based on tissue heating



FCC Guidelines adopted by OSHA for general industry exposures

HF Radio Waves (VHF/UHF)

Protections

- Awareness
  - Warning signs
  - Training

- System maintenance/RF "leakage"
- Never touch a powered RF emitter!
- Distance (and direction for directional antennae)
- RF monitors (appropriate to frequency, isotropic)
- RF blocking suits

Microwaves

1 mm – 10 m / 30 MHz - 300 GigaHz

Sources

- Microwave communications (Usually directionally focused Defined beam)
- RF Welding
- Microwave cooking

Hazards/Risks

- Tissue warming
- Medical device interference
- RF Burns

Microwaves

Protections

- Equipment shielding
- For broadcast, similar to RF. But…

… Avoid the beam!

LF Radio Waves

60 m – 500 m / 500 KHz - 5 MHz

Sources

- AM Radio

Hazards/Risks

- Induced current on large conductive structures
- RF burns
- Reduced energy absorption
- Health impacts largely unknown

Protections

- Distance
- "Detuning"

Extremely Low Frequency

5000 - 6000 km / 50-60 Hz

Sources

- AC Power

Hazards/Risks

- Induced current: High power, but takes a very large conductor to be a good receiving antenna
- Known to induce current in living bodies: No known adverse health effects
- Health impacts of moderate power direct exposure largely unknown: Many anecdotal
- High power exposure can cause tingling, fantom light flickers in the eyes.
- Extremely high power can cause tissue burns and cardiovascular damage, similar to electrical shock.

Resources for Further Information

OSHA - Non-Ionizing Radiation
https://www.osha.gov/SLTC/radiation_nonionizing/index.html

FCC – Radio Frequency Safety
https://www.fcc.gov/general/radio-frequency-safety-0

FDA – Radiation Emitting Products
https://www.fda.gov/Radiation-EmittingProducts/default.htm

CDC – Radiation and Your Health – Non-Ionizing Radiation & EMF
https://www.cdc.gov/nceh/radiation/nonionizing_radiation.html
https://www.cdc.gov/niosh/topics/emf/default.html

National Cancer Institute – Electromagnetic Fields and Cancer
https://www.cancer.gov/about-cancer/causes-prevention/risk/radiation/electromagnetic-fields-fact-sheet

International Commission on Non-Ionizing Radiation Protection
https://www.icnirp.org/

The Netherlands Organisation for Scientific Research (NWO)
https://www.nwo-i.nl/en/personnel/working-conditions/radiation/non-ionising-radiation/what-are-the-risks-of-non-ionising-radiation/
Very good layman's discussion of risks

World Health Organization
http://www.who.int/topics/radiation_non_ionizing/en/

ICNIRP (International Commission on Non-ionizing Radiation Protection)
https://www.icnirp.org/en/home/index.html
Highly technical evaluative group – tends to be conservative against presumed hazards

AIHA
https://www.aiha.org/get-involved/VolunteerGroups/LabHSCommittee/Pages/Technical-Topics---Non-Ionizing-Radiation.aspx