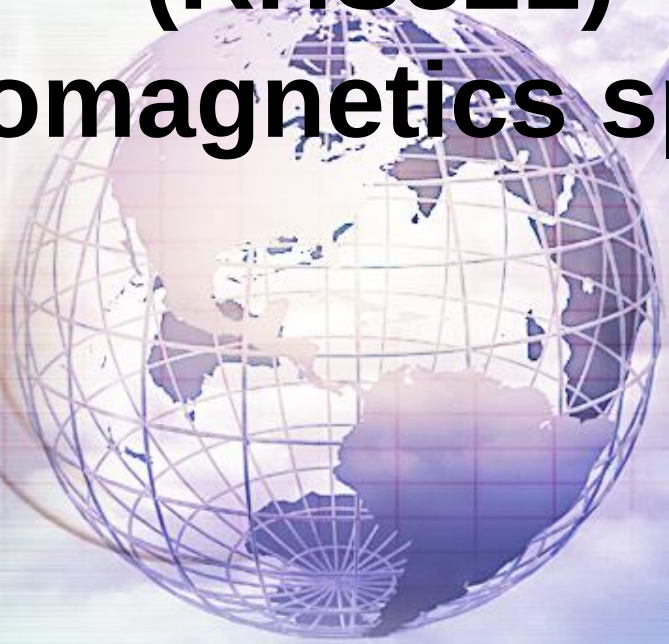
LOGO

Physical therapy procedures -1- (RHS321)
Electromagnetics spectrum



Mohammed T.A. Omar, PhD, PT

RHSD-CAMS-KSU

Objectives

1. Define the electromagnetic spectrum (EM) and explain its physical properties

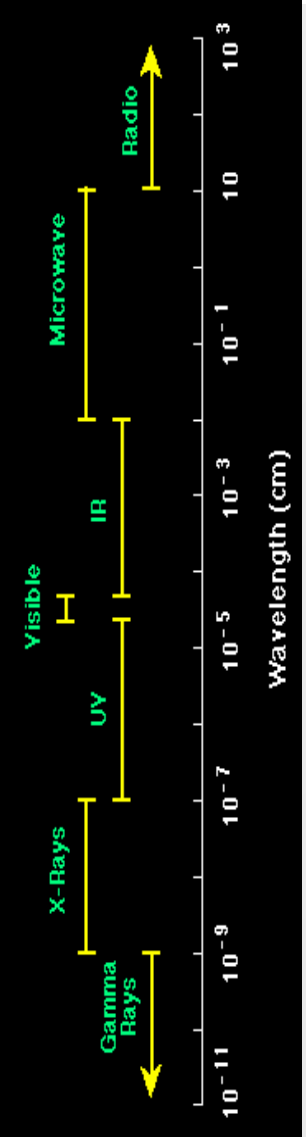
2. Define waveform and frequency and understand the relation between them.

3. Explain how the laws governing EM energy apply to different therapeutic modalities

Contents

- Define electromagnetic spectrum, wavelength and frequency
- Laws and principles related to electromagnetic radiations
  - Reflection, Refraction and Absorption
  - Inverse Square law
  - Law of Grotthus-Draper
  - Cosine Law
  - Arndt-Shultz Principle

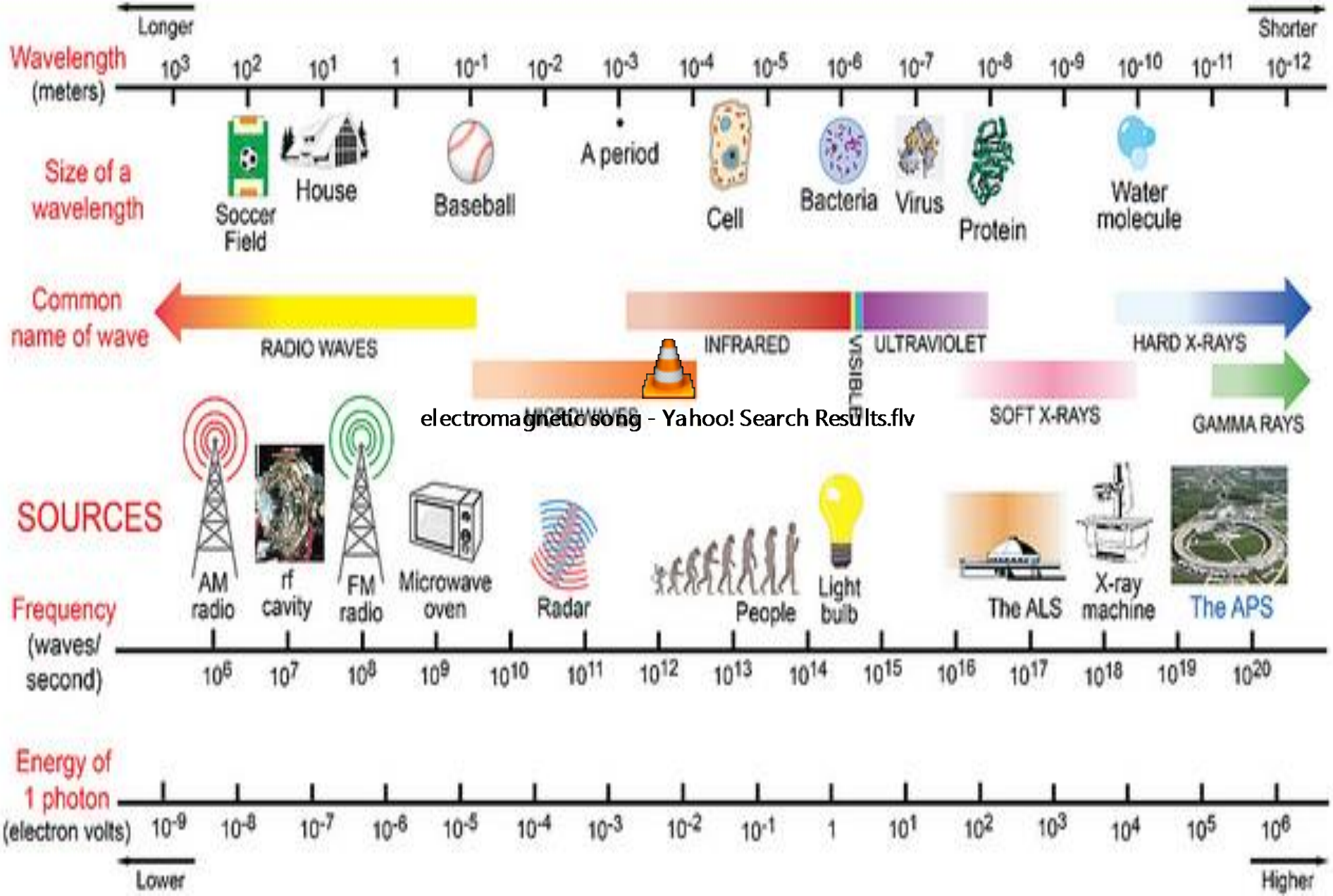
Electromagnetic spectrum?



The electromagnetic spectrum is a line contains different kinds of electromagnetic waves (radiations) , which are differentiated by their **wavelengths , frequency and energy.**

Radiation is a process by which electromagnetic energy travels from its source outward through space.

THE ELECTROMAGNETIC SPECTRUM

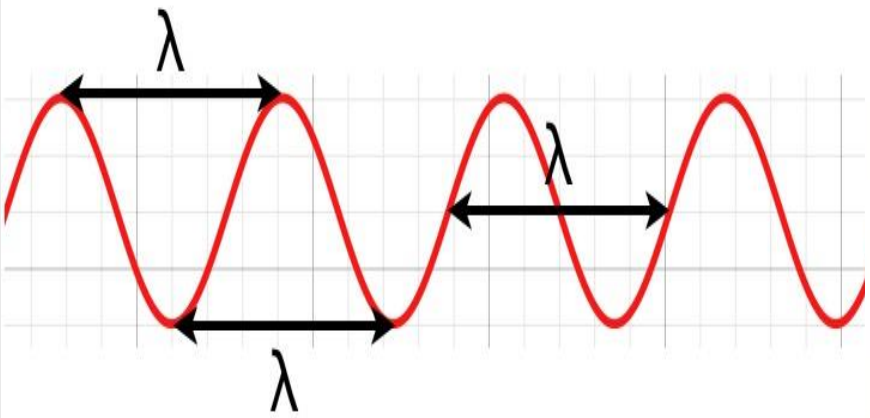


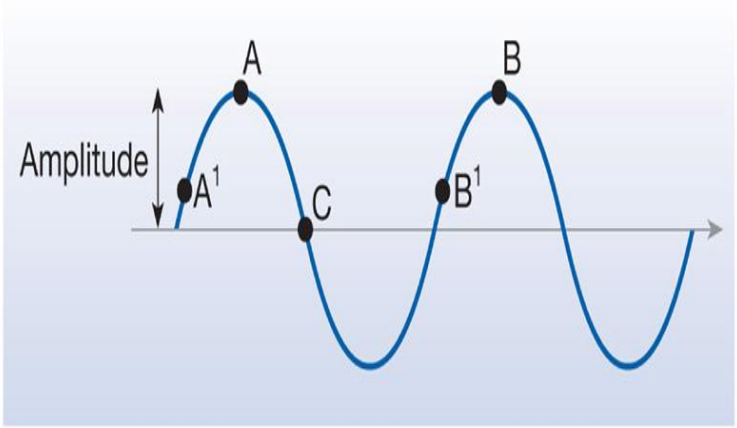
Electromagnetic spectrum

- Operate at specific wavelengths , frequencies & energy
- All are called electromagnetic waves.
- All are moving through space (vacuum)
- All travel as sinusoidal waves in straight line .
- All travel at the same speed in space (3×10^8 m/s).
- All can be reflected, refracted, absorbed &transmitted

Wavelength

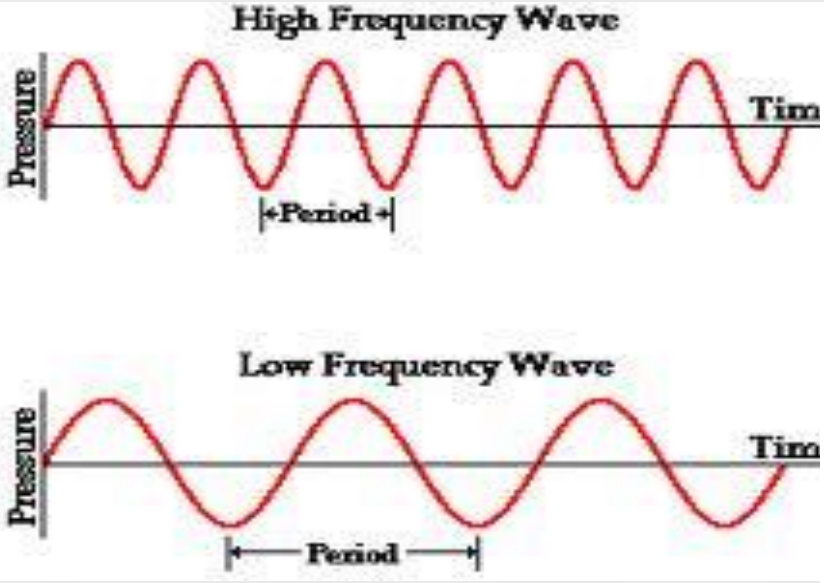
Wavelength (λ) is the distance between two identical points in a wave. It is typically measured between two identifiable points (e.g. two adjacent crests or troughs), wavelength is measured in meters, centimeters, millimeters or nanometer.

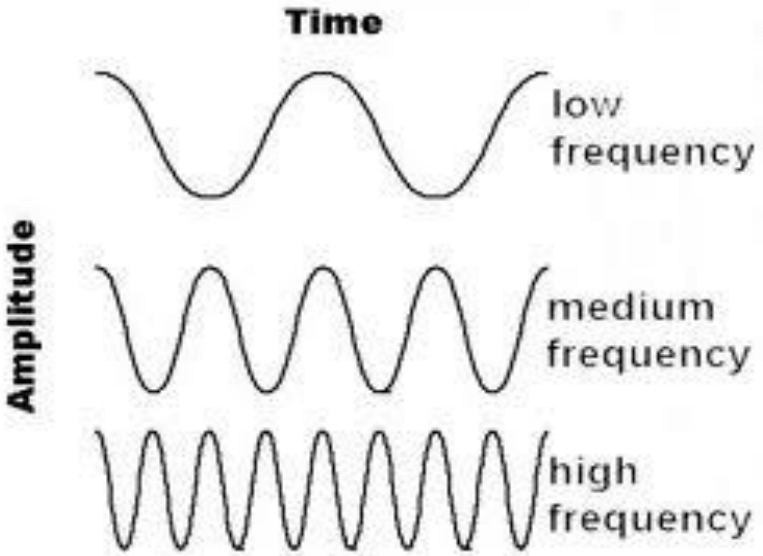




Frequency

Frequency (F) is the number of waves that pass a fixed point in a given amount of time. (cycle /second). It is expressed in Hertz (Hz). One Hertz is one cycle per second





Velocity

Velocity (v) is the rate of changes distance in a particular direction. It is the constant for all forms of electromagnetic waves, being $3x10^8$ m/sec {i.e. the speed of light}.

As the velocity is constant for all electromagnetic waves if there is no distribnace

Wavelength = Speed of light / Frequency

$$\lambda = V/f$$

Relation between wavelength and frequency

Longest Wavelength

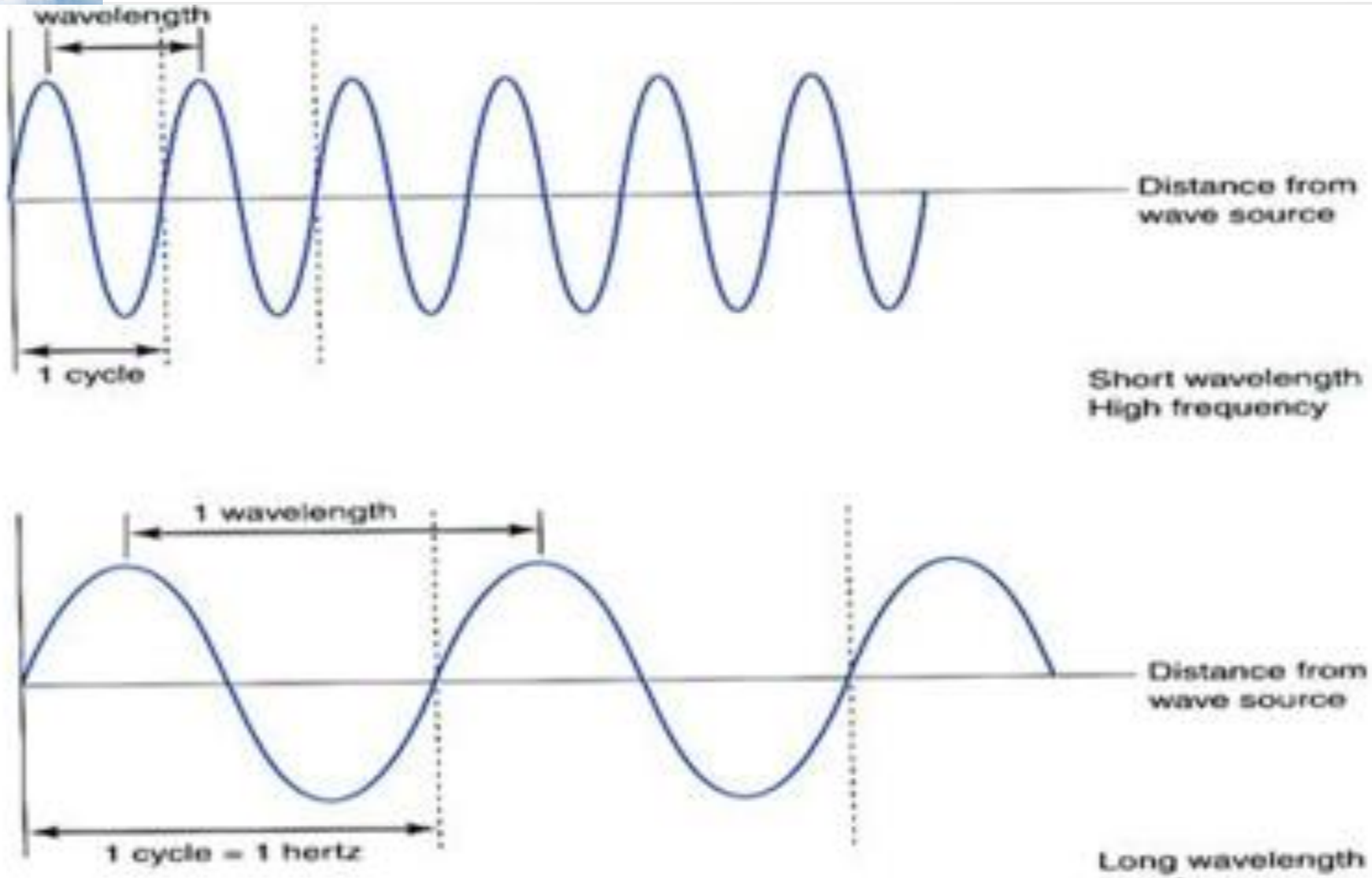
Shortest Wavelength

Region	Wavelength (centimeters)	Frequency (Hz)	Energy (eV)
Radio	> 10	$< 3 \times 10^{9}$	$< 10^{-5}$
Microwave	10 - 0.01	3×10^{9} - 3×10^{12}	10^{-5} - 0.01
Infrared	0.01 - 7×10^{-5}	3×10^{12} - 4.3×10^{14}	0.01 - 2
Visible	7×10^{-5} - 4×10^{-5}	4.3×10^{14} - 7.5×10^{14}	2 - 3
Ultraviolet	4×10^{-5} - 10^{-7}	7.5×10^{14} - 3×10^{17}	3 - 10^{3}
X-Rays	10^{-7} - 10^{-9}	3×10^{17} - 3×10^{19}	10^{3} - 10^{5}
Gamma Rays	$< 10^{-9}$	$> 3 \times 10^{19}$	$> 10^{5}$

Lowest Frequency Energy

Highest Frequency Energy

Graphic Relation between wavelength and frequency

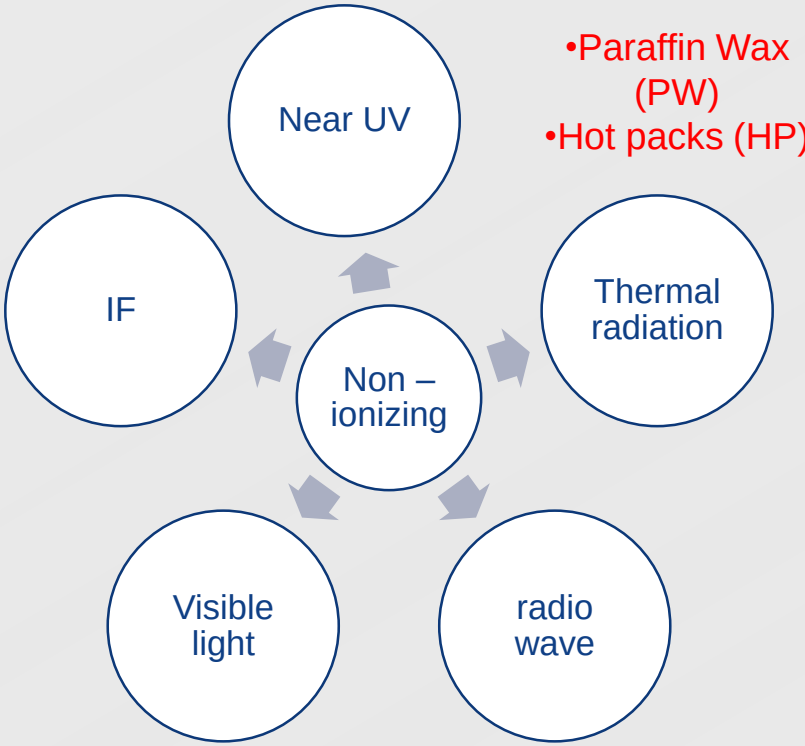


The relationship between wavelength and frequency.

Non-Ionizing Radiation

Non-Ionizing radiation includes all kinds of electromagnetic radiations with frequencies < 10^{15} Hz and wavelengths $\lambda=10^{-8}$-10^{4} m.

Non-ionizing radiation cannot break molecular bonds produce ions, and used for therapeutic medical applications

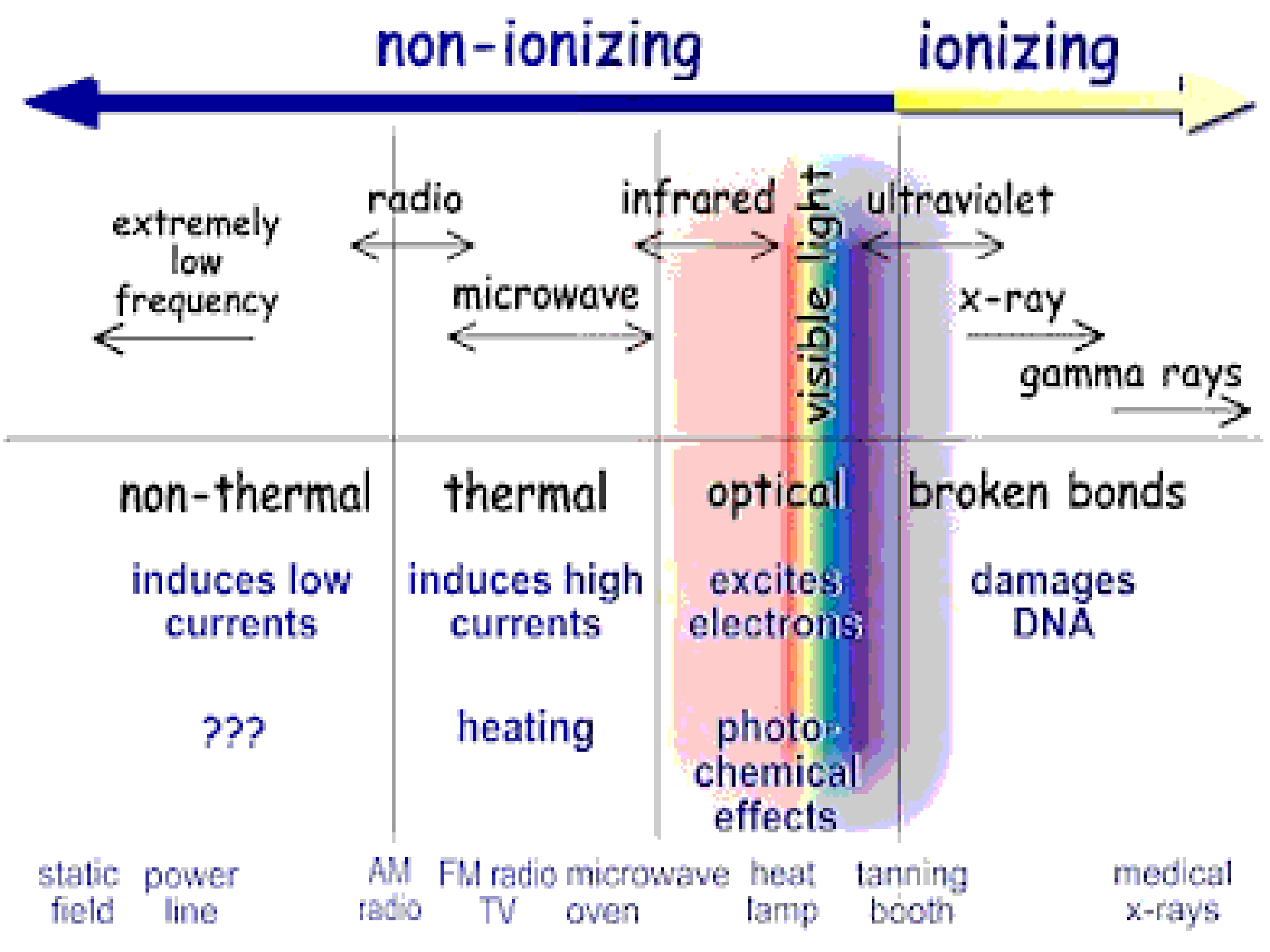


Ionizing Radiation

Ionizing Radiation is an electromagnetic radiation that has enough energy to break molecular bonds to form ions

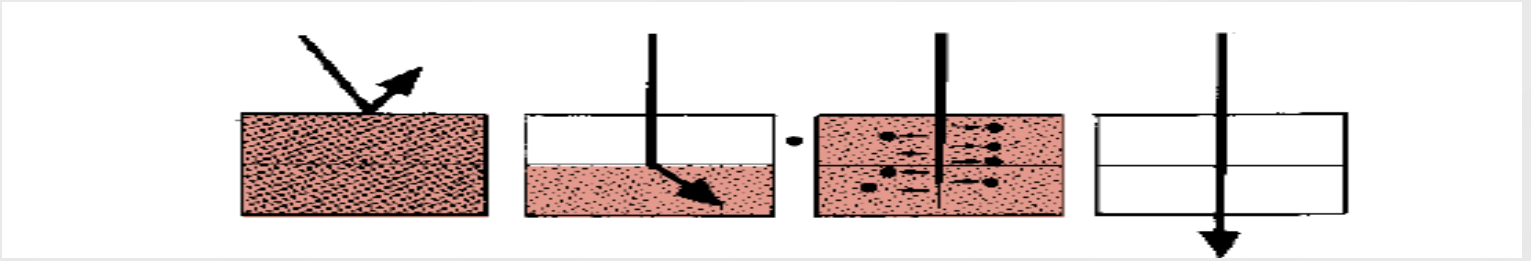
- X-ray
- Gamma ray

Ionizing radiation can inhibit cell division and is therefore used in very small doses for imaging, or in larger doses to destroy tissue Treatment of cancer

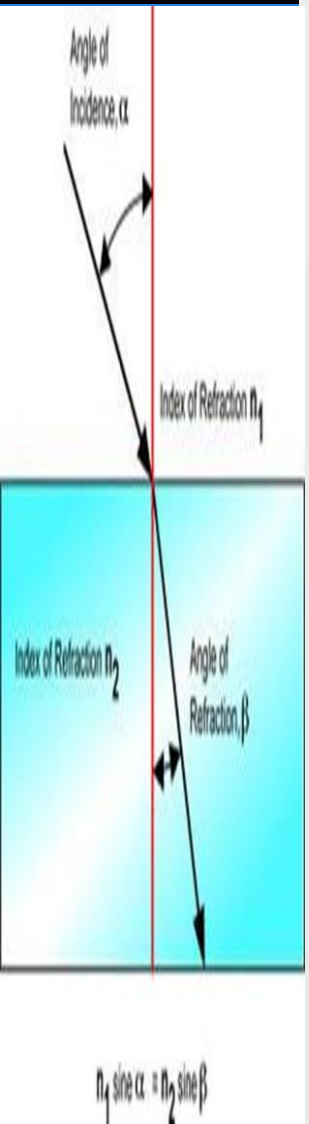

non-ionizing
ionizing
extremely low frequency
radio
microwave
infrared
visible light
ultraviolet
x-ray
gamma rays
non-thermal
thermal
optical
broken bonds
induces low currents
induces high currents
excites electrons
damages DNA
???
heating
photo-chemical effects
static field
power line
AM radio
FM radio TV
microwave oven
heat lamp
tanning booth
medical x-rays

Laws Governing Radiation

- Reflected
- Refracted
- Absorbed and penetrate



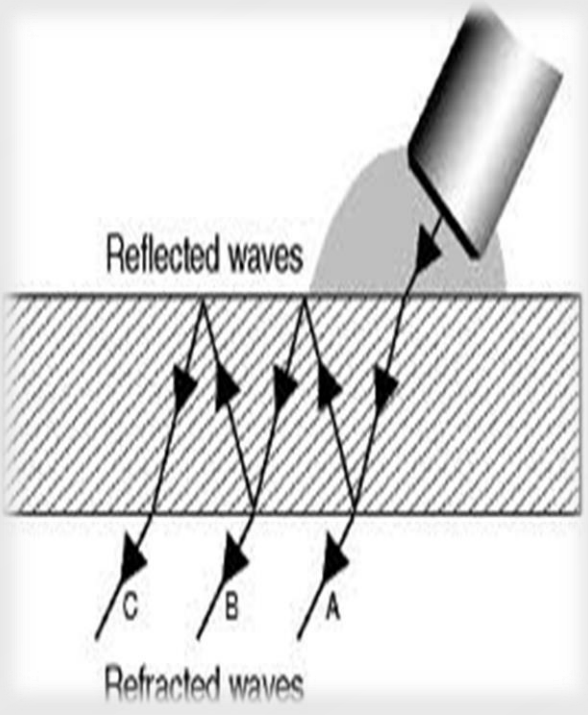
Refraction



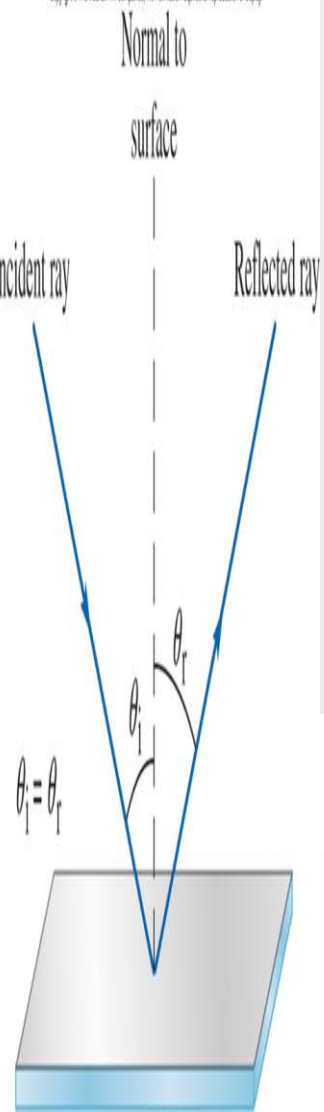
- Refraction occurs when electromagnetic rays are transmitted from one medium to another with different optical density and an angle of incidence greater than zero.

- Refraction causes the ray to be bending from its original course by an amount depending on;
  - Media involved
  - Angle of incidence (Snell' law).

Clinical application: using coupling media as in treatment of ultrasound (water coupling media).



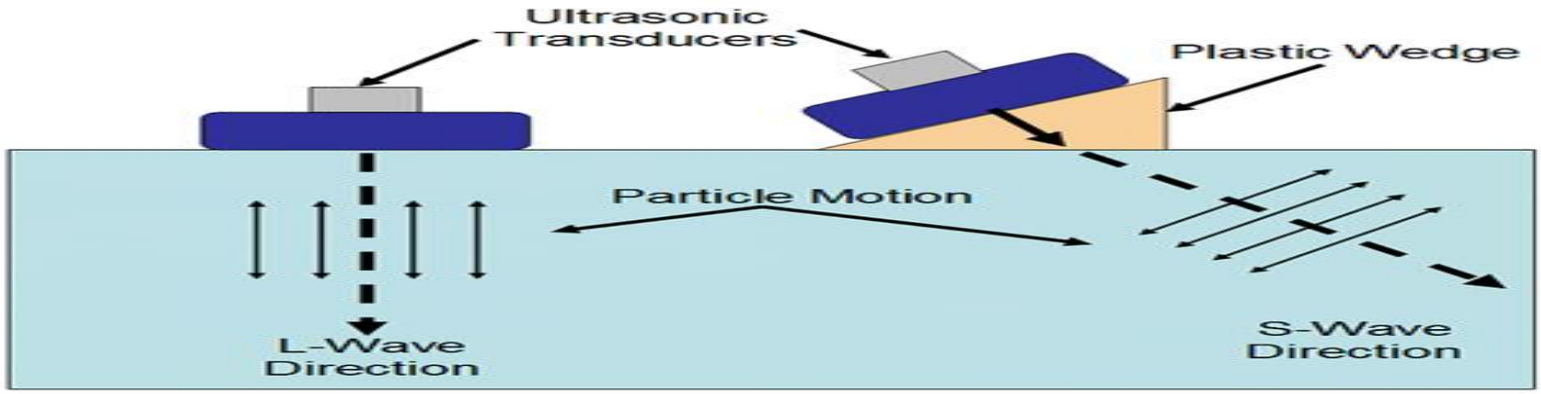
Reflection



- Reflection occurs when electromagnetic waves encounters a medium which will not transmit it. In this case, the ray is reflected back into the same plane .

Clinical applications

- 1-In infra-red and ultraviolet, where the re-direction of rays towards an appropriate target is required.
- 2-InUS therapy, {tissue air interface, How?}



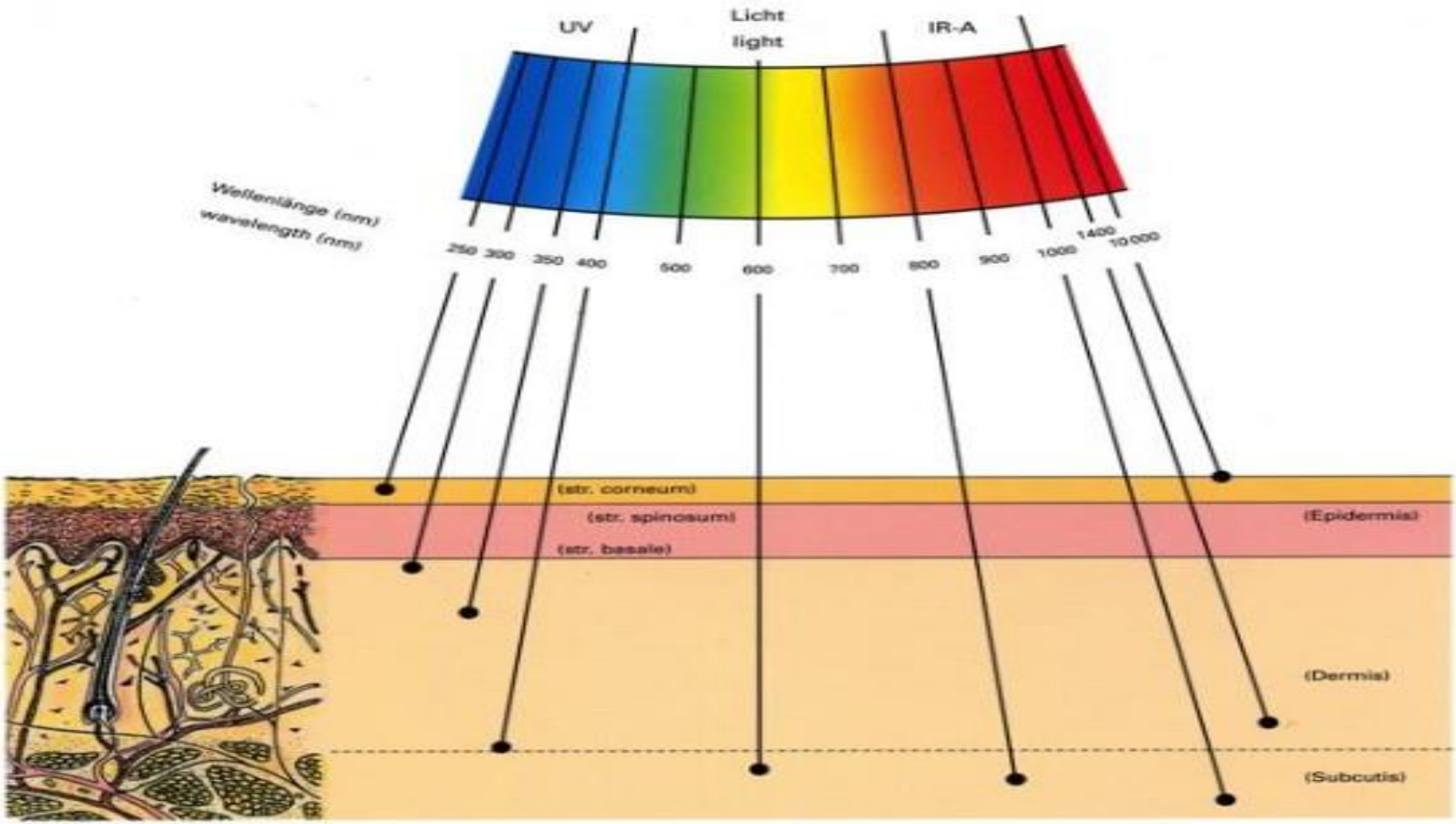
Absorption

When an electromagnetic wave strike a new medium they may be partially absorbed and produce an effect (**Heat**), and the amount of rays absorbed depends on:

1. Wavelength & Frequency
2. Angle of incidence
3. Nature of a medium
4. Intensity of radiation.

Shorter wavelengths will have higher energy and frequencies and low depth of penetration and greater absorption in superficial tissue.

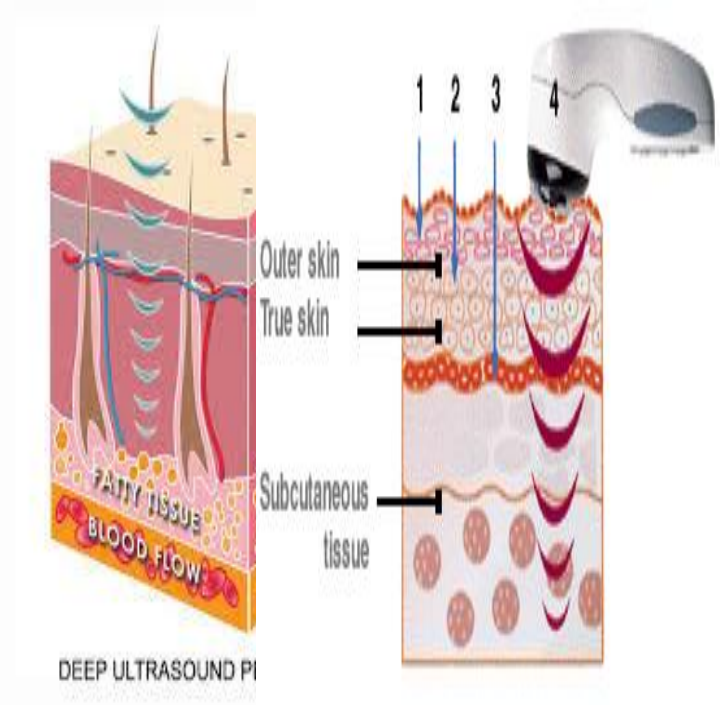
Absorption


UV
Licht
light
IR-A
Wellenlänge (nm)
wavelength (nm)
250 300 350 400 500 600 700 800 900 1000 1400 10.000
(str. corneum)
(str. spinosum)
(str. basale)
(Epidermis)
(Dermis)
(Subcutis)

Law of Grotthus Draper

- The law of Grotthus Draper describes the inverse relationship between the **penetration** and **absorption** of energy. If the energy is not absorbed by the superficial tissues it will penetrate to deeper tissues. So some physiological response will occur

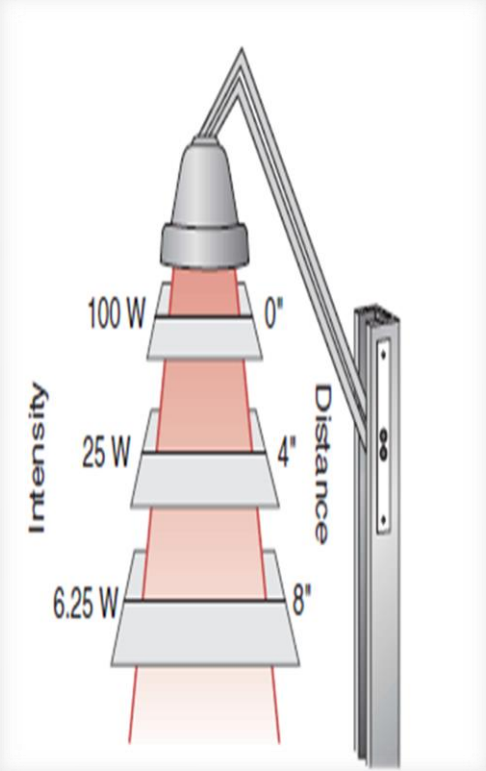
In clinical; using US at a frequency of 1MHz would be more effective than at 3MHz, because less energy would be absorbed superficially at 1MHz and thus more energy penetrate to deeper tissues.



Inverse Square Law

"Intensity of radiation is inversely proportional to the square of the distance" from the source.

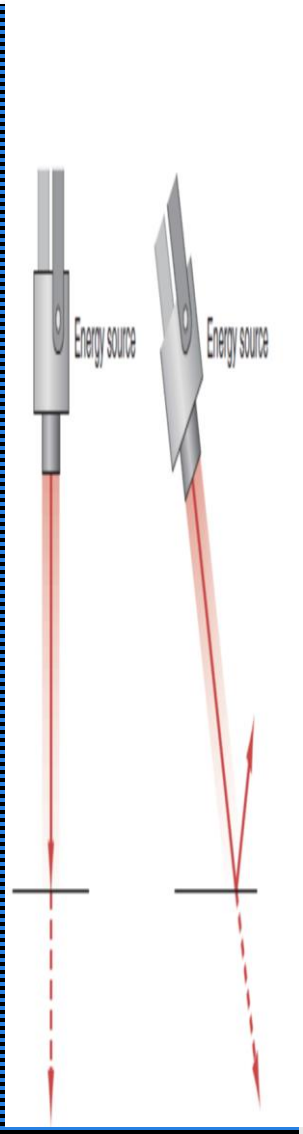
- Inverse Square Law $E=E_o/D^2$
  - E= energy received by the tissues
  - E_o= energy produced by the source
  - D^2= Distance Squared



Inverse square law can be employed in practice;

The closer the source of radiation , the greater the intensity of radiation being received by the skin, the further away, the less the intensity.

Cosine Law (right angle law)



- The optimum radiation occurs when the source of the radiation is perpendicular to the center of the surface of the area to be radiated. When the source is at an angle, some of it is reflected to the side rather than moving into the tissue.

In clinical; when applying UV, IR, US, great efforts should be made to ensure that the maximum number of radiated energy strike the treatment area at a right angle **(angle of incidence = 0degree).**

- For the most effective absorption of energy. Keep the US head flat on treated body surface **(Why?).**

Arndt-Schultz Principle

Too small

No significant reaction

Adequate

Enhance normal function

Amount of energy

To higher

disruption and loss of function

It states that “No reactions or changes can occur in the body tissues if the amount of energy absorbed is insufficient to stimulate the tissues

Conclusion

- Physical modalities, shortwave diathermy (SWD) and microwave diathermy (MWD), the infrared (IR) laser, and ultraviolet (UV) are all classified as portions of the electromagnetic spectrum according to corresponding wavelengths & frequencies associated with each region.

- All electromagnetic radiations travel at the same velocity; thus wavelength and frequency are inversely related. Those radiations with the longer wavelengths tend to have the greatest depth of penetration.

- Radiations may be reflected, refracted, absorbed, or transmitted in the various tissues.

- The purpose of using any therapeutic modality is to stimulate a specific tissue to perform its normal function.

REVIEW QUESTIONS

1. What is the electromagnetic spectrum and radiant energy?
2. What is the relationship between wavelength and frequency?
3. What are the characteristics of electromagnetic energy
4. According to the Law of Grotthus–Draper, what happens to electromagnetic energy when it comes in contact with and/or penetrates human biologic tissue?
5. Explain the cosine and inverse square laws relative to tissue penetration of electromagnetic energy.

Multiple Choice

1-Which of the following is NOT an electromagnetic energy modality?

a. Ultraviolet light
b. Ultrasound
c. Low-power laser
d. Shortwave diathermy

2. Sound or radiation waves that change direction when passing from one type of tissue to another are said to.

a. Transmit
b. Absorb
c. Reflect
d. Refract

3. The states that if superficial tissue does not absorb energy, it must be transmitted deeper.

a. Law of Grotthus–Draper
b. Cosine law
c. Inverse square law
d. Arndt–Schultz principle

4. According to the cosine law, to minimize reflection and maximize absorption, the energy source must be at a angle to the surface.

a. 45 degree
b. 90 degree
c. 180 degree
d. 0 degree

5.In each of the following pairs, circle the form of radiation with the LONGER WAVELENGTH:

a) Microwaves or radio waves
b) Infrared radiation or visible light
c) Gamma rays or UV radiation
d) x-ray and infrared

6. In each of the following pairs, circle the form of radiation with the GREATER FREQUENCY:

a) Gamma rays or UV radiation
b) X-rays and gamma rays
c) UV radiation or radio wave
d) UV radiation or visible light

7.In each of the following pairs, circle the form of radiation with the Higher ENERGY:

a) Gamma rays or UV radiation
b) X-rays and gamma rays
c) UV radiation or radio wave
d) UV radiation or visible light