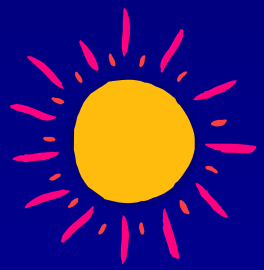
OBJECTIVES FOR TODAY'S CLASS:



To understand the key differences between

Solar radiation

&

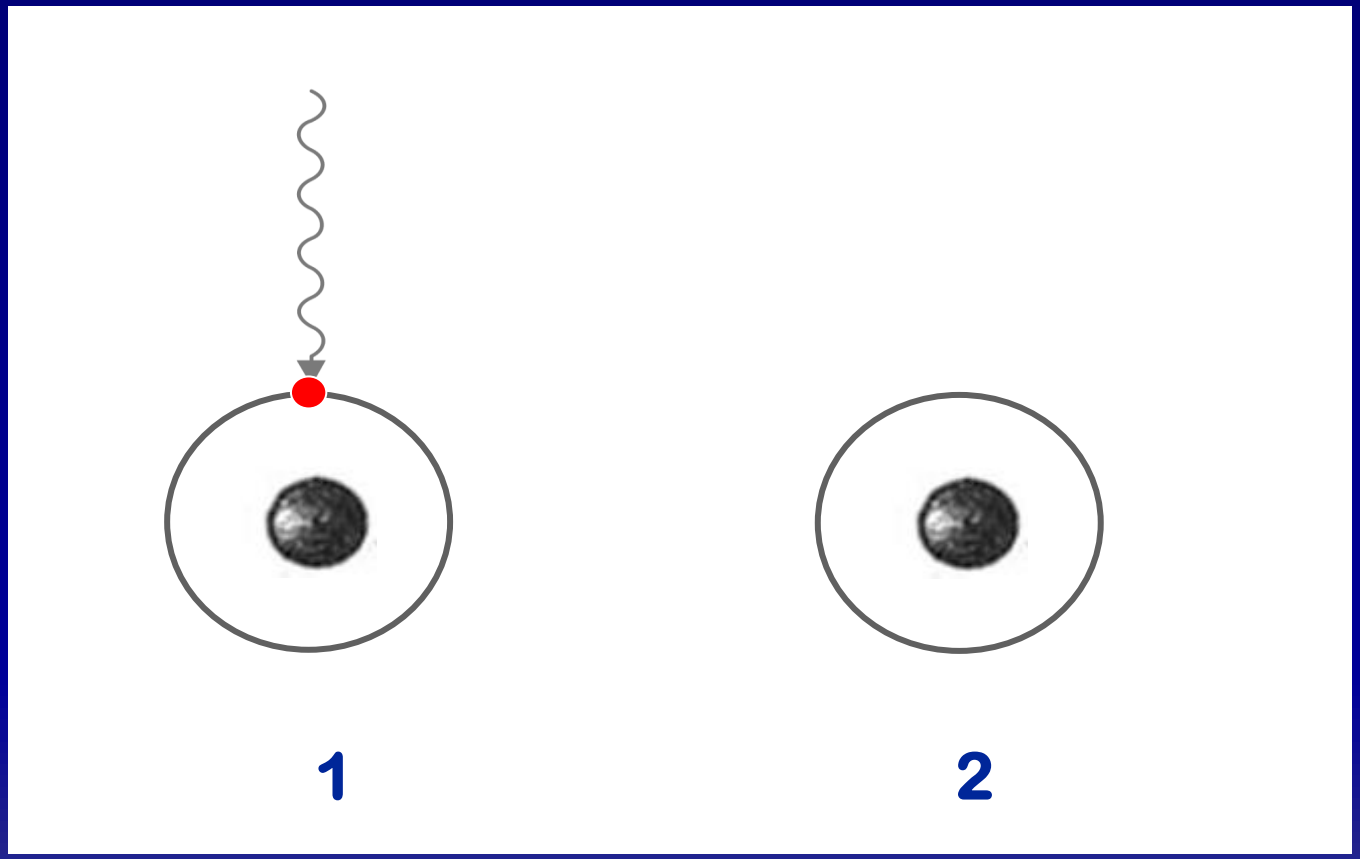
Terrestrial radiation

based on the principles of the **"Radiation Laws."**

WRAP UP OF TOPIC #4 . . .

ELECTROMANGETIC RADIATION & THE ELECTROMAGNETIC SPECTRUM

Sketch what happens next in the atom's quantum behavior!

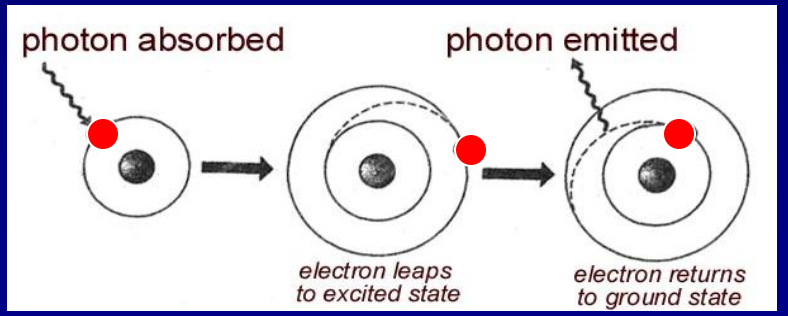


Class Notes Closed!

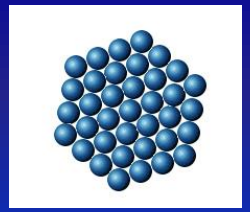
Answer on p 19

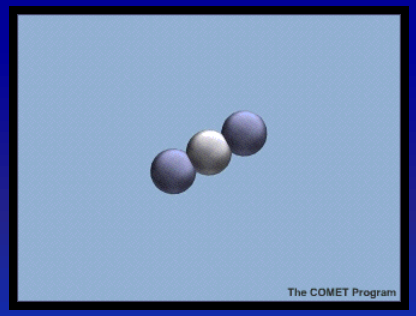
ATOMS vs MOLECULES

Quantum leap of electrons
WITHIN an ATOM
when photons are
absorbed or emitted →



Quantum **MOLECULAR MOTION**
behavior when photons are
absorbed or emitted





Review p 19-20

"Rotation" " Vibration" "Bending"

Come forth into the
light of things.

Let nature be your teacher.

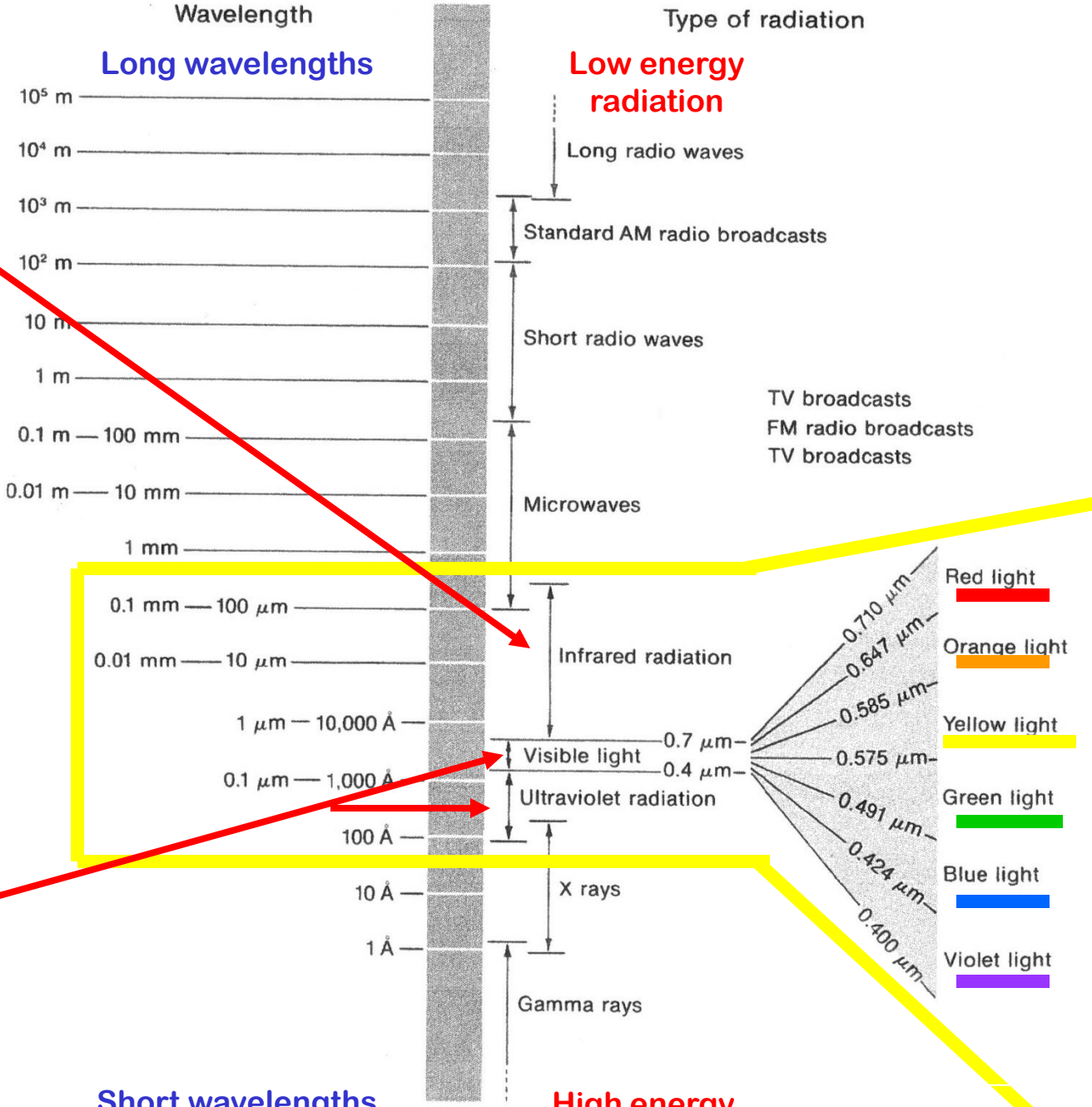
~ William Wordsworth

Longwaves (LW)

The Electro-magnetic Spectrum

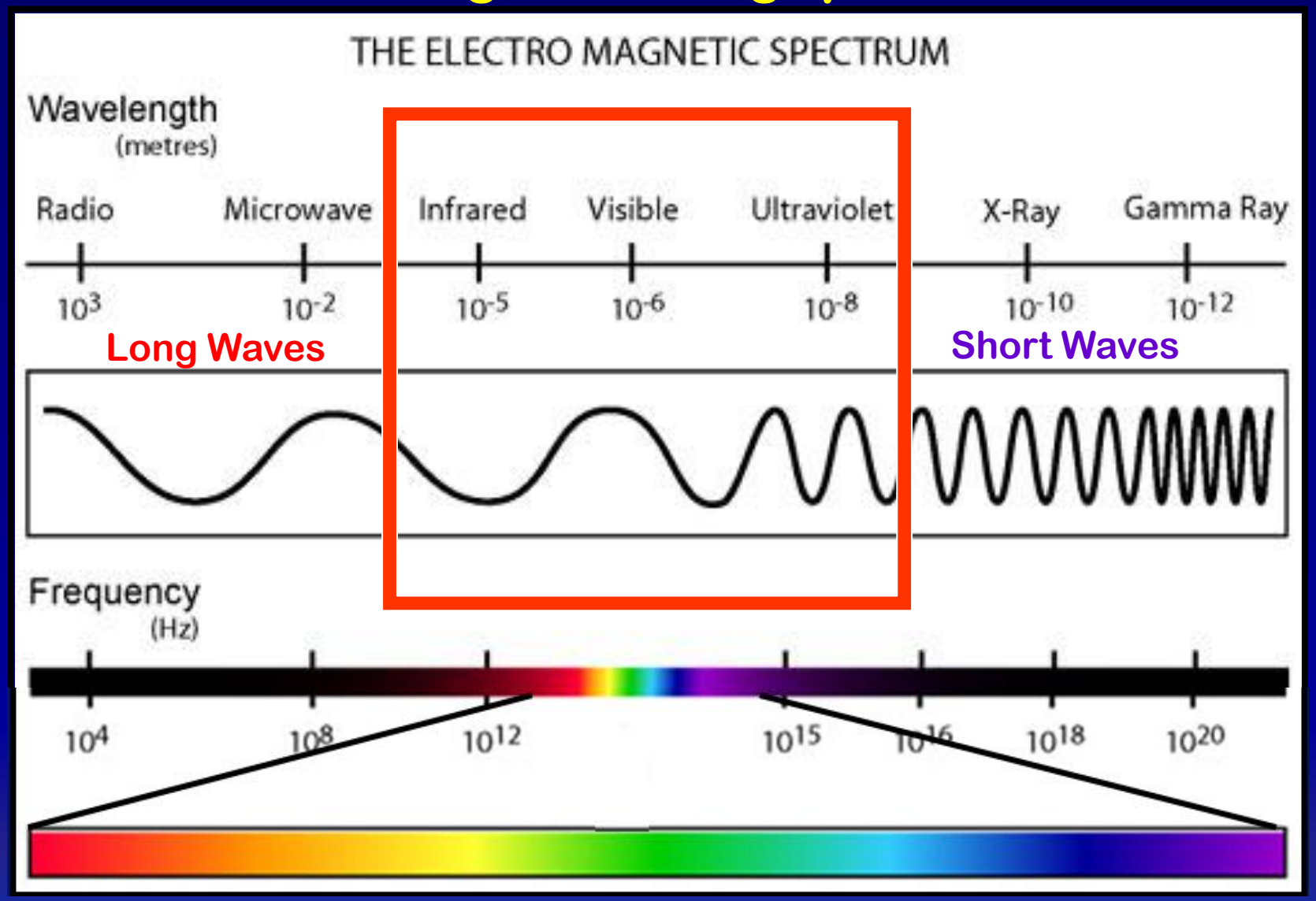
(another view)

Shortwaves (SW)



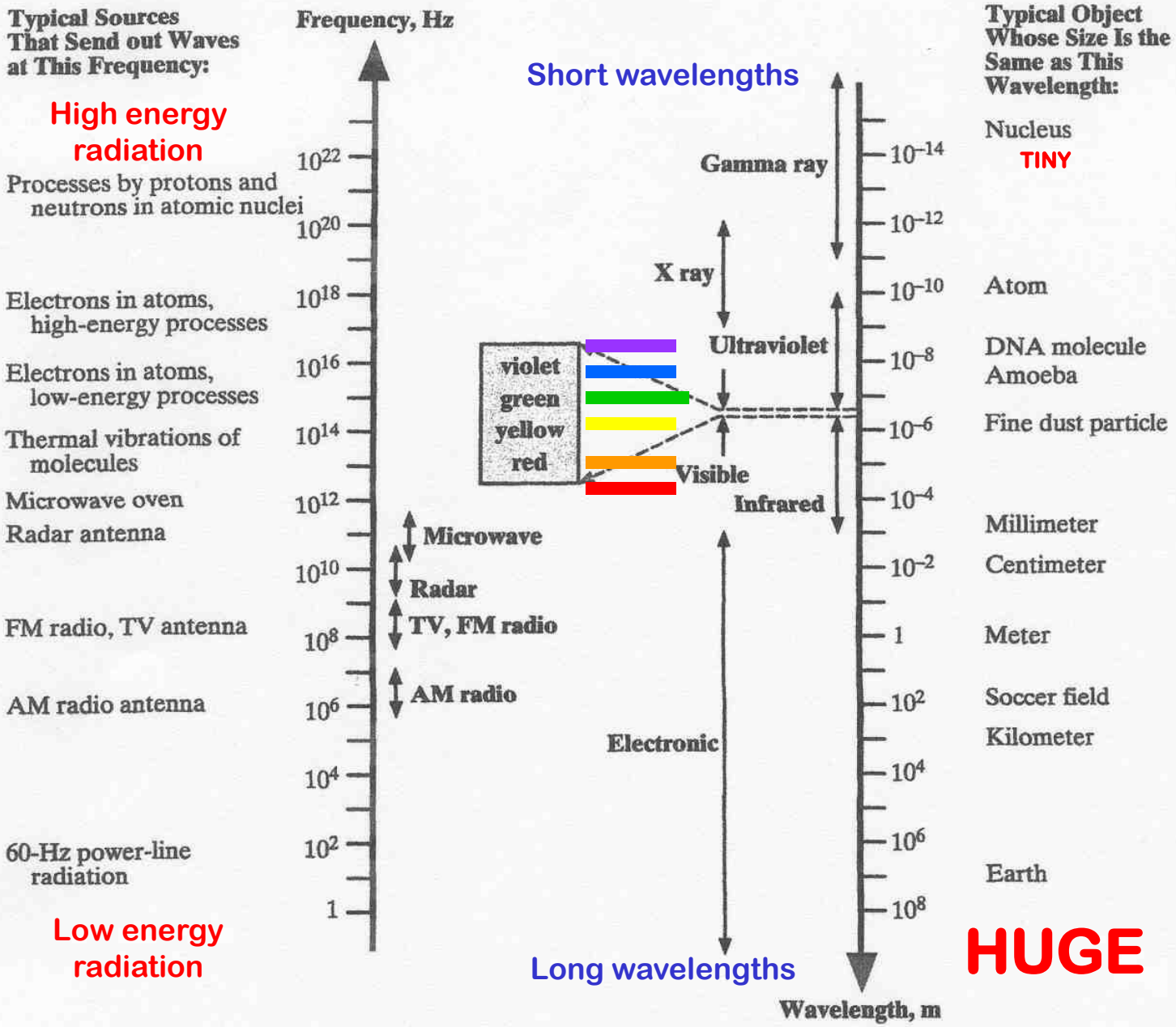
The electromagnetic spectrum.

These are the wavelength ranges most critical to global change processes!



R O Y G B (I) V

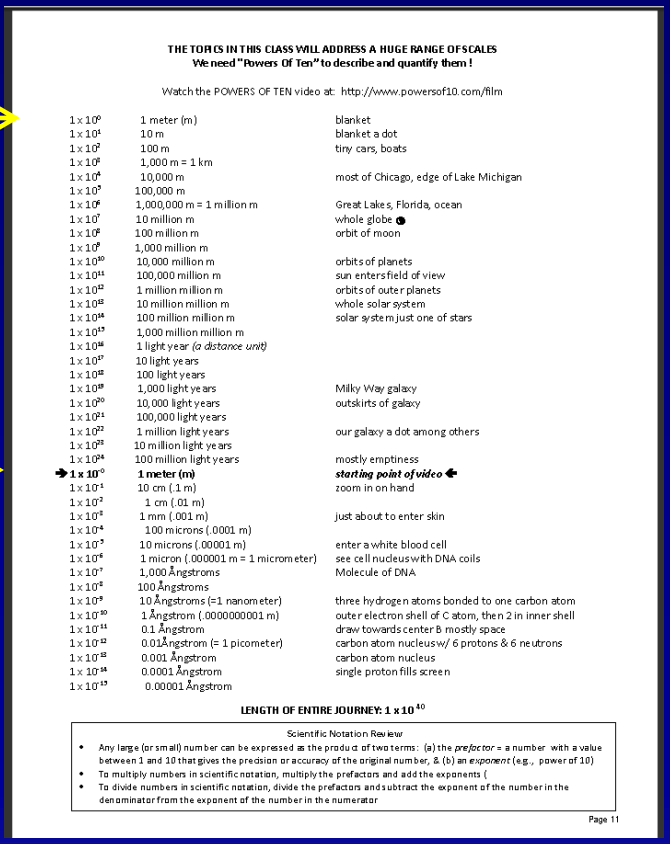
Another (flipped) view:



EQUATIONS, SCIENTIFIC NOTATION and the POWERS OF 10

1 meter →

1 meter →



THE TOPICS IN THIS CLASS WILL ADDRESS A HUGE RANGE OF SCALES
We need "Powers Of Ten" to describe and quantify them !

Watch the POWERS OF TEN video at: http://www.powersof10.com/film

1×10^{0}	1 meter (m)	blanket
1×10^{1}	10 m	blanket a dot
1×10^{2}	100 m	tiny cars, boats
1×10^{3}	1,000 m = 1 km	
1×10^{4}	10,000 m	most of Chicago, edge of Lake Michigan
1×10^{5}	100,000 m	
1×10^{6}	1,000,000 m = 1 million m	Great Lakes, Florida, ocean
1×10^{7}	10 million m	whole globe
1×10^{8}	100 million m	orbit of moon
1×10^{9}	1,000 million m	
1×10^{10}	10,000 million m	orbits of planets
1×10^{11}	100,000 million m	sun enters field of view
1×10^{12}	1 million million m	orbits of outer planets
1×10^{13}	10 million million m	whole solar system
1×10^{14}	100 million million m	solar system just one of stars
1×10^{15}	1,000 million million m	
1×10^{16}	1 light year *(a distance unit)*	
1×10^{17}	10 light years	
1×10^{18}	100 light years	
1×10^{19}	1,000 light years	Milky Way galaxy
1×10^{20}	10,000 light years	outskirts of galaxy
1×10^{21}	100,000 light years	
1×10^{22}	1 million light years	our galaxy a dot among others
1×10^{23}	10 million light years	
1×10^{24}	100 million light years	mostly emptiness
➔ 1×10^{0}	**1 meter (m)**	***starting point of video*** ←
1×10^{-1}	10 cm (.1 m)	zoom in on hand
1×10^{-2}	1 cm (.01 m)	
1×10^{-3}	1 mm (.001 m)	just about to enter skin
1×10^{-4}	100 microns (.0001 m)	
1×10^{-5}	10 microns (.00001 m)	enter a white blood cell
1×10^{-6}	1 micron (.000001 m = 1 micrometer)	see cell nucleus with DNA coils
1×10^{-7}	1,000 Ångstroms	Molecule of DNA
1×10^{-8}	100 Ångstroms	
1×10^{-9}	10 Ångstroms (=1 nanometer)	three hydrogen atoms bonded to one carbon atom
1×10^{-10}	1 Ångstrom (.0000000001 m)	outer electron shell of C atom, then 2 in inner shell
1×10^{-11}	0.1 Ångstrom	draw towards center B mostly space
1×10^{-12}	0.01Ångstrom (= 1 picometer)	carbon atom nucleus w/ 6 protons & 6 neutrons
1×10^{-13}	0.001 Ångstrom	carbon atom nucleus
1×10^{-14}	0.0001 Ångstrom	single proton fills screen
1×10^{-15}	0.00001 Ångstrom	

LENGTH OF ENTIRE JOURNEY: 1×10^{40}

Scientific Notation Review

- Any large (or small) number can be expressed as the product of two terms: (a) the *prefactor* = a number with a value between 1 and 10 that gives the precision or accuracy of the original number, & (b) an *exponent* (e.g., power of 10)
- To multiply numbers in scientific notation, multiply the prefactors and add the exponents (
- To divide numbers in scientific notation, divide the prefactors and subtract the exponent of the number in the denominator from the exponent of the number in the numerator

Page 11

p 11 in CLASS NOTES (Based on the classic "Powers of Ten" video

The Smallest to the Biggest thing in the Universe!

https://www.youtube.com/watch?v=EMLPJqeW78Q

SCIENTIFIC NOTATION REVIEW

Any number (#) can be expressed as product of 2 terms:

PREFACTOR = # between 1 and 10
(indicates the **precision** / **accuracy** of original #

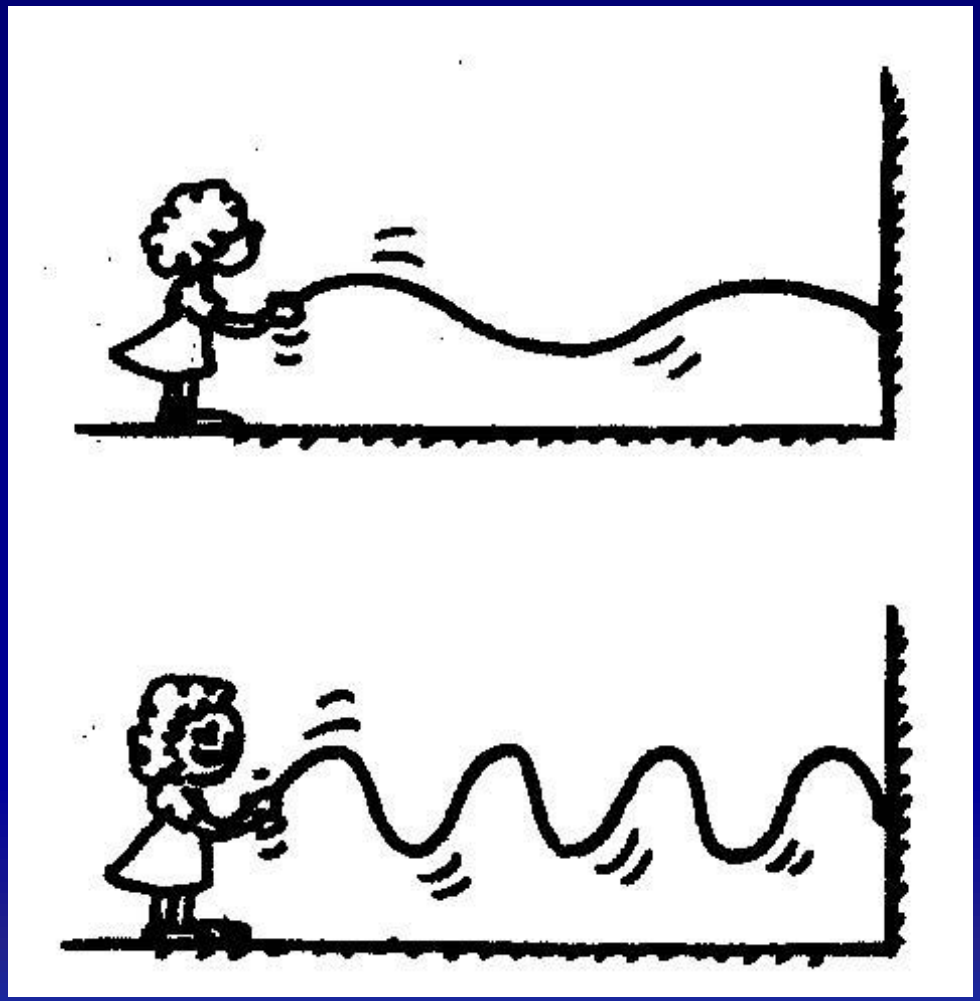
EXPONENT = a "power of 10" e.g., 1×10^{3} (= 1,000)
1×10^{-3} (= .001

To multiply: x the prefactors and + the exponents

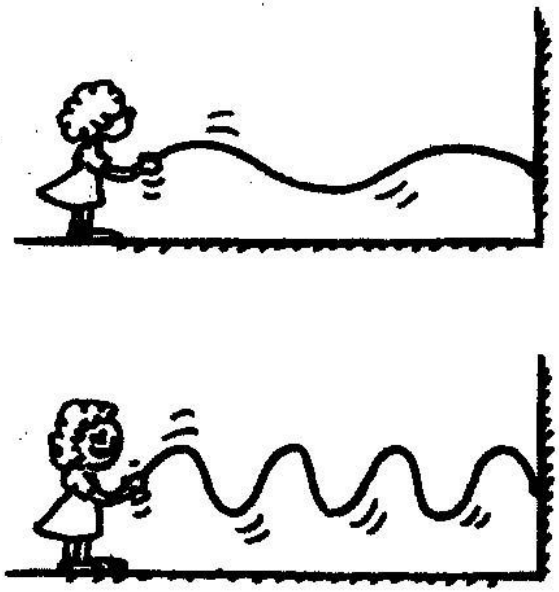
To divide: ÷ the prefactors and
subtract the exponent of # in the denominator
from exponent of # in the numerator

Practice Q's will be posted online in Class Follow Up

Wavelengths



Wavelength & Frequency



NOTE: Shorter wavelengths are produced when the rope is shaken more vigorously.

*"The **shorter** the wavelength*

*the **GREATER the energy***

&

*the **HIGHER the frequency**"*

Define these terms in your own words

Wavelength (symbol = **lambda** λ)

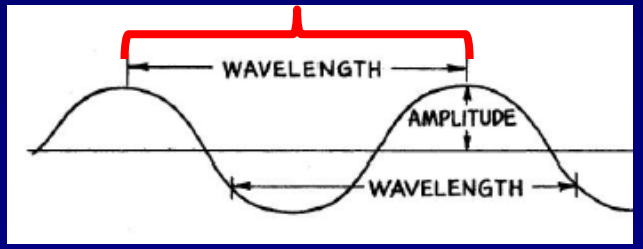
Frequency (symbol = **nu** ν in E-Text)

Speed (symbol = c the speed of light)

Quantifying Frequency & Wavelengths

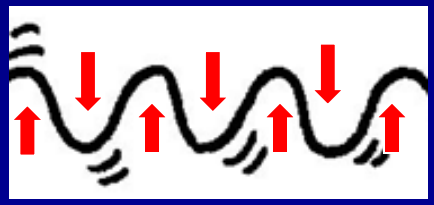
Terminology for describing the WAVE-like behavior of electromagnetic energy:

Wavelength = distance between adjacent crests (or troughs) (symbol = **lambda** λ)



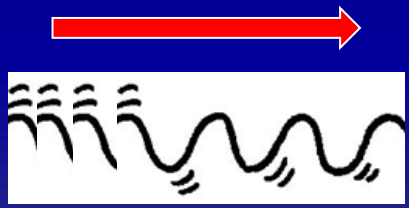
Frequency = how fast the crests move up and down

(symbol = **nu** ν in E-Text)



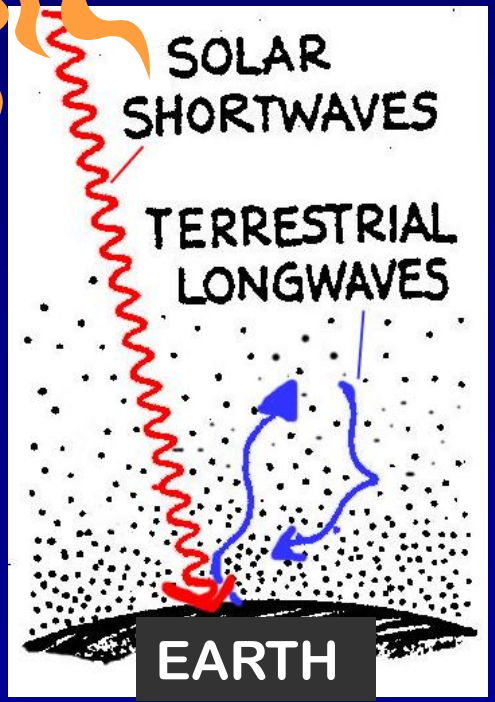
Speed = how fast the crests move forward (symbol = **c** in E-text)

c = the speed of light



SOLAR RADIATION: greatest intensity in **SHORT** wavelengths

(high energy & frequency)



EARTH RADIATION: entirely in **LONG** wavelengths

(low energy & frequency)

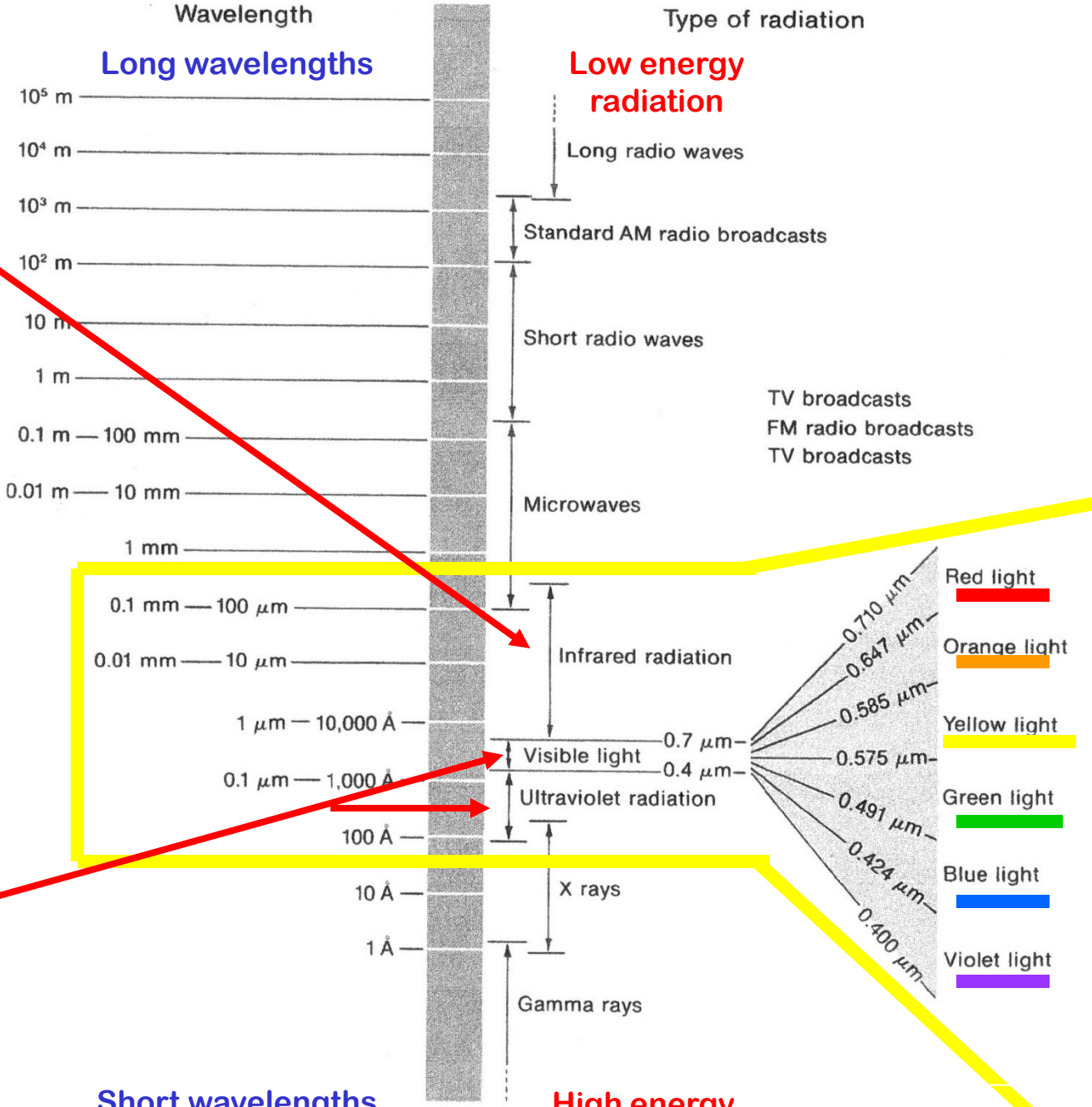
The wavelength determines how the electromagnetic ENERGY (photon) will interact with MATTER !

Longwaves (LW)

The Electro-magnetic Spectrum

(another view)

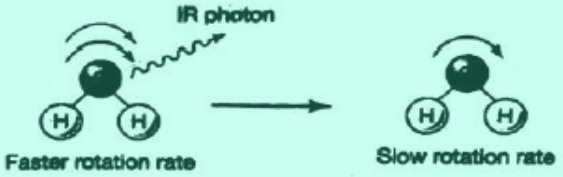
Shortwaves (SW)



The electromagnetic spectrum.

Details on the spectrum: UV Vis IR

Visible Light range = 0.4 – 0.7 micrometers

Type of Electromagnetic Radiation	Range of Wavelengths (in units indicated)	Additional Information
Gamma rays	10^{-16} to 10^{-11} in meters (m) using scientific notation	Involve high-energy processes within a nucleus caused by the strong force
UV Ultraviolet radiation UVC .20 - .29 UVB .29 - .32 UVA .32 - .40 Shortwave Solar	.0001 to 0.4 in micrometers (μm)	Involve electrons moving (quantum leaps) within atoms 
VIS Visible light	0.4 to 0.7 in micrometers (μm)	
IR Infrared radiation	0.7 to ~30 (up to 1000) in micrometers (μm)	Involve chaotic thermal kinetic motion of molecules due to their thermal energy 
IR Near Infrared radiation Longwave Infrared	0.7 - 1.0 in micrometers (μm)	
IR Far Infrared	1.0 - ~30 (up to 1000) in micrometers (μm)	
Microwaves	10^{-4} to 10^{-2} in meters (m) using scientific notation	occur in nature & also electronically produced by a "magnetron" in a microwave oven
AM Radio waves	10 to 10^{2} in meters (m) using scientific notation	occur in nature & also electronically produced in human-made electrical circuits

What is the relationship between . . .

ENERGY E and FREQUENCY ν

OF PHOTONS ?

KEY CONCEPT #1:

The **Energy E** of photons is **directly proportional to their frequency** ν

$\propto$ = "is proportional to"

$$E \propto \nu$$

From your RQ #2 chapter reading!

What is the relationship between . . .

ENERGY E and WAVELENGTH λ

OF PHOTONS ?

KEY CONCEPT #2:

The Energy E of photons is inversely proportional to their wavelength λ

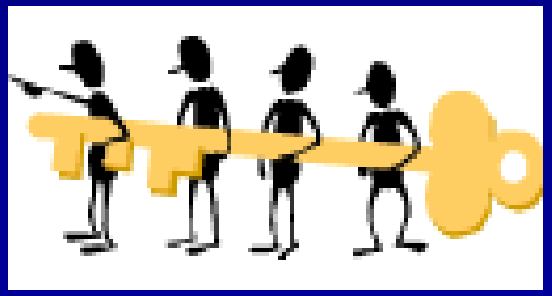
$$E \propto c / \lambda$$

c = speed of light = a constant

From your RQ #2 chapter reading!

TOPIC # 5 – Part 1
The RADIATION LAWS

The KEY to unlocking the topics of:
The GREENHOUSE EFFECT,
GLOBAL WARMING &
OZONE DEPLETION!



$E = \sigma T^4$

$(1/d^2)$

"The equations we seek are the poetry of nature . . . . Why is nature that way?

Why is it possible for these powerful manifestations of forces to be trapped in a very simple, beautiful formula?"

$E = h c / \lambda$

$\lambda_m = a/T$

"This has been a question which many people have discussed, but there is no answer."

~ Chen Ning Yang (b. 1922) US physicist

LAW #1

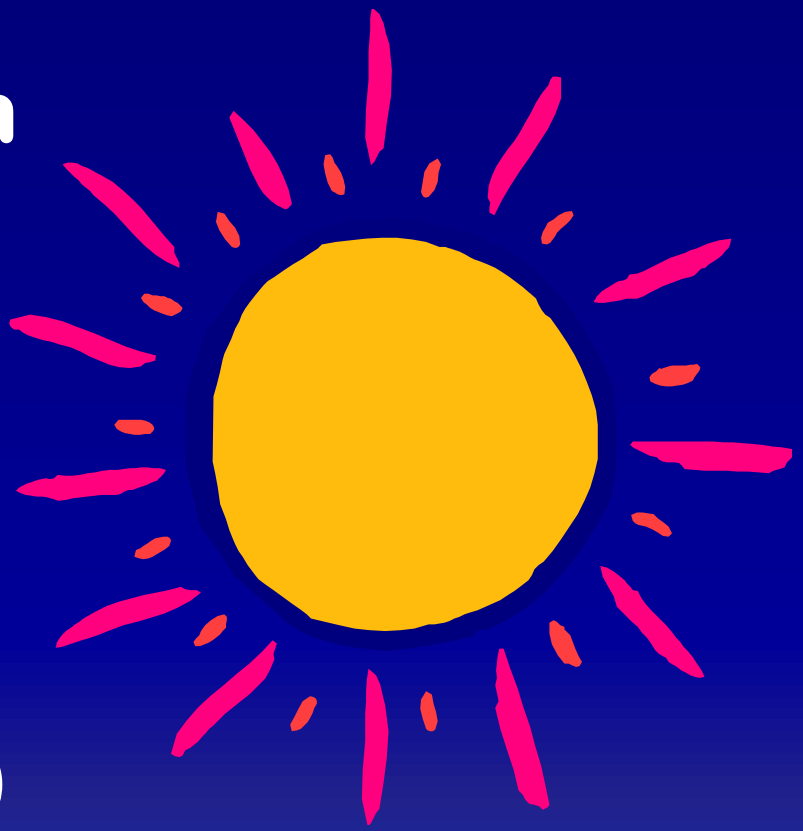
Emission of radiation

All substances emit radiation as long as their temperature is above absolute zero

(-273.15°C or 0 Kelvin).

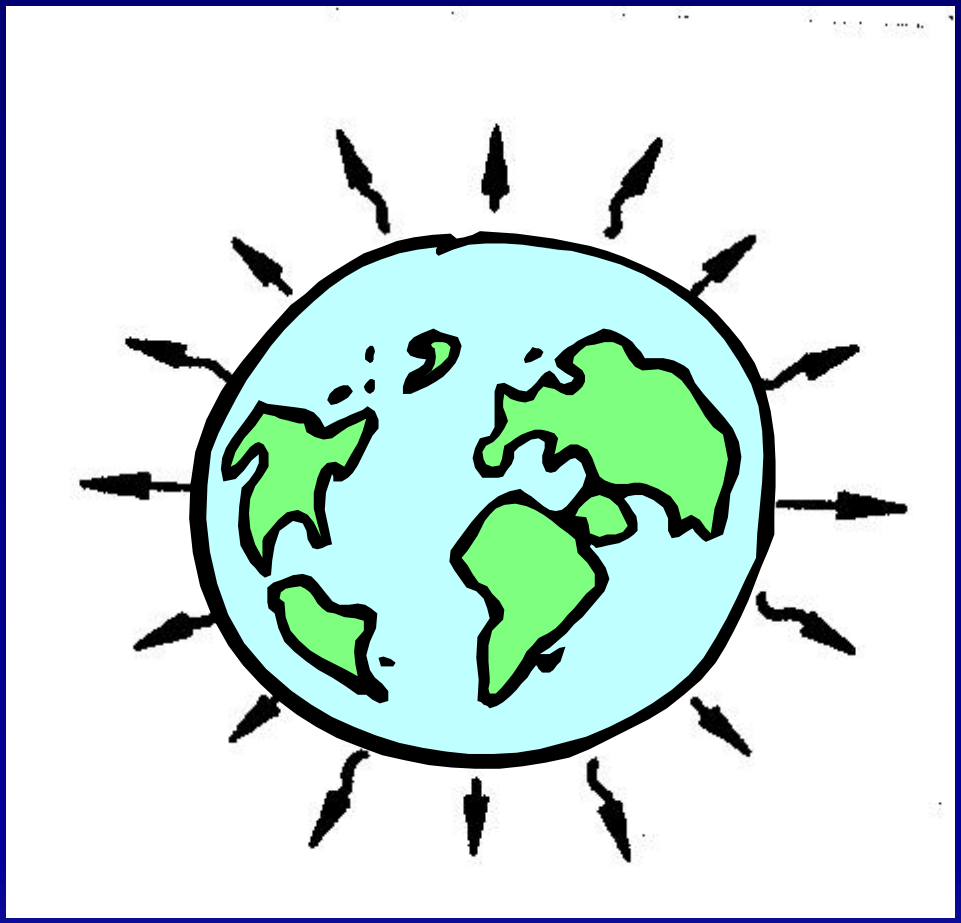
TYING THE RADIATION "LAWS" to GLOBAL CHANGE

The Sun's energy (solar) is emitted in the form of electromagnetic radiation.



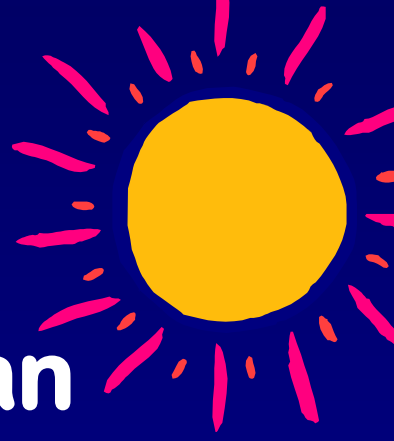
mostly
Shortwave (SW)
(but also some LW)

The Earth's energy (terrestrial) is also emitted in the form of electromagnetic wavelengths . . .



but in LW INFRARED (IR) wavelengths

LAW #2 BLACKBODY & PLANCK FUNCTION CONCEPT



The Sun is very similar to an "ideal emitter" (or "Black body")

(NOTE: the Earth is NOT a VERY good "black body" emitter)

Black body (def): a body that **emits** equally well at **all wavelengths**

(i.e. radiates with 100% efficiency)

It also **absorbs** equally well at all wavelengths and is a **"perfect absorber"**

(hence described as "black")

Blackbodies ("ideal emitters") exhibit a *defined relationship* between:

the **intensity** of radiation **energy** (E)
(i.e. amount of radiation flux) they give off
&
the **wavelength** of that radiation.

This relationship is called the **Planck function** :

E = h * speed of light / wavelength

Where (h) is Planck's constant.

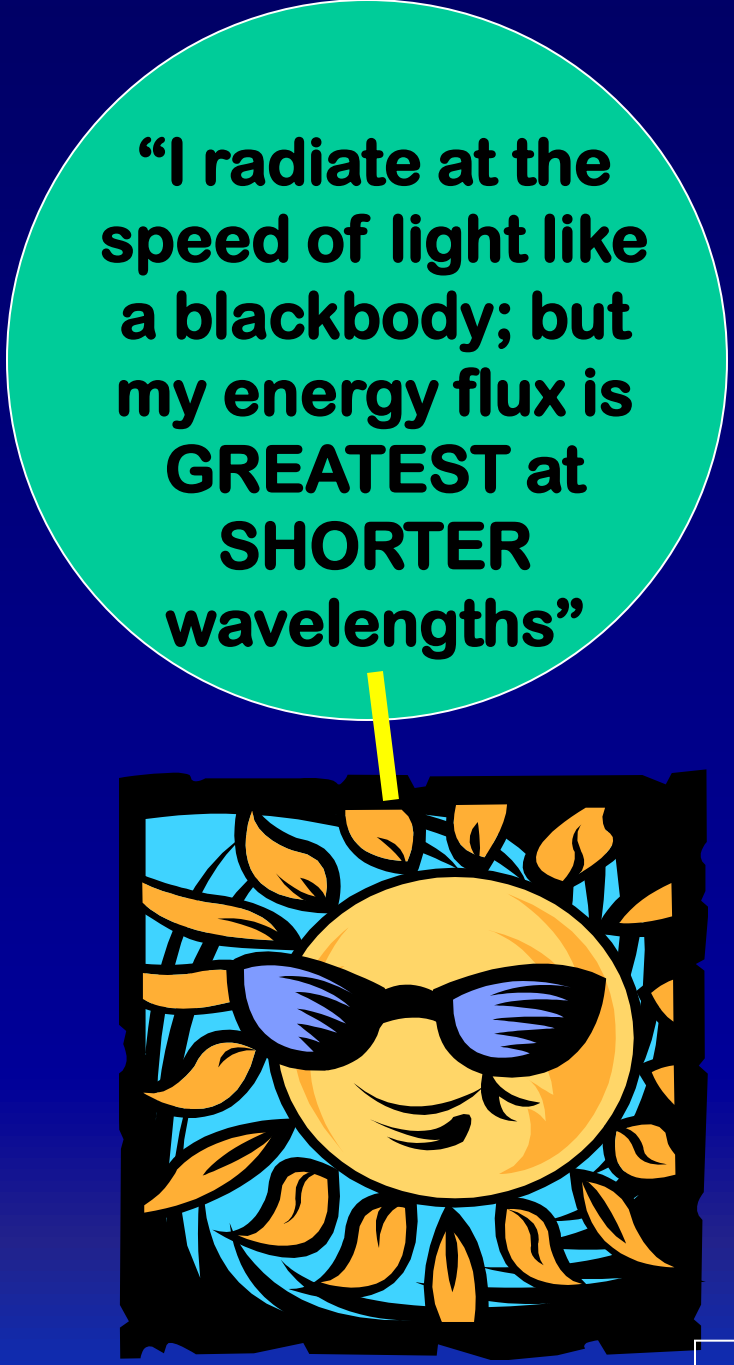
or

E = h c / λ

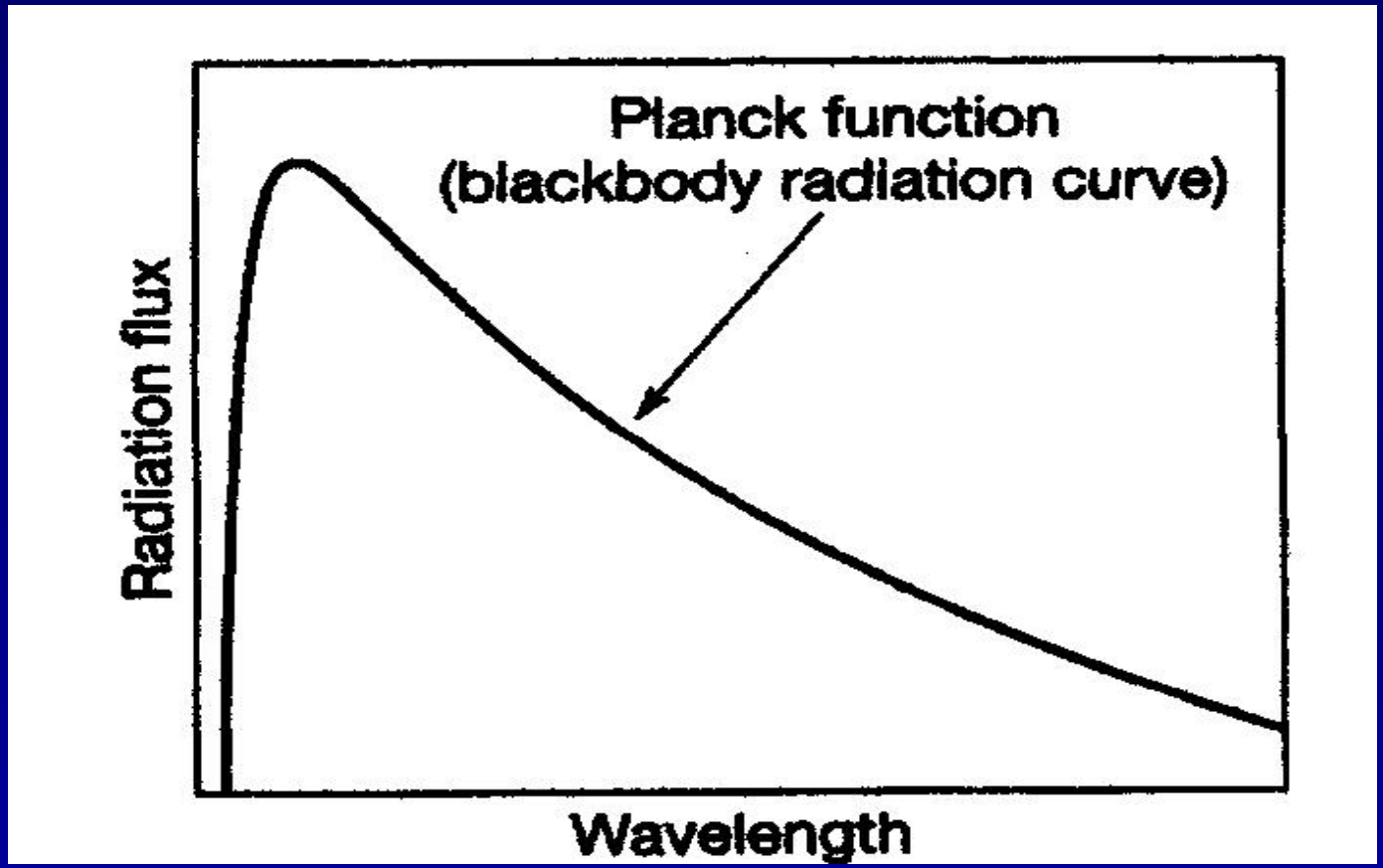
Planck Function:

The Sun emits energy at ALL wavelengths . . .

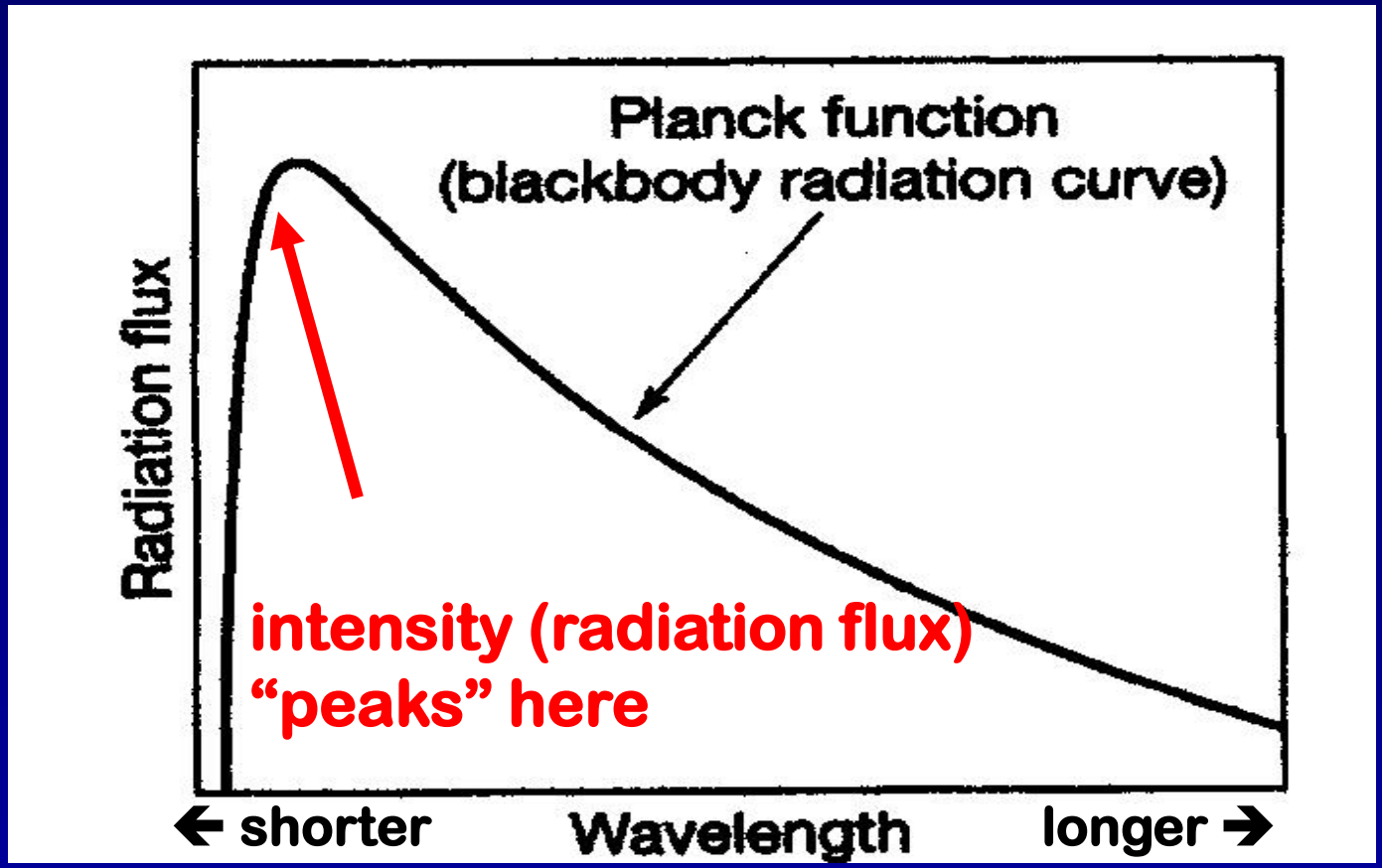
but the amount of Energy emitted is inversely related to the wavelength of emission



How is this depicted in this figure?



This can be depicted in a graph:



An emitting blackbody's SHORTER wavelengths have HIGHER intensity radiation (and greater energy flux) than the LONGER wavelengths

Easy way to remember the PLANCK FUNCTION / BLACKBODY concept:

"The shorter the wavelength, the GREATER the intensity of the energy flux"

Q1 - Gamma radiation involves a greater energy flux than microwave radiation.

1. True
2. False
3. Both wavelength bands have the same energy flux
4. We haven't learned enough yet to answer this!

Record your Q1 answer now

Q1 - Gamma radiation involves a greater energy flux than microwave radiation.

1. True
2. False
3. Both wavelength bands have the same energy flux
4. We haven't learned enough yet to answer this!

LAW #3: THE STEFAN-BOLTZMANN LAW:

If the substance is an ideal emitter (black body),

The total **AMOUNT** of radiation given off
is proportional
to the fourth power of
its absolute **TEMPERATURE.**

$$E = \sigma T^4$$

where σ is a constant

(the Stefan-Boltzmann constant) which has a value of

5.67×10^{-8} W/m^{-2}

(or 5.67×10^{-8} J / m^2)

and T is the absolute temperature

(in Kelvin)

$$\text{Energy} = \sigma T^4$$

Stefan-Boltzmann Law (easy way)

What is this law linking together and in what way?

"the hotter the body, the (much) greater the amount of energy flux or radiation"

Stefan-Boltzmann Law (easy way)

This law links:

(E) the total amount of energy flux that is emitted by a blackbody & (T) the body's temperature

(specifically, the 4th power of the body's absolute temperature)

"the hotter the body, the (much) greater the amount of energy flux or radiation"

The total amount of energy flux described by the Stefan-Boltzmann Law is proportional to the area under the Planck function curve

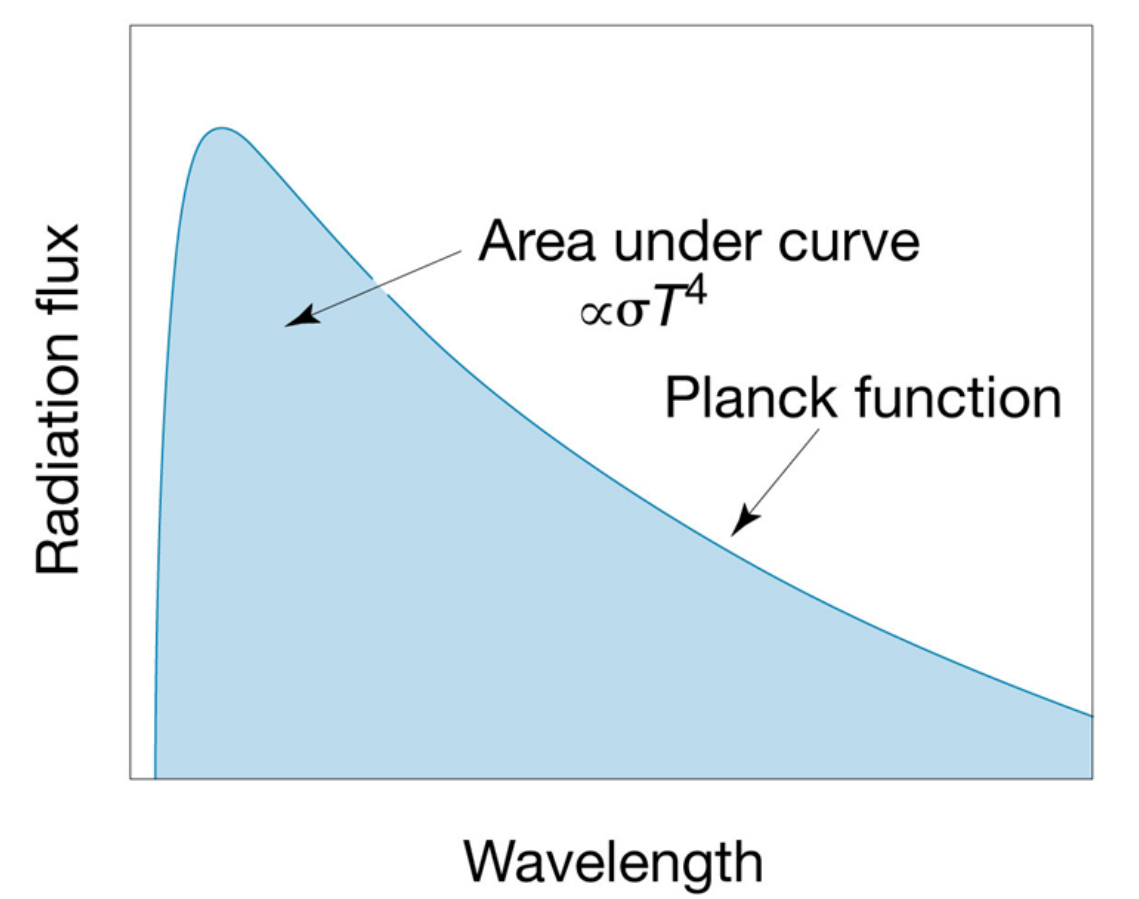


Figure on p 42 in SGC E-text

Stefan-Boltzmann Law:

"I'm HOT, so I emit LARGE amounts of high intensity energy"

"I'm COOL, so I emit much LESS energy . . .AND <u>MY</u> energy is at a lower intensity than Mr. Sun over there!"

Why is this concept important?

Because it means that:

the **amount** of radiation
given off by a body
is a very *sensitive* function
of its **temperature**

Therefore . . . small changes in temperature can lead to BIG changes in the amount of radiation given off.

$$E = \sigma T^4$$

Q2 – Which would you use:
the Planck Function or the Stefan-Boltzmann Law
to accurately compute
the total amount of ENERGY
emitted to space by planet Earth?

1. The Planck Function
2. The Stefan Boltzmann Law
3. Both of them together
4. Neither one is appropriate because the Earth is NOT a blackbody

Q2 – Which would you use:
the Planck Function or the Stefan-Boltzmann Law
to accurately compute
the total amount of ENERGY
emitted to space by planet Earth?

1. The Planck Function
2. The Stefan Boltzmann Law
3. Both of them together
4. Neither one is appropriate because the Earth is NOT a blackbody

Q3 – Which would you use:
the Planck Function or the Stefan-Boltzmann Law
to compute the total amount of energy
emitted to space by planet Earth,
IF you assume the Earth emits like a blackbody
& you know the Earth's temperature?

1. The Planck Function

2. The Stefan Boltzmann Law

3. Neither one is appropriate because you would need to know the wavelengths of radiation the Earth emits

4. Don't know

Q3 – Which would you use:
the Planck Function or the Stefan-Boltzmann Law
to compute the total amount of energy
emitted to space by planet Earth,
IF you assume the Earth emits like a blackbody
& you know the Earth's temperature?

1. The Planck Function
2. The Stefan Boltzmann Law
3. Neither one is appropriate because you would need to know the wavelengths of radiation the Earth emits
4. Don't know

How to do it:

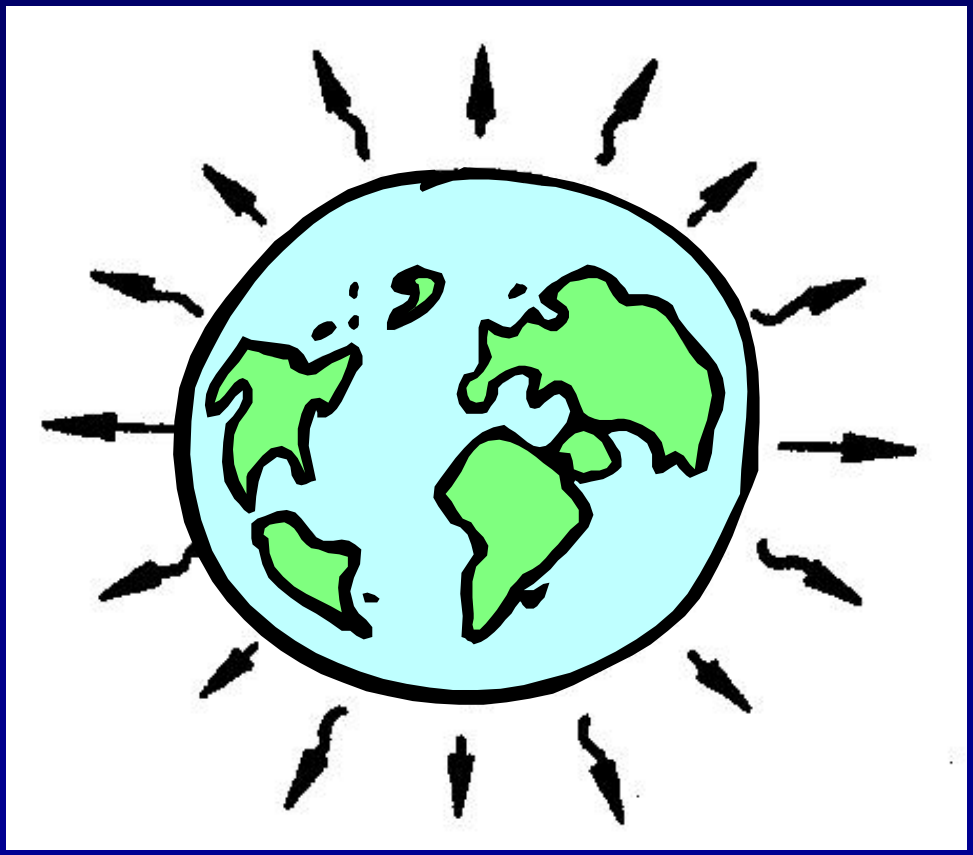
$$E = \sigma T^4$$

E = **Energy per unit area**, so all we need to know is the **AREA** of the emitting Earth's surface + what T is.

From geometry:
Do you remember the formula for computing the area of a sphere?

The area of a sphere of radius R is

$$4 \prod R^2$$



$$E = 4 \prod R^2 \times \sigma T^4$$

See box on p 44 in SGC E-text for more details

RADIATION LAWS # 4 - #6

to be continued . . . . .