TOPIC # 5 - Part II
THE ELECTROMAGNETIC SPECTRUM

Class Notes:
pp 27-28

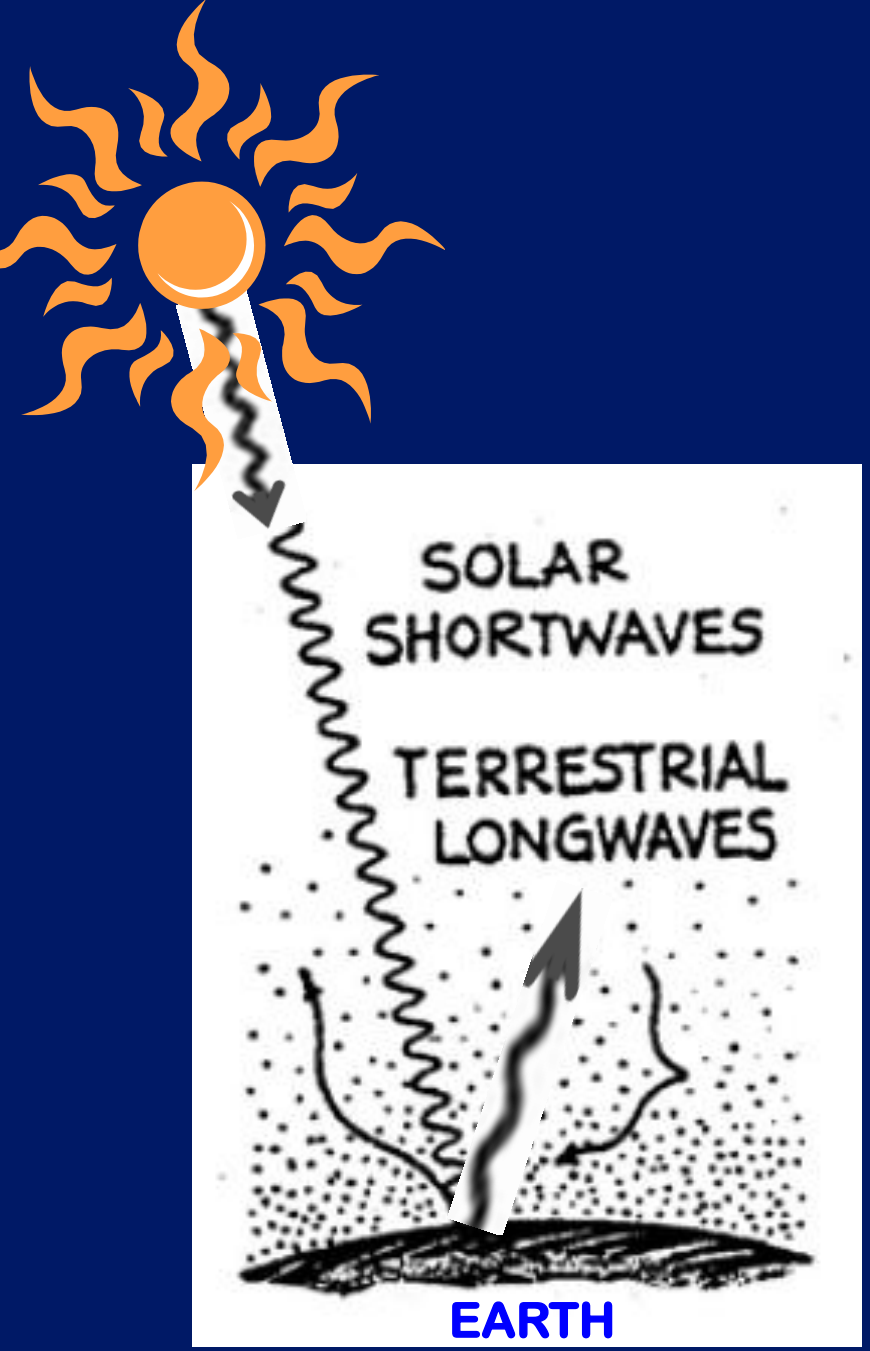
Come forth into the
light of things.

Let nature be your teacher.

~ William Wordsworth

Frequency, Wavelengths & Energy of Photons

Energy emitted from the sun (i.e, electromagnetic radiation) exhibits both a wave-like (electromagnetic wave) and particle-like (photon) nature.



Both Sun & Earth are radiating energy . . . .

. . . at different electromagnetic wavelengths

. . . . and at different frequencies

Figure on p 27

the symphony of science

Richard Feynman, Quantum Physicist

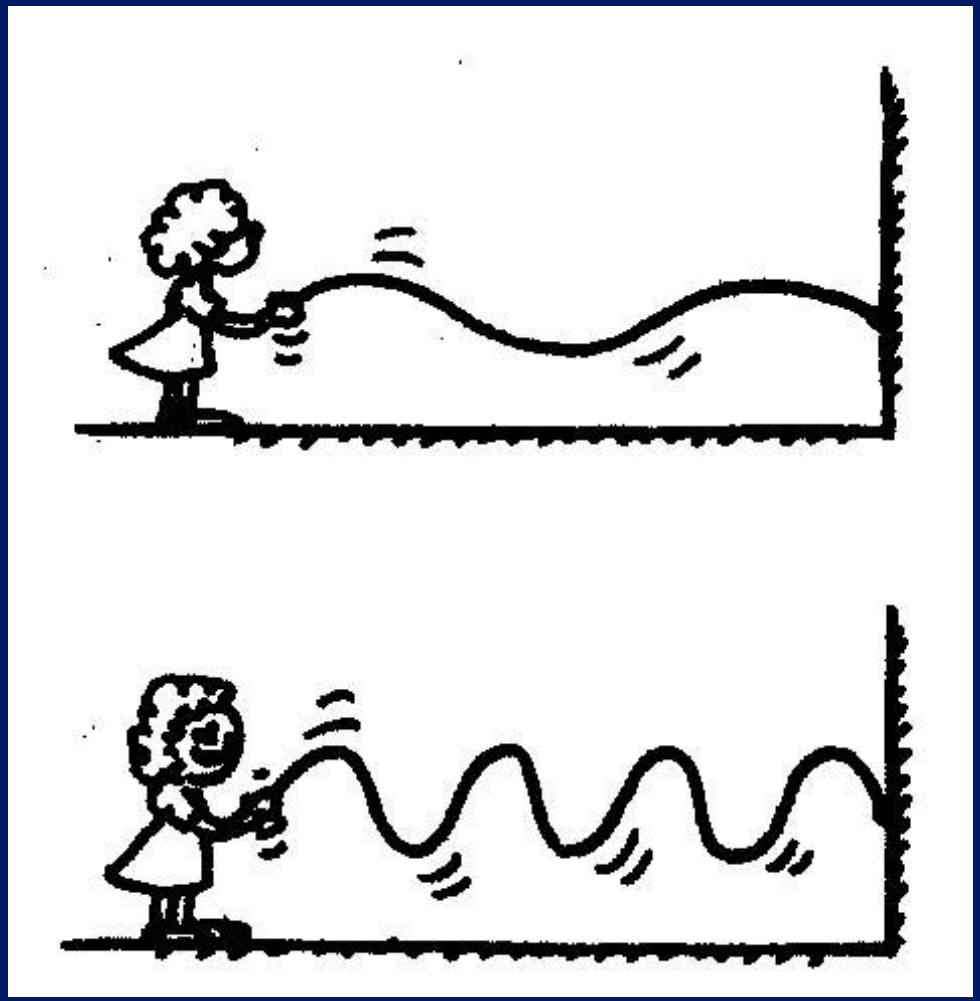
There's this tremendous mess

Of waves all over in space

Which is the light bouncing around the room

And going from one thing to the other

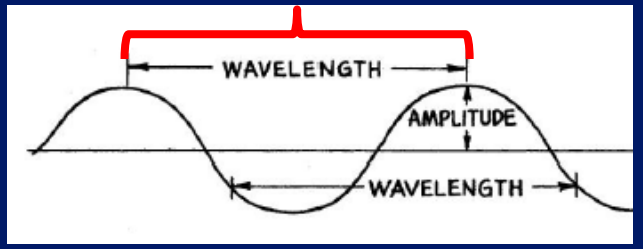
Wavelengths



Quantifying Frequency & Wavelengths

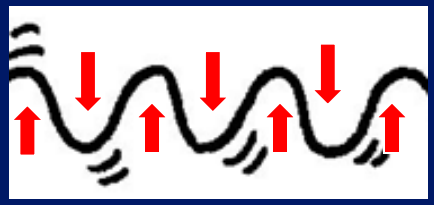
Terminology for describing the WAVE-like behavior of electromagnetic energy:

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



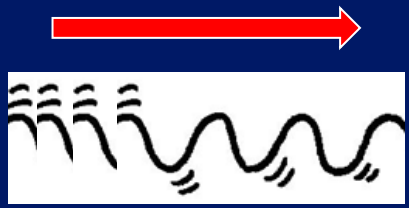
Frequency = how fast the crests move up and down

(symbol = **nu** ν in E-Text)

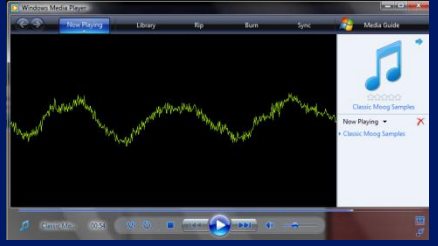


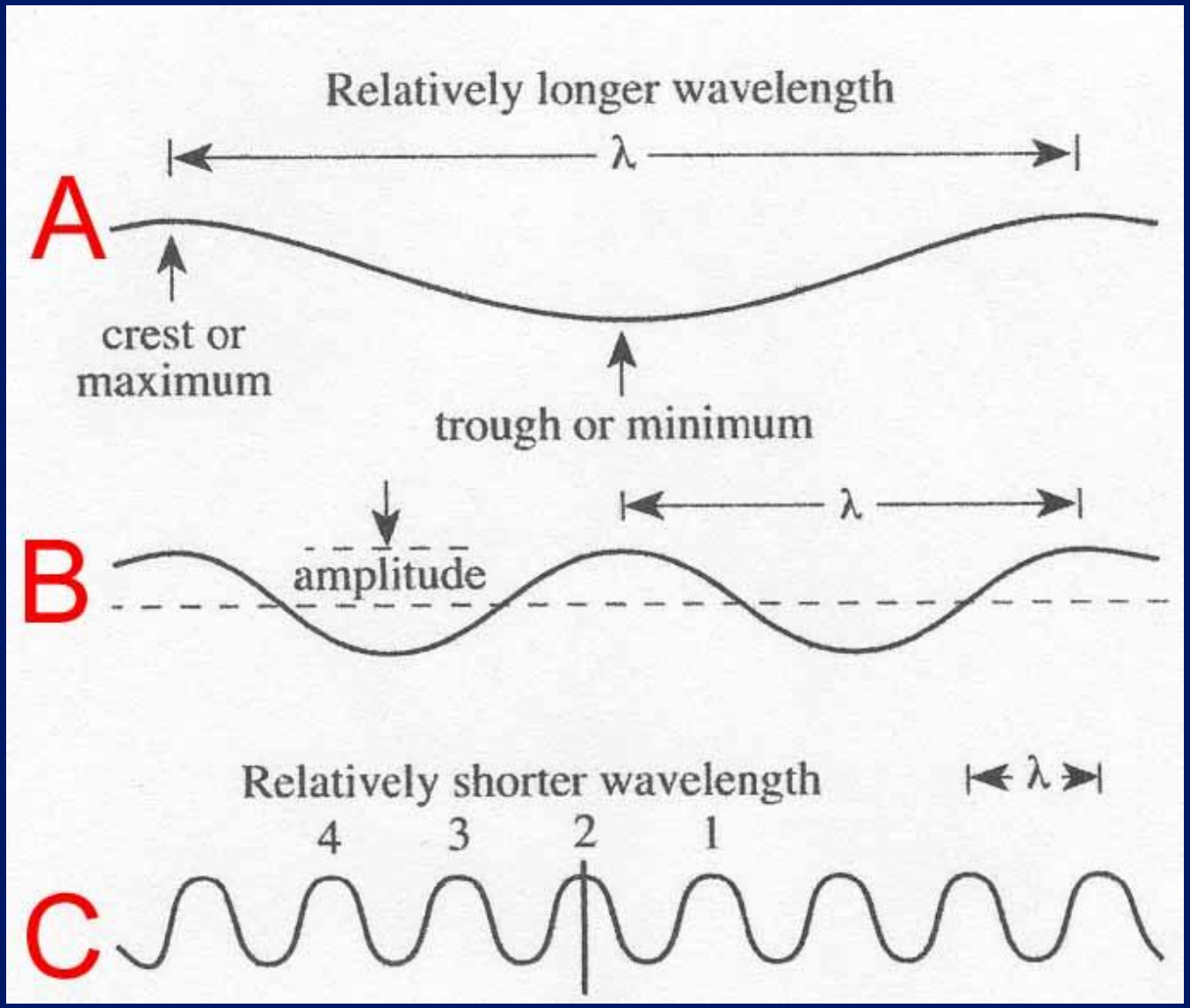
Speed = how fast the crests move forward (symbol = **c** in E-text)

c = the speed of light

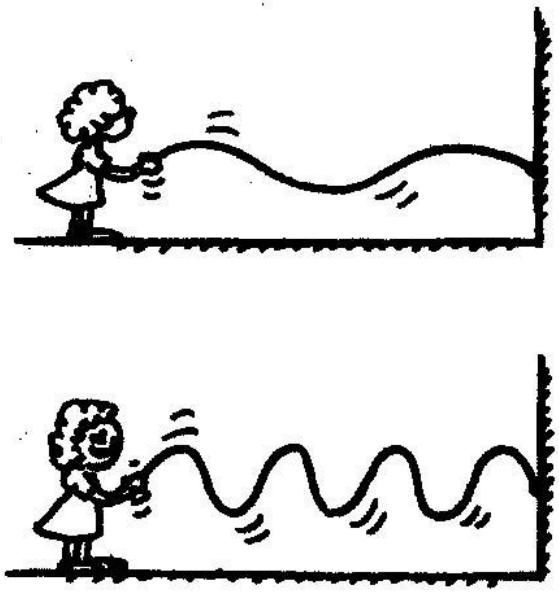


Another view:





Wavelength & Frequency



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

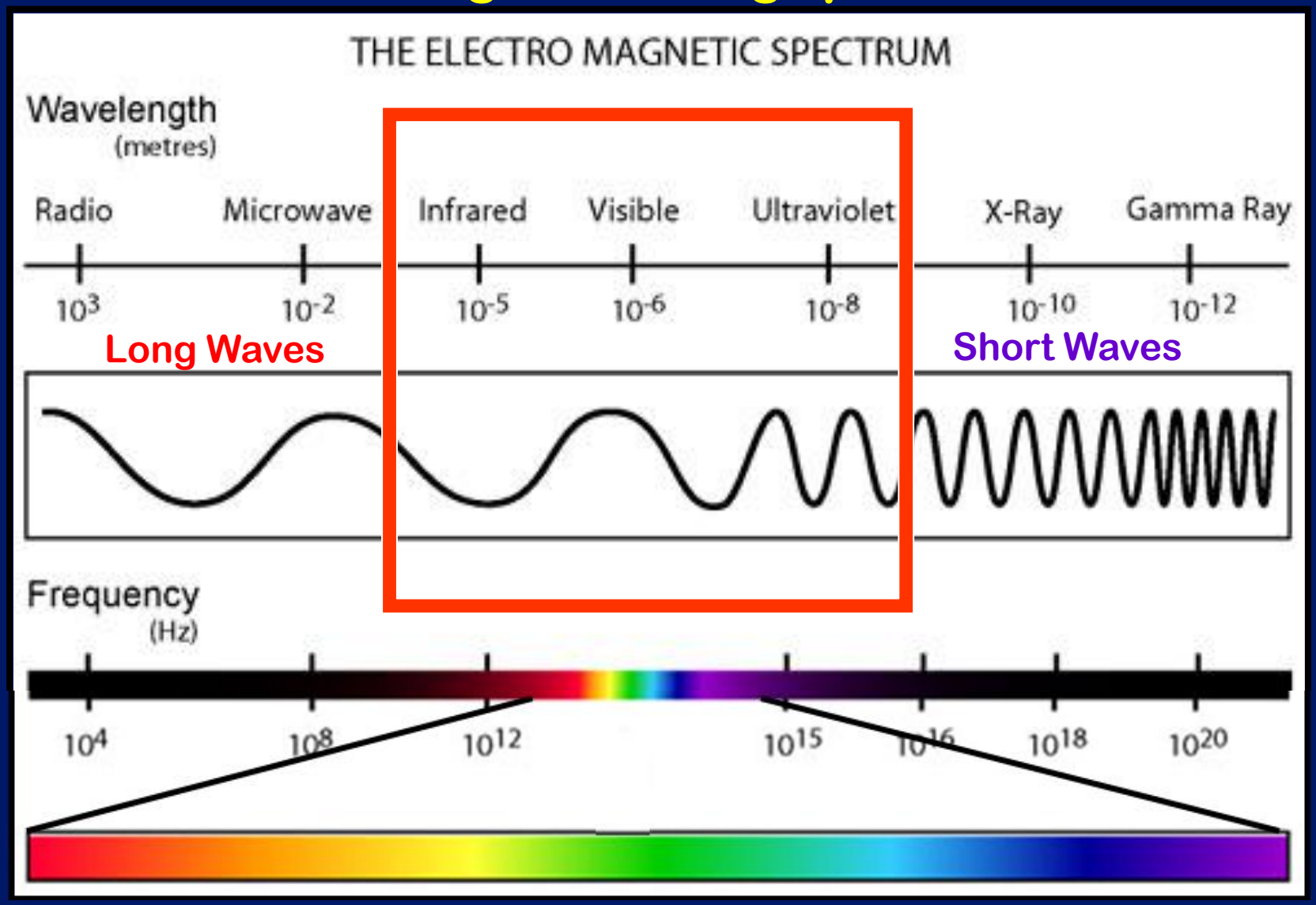
*"The **shorter** the wavelength*

*the **GREATER the energy***

&

*the **HIGHER the frequency**"*

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



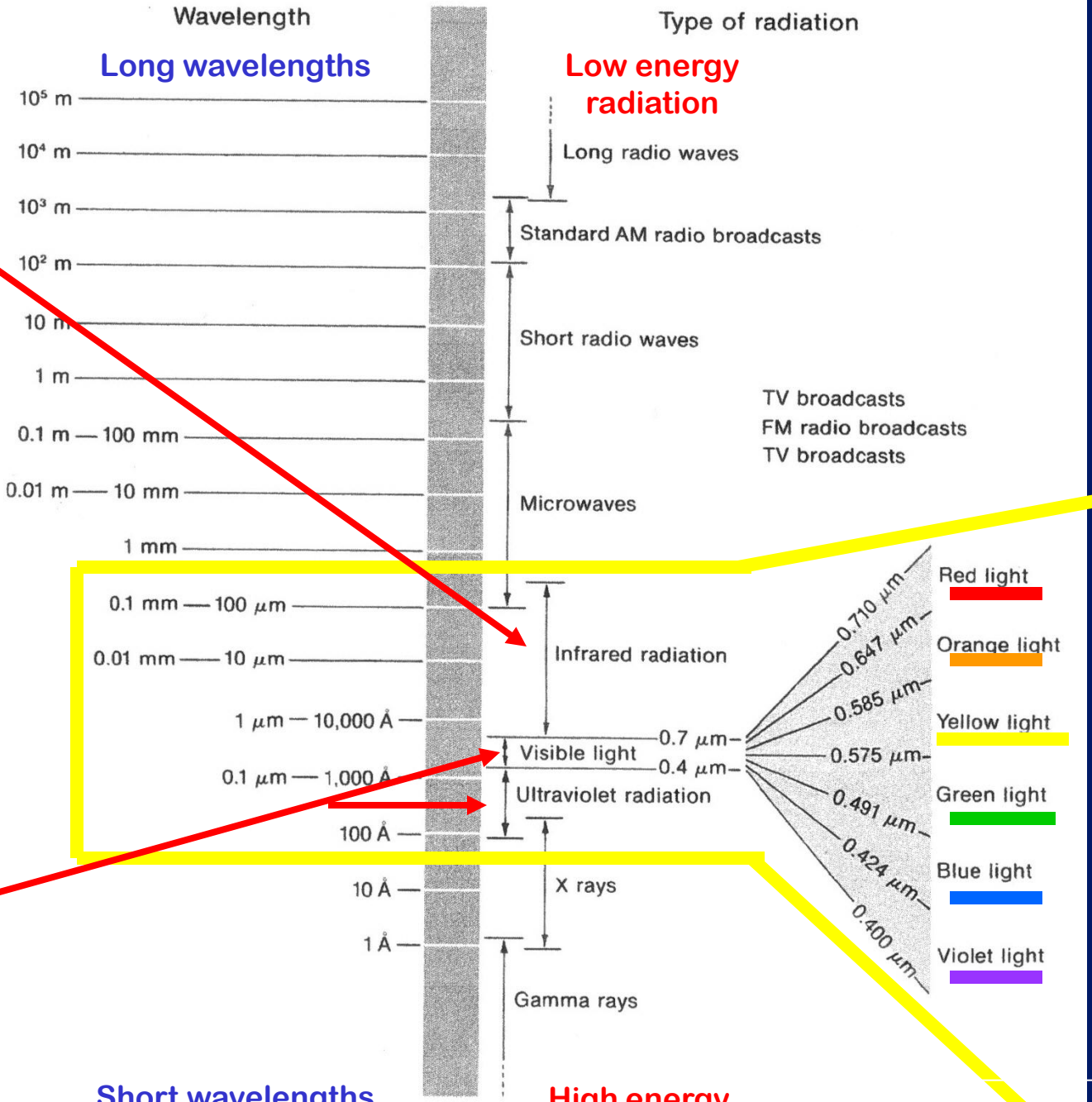
R O Y G B (I) V

Longwaves (LW)

The Electro-magnetic Spectrum

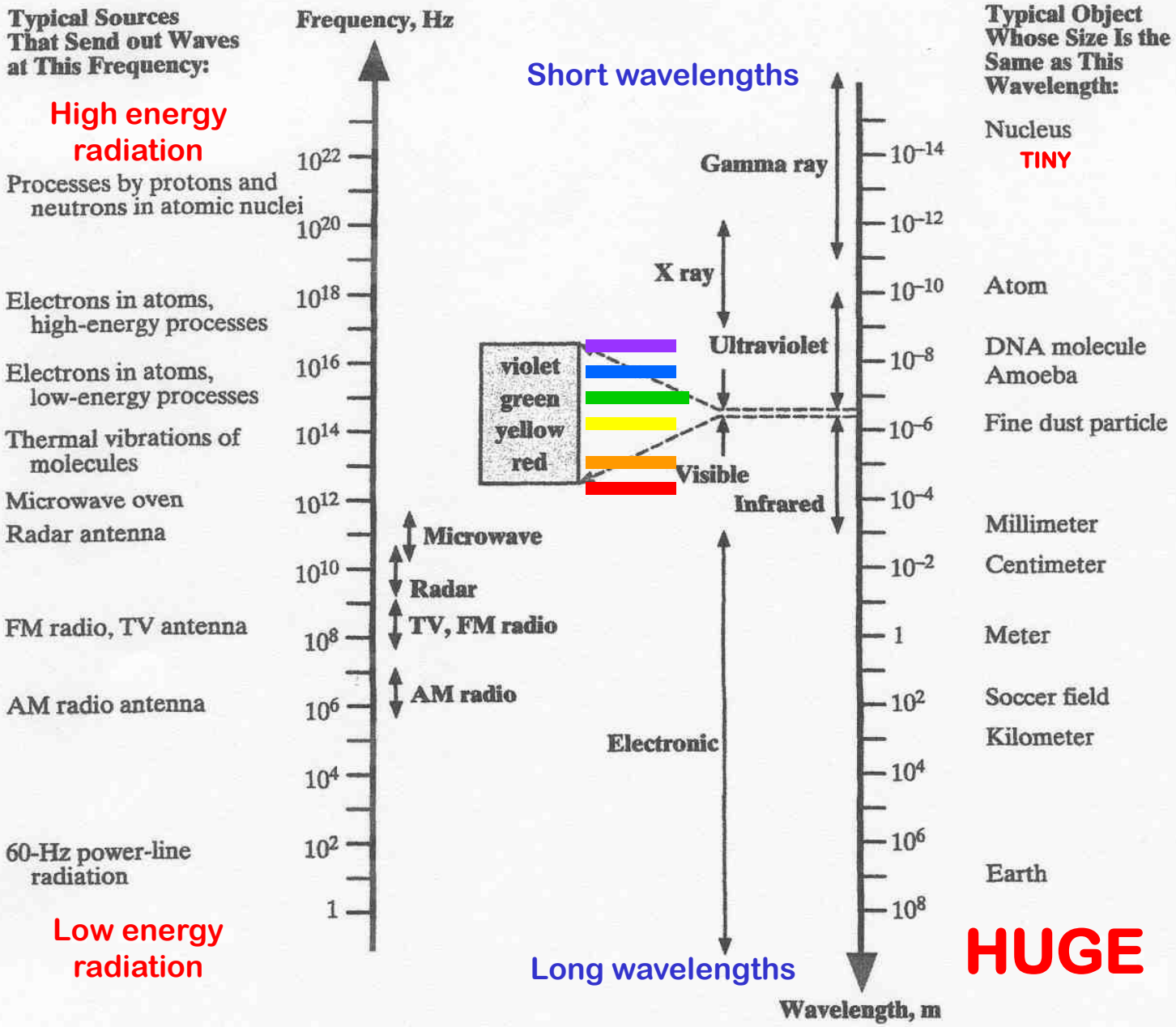
(another view)

Shortwaves (SW)

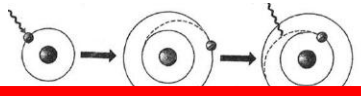
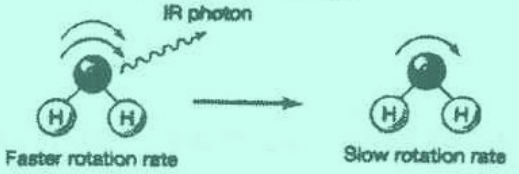


The electromagnetic spectrum.

Another (flipped) view:



What are the "sources" of different wavelengths of electromagnetic radiation?

Type of Electromagnetic Radiation	Range of Wavelengths (in units indicated)	Typical Source
Gamma rays	10^{-16} to 10^{-11} in meters (m) using scientific notation	high-energy processes within nucleus caused by the strong force
Ultraviolet radiation	.0001 to 0.4 in micrometers (μm)	electrons moving (quantum leaps) within individual atoms 
Visible light	0.4 to 0.7 in micrometers (μm)	
Infrared radiation	0.7 to ~30 (up to 1000) in micrometers (μm)	chaotic thermal kinetic motion of molecules due to their thermal energy 
Near Infrared radiation	0.7 - 1.0 in micrometers (μm)	
Far Infrared	1.0 - ~30 (up to 1000) in micrometers (μm)	
Microwaves	10^{-4} to 10^{-2} in meters (m) using scientific notation	electronically produced by microwave oven

Shortwave Solar

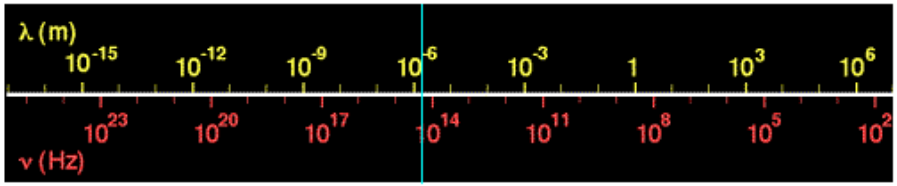
THE GREENHOUSE EFFECT

Neat website . . Check it out!

ELECTROMAGNETIC SPECTRUM JAVA APPLET:

http://lectureonline.cl.msu.edu/~mmp/applist/Spectrum/s.htm

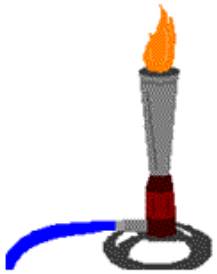
Applet: Spectrum



Wavelength	= 1.643e-6 m	= 1642.9 nm
Frequency	= 1.825e14 Hz	= 182482.3 GHz
Energy	= 1.209e-19 J	= 0.754 eV

Infrared, heat radiation

Origin: Molecular vibrations
Detection: Bolometer



What is the relationship between . . .

ENERGY **E**

FREQUENCY ν and

WAVELENGTH λ

OF PHOTONS ?

KEY CONCEPT #1:

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

$\propto$ = "is proportional to"

$$E \propto \nu$$

What is the relationship between . . .

ENERGY **E**

FREQUENCY ν and

WAVELENGTH λ

OF PHOTONS ?

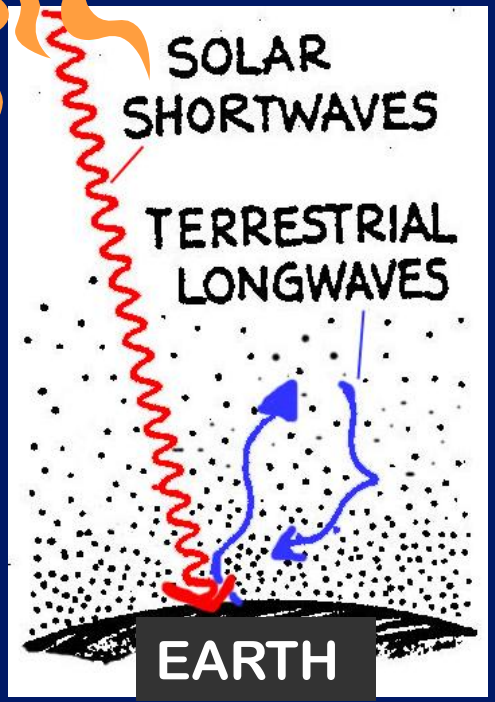
KEY CONCEPT #2:

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

$$E \propto c / \lambda$$

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

(high energy & frequency)

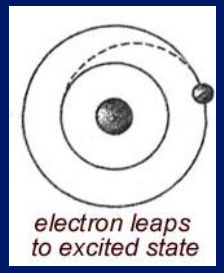


EARTH RADIATION: entirely in **LONG** wavelengths

(low energy & frequency)

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

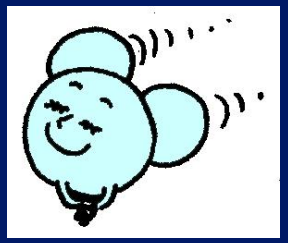
Photons + ATOMS vs Photons + MOLECULES



The quantum leap of electrons:
takes place WITHIN an ATOM between discrete energy levels (shells) when photons are absorbed or emitted . . .

but

Quantum theory also involves the *behavior of molecules*



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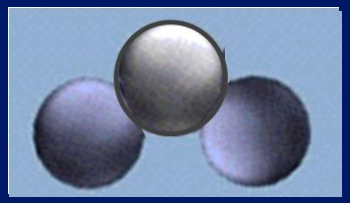
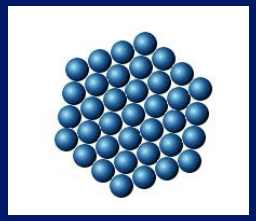
When some molecules absorb and emit certain wavelengths of electromagnetic energy they bend, rotate, and spin in a specific way



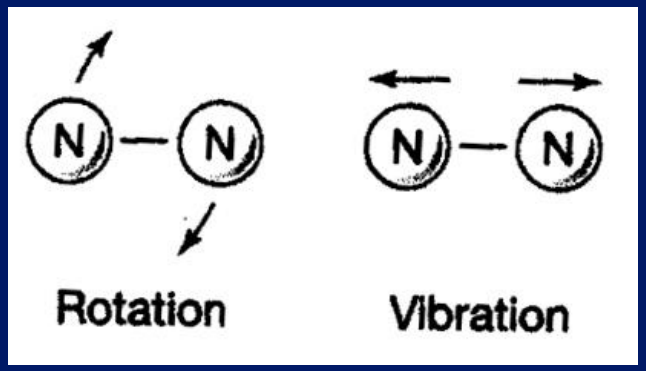
rotation
bending
vibration



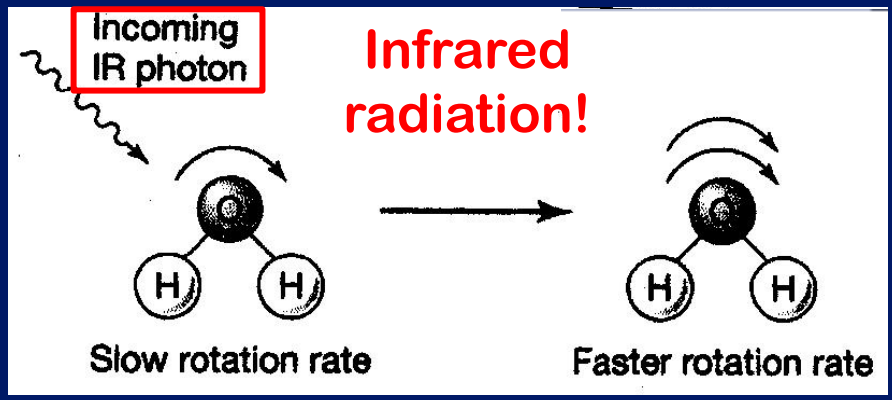
Review p 26

Greenhouse gases!

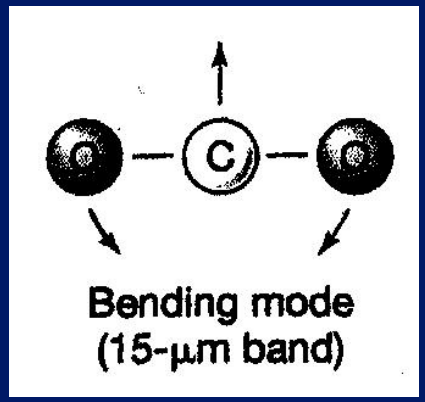
NITROGEN GAS MOLECULE
N_2

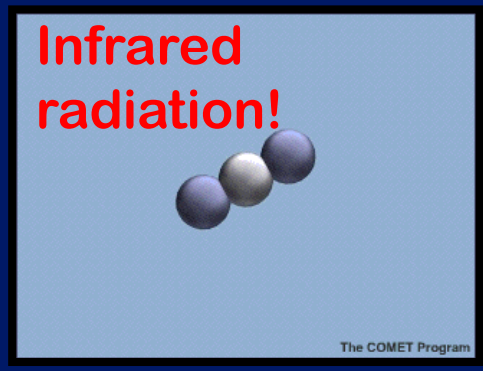


WATER VAPOR MOLECULE
H_2O



CARBON DIOXIDE GAS MOLECULE
CO_2



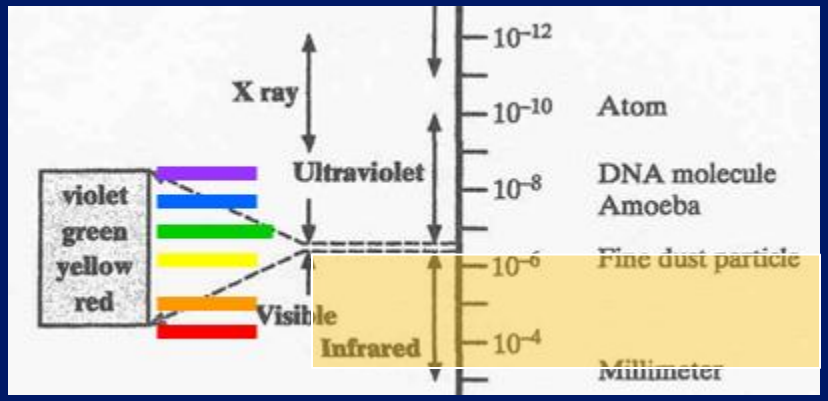


Figures on p 26

So what is a Greenhouse Gas?

abbreviation we'll use = GHG

GHG = a gas than can absorb and emit (re-radiate) INFRARED wavelengths of Electromagnetic Radiation



IR radiation

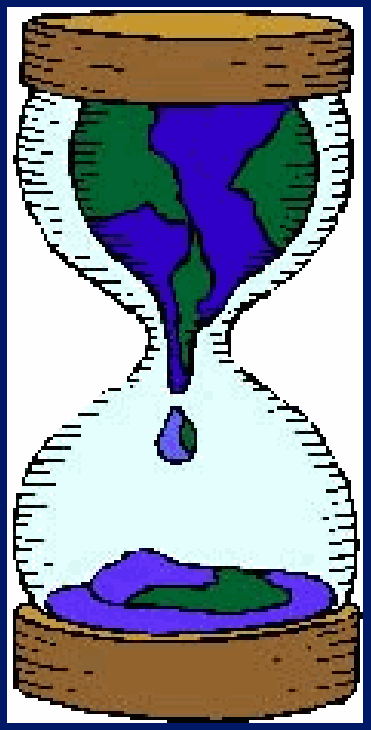
> 0.7 - 1000 micrometers

KEY POINT:

The QUANTUM BEHAVIOR of
CERTAIN MOLECULES
with respect to
INFRARED RADIATION
is the
REASON THAT GREENHOUSE
GASES ARE GREENHOUSE GASES!!

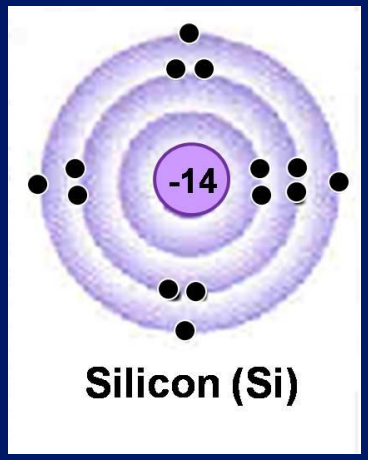
And NOW another . . .

SUSTAINABILITY SEGMENT



More of:

Starring:

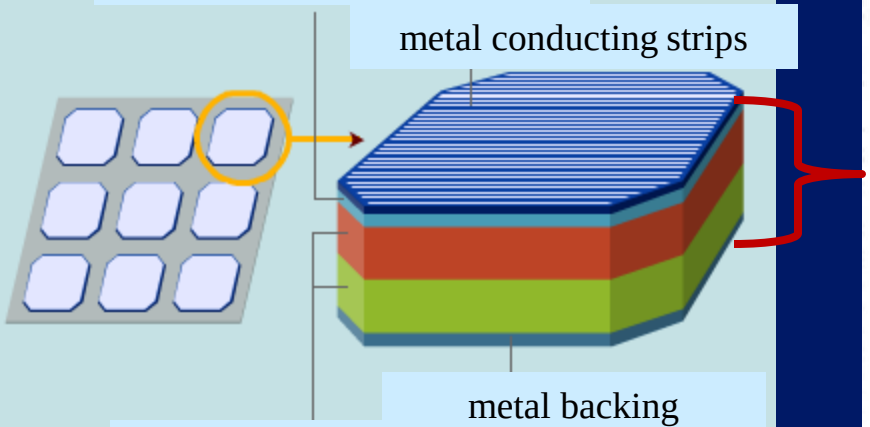


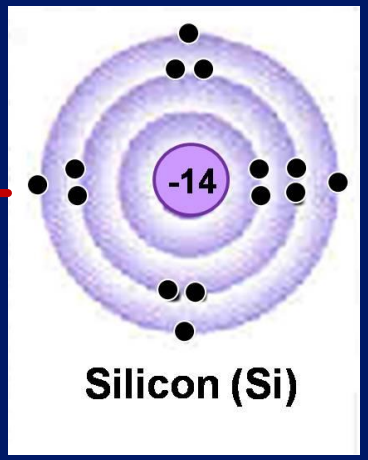
http://www.pbs.org/wgbh/nova/tech/saved-by-the-sun.html

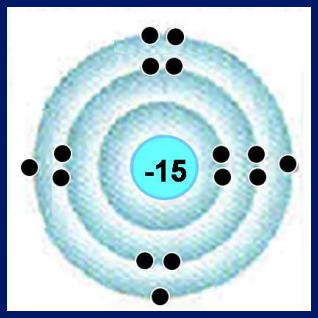
INSIDE A SOLAR CELL

SOLAR PANEL

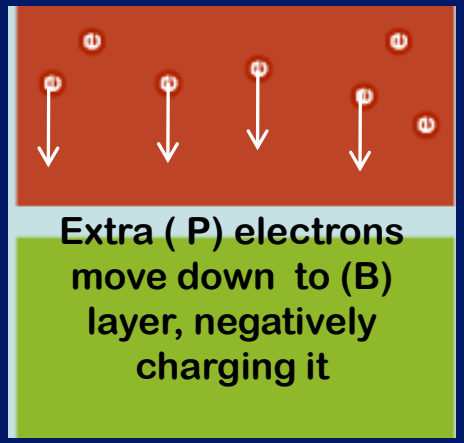
PHOTOVOLTAIC CELL (PV)



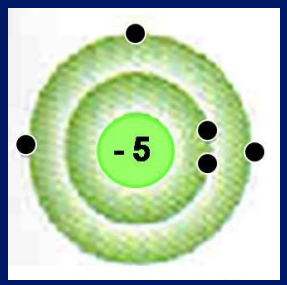




Phosphorus (P) "doped" Si layer



Boron (B) "doped" Si layer



Read this explanation at:

http://www.pbs.org/wgbh/nova/tech/how-solar-cell-works.html /

INSIDE A SOLAR CELL