

Tuesday Sep 9th

ANNOUNCEMENTS

- **Assignment I-1** is due tonight before midnight (11:59 pm)
- **RQ-2** is now posted and is due Thursday Sep 11th (30 minutes before class.)
- **TEST #1** is one week from today on **TUESDAY Sep 16th**

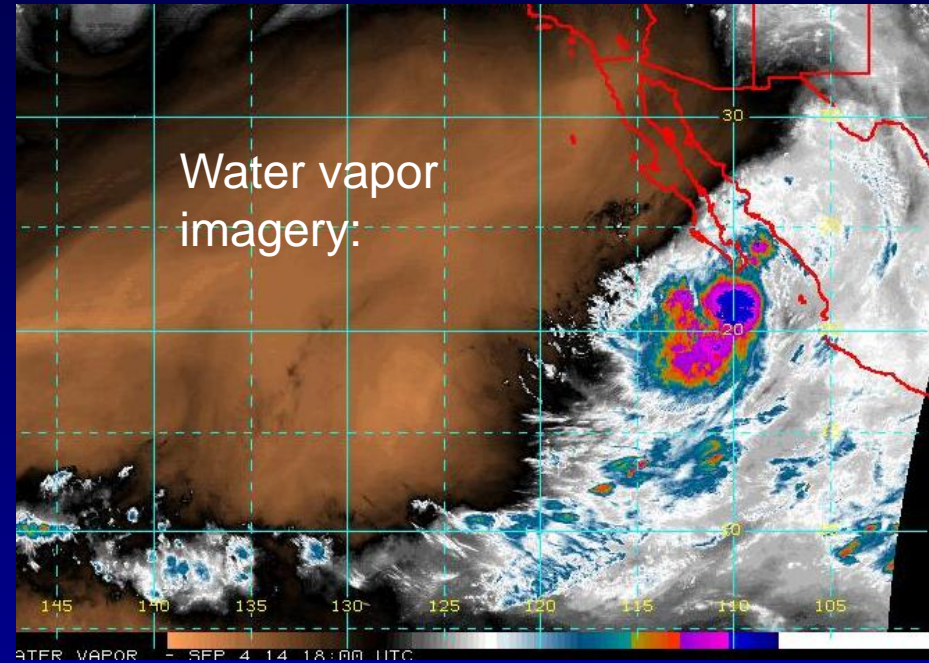
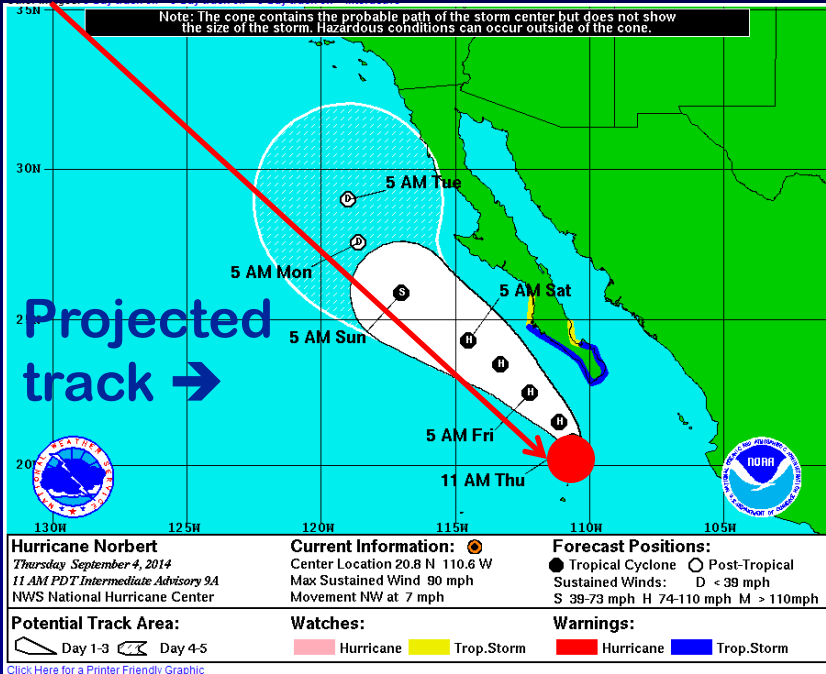
The “TOP TEN THINGS TO STUDY” study guide is **NOW** posted in D2L – includes this week’s classes.
(INFO about a **STUDY SESSION** on Monday TBA later)

- **FYI: The CLASS will sit in assigned GROUPS → for the first time in THURSDAY’S CLASS !**
(Your groups details will be given in class Thursday)



When we last met

This was where HURRICANE NORBERT was:



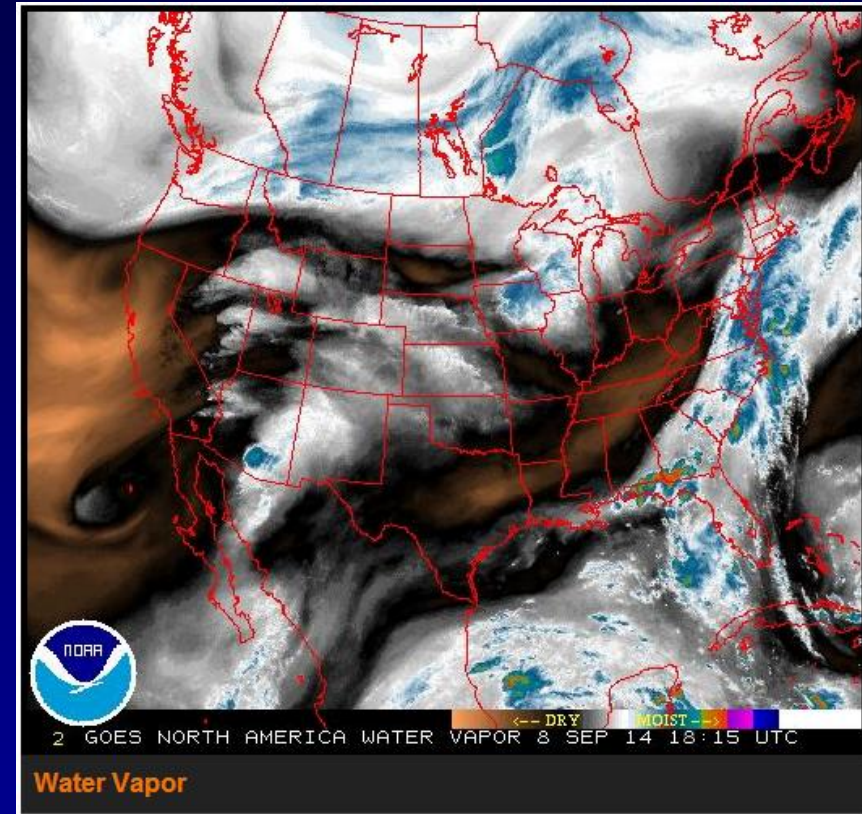
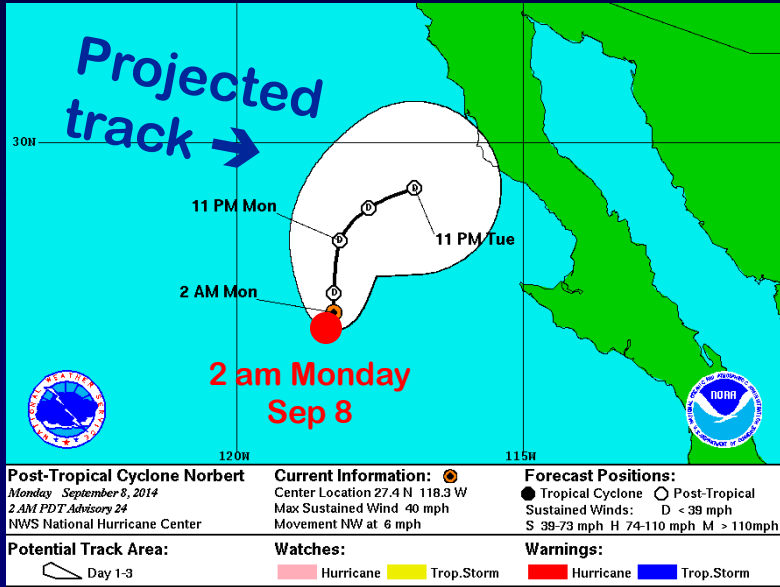
Here's where Norbert actually went:

http://www.nhc.noaa.gov/archive/2014/graphics/ep14/loop_3W.shtml

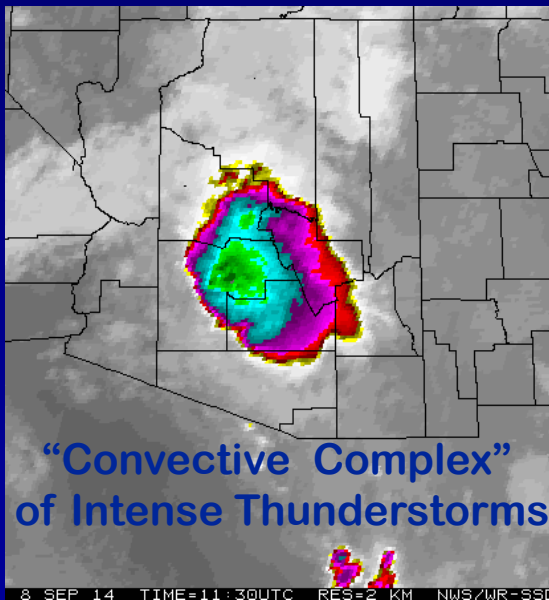
YESTERDAY'S EVENTS:

WATER VAPOR

~ 11:00 am Monday Sep 8
(Tucson time)



~ 4:00 am
Monday
Sep 8



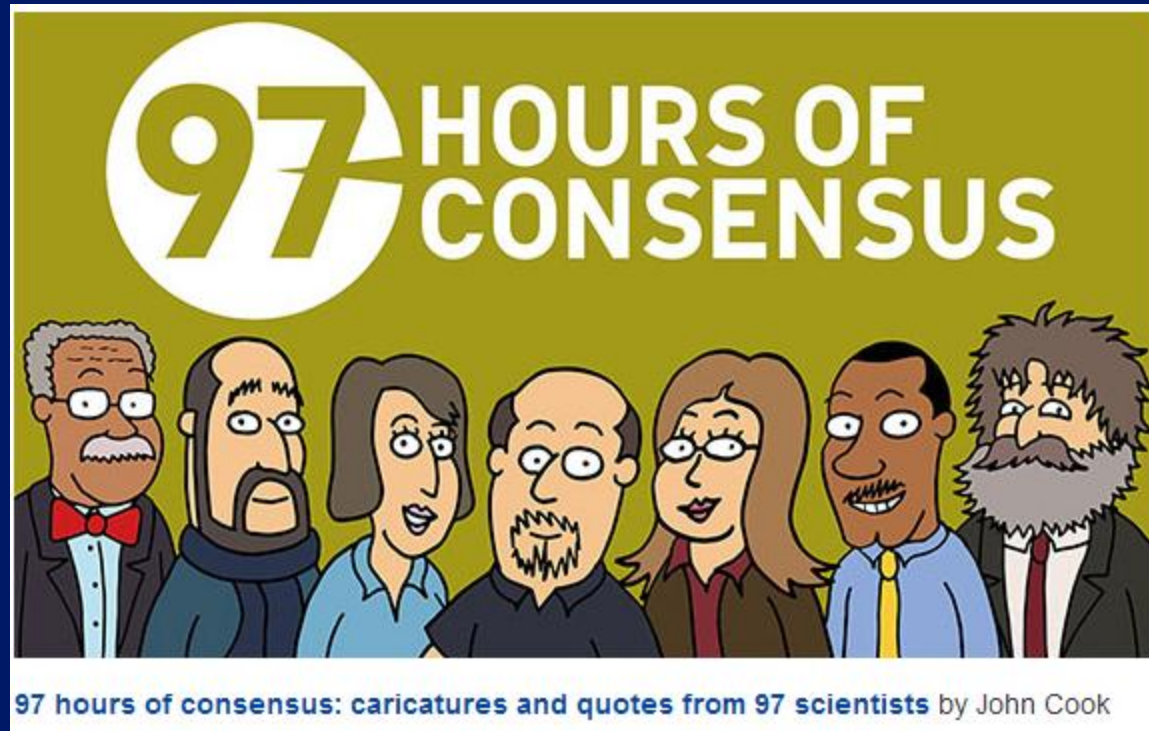
Bright and colored areas indicate **high water vapor (moisture) content**. Black and brown areas indicate little or no moisture present.

<http://www.weather.gov/satellite?image=ww#wv>

Now? It's “Post-Tropical Cyclone Norbert

GUESS WHAT?

At this very moment, we are in the middle of:



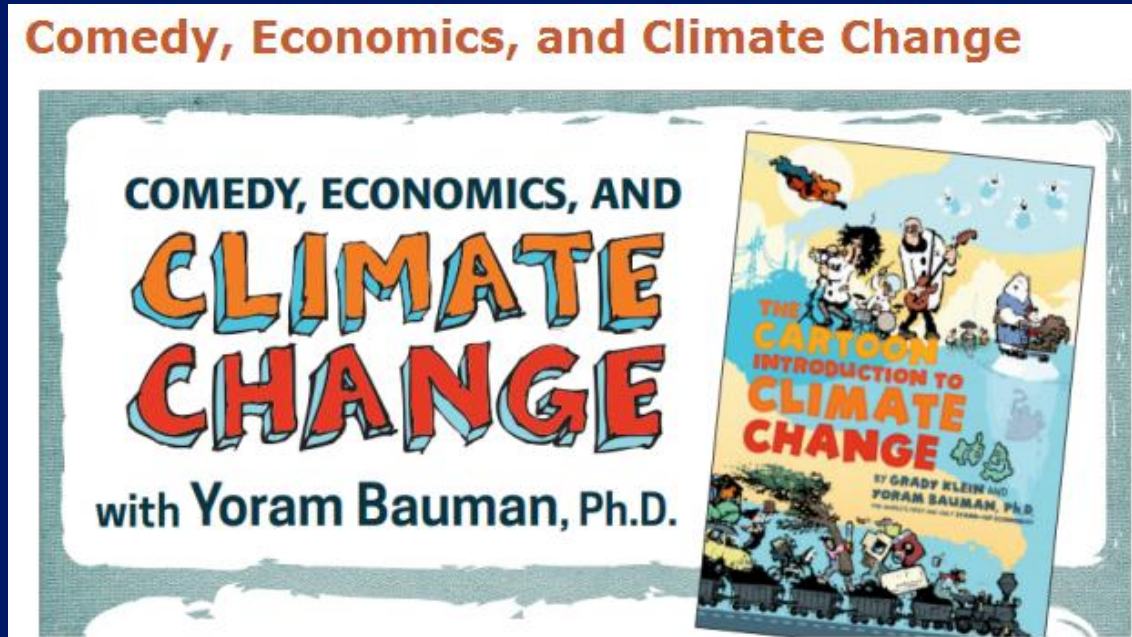
<http://www.skepticalscience.com/nsh/>

All comments are being posted at:

<http://skepticalscience.com/graphics.php?c=9>

And speaking of cartoons . . .

Coming to the UA:



Monday September 29 @ 5:30 – 7:30 pm
in McClelland Hall, Berger Auditorium

Sponsored by :



www.environment.arizona.edu/

NOW BACK TO CLASS TOPICS!

WRAP UP OF TOPIC #3:

ENERGY: QUICK REVIEW

from last week

**What are the key things
you need to know NOW?**

(more will be covered in Topic #7)

Re-cap: Energy Terms & Units

ENERGY TERMS & UNITS

Energy - the quality of an object that enables it to do "work;" the capacity to exert force over a distance.

Mass - Mass (m) is the amount of matter in a particle or object; standard unit = kilogram (kg)

Force - A push or pull that, acting alone, causes a change in acceleration of the object on which it acts.

Force is expressed in units called **newtons (N)**. A newton is a unit of force needed to accelerate a mass of 1 kilogram by 1 meter per second squared.

Work - Work (W) is done whenever a force (F) is exerted over a distance (d). Work is equal to the force that is exerted times the distance over which it is exerted (i.e. the product of the force applied to an object and the distance through which the object moves). $W = F \times d$

Work is expressed in units called **joules**. A joule is the amount of work done when you exert a force of one newton through a distance of one meter.

Power - Power (P) is equal to work (W) done divided by the time (t) it takes to do it. $P = W/t$

Power can be expressed in joules/sec = **watts**

1 watt of power = (1 joule of energy) ÷ (1 second of time)

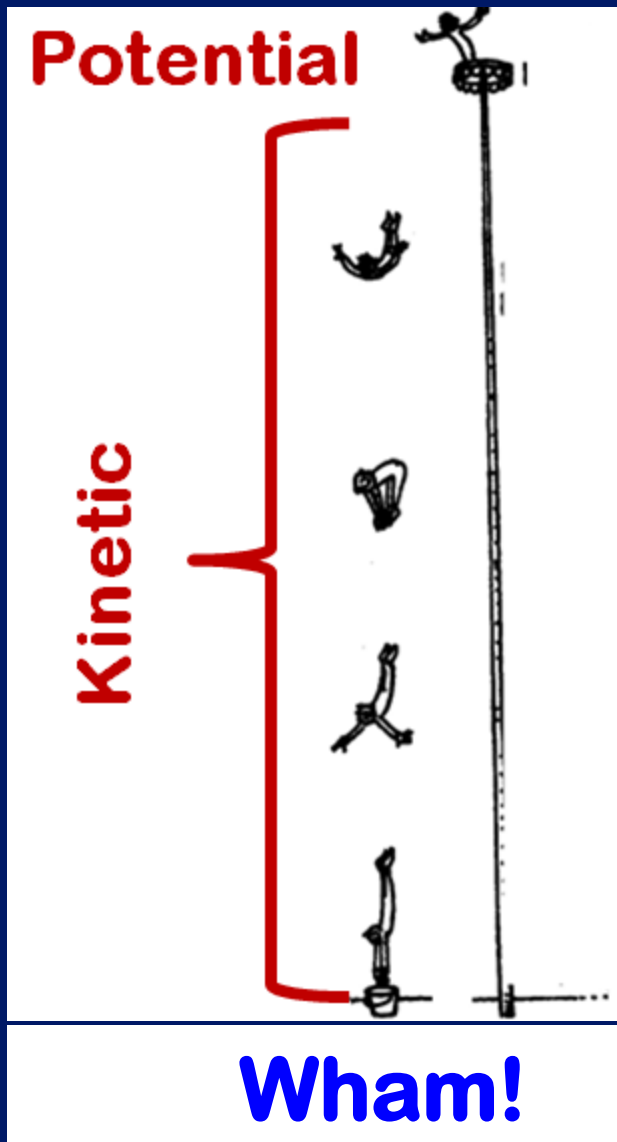
Energy can therefore also be expressed in terms of power and time:

energy (in joules) = power (in watts) x time (in seconds)

ENERGY (def) = the quality of an object that enables it to do **“WORK”**

WORK (def) = action of a **FORCE** exerted over a **DISTANCE** . . . or the **TRANSFER OF ENERGY** from one object to another (especially to make the second object move in a certain direction)

Two Main Kinds of Energy



- **Potential** = energy a system possess if it is capable of doing work, but is *not* doing work now
- **Kinetic** = energy of motion; the ability of a mass to do **WORK** !

POTENTIAL ENERGY (PE) – The energy a system possesses if it is capable of doing work, but is not doing work now.

Quick summary of different forms of potential energy:

Gravitational - Energy associated with the position of a mass in a gravitational field; *energy stored by virtue of its position.*

Elastic - Energy stored in a flexed muscle, a coiled spring, a stretched rubber band, etc.

Chemical - Energy stored in the electrical bonds that bind together the molecules or atoms of a substance.
In any process in which atoms rearrange to form different molecules, a chemical reaction occurs, during which energy is absorbed or released by matter.

Electrical - Energy associated with the position of a charge in an electric field; an electric charge is an excess or deficit of electrons on an object. .

Magnetic - Energy stored in a magnetic field. Magnetic fields can be created by the motion of electrical charges.

Different forms of POTENTIAL ENERGY

Review these definitions on your own . . .

HERE ARE SOME EXAMPLES →

ENERGY IN OUR EVERYDAY LIVES . . .

ENERGY: think of it as "stuff" that can't be created or destroyed, but can be converted in form. The form might be:

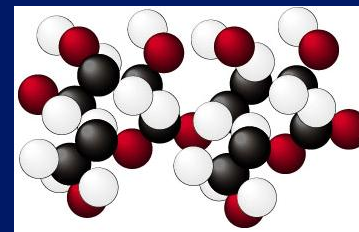
- **A MOVING MASS (KE)**
(a large truck going 80 mph)



- **AN ELEVATED MASS (PE)**
(a boulder poised on a hill)



- **A PARTICULAR CHEMICAL COMBINATION (PE)**



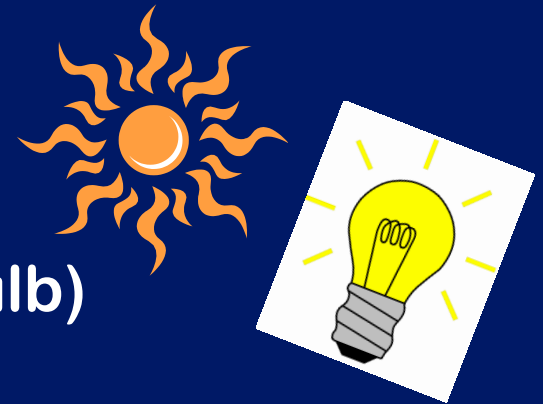
a Glucose molecule

ENERGY IN OUR EVERYDAY LIVES ...

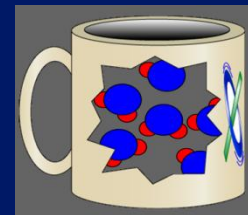
- **ELECTRICITY** (PE)
(electrons flowing through a wire)



- **LIGHT / ELECTROMAGNETIC ENERGY** (PE)
(solar radiation or light from a bulb)



- **HEAT / THERMAL ENERGY** (PE)
(energetic jiggling molecules in a hot substance)



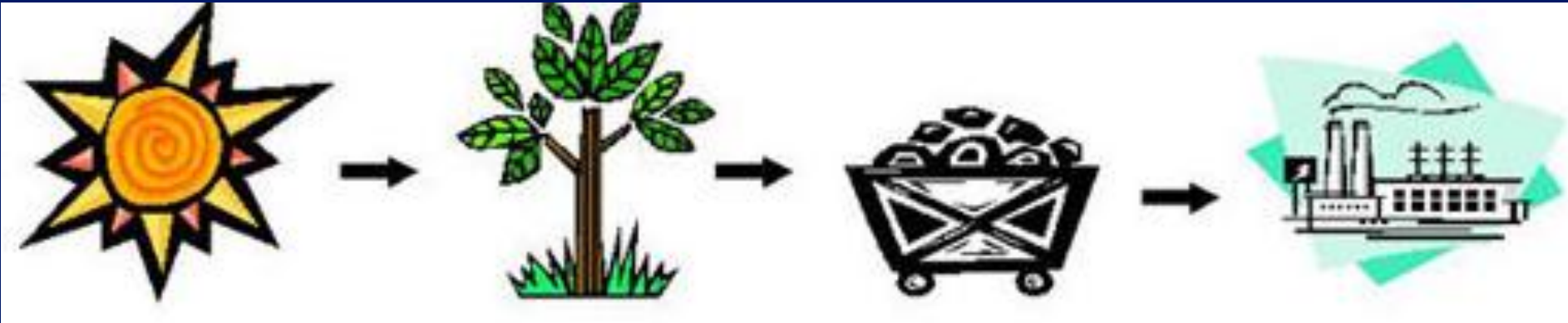
The Law of Conservation of Energy:

Energy cannot be created or destroyed.

*It can be transformed (converted)
from one form to another but*

**THE TOTAL AMOUNT OF ENERGY
NEVER CHANGES.**

KEY POINT FOR GLOBAL CLIMATE CHANGE: ENERGY IS CONVERTED FROM ONE FORM TO ANOTHER



The Sun produces Electromagnetic Energy

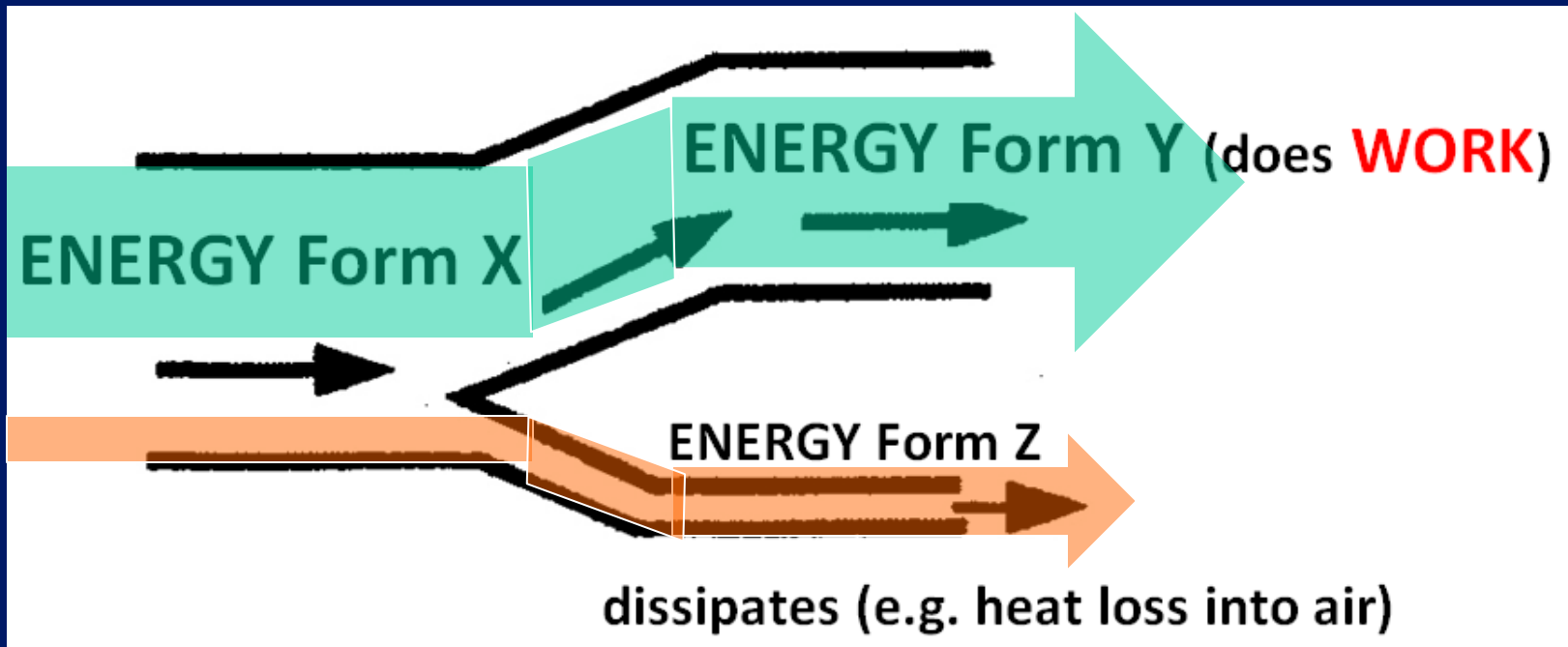
Plants turn the solar energy into Chemical Energy through photosynthesis

Plants are fossilized & compressed (over millions of years) and become Fossil Fuels such as coal and oil

Fossil fuels are burned in power plants to produce Electricity for our homes, businesses & industry

A KEY POINT: IN EVERY ENERGY CONVERSION . . .

- Some of it goes where you want it:



- Some goes elsewhere:
(usually as heat loss or “exhaust”)

Although energy may not be destroyed,
it can become **INEFFICIENT**

i.e., is not easily used or available to do work!

Efficiency = work done / energy used



*This concept is critically important for designing
successful **GREEN TECHNOLOGIES** & for mapping
out **SOLUTIONS** for addressing climate change*

To wrap up the matter
& energy section

RESPONSE TIME!

Clicker



**ENTER
CHANNEL = 28**

ResponseWare Device



Open your “APP” or
login to: rwpoll.com

**ENTER SESSION ID
(see above)**

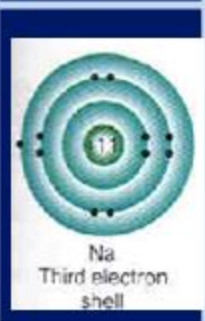
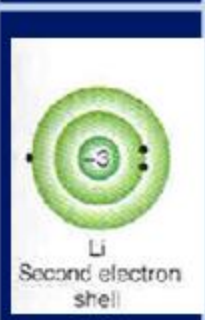
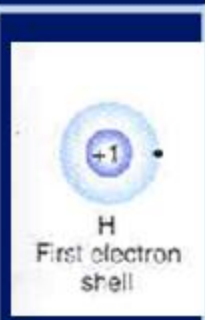


Q1. Where does Boron fit in the Table?

(Answer with a number from 1 – 7)

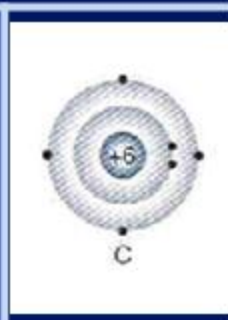
Hint – see electron configuration table on p 18

1

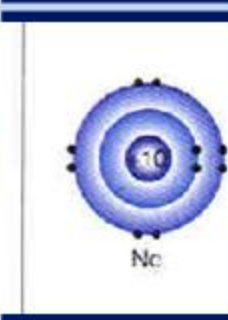
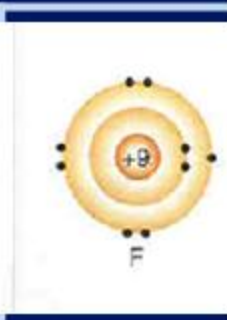
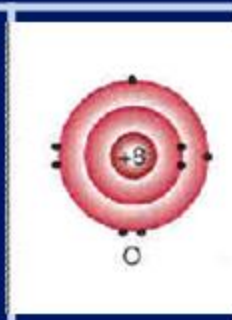


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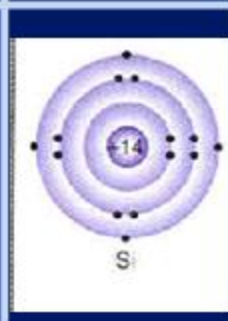


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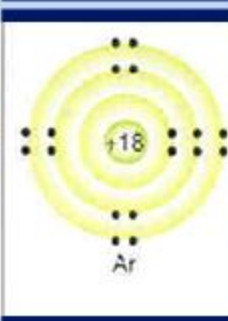
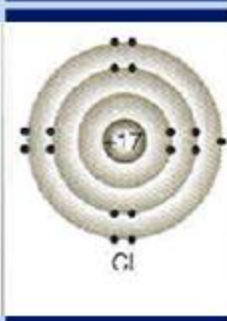
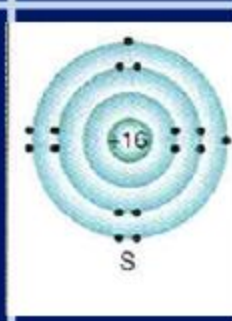


5

6



7



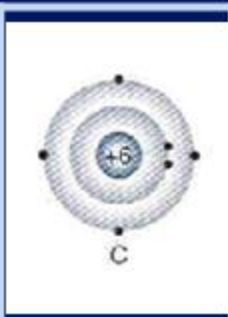
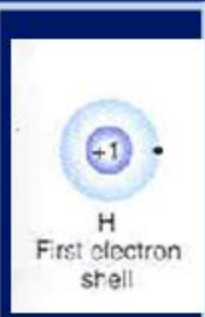
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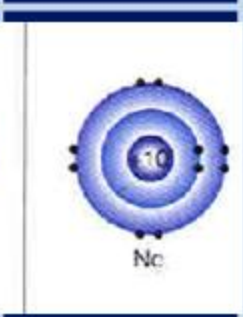
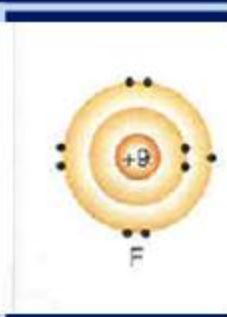
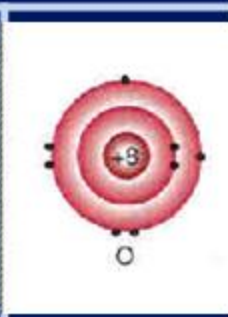
3 or "c" is correct!

(2 shells & 3 electrons in the outer shell)

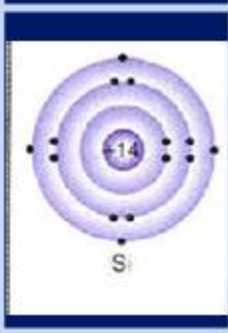
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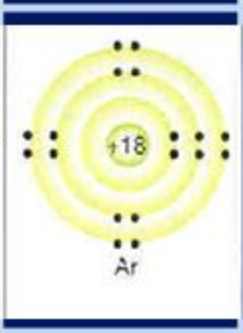
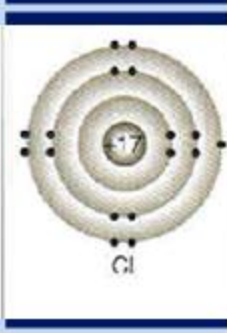
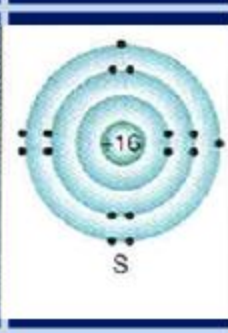
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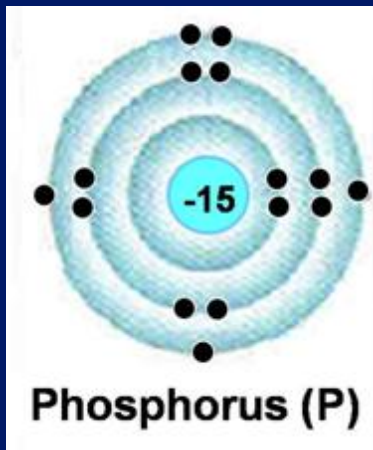
6



7



Q2. Where does Phosphorus fit in the Table?

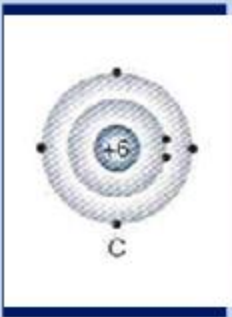


1

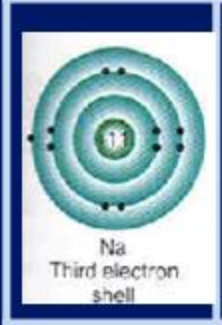
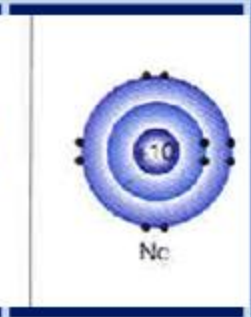
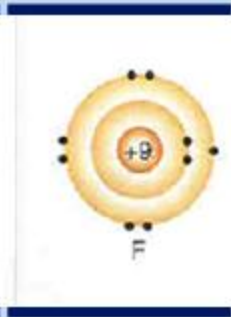
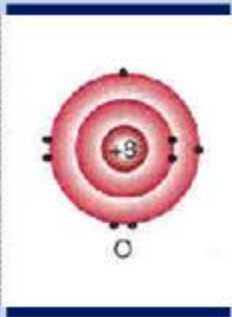


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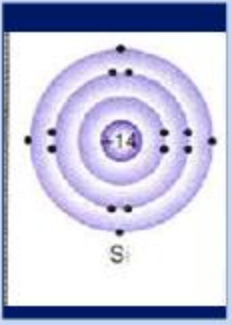


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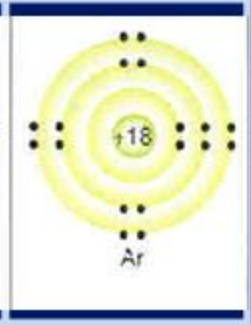
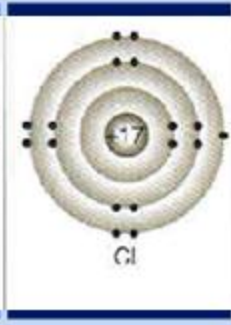
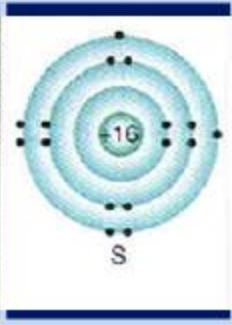


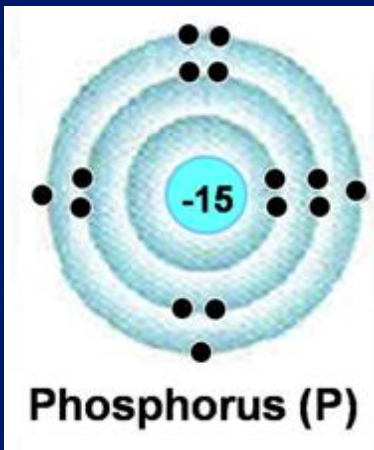
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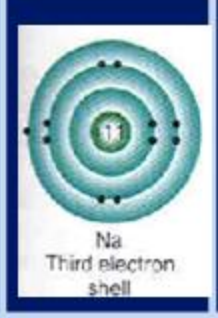
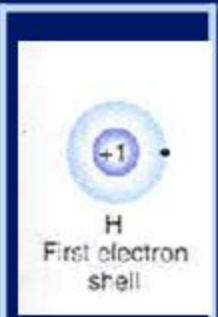


Q2. Where does Phosphorus fit in the Table?

7 or “g” **is correct!**

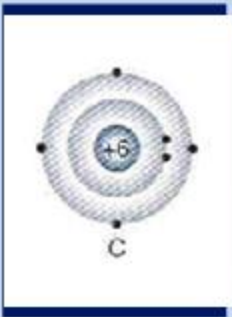
(3 shells & 5 electrons in the outer shell)

1

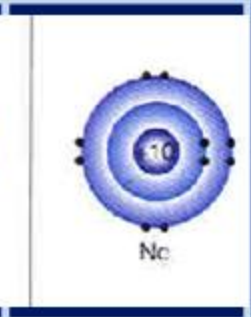
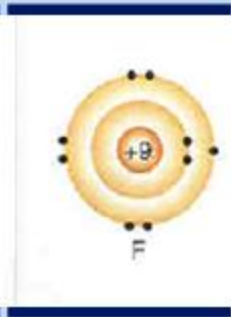
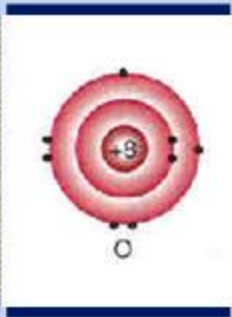


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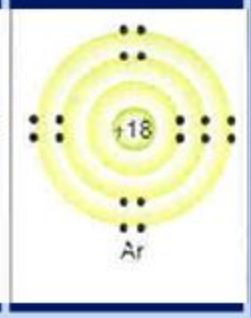
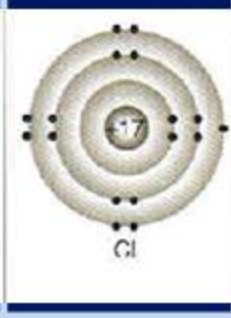
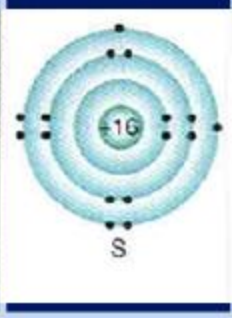
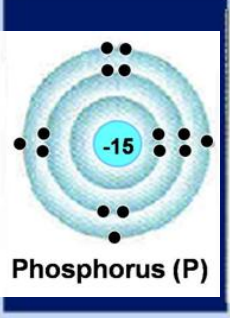
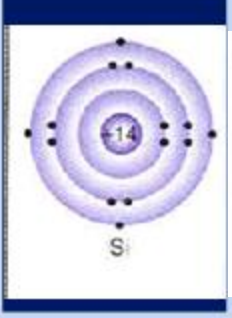


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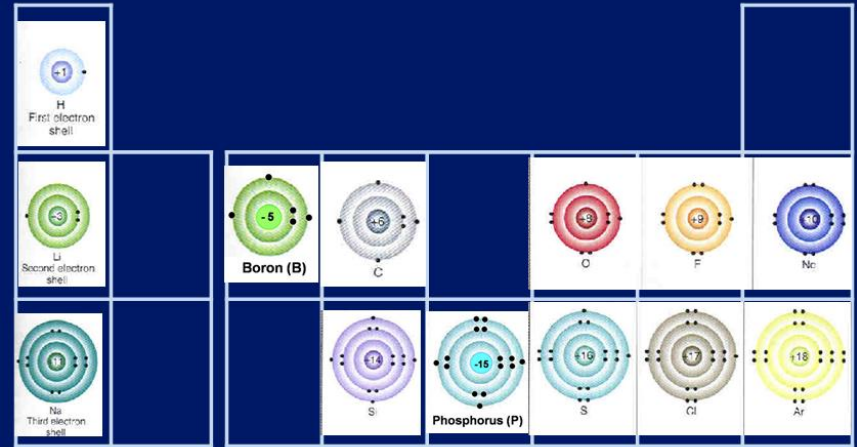
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6



HOW ARE MATTER & ENERGY RELATED?

Because each element
of matter has a
**unique set of electron
arrangements**
within its
ENERGY LEVELS ...

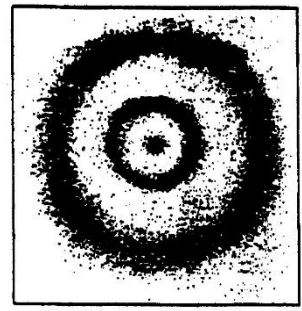


... each element is “attuned” to
**a unique, discrete set of
ENERGY “PULSES”**

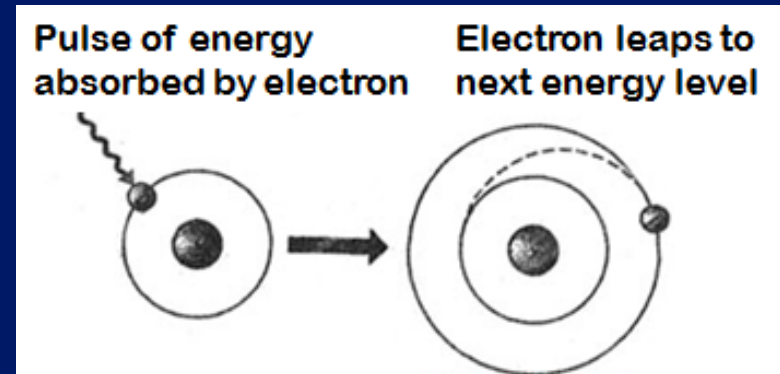
the Bohr
model of
an atom

The **quantum model** of the atom states:

electrons can exist only in discrete allowed energy levels and not in between.



Electrons move not by the “Laws of Motion” defined by Isaac Newton, but by “Quantum mechanics”



... When an electron **absorbs the exact (discrete) amount of energy** needed for the next energy level, it can make an instantaneous “**quantum leap**” from one energy level to the other

Anyone who says that they can
contemplate quantum mechanics
without becoming dizzy . . .

. . . has not understood
the concept in the least.

~ Niels Bohr

TOPIC # 4 ELECTROMAGNETIC RADIATION & THE ELECTROMAGNETIC SPECTRUM

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

Class Notes: pp 23-26



Objectives

- 1) Understand the key aspects of **ELECTROMAGNETIC RADIATION** and the **ELECTROMAGNETIC SPECTRUM** that most directly relate to **GLOBAL CHANGE!**
- 2) Learn how principles of **MATTER & ENERGY** tie into this
- 3) . . . and how they relate to one important Global Climate Change solution:
SOLAR POWER

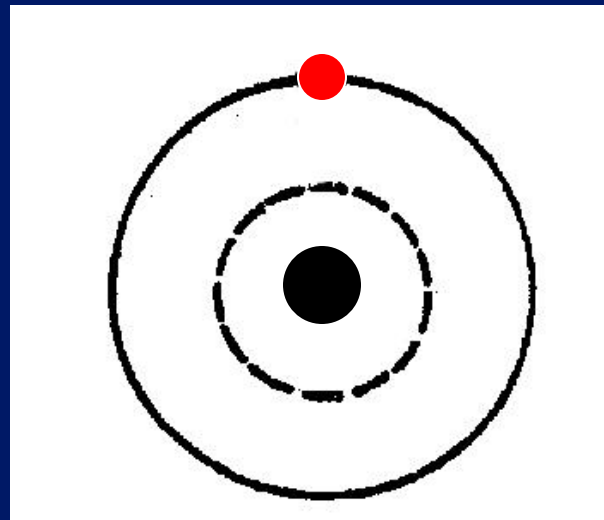
ELECTROMAGNETIC RADIATION

**Not only is the universe
stranger than we imagine, it is
stranger than we can imagine.
~Arthur Eddington**

An electron moves between energy levels by “quantum leaps,”

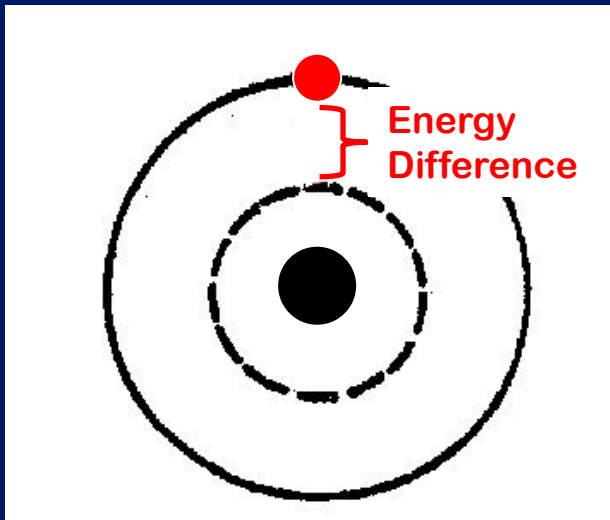
i.e., it disappears from one energy level and reappears in another without ever traversing any of the positions in between!

What causes the “leap” ?



Electrons make transitions (leaps) between the orbits (or energy levels) by:

absorbing or emitting energy



BUT: the energy absorbed or emitted has to be equivalent to exactly the energy difference

between the orbits for that atom!

The energy involved in the electron leaps
is called

ELECTROMAGNETIC ENERGY

It can be viewed either as:

pulses of energy traveling in **WAVES**
(of a specified wavelength and speed)

OR

as bundles of **particle-like energy**
called **PHOTONS**



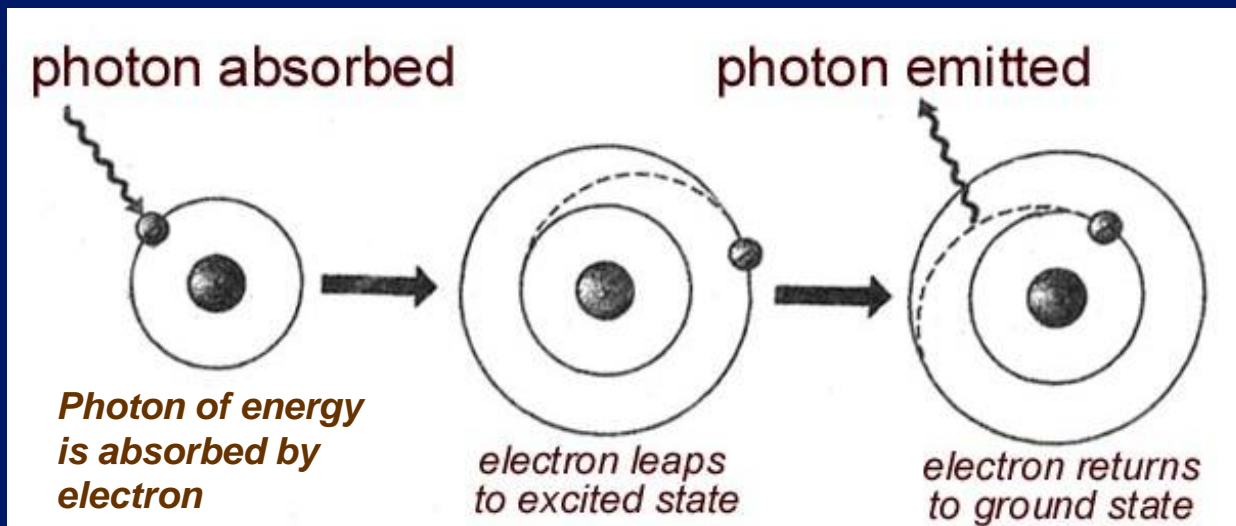
PHOTON =

A particle-like unit of electromagnetic energy (light), **emitted or absorbed** by an atom when an electrically charged electron changes state.

[can also be described as the form in which a single packet of **ELECTROMAGNETIC ENERGY** travels]

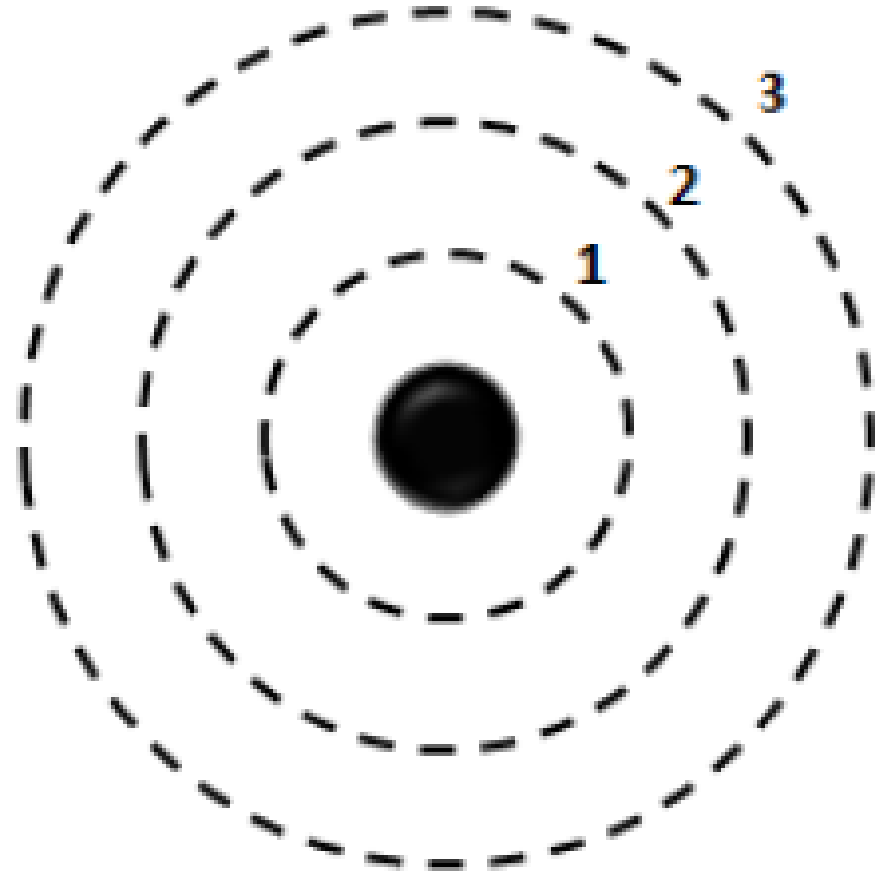
Photons, NOT protons!

The Quantum Behavior of Electrons in Atoms produces Electromagnetic Energy



Illustrate the **photon behavior** and **electron behavior** that takes place when a photon is *emitted* (given off) by an electron:

**Try it yourself
on page 24:**



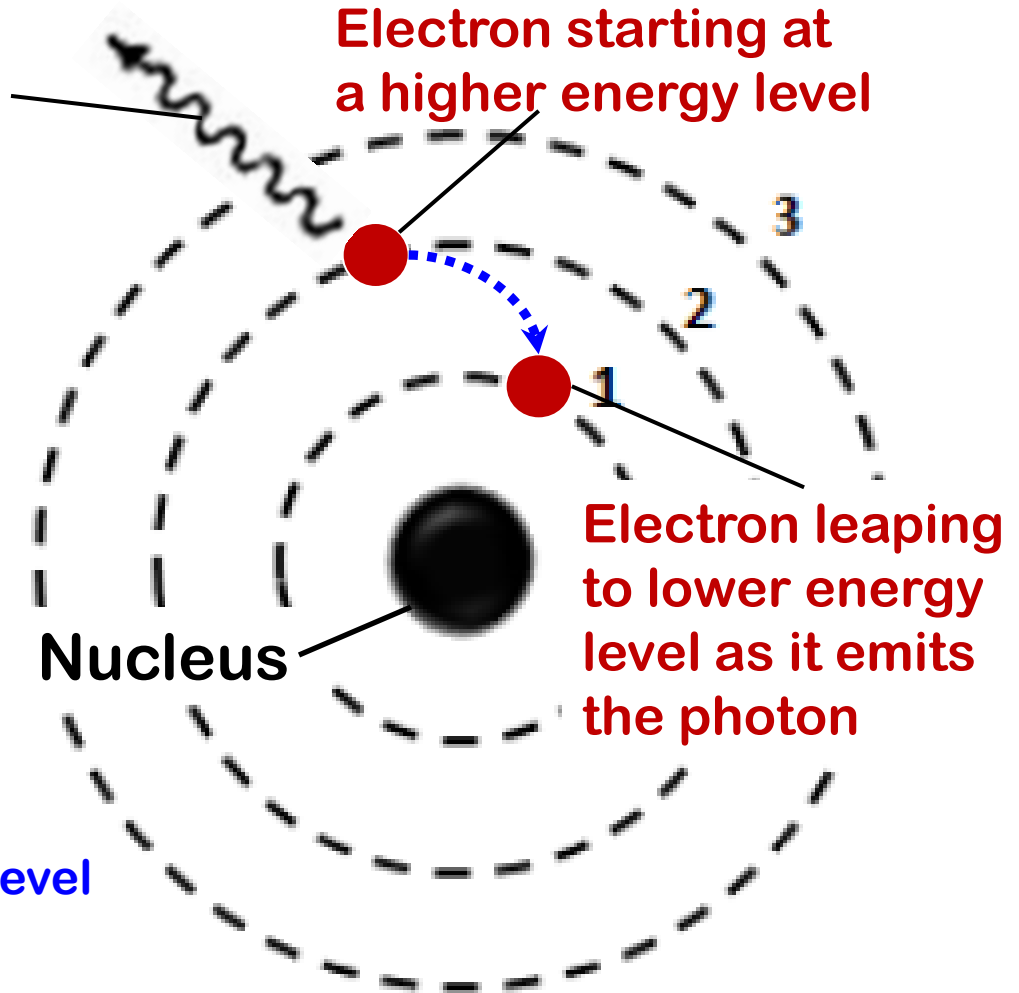
Illustrate the **photon behavior** and **electron behavior** that takes place when a photon is ***emitted*** (given off) by an electron:

Photon being emitted by electron

Electron starting at a higher energy level

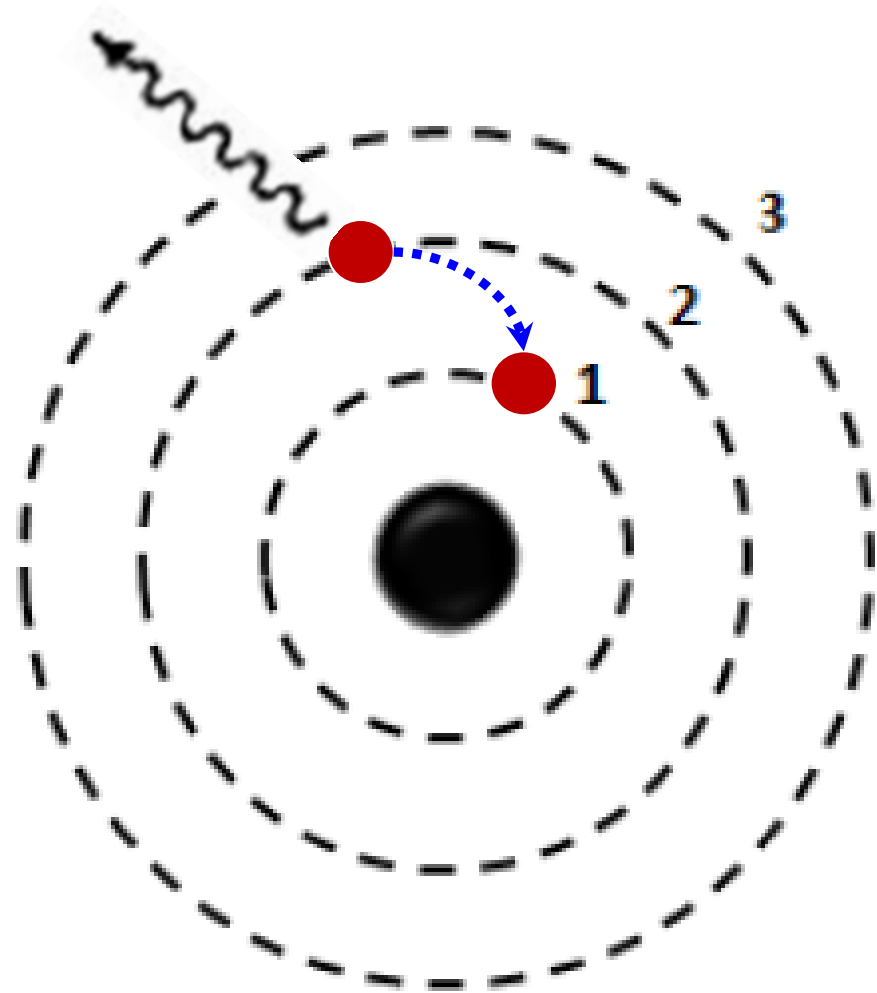
LABEL your sketch:

- Identify the names of the features in your diagram
- Explain what is happening to them:
 - being absorbed
 - being emitted
 - leaping to a lower/higher level



Illustrate the **photon behavior** and **electron behavior** that takes place when a photon is emitted (given off) by an electron:

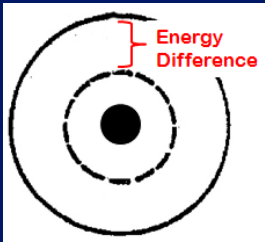
But
it all takes place
instantaneously!!



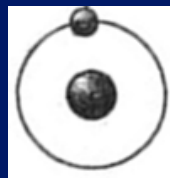
Could you do the sketch for a photon being absorbed by an electron?

RECAP: QUANTUM MECHANICS at the SUBATOMIC SCALE

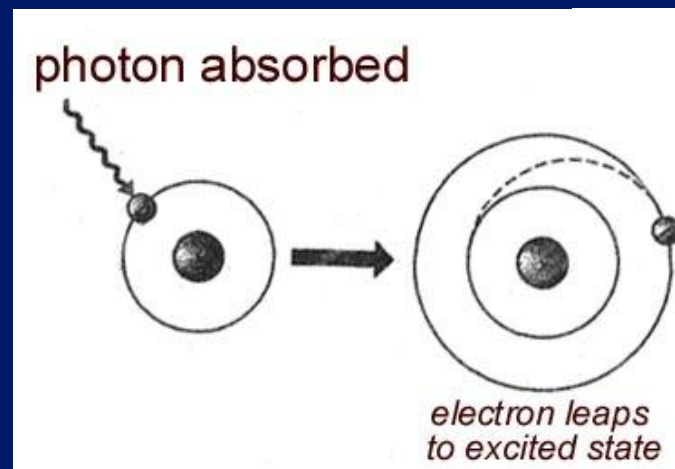
- If a photon of electromagnetic energy strikes an atom,
- and if the **FREQUENCY** of the electromagnetic radiation is such that it is equal to: the *difference* in the energy of the ground level & the first excited level,
- the electron **ABSORBS** the photon energy and . . .
- the electron makes a “quantum leap” to Level 2



Hydrogen atom:



with electron in
ground state
(Level 1 shell)



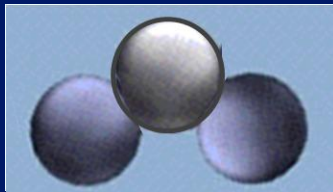


But what happens if **PHOTONS**
of electromagnetic energy
strike an entire MOLECULE ?
(not just a single atom)

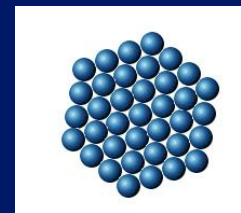


Quantum theory also involves the *behavior of molecules*:


as seen in their **molecular-scale
motions**:



rotation
bending
vibration



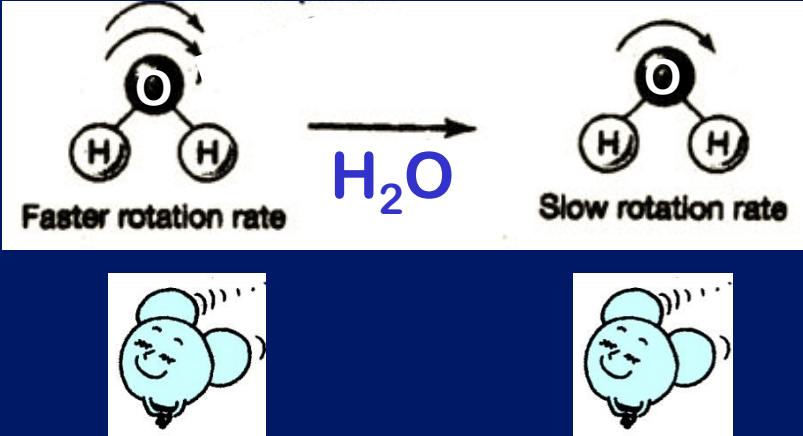
Infrared photons absorbed
by CO₂



Infrared photons emitted
by CO₂

The COMET Program

Infrared photon is emitted →



Faster rotation rate

H₂O

Slow rotation rate

LINK TO GLOBAL CHANGE:

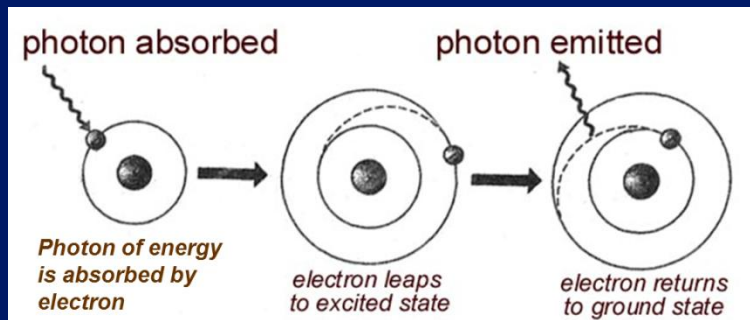
The type and frequency of molecular motions in gases like **CARBON DIOXIDE** and **WATER VAPOR** explain why THEY contribute to **The Greenhouse Effect** while other gases (O₂, N₂ ...) do not!!

(more on this later . . .)

Recap of Key Concept:

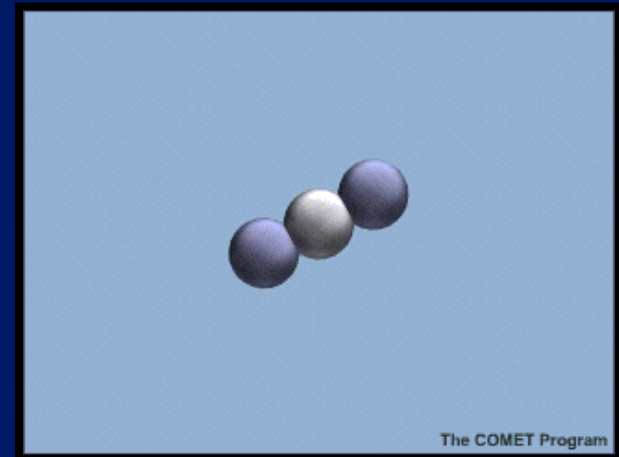
ENERGY & MATTER INTERACT !!!

within atoms



&

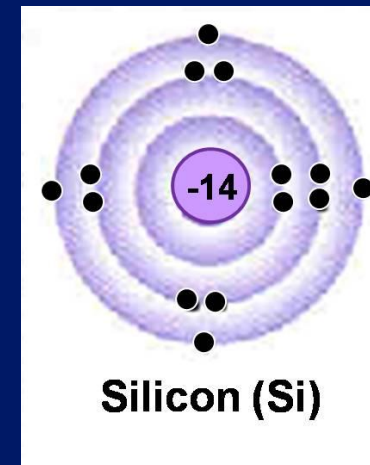
within molecules



PRESENTING A New Feature: The SUSTAINABILITY SEGMENT!!!



Staring:
The **SUN**
&



<http://www.pbs.org/wgbh/nova/solar/>

TOPIC # 4 (cont.)
THE ELECTROMAGNETIC
SPECTRUM

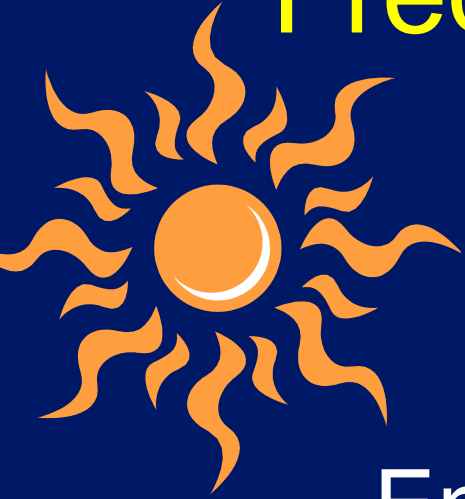
Class Notes:
pp 25-26

**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**

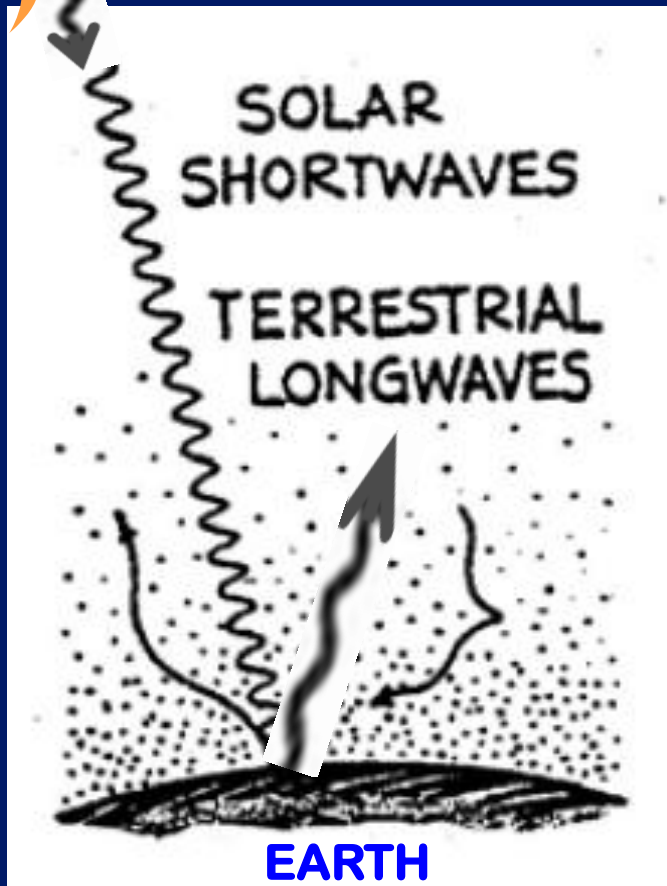


Figure on p 25

the
symphony of science

There's this tremendous mess

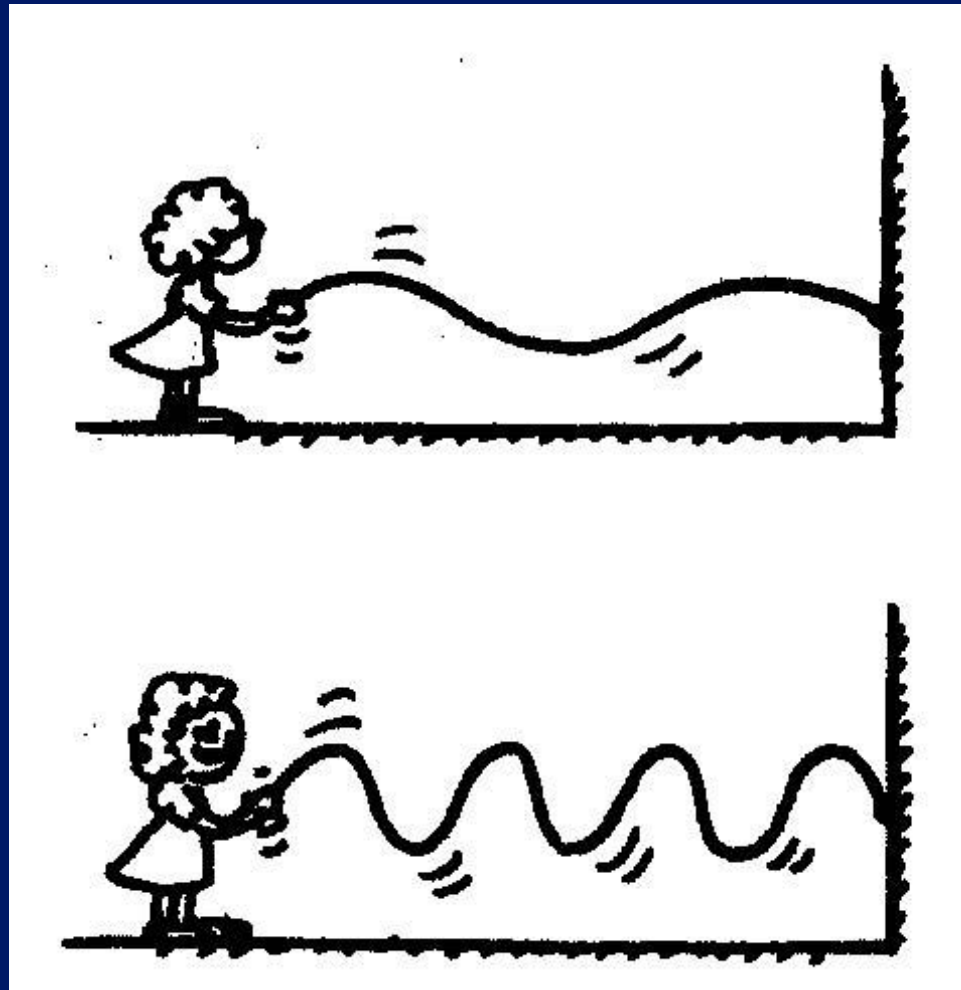
Of waves all over in space

Which is the light bouncing around the room

And going from one thing to the other

Richard Feynman, Quantum Physicist

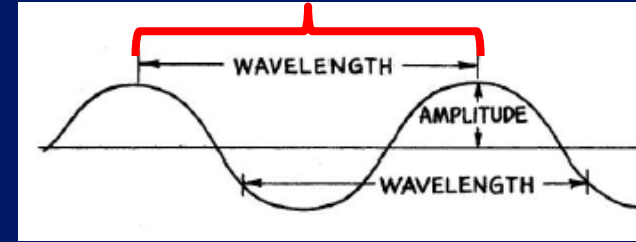
Wavelengths



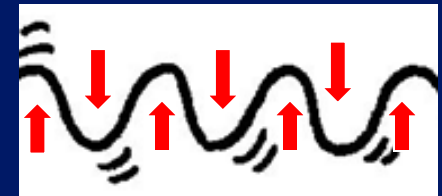
Quantifying Frequency & Wavelengths

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

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



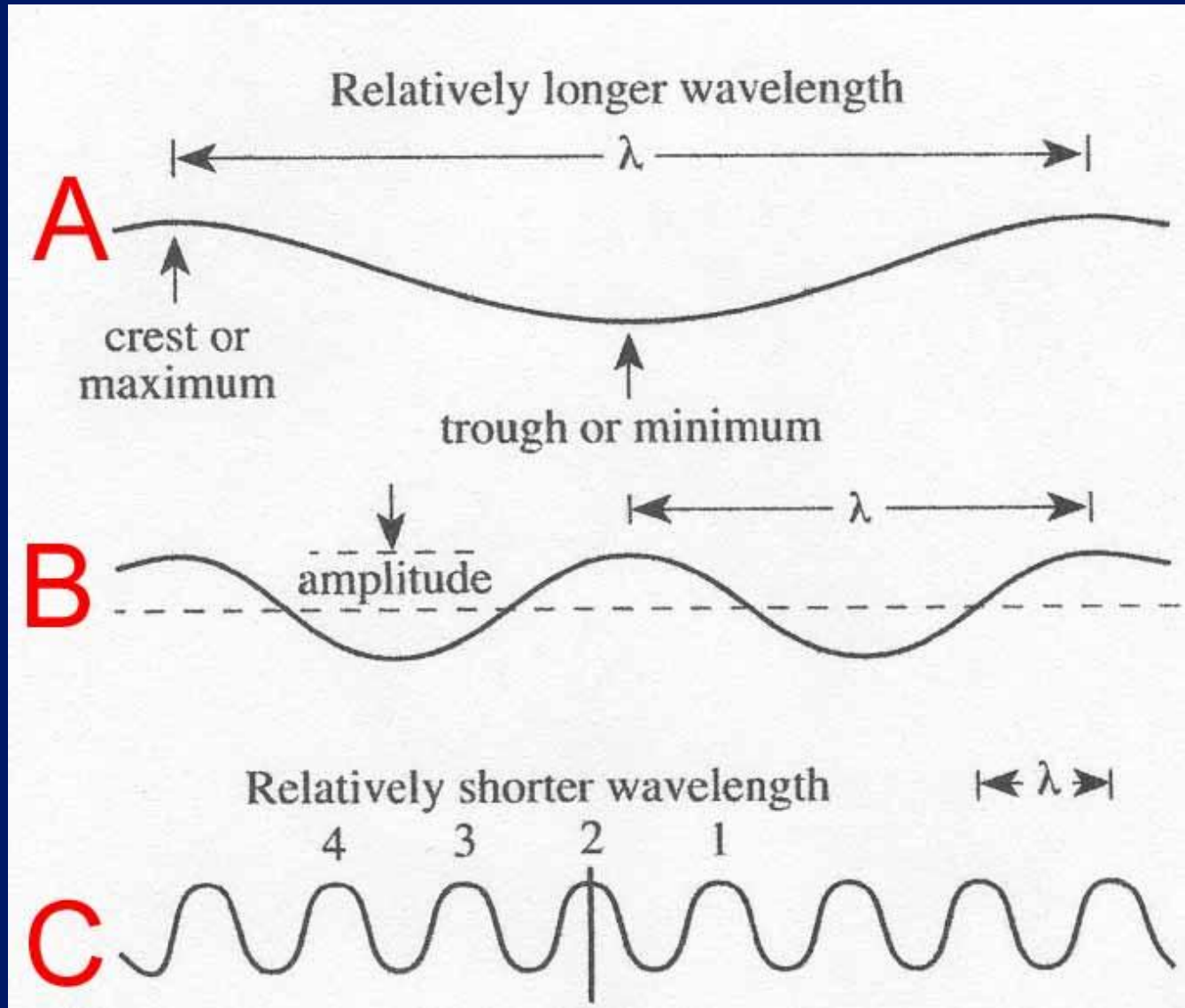
Frequency = how fast the crests move up and down
(symbol = **nu** ν in E-Text)



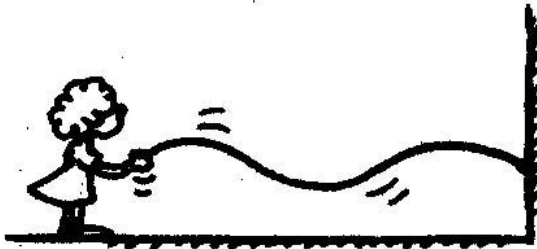
Speed = how fast the crests move forward
(symbol = **c** in E-text)
c = the speed of light



Another view:



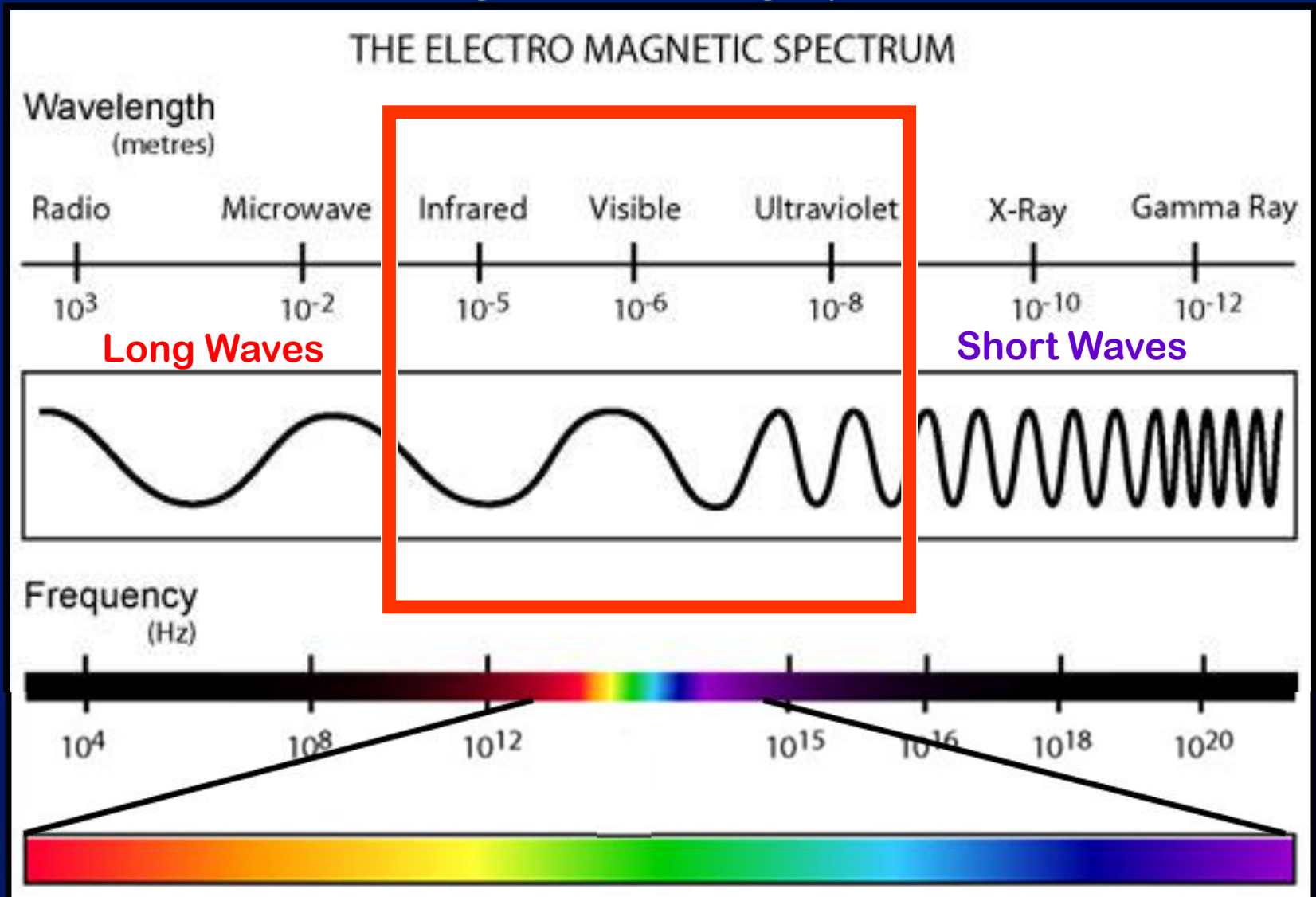
Wavelength & Frequency



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

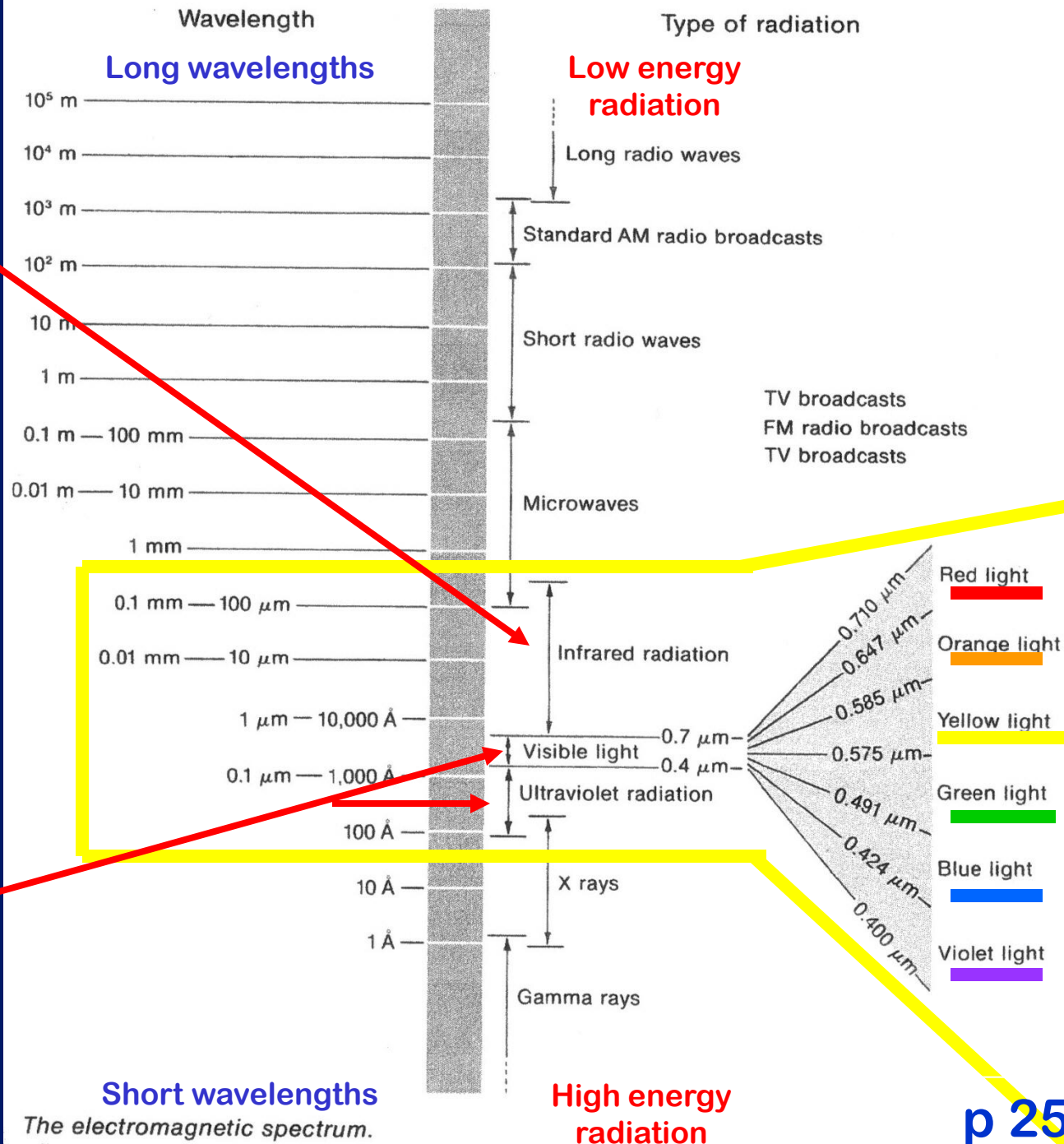
(I)

V

Longwaves (LW)

The Electromagnetic Spectrum (another view)

Shortwaves (SW)



Another (flipped) view:

Typical Sources That Send out Waves at This Frequency:

High energy radiation

Processes by protons and neutrons in atomic nuclei

Electrons in atoms, high-energy processes

Electrons in atoms, low-energy processes

Thermal vibrations of molecules

Microwave oven
Radar antenna

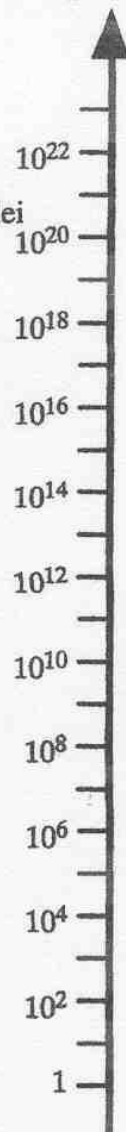
FM radio, TV antenna

AM radio antenna

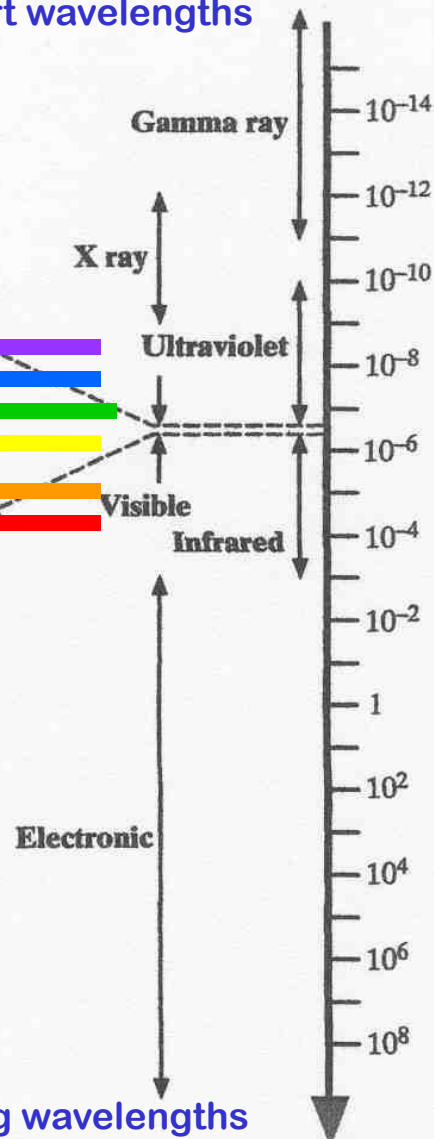
60-Hz power-line radiation

Low energy radiation

Frequency, Hz



Short wavelengths



Long wavelengths

Typical Object Whose Size Is the Same as This Wavelength:

Nucleus
TINY

Atom

DNA molecule
Amoeba

Fine dust particle

Millimeter
Centimeter

Meter


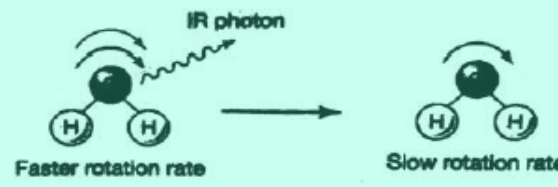
Soccer field
Kilometer

Earth

HUGE

Wavelength, m

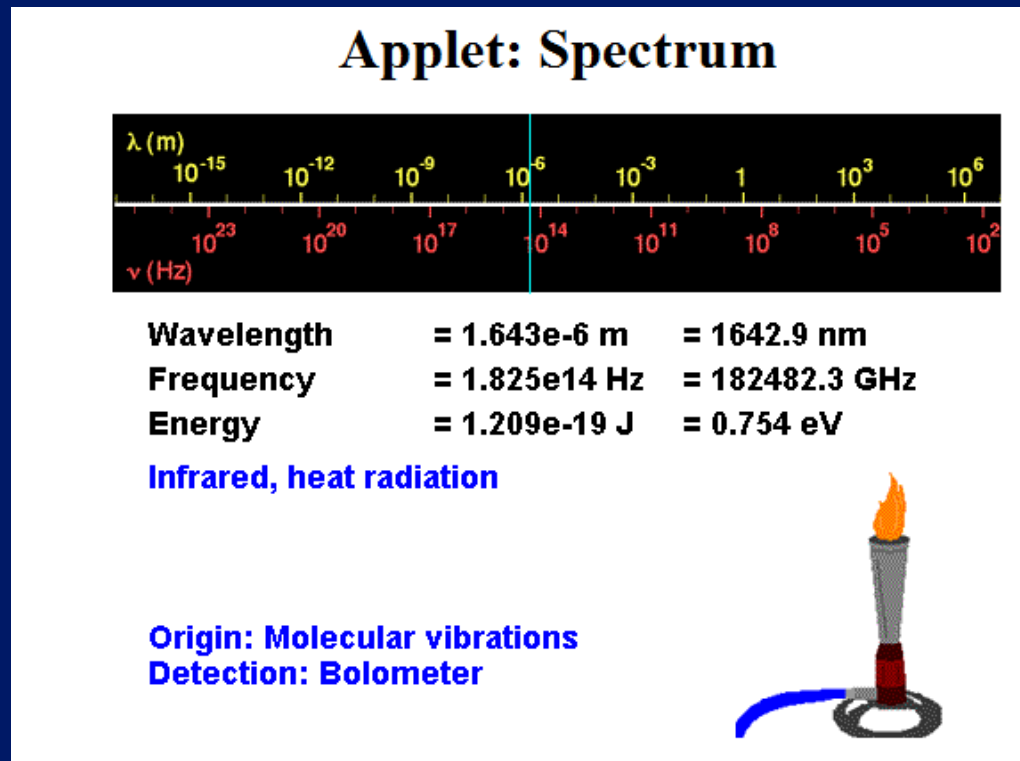
What are the “sources” of different wavelengths of electromagnetic radiation?

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 <u>within a nucleus</u> caused by the strong force
UV Ultraviolet radiation UVC .20 - .29 UVB .29 - .32 UVA .32 - .40	.0001 to 0.4 in micrometers (μm)	Involve electrons moving (quantum leaps) <u>within atoms</u> 
VIS Visible light Solar	0.4 to 0.7 in micrometers (μm)	
IR Infrared radiation	0.7 to ~30 (up to 1000) in micrometers (μm)	Involve chaotic thermal <u>kinetic motion of molecules</u> due to their thermal energy 
IR Near Infrared radiation	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

Neat website . . Check it out!

ELECTROMAGNETIC SPECTRUM JAVA APPLET:

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



The following slides were covered very quickly at the end . . . and we ran out of time.

Read them here now!

We'll review them again on Thursday.

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 ?

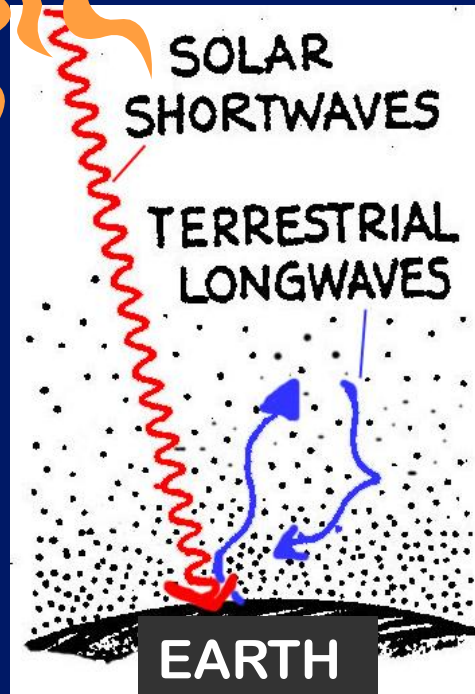
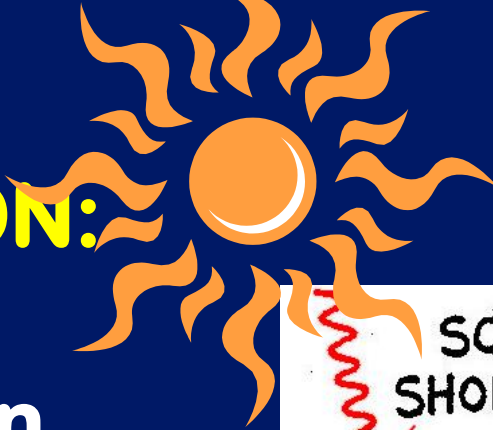
KEY CONCEPT #2:

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)

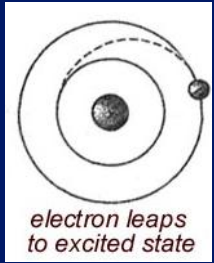


EARTH RADIATION:
entirely in **LONG** wavelengths
(low energy & frequency)

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



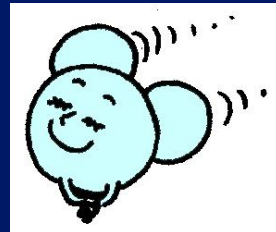
Photons + ATOMS vs Photons + MOLECULES



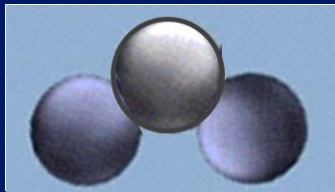
The quantum leap of electrons:
takes place WITHIN an ATOM between
discrete energy levels (shells) when
photons are absorbed or emitted . . .

but

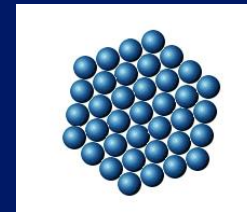
Quantum theory also involves
the *behavior of molecules*



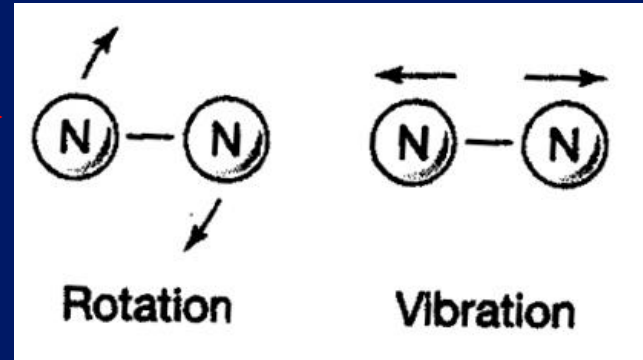
When **some molecules** absorb and emit **certain wavelengths** of electromagnetic energy they bend, rotate, and spin in a specific way



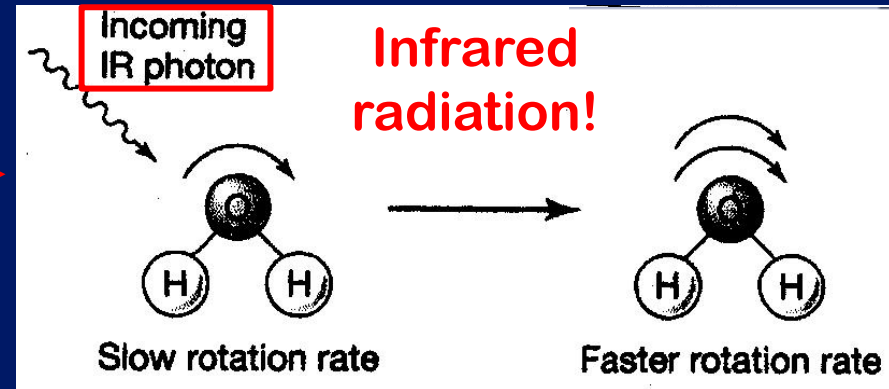
rotation
bending
vibration



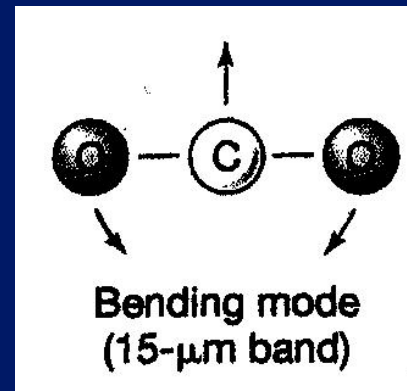
NITROGEN GAS
MOLECULE
 N_2



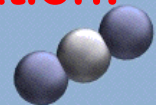
WATER VAPOR
MOLECULE
 H_2O



CARBON
DIOXIDE GAS
MOLECULE
 CO_2



Infrared
radiation!



The COMET Program

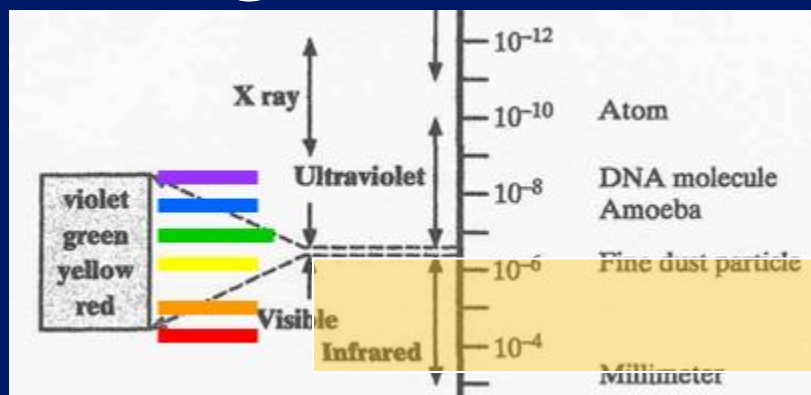
Greenhouse gases!

Figures on p 24

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!!

Tuesday Sep 9th

Re-cap of ANNOUNCEMENTS

- **Assignment I-1** is due tonight before midnight (11:59 pm)
- **RQ-2** is now posted and is due Thursday Sep 11th (30 minutes before class.)
- **TEST #1** is one week from today on **TUESDAY Sep 16th**

The “TOP TEN THINGS TO STUDY” study guide is **NOW** posted in D2L – includes this week’s classes.
(INFO about a STUDY SESSION on Monday TBA later)

- **FYI: The CLASS will sit in assigned GROUPS → for the first time in THURSDAY’S CLASS !**
(Your groups details will be given in class Thursday)

