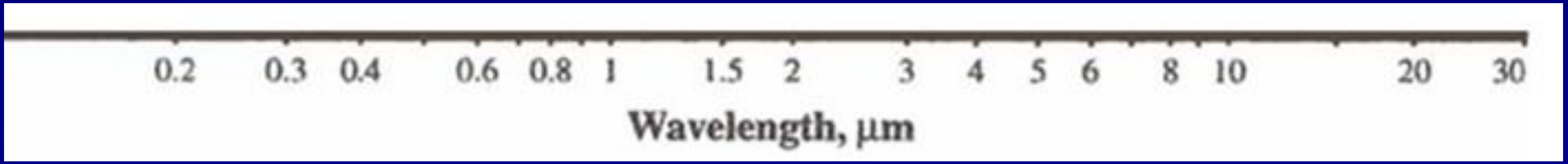
TOPIC 5 (cont.)
RADIATION LAWS - Part 2

Quick review
ELECTROMAGNETIC SPECTRUM

Our focus in this class is on: **UV – VIS – IR**



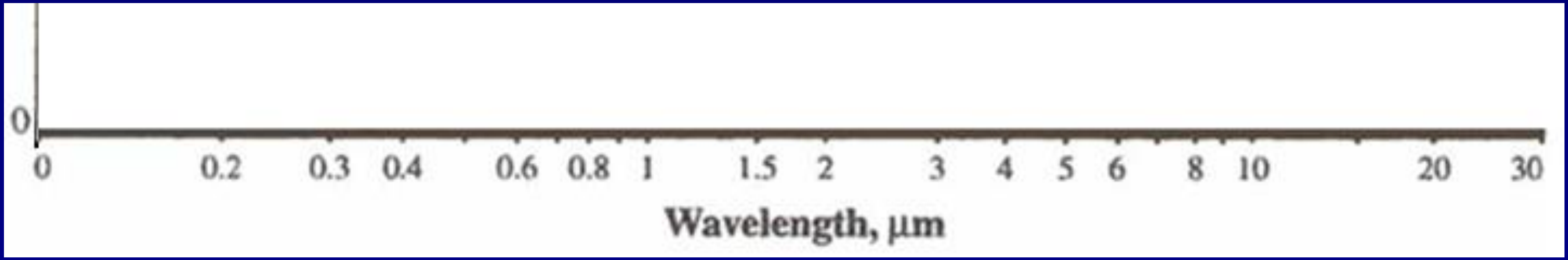
μm = micrometers *(aka microns)*

nm = nanometers *(also commonly used)*

$$1\ \mu m = 1000\ nm$$

$$1\ nm = 10^{-3}\ \mu m$$

Q1. The first thing you should do when you are given a graph with **WAVELENGTHS (λ's)** on the horizontal axis is . . .



A) Panic

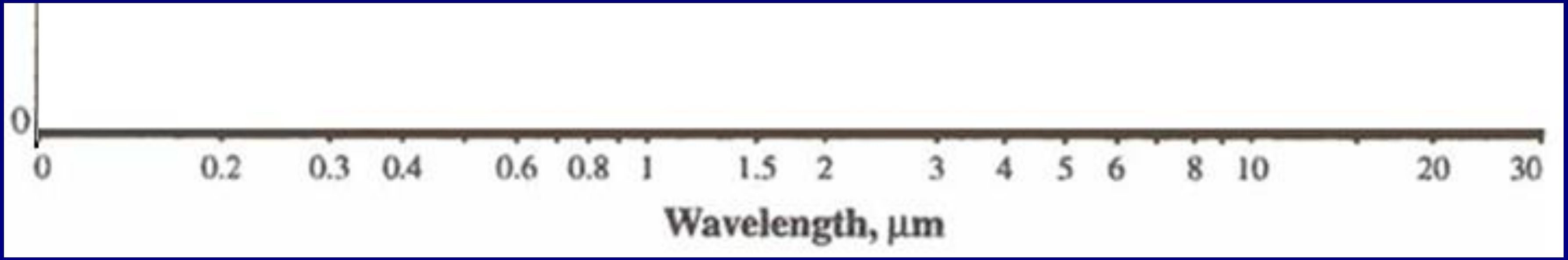
B) Convert micrometers to nanometers

C) Find & mark the range of visible light λ's

D) Label areas of UV, Visible, and IR λ's

E) First C, then D

Q1. The first thing you should do when you are given a graph with **WAVELENGTHS (λ's)** on the horizontal axis is . . .



A) Panic

B) Convert micrometers to nanometers

C) Find & mark the range of visible light λ's

D) Label areas of UV, Visible, and IR λ's

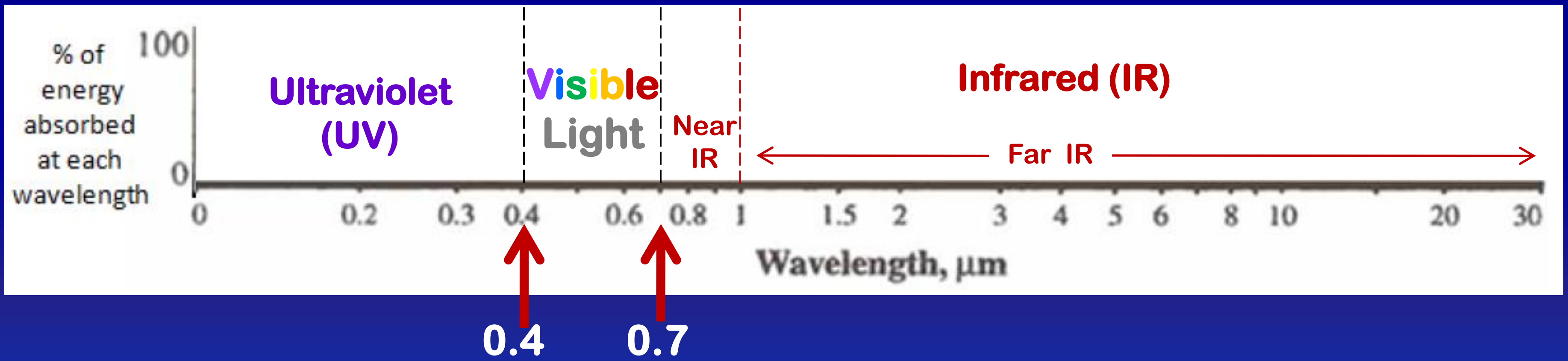
E) First C, then D

The first thing you should do when you are given a graph with **WAVELENGTHS (λ's)** on the horizontal axis is . . .

Find & mark 0.4 – 0.7 μm **= Visible light**

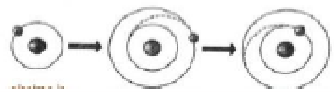
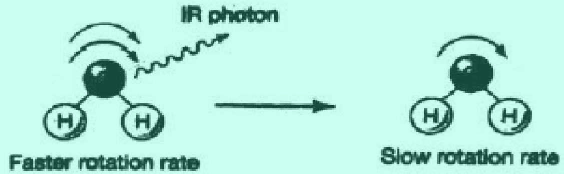
(400 – 700 nm)

Then label **UV – VIS – IR** regions on it!



Understand these details on the spectrum

& <u>memorize</u> Visible Light range = 0.4 – 0.7 μm

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	.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	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

"Shortwave" Solar

"Longwave" Infrared

GROUP Q's COMING UP . . . .

COUNT OFF
#1 through #4
at your table
&
REMEMBER YOUR NUMBER!

GROUP Q

Q2. What type of radiation is MISSING in the Table on p 22?

(It's a type of radiation that you've probably absorbed at some point . . .)

Student #3 answers for the Group!

More Q's?

30 second TABLE CHAT

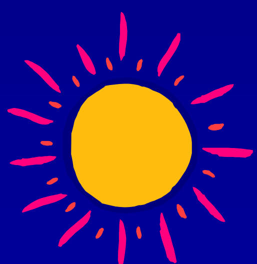
Come up with a group question!

OBJECTIVES FOR TODAY'S CLASS:

Continue

THE RADIATION LAWS

to understand the key differences between

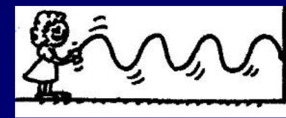


Solar radiation

&

Terrestrial radiation

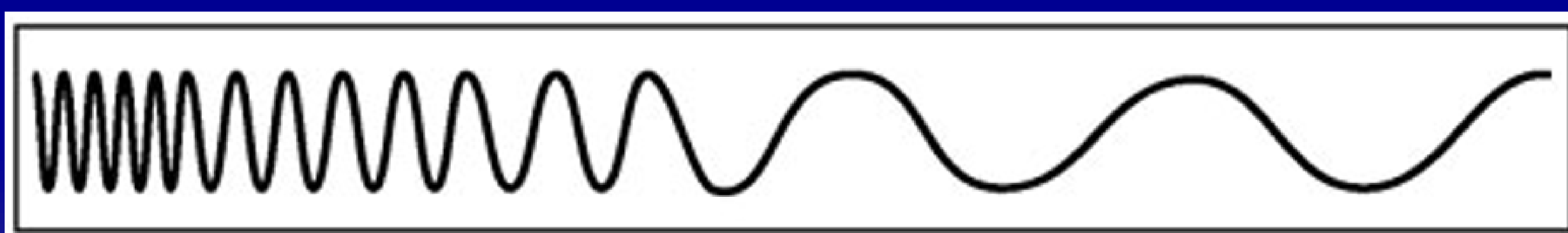
KEY CONCEPT #1:



More ENERGY → Higher FREQUENCY

Energy E is **directly** proportional to **frequency** ν

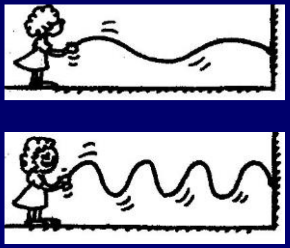
$$E \propto \nu$$



Higher energy **Lower energy**

Review

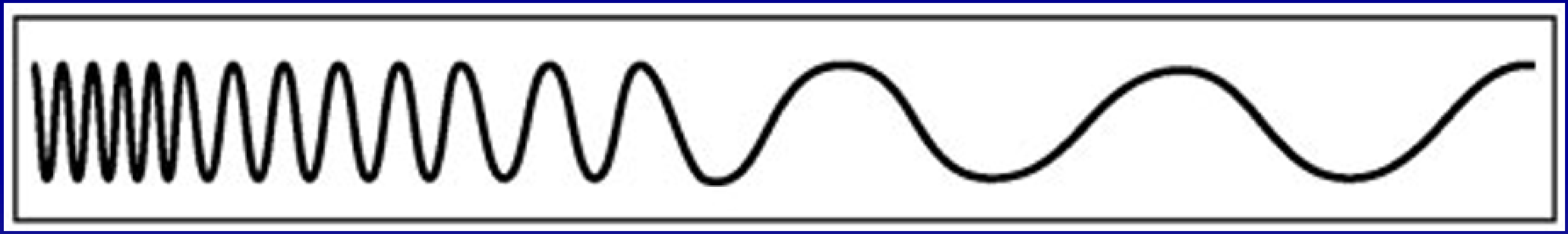
KEY CONCEPT #2:



More ENERGY → Shorter WAVELENGTHS

Energy E is inversely proportional to wavelength λ

$$E \propto c / \lambda$$



Higher energy

Lower energy

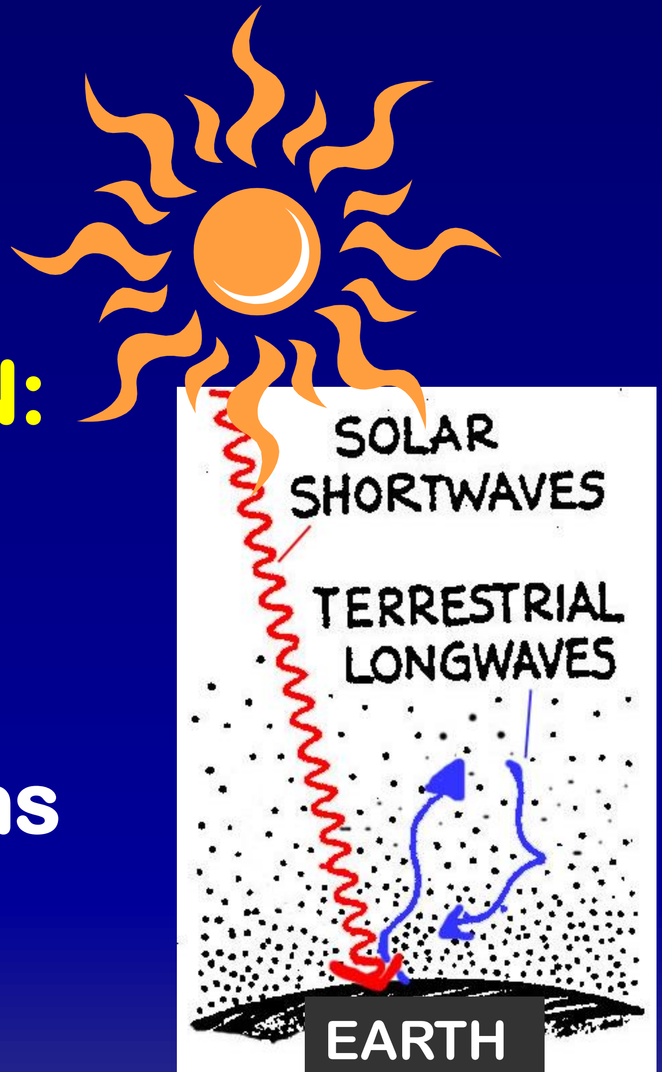
Review

APPLICATION TO REAL WORLD:

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

➔ high E

➔ high frequency



EARTH RADIATION:

entirely in **LONG** wavelengths

➔ low E
➔ low frequency

Review

TOPIC # 5 Part 1 Recap:

What are the 3 Laws?

Law # 1 ?

Law # 2 $E = h\,c\,/\,\lambda$

Law # 3 $E = \sigma T^4$

#2 Planck Function Law: $E = hc / \lambda$

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

#3 Stefan-Boltzmann Law: $E = \sigma T^4$

"The higher the temperature, the (much) GREATER the **amount** of energy"

GLOBAL CHANGE LINK

30 Sec
GROUP Q:

Q. Which LAW (#1, #2, or #3) do you think is <u>especially</u> important for scientists studying the effects of Global Climate Change?

<u>WHY!</u>

Student # 4 speaks . . .

ON TO THE NEXT RADIATION LAW . . .

Law # 4

☺

LAW # 4: Temperature and wavelength

As substances get HOTTER, the wavelength at which radiation is emitted will become SHORTER.

This is called Wien's law.

Wien's Law can be represented as:

$$\lambda_m = a/T$$

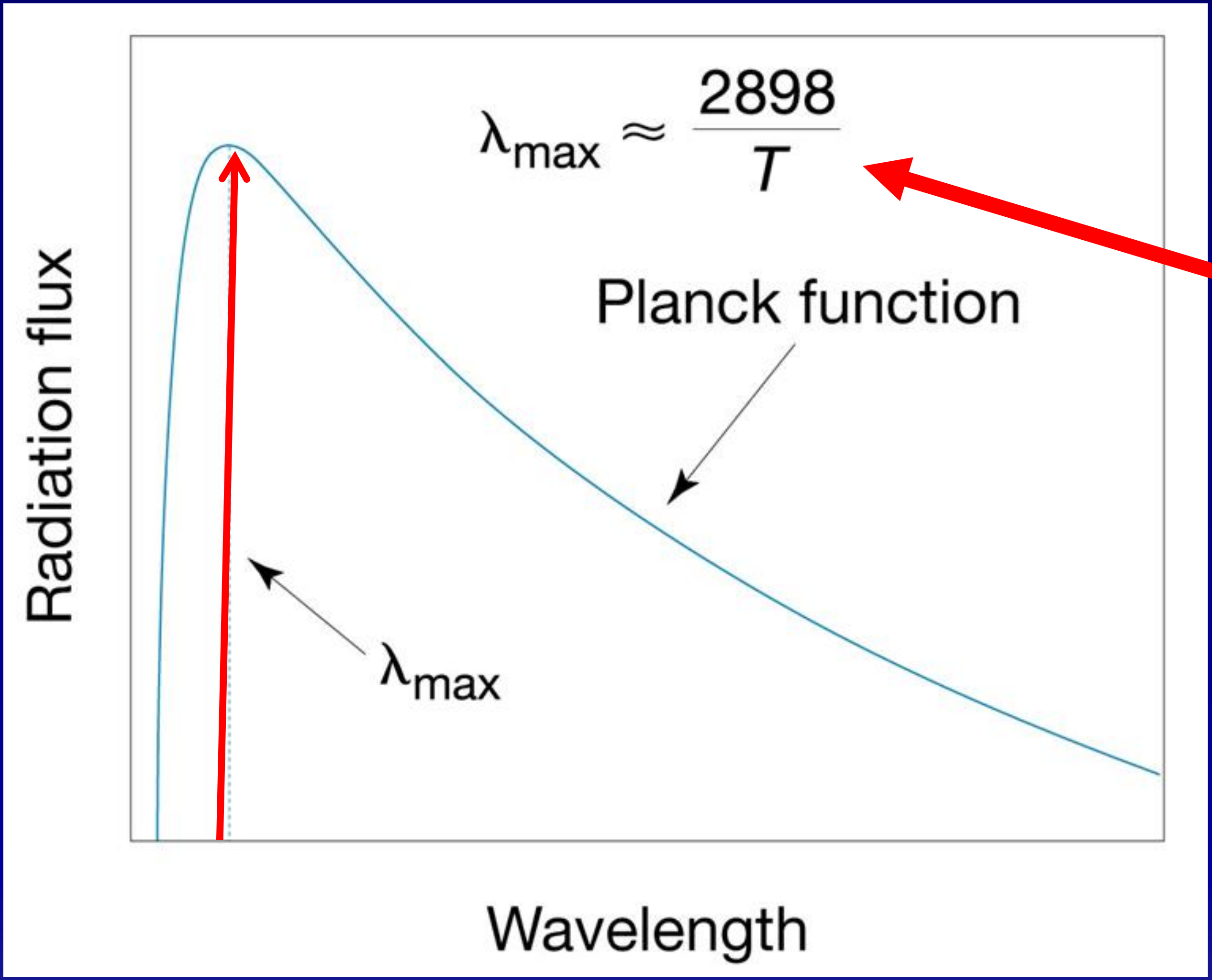
where λ_m is the WAVELENGTH in the spectrum at which the energy peak occurs

(m indicates "max" or peak)

T is the absolute TEMPERATURE of the body

a is a constant (with a value of 2898)

(if λ_m is expressed in micrometers.)



Note the INVERSE relationship between wavelength and temperature

See figure on p 42 in SGC

Wien's Law (easy way)

λ_{max} = constant / T

(Inverse relationship between wavelength and temperature)

"The hotter the body, the shorter the wavelength"

"The cooler the body, the longer the wavelength"

Wein's Law:

"I'm HOT, so I emit my maximum amount of radiation at SHORTER wavelengths"

SW = visible (VIS) & ultraviolet (UV)

"I'm COOL, so I emit my maximum amount of radiation at LONGER wavelengths"

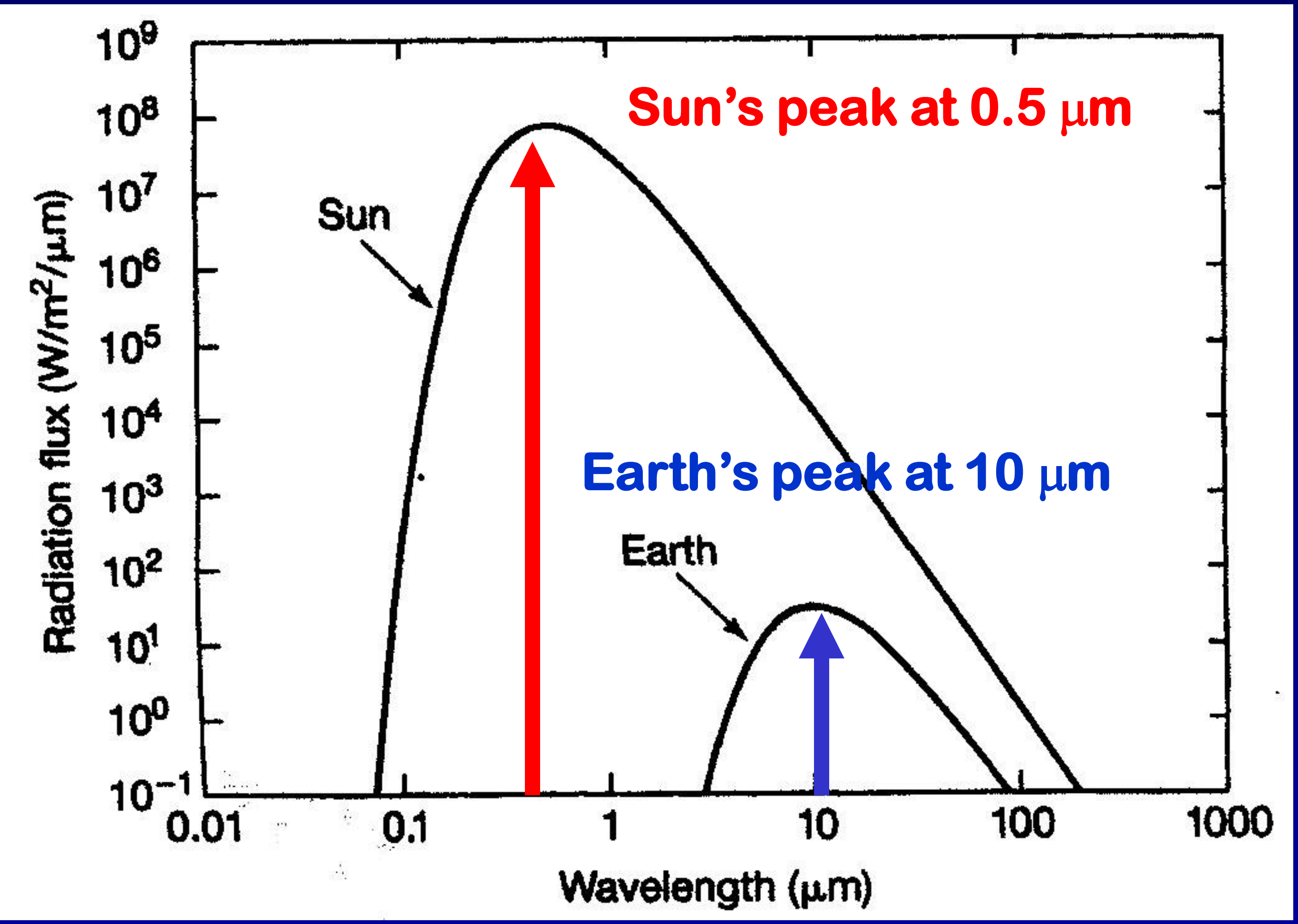
LW = infrared (IR)

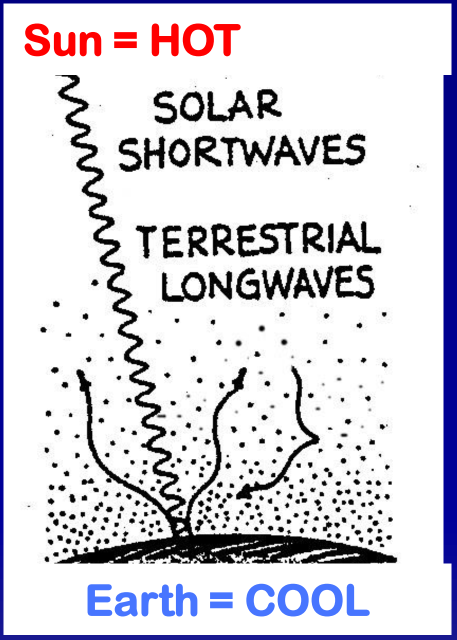
Wien's Law -- Why is this concept important?

Because it means that **very HOT objects** (like the sun) that radiate like blackbodies will radiate the maximum amount of energy at **SHORT wavelengths**,

while **COOLER** bodies will radiate most of their energy at **LONGER wavelengths.**

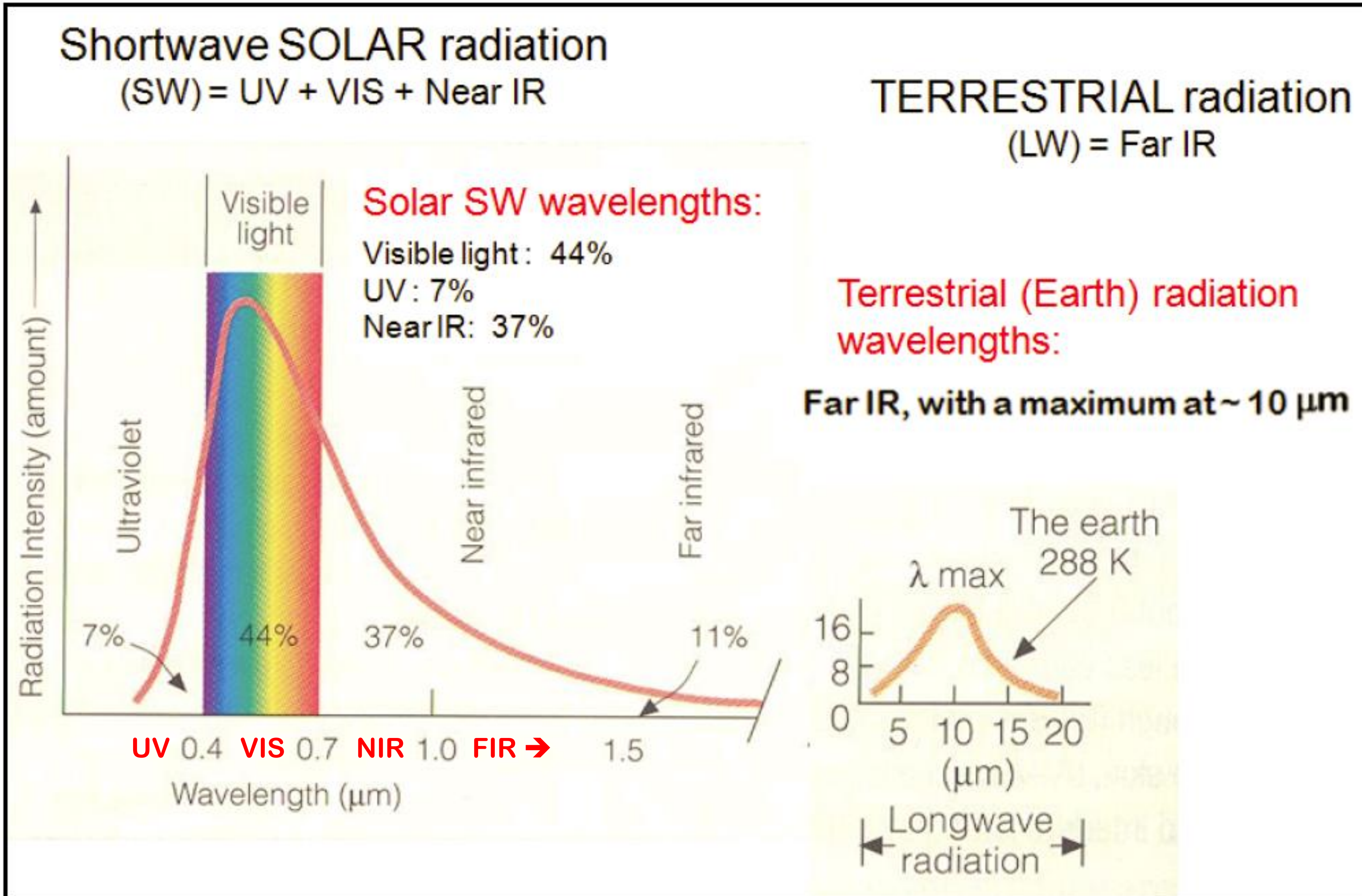
Wein's is the law behind this cartoon (back on p 21)



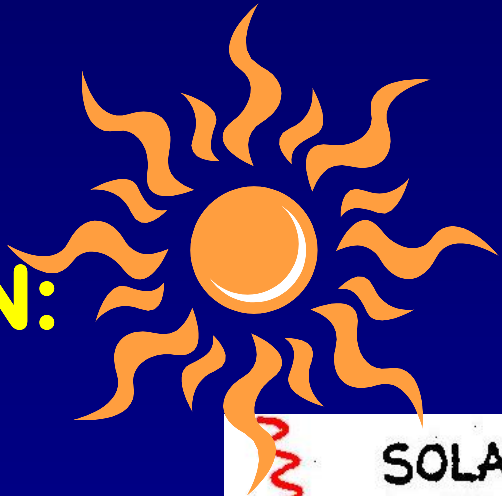


NOTE: the logarithmic scale . . . values **increase exponentially** to the right

Another view of the same concept:

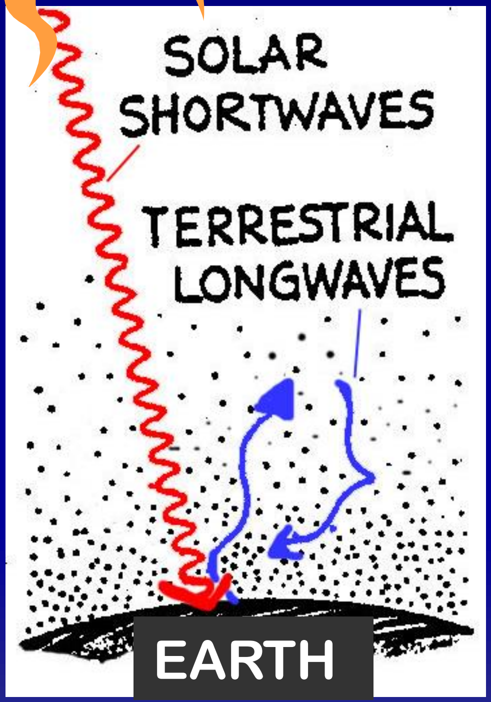


APPLICATION TO REAL WORLD:



SOLAR RADIATION: greatest intensity in <u>SHORT</u> wavelengths

high E
high frequency
<u>hotter T's</u>



EARTH RADIATION: entirely in <u>LONG</u> wavelengths

low E
low frequency
<u>cooler T's</u>

Re-cap of Laws # 2 - 4

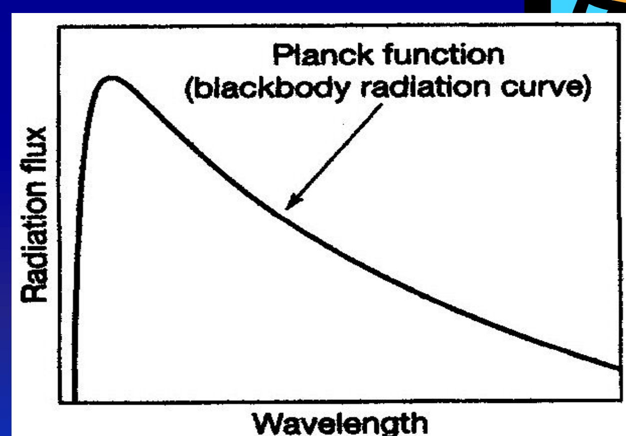
☺

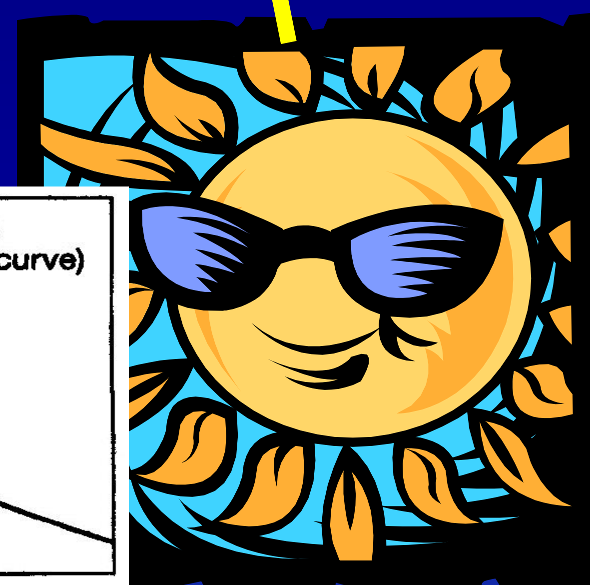
Planck Function:

$$E = h\,c\,/\,\lambda$$

The Sun can emit energy at ALL wavelengths, but the amount of energy emitted is inversely related to its wavelength.

> **"I radiate at the speed of light like a blackbody; most of my energy is emitted at shorter wavelengths "**





Stefan-Boltzmann Law:

$$E = \sigma T^4$$

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

"I'm COOL, so I emit LESSER amounts of energy; *plus* my ENERGY is at a lower intensity"

Wein's Law: $\lambda_m = a / T$

"I'm HOT, so I emit my maximum amount of radiation at <u>SHORTER</u> wavelengths"

SW = visible & ultraviolet (UV)

"I'm COOL, so I emit my maximum amount of radiation at <u>LONGER</u> wavelengths"

LW = infrared (IR)

☺

Match each equation with the correct phrase below & fill in the name of the LAW . . . .

(a) $E = \sigma T^4$ (b) $E = hc/\lambda$ (c) $\lambda_m = a/T$

"The hotter the body, the shorter the wavelength"
The cooler the body, the longer the wavelength"

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

"SHORTER wavelengths have HIGHER intensity radiation than LONGER wavelengths"

DO IT INDIVIDUALLY on Top of p 25 then check w/ group

OK, take a MEDIA <u>MINUTE</u> !

ANSWER!

Match each equation with the correct phrase below & fill in the name of the LAW . . . .

(a) $E = \sigma T^4$ (b) $E = hc/\lambda$ (c) $\lambda_m = a/T$

(c) "The hotter the body, the shorter the wavelength"
The cooler the body, the longer the wavelength"

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

(b) "SHORTER wavelengths have HIGHER intensity radiation than LONGER wavelengths"

On to the last two laws . . . .

#5 and #6

LAW #5: Radiation & distance -- the inverse-square law

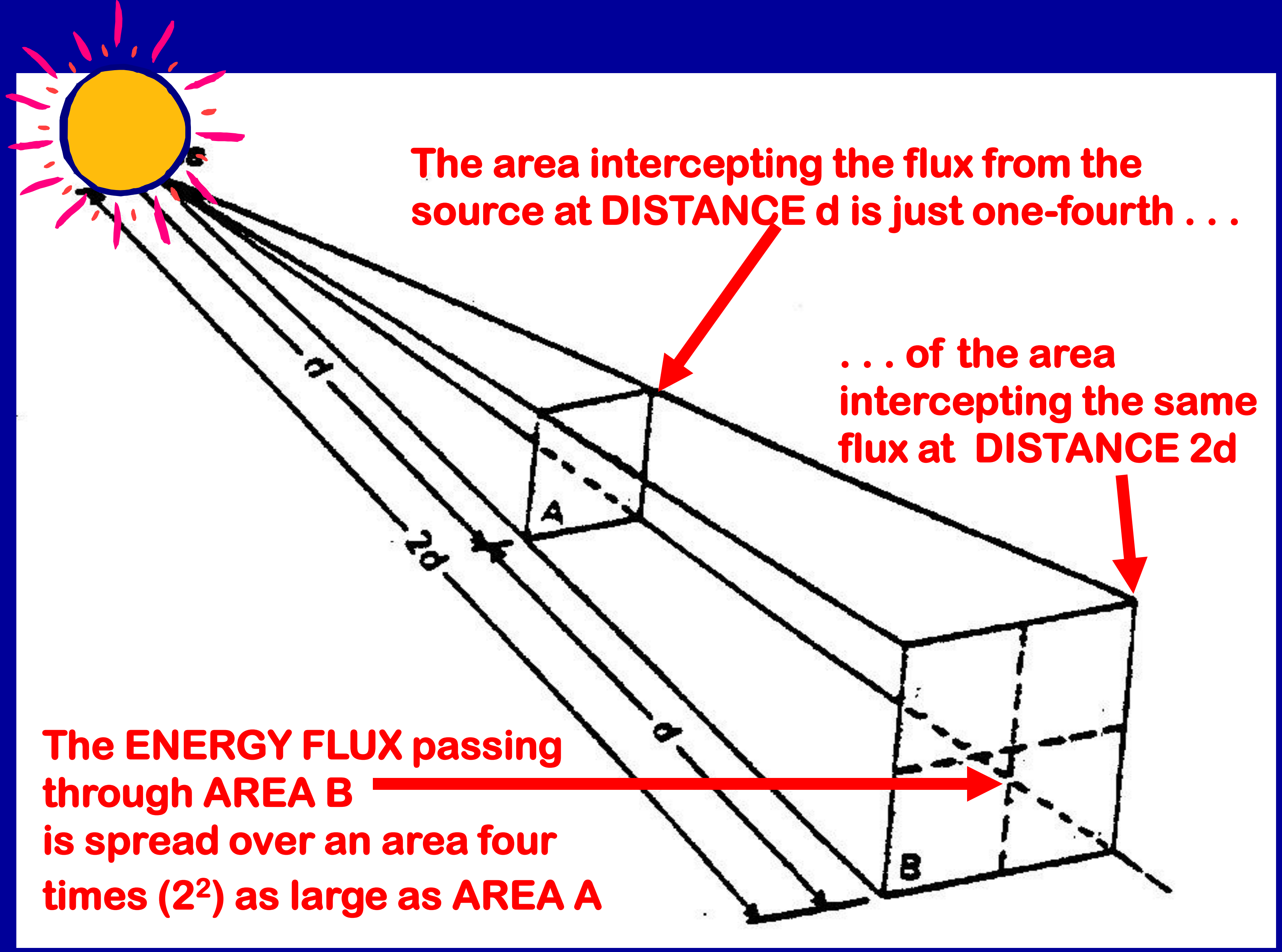
The inverse square law describes:

how the FLUX of ENERGY from a source (like the Sun) DECREASES with increasing DISTANCE from the source

USING A FLASHLIGHT APP
ON YOUR PHONE
DEMO THIS LAW !!

What did you observe?

(Student # 3 answers!)


The area intercepting the flux from the source at DISTANCE d is just one-fourth . . .
. . . of the area intercepting the same flux at DISTANCE 2d
The ENERGY FLUX passing through AREA B is spread over an area four times (2^2) as large as AREA A
d
2d
d
A
B
S

INVERSE SQUARE LAW =

The amount of radiation passing through a particular unit area is:

INVERSELY PROPORTIONAL

to the

SQUARE of the distance

of that unit area from the source

$$(1/d^2)$$

Inverse-Square Law (easy way):

If we <u>double</u> the distance from the source to the interception point, the intensity of the radiation <u>decreases</u> by a factor of

$(1/2)^2 = 1/4$

OR

If we <u>triple</u> the distance from the source to the interception point, the intensity <u>decreases</u> by a factor of

$(1/3)^2 = 1/9$ . . . . etc, etc.

☺

OR

if we reduce the distance from the source to the interception point by a factor of 2 or 3, the intensity of the radiation increases by a factor of

$2^2 = 4$

or

$3^2 = 9$

. . . etc, etc.

☺

Why is this concept important?

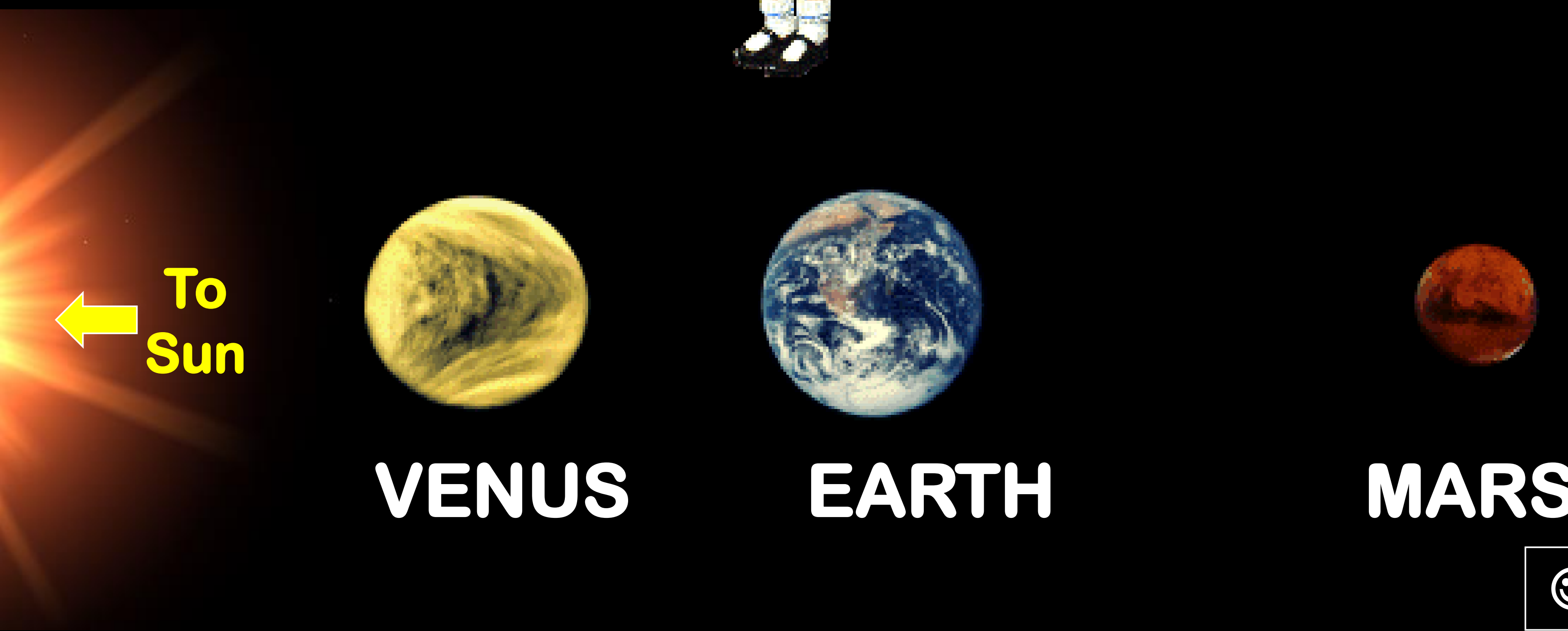
THINK . . . .
Then discuss with your group!

Why is this concept important?

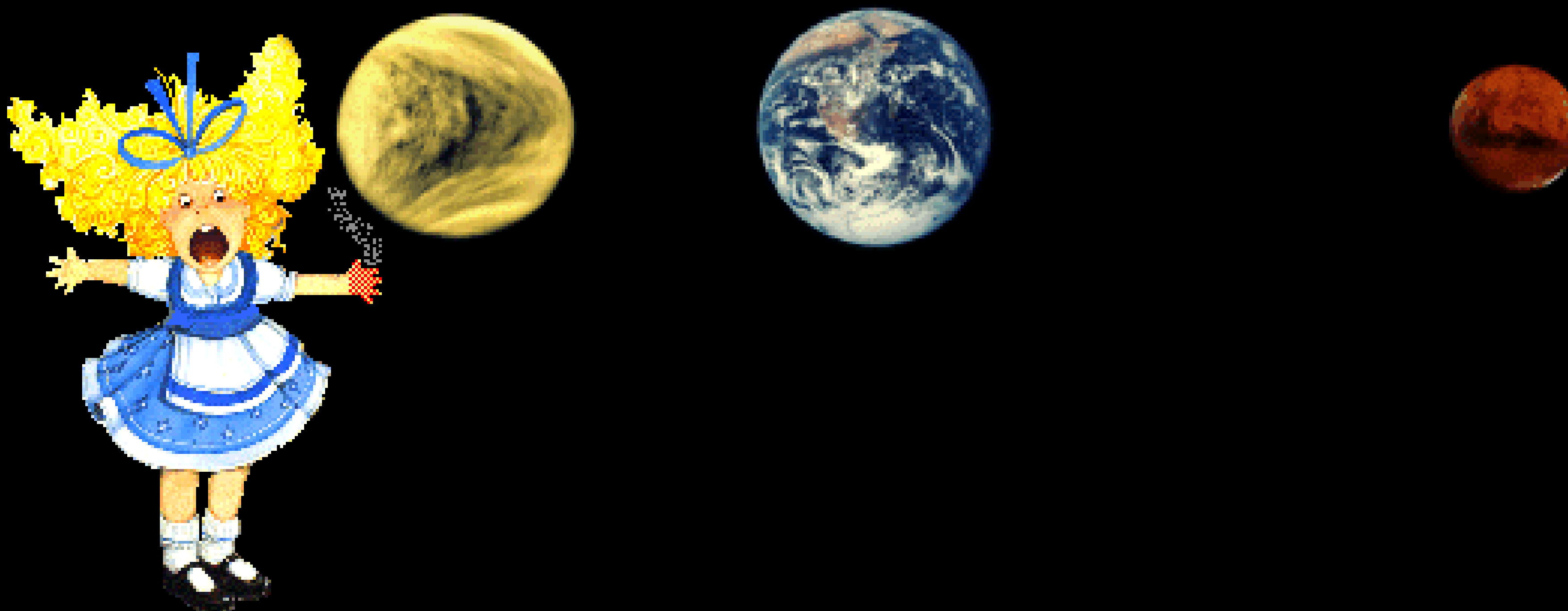
SMALL changes in distance from the source of energy (e.g., the Sun)

can result in LARGE changes in the amount of energy received by a planet’s surface.

GOLDILOCKS & THE 3 PLANETS



GOLDILOCKS & THE 3 PLANETS

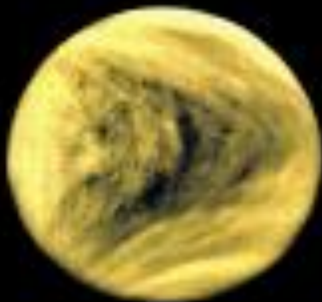


Yikes! Venus is too HOT!

GOLDILOCKS & THE 3 PLANETS

Brrrrrrrr, Mars is too COLD!!

GOLDILOCKS & THE 3 PLANETS



Ahhhh! Earth is JUST RIGHT!

THE LAST LAW!

Law #6:

(Law #6 will not be on Test 1 but today's G-1 Assignment will be graded !)

"Selective Absorption and Emission"

LAW #6: Selective emission and absorption (of gases)

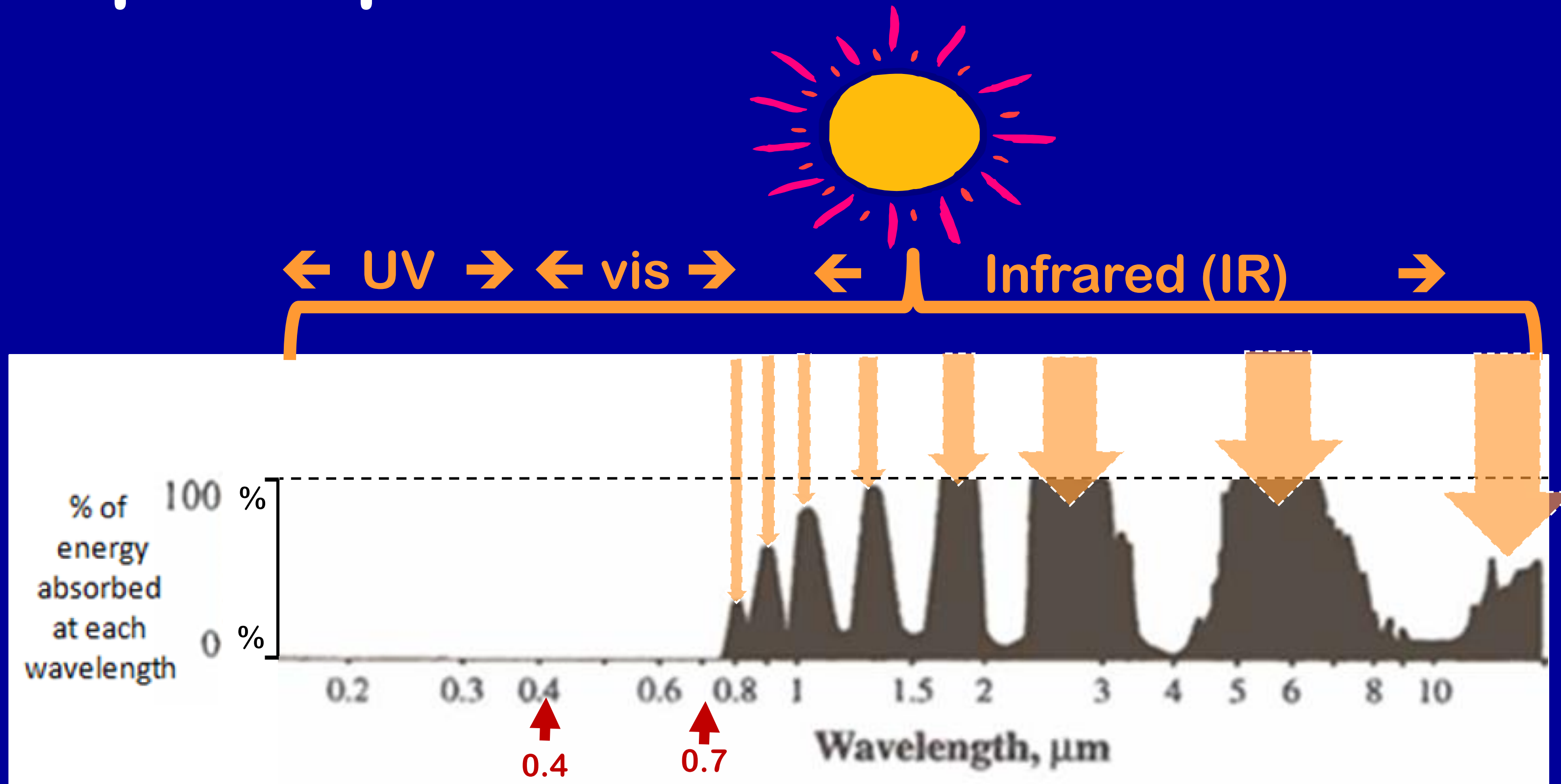
has 2 parts:

a) Some substances emit and absorb radiation at certain wavelengths only.

(This is mainly true of gases.)

b) These substances absorb only radiation of wavelengths they also emit.

The pattern of electromagnetic wavelengths that are **absorbed or emitted)** by a particular gas molecule . . . is called the gas's Absorption Spectrum or **ABSORPTION CURVE**



Radiation is **ABSORBED (or partially ABSORBED)** at THESE wavelengths by this particular gas!

☺

And now . . . .

GROUP ASSIGNMENT G-1

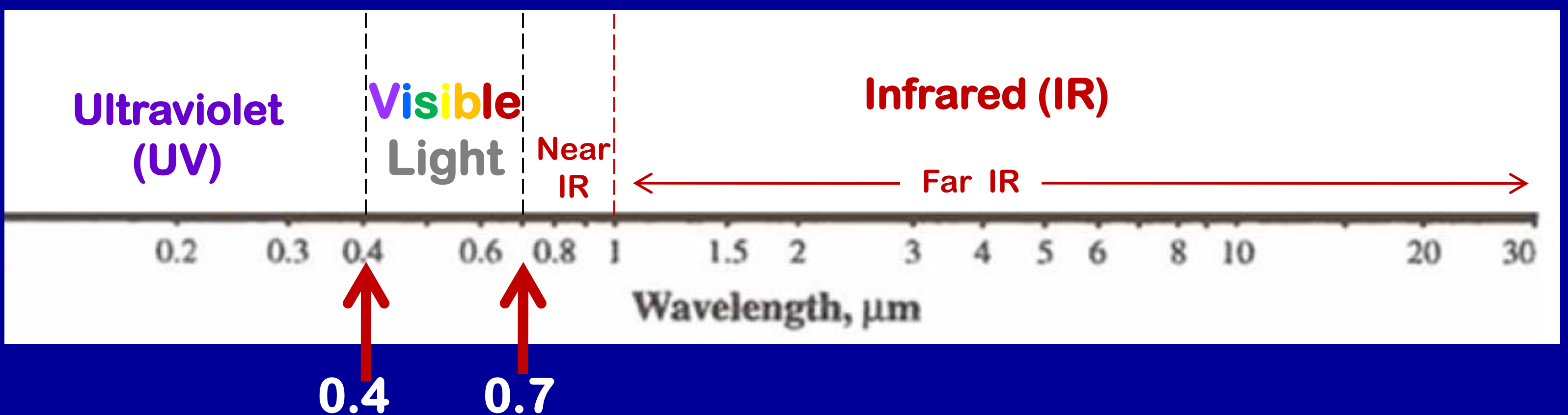
Understanding Radiation, Absorption & Wavelengths of the Electromagnetic Spectrum

WORTH 10 pts

(While the preceptors are locating their groups)

Start by tying Law #6 to the Electromagnetic Spectrum

Here's a spectrum . . .
Draw it on your whiteboard:



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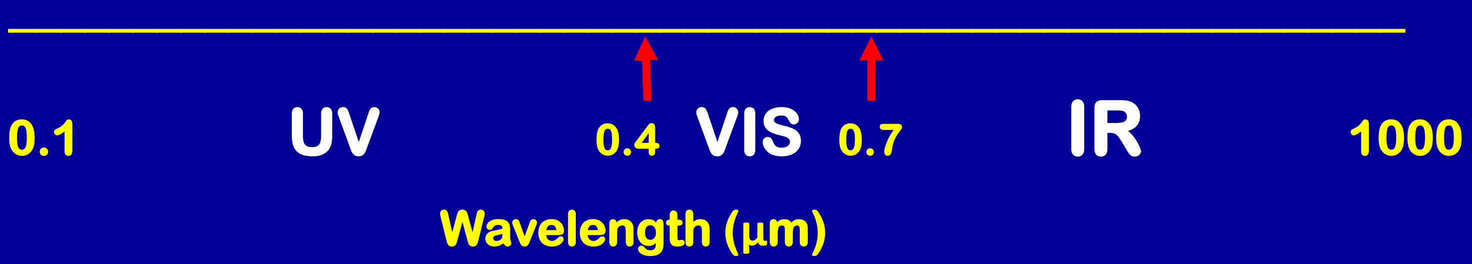
HORIZONTAL AXIS: **WAVELENGTH**

Now add a
VERTICAL AXIS: **% of energy** at each wavelength
that is **ABSORBED**



What would a curve for a hypothetical gas that absorbs **ALL VISIBLE LIGHT** but **ZERO UV** or **IR**

LOOK LIKE ??

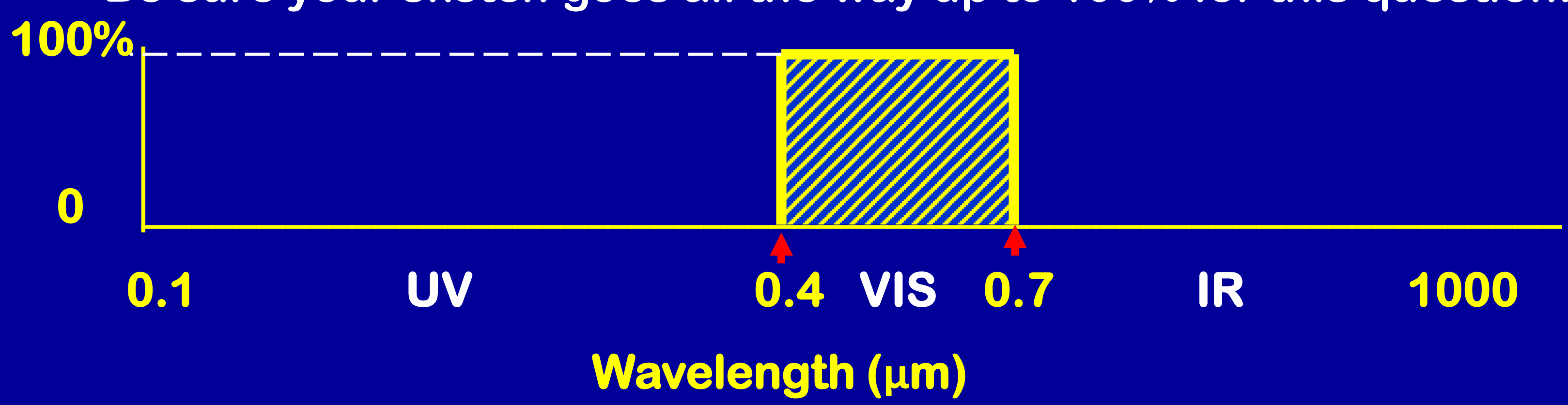
SKETCH IT IN . . . .

What would a curve for a hypothetical gas that absorbs **ALL VISIBLE LIGHT** but **ZERO UV** or **IR**

LOOK LIKE ??

SKETCH IT IN . . . .

Be sure your sketch goes all the way up to 100% for this question!



G-1 GROUP WORK LOGISTICS:

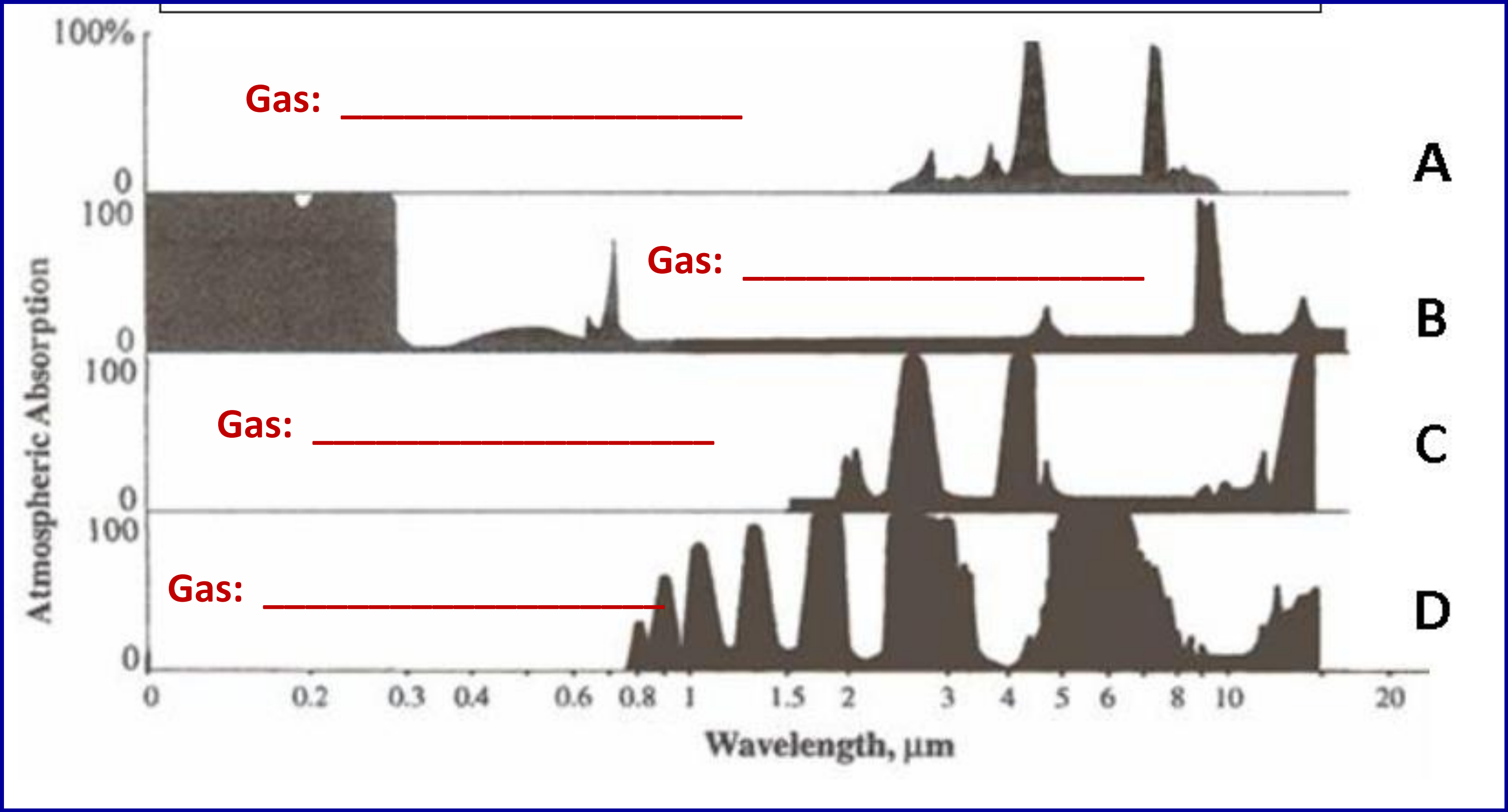
Student # 1 is Today's Folder Monitor
Student # 2 is Today's Whiteboard Monitor

Student # 1 writes answer to Q1 on Group Form,
Student # 2 writes answer to Q2 on Group Form
and so forth . . .

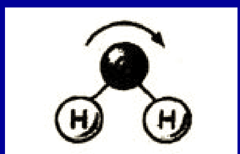
All work together on Q5 & Q6 . . .

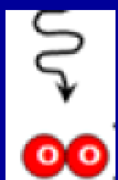
Q6. Match the GAS with its Absorption Curve:

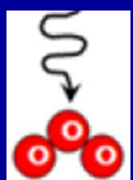
CHOICES: CO_2 H_2O $O_2 + O_3$ N_2O

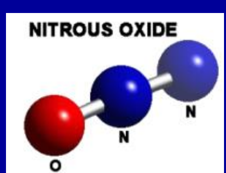


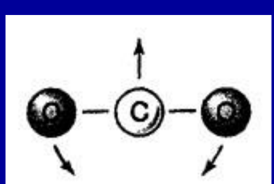
Use this table→ to do it











Here are the specific wavelengths each gas absorbs!

Gas	Primary absorption wavelengths *(in micrometers)*	
Water vapor (H_2O)	0.8 1 1.5 2 to 3.5	4 to 7 9 to 10 11 to 20
Molecular oxygen (O_2) and Ozone (O_3)	0.0001 to 0.280 8.5 to 10	
Nitrous oxide (N_2O)	4 to 5 7 to 7.5	
Carbon dioxide (CO_2)	2 to 2.5 3 to 4 13 to 20	

Did you FINISH Q1-Q-6?

Work on the
GROUP THOUGHT Q !

Didn’t FINISH Q1- Q6?

G-1 will be completed
AFTER the GROUP TEST
on Wednesday . . .