Light Packet Names Mr. Sudbury - Key Block____

The Electromagnetic Spectrum is made up of (in random order) radio waves, UV (ultraviolet) light, microwaves, visible light, gamma rays, infrared, and X-rays.

Light has a dual nature. This means that it acts like a particle and a wave at the same time. Under the photon theory of light, a photon is a discrete bundle (or quantum) of electromagnetic (or light) energy. Photons are always in motion and, in a vacuum, have a constant speed of light to all observers, at the vacuum speed of light (more commonly just called the speed of light) of $c = 2.998 \times 10^8$ m/s, (we can round that to 3.0×10^8 to make life simple). According to the photon theory of light, photons . . .

- move at a constant velocity, (i.e. "the speed of light"), in free space
- have zero mass and rest energy
- carry energy and momentum, which are also related to the frequency *(f)* and wavelength *(λ)* of the electromagnetic wave
- can be destroyed/created when radiation is absorbed/emitted
- can have particle-like interactions (i.e. collisions) with electrons and other particles

1. Rank the EM spectrum based on increasing wavelength (shortest to longest):

   gamma, x-ray, UV, Visible, infrared, microwave, radio

2. Rank the EM spectrum based on increasing frequency (highest to lowest):

   gamma, x-ray, UV, Visible, infrared, microwave, radio wave.

3. What is the only portion of the EM spectrum we can see?

   Visible light

4. What colors can we see?

   RoyGBIV: red, orange, yellow, green, blue, indigo, violet

5. What is the difference between the different visible colors of the visible spectrum?

   their wavelength (λ) Red (700nm) to Violet (440 nm)

6. In each of the following pairs, circle the form of radiation with the LONGER WAVELENGTH: *(Circle one)*

   a. red light **or** blue light
   b. microwaves **or** radio waves
   c. infrared radiation **or** red light
   d. gamma rays **or** UV radiation

7. In each of the following pairs, circle the form of radiation with the GREATER FREQUENCY: *(Circle one)*

   a. yellow light **or** green light
   b. x-rays **or** gamma rays
   c. UV radiation **or** violet light
   d. AM radio waves **or** FM radio waves

8. In each of the following pairs, circle the form of radiation with the LOWER ENERGY:*(Circle one)*

   a. red light **or** blue light
   b. microwaves **or** radio waves
   c. infrared radiation **or** red light
   d. gamma rays **or** UV radiation

e. yellow light **or** green light

f. x-rays **or** gamma rays

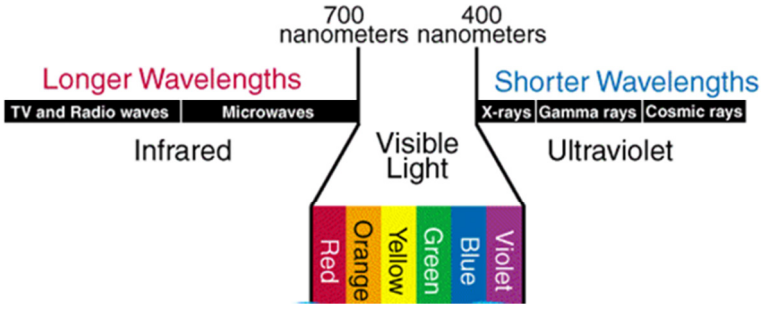
g. UV radiation **or** violet light

h. AM radio waves **or** FM radio waves

9. Springfield's "Classic Rock" radio station broadcasts at a frequency of 102.1 MHz. What is the length of the radio wave **in meters**? ***(G.U.E.S.S.)*** *(Hint: The prefix mega- means 10^6 or 1,000,000.)*

$V = f \cdot \lambda \therefore \lambda = \frac{V}{f} = \frac{2.998 \times 10^8 \text{ m/s}}{102.1 \times 10^6 \text{ Hz}} = 29.36 \text{ m}$

Visible light: The entire range of different kinds of light including the ones the human eye can see is called the electromagnetic spectrum. What we can see is called *visible light*. A rainbow shows the colors of visible light. Visible light has wavelengths that range between 400 and 700 nanometers (one billionth of a meter).



10. What are the colors of the visible spectrum in order? (or the abbreviation)

ROYGBIV

	λ
R	625 nm - 740 nm
O	590 nm - 625 nm
Y	565 nm - 590 nm
G	520 nm - 565 nm
B	475 nm - 510 nm
I	435 nm - 475 nm
V	380 nm - 435 nm

11. A beam of light has a wavelength of 506 nanometers. What is the frequency of the light? What color is the light? *(Hint: The prefix nano- means 10^{-9} or 0.000,000,001)*

$f = \frac{V}{\lambda} = \frac{2.998 \times 10^8 \text{ m/s}}{506 \times 10^{-9}} = 5.9 \times 10^{-9}$

590 nm = The question said 506 nm. Just realize that the nm = λ = color

12. Blue light has a frequency of 6.98×10^{14} Hertz. Calculate the wavelength of blue light **in meters.**

$\lambda = \frac{V}{f} = \frac{2.998 \times 10^8 \text{ m/s}}{6.98 \times 10^{14} \text{ Hz}} = 4.28 \times 10^{-7} \text{ nm}$

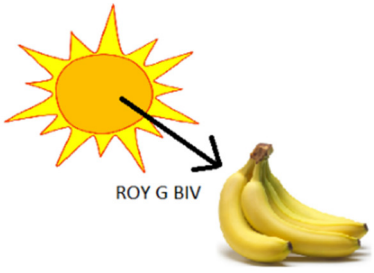
13. Reflected light has a wavelength of 480 nm. What color is the light?

Blue

What we see: We see objects that are certain colors because they reflect that particular wavelength of light. For example, white light (ROY G BIV) shines on an apple and we see the apple to be red because it absorbs OY G BIV, and reflects red.

14. You are in natural light (white light, the combination of ROY G BIV) and see bananas on a table. What colors of light are absorbed by the bananas and what light is reflected by the banana?

Absorbed: ROGBIV Reflected: Yellow

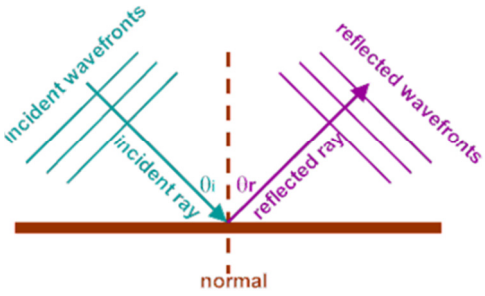


Reflection: Light waves (all waves for that matter, but specifically light wave) reflect off of surfaces.

15. What law states that a reflected light wave's angle of incidence (angle shining in) must equal the angle of reflection (angle it reflects out at)?

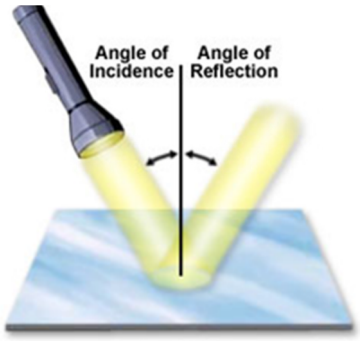
Law of Reflection

16. The incoming ray is called the incident ray and the outgoing ray is called the reflected ray.

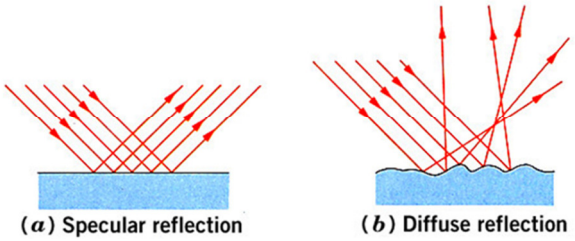


17. Light from a flashlight strikes a mirror's surface at 60 degrees to the normal. What will the angle of reflection be?

60°



Diffused Reflection: When light bounces off of a flat surface, it reflects in a predictable way. When light bounces off of an irregular surface, it acts in an unpredictable way, aka diffused reflection.

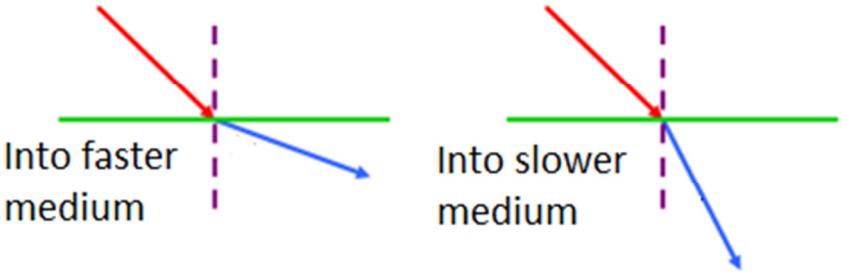


18. A flat mirror and a disco ball have light reflected off of them. Label each with the type of reflection.

specular reflection

diffused reflection

Refraction: Often the light will penetrate a surface rather than being reflected from it. As most media have slightly different physical properties they will also exhibit different optical (light properties). The optical density is a term which describes the ease or speed with which light moves through a substance. The higher the optical density the slower light moves through that substance. When light enters a new substance its speed changes and this results in a change in wavelength and frequency. The frequency of any wave (light included) will remain the same however when changing media. The new speed causes the light wave to bend or refract. When a (light) wave enters a medium and is able to go faster the wave will refract or bend away from the normal, when the (light) wave enters a medium in which it propagates more slowly it will bend toward normal.



19. What is refraction? (You can use the picture to explain.)

Light waves bend when they change medium

Ex: Light in air shining in water.

20. Why does light refract?

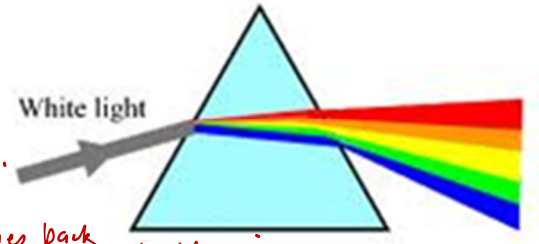
Because light has different velocities in different medium.

21. A prism separates light into ROY G BIV. Why does this happen?

Light slows as it moves from air into glass

it refracts different amounts based on its wavelength.

It will also refract again as it leaves the prism and goes back into the air.



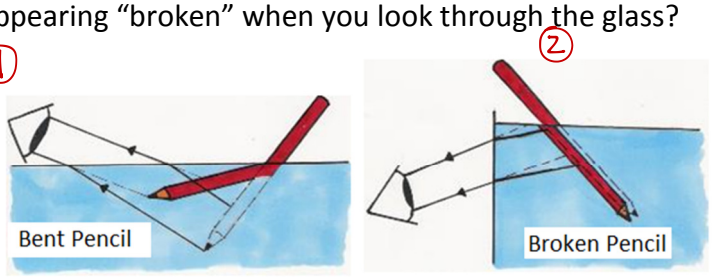
22. A pencil is in a cup of water. Explain why the picture looks the way it does.

Refraction: the light bends as it leave air and enters the water. That is why the pencil looks "broken."

23. In the picture below, the pencil is being refracted by the bending of light as the waves change medium. The pencil is actually unharmed in this experiment. What causes the difference between the pencil being "bent" when you look from above and appearing "broken" when you look through the glass?

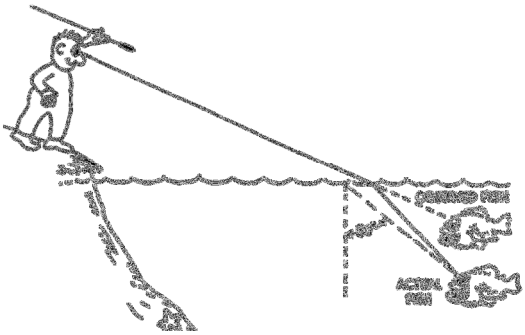
In pic #1 Light bends from air into water

In pic 2: Light bends as it travels through air, glass, & then water.

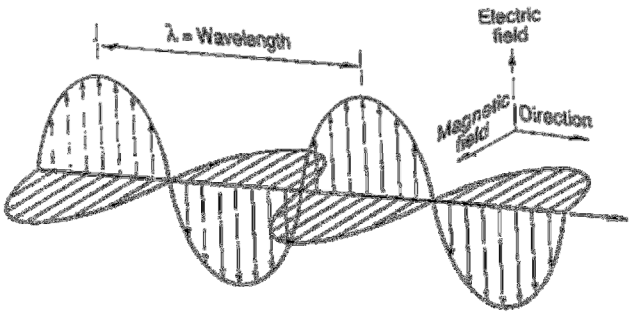


24. A spear fisherman is unsuccessful and has never actually "caught" a fish this way. Explain to him (in words even a caveman will understand) why he always misses the fish. Also offer advice that will help him be a more successful spear fisherman.

He always misses because he aims over the actual fish. He should aim low (below the fish) to hit the fish.

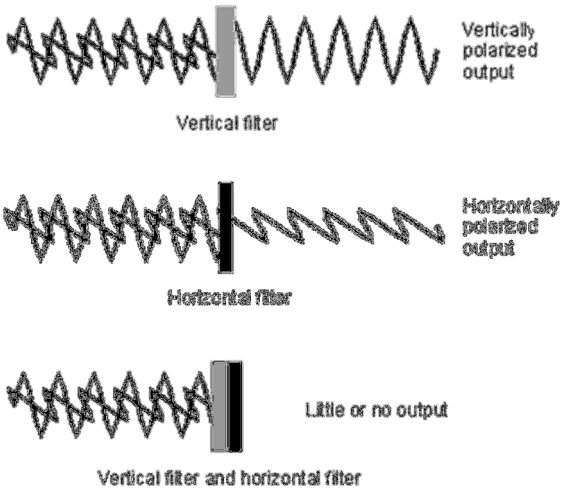


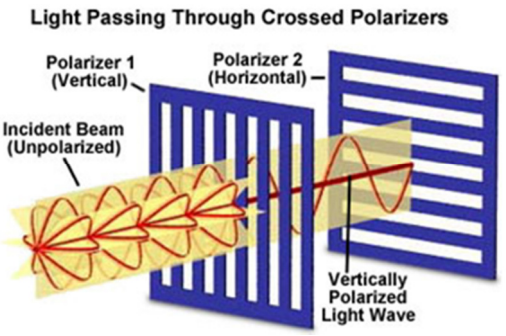
Polarization: Visible light, an electramagnetic wave, travles on multiple planes simultaneously (see diagram). For simplicity, it is like the electro portion of the electromagnetic light wave travels vertically, and the magnetic portion of the electromagnetic light wave travels horizontally.



When the light is polarized, one of the wave direction is eliminated and only part of the wave travels through.

When two filters are overlapped, at 45 degrees to each other, you can filter out all the light.





25. When a light wave vibrates in a variety of directions, the light is said to be ____. *(Circle one)*
    a. Transverse
    b. Polarized
    c. Unpolarized

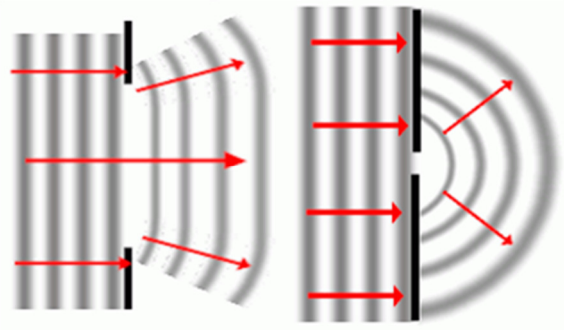
26. When a light wave's are isolated to a single plane, the light is said to be ____. *(Circle one)*
    a. Transverse
    b. Polarized
    c. Unpolarized

27. Polaroid filter polarizes light by _____. *(Circle one)*
    a. re-orienting all the wave vibrations such that they vibrate in a single plane
    b. blocking part of the vibrations while letting through those that are in a specific plane

28. Filters allow light to pass through. Polaroid filters are very selective about the orientation of the light vibrations that are allowed through. The light that passes through a Polaroid filter is vibratingin a direction that is _____. *(Circle one)*
    a. parallel to the orientation of the molecules that make up the alignment
    b. parallel to the polarization axis or transmission axis of the filter
    c. parallel to the ceiling or the sky (if the source of light is on the ceiling or in the sky)
    d. always horizontal, regardless of what the light source is

29. A student is driving down the road on a sunny day. Reflection of light off the road surface results in a large amount of polarization and a subsequent glare. Annoyed by the glare, the student pulls out his Polaroid sunglasses. How must the axes of polarization be oriented in order to block the glare? (Note: the lines on the filters below represent the axis of polarization.) *(Circle the glasses that would best reduce glare.)*

Diffraction: Diffraction is the slight bending of light as it passes around the edge of an object. The amount of bending depends on the relative size of the wavelength of light to the size of the opening. If the opening is much larger than the light's wavelength, the bending will be almost unnoticeable. However, if the two are closer in size or equal, the amount of bending is considerable, and easily seen with the naked eye.



30. On the figure to the right, draw that light waves that are diffracted (you can ignore the reflection back off of the surface.)