Physics 100 Name: _____

Notes: Light, part I

1. What is light? Electromagnetic radiation with visible wavelengths between about 400 – 700 nanometers

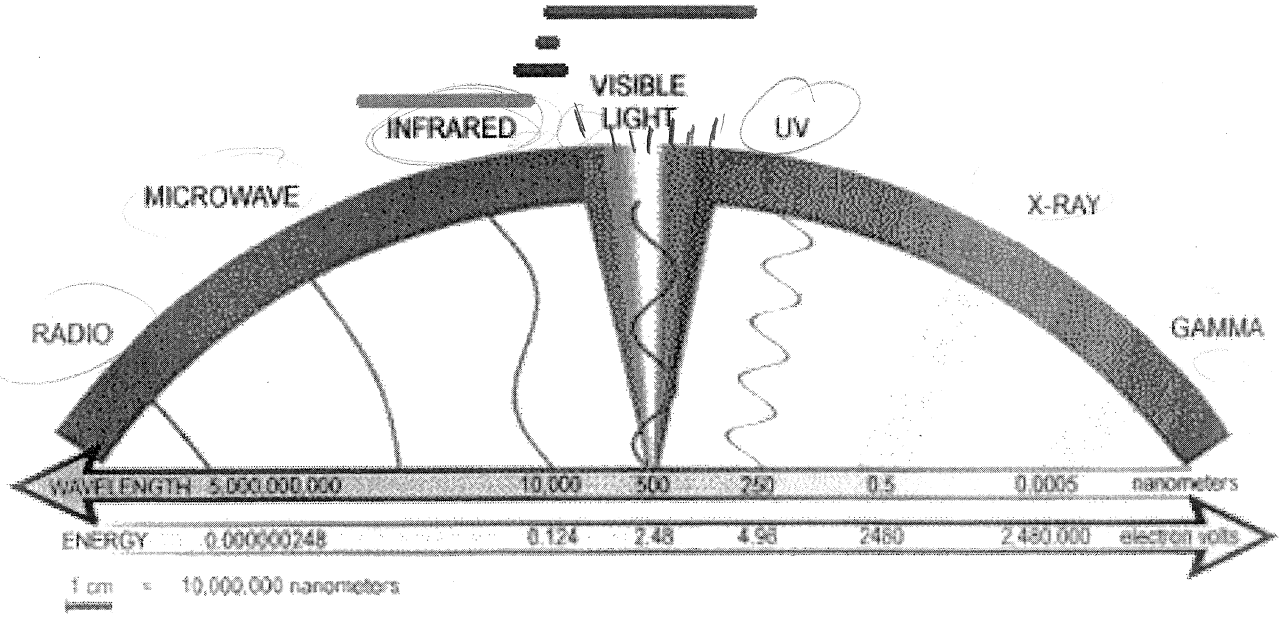
0.0000004m

The "wave-particle duality" of light (and all electromagnetic radiation):

2. How is light like a particle?
   - It's made of particles called photons
   - Light has momentum; it can push things
   - Light is pulled by gravity
   - Light can travel in a vacuum

3. How is light is like a wave?
   - It is an oscillation that travels through space
   - Has measurable wavelength, frequency, etc.
   - Has other wave properties: refraction, reflection, scattering

The Electromagnetic Spectrum



4. Light waves from longest to shortest wavelength:

ROY G. BIV

Red Orange Yellow Green Blue Indigo Violet

5. Nicknames for The Two Ends Of The Spectrum:

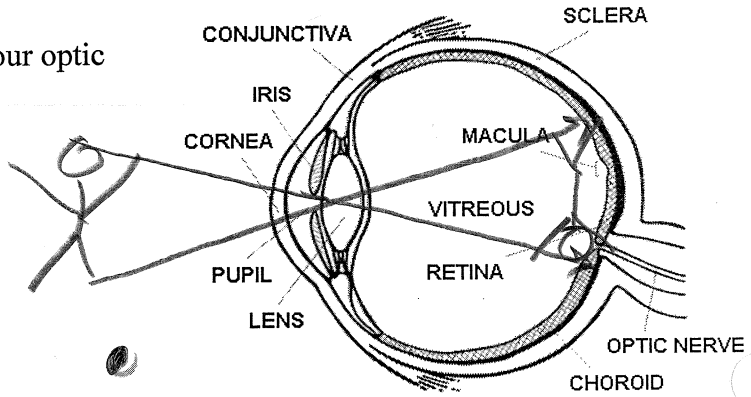
- The long-wavelength end of the visible spectrum is called the Red end.
- The short-wavelength end of the visible spectrum is called the Blue end.

6. Describe two ways to show that white light is actually made up of a rainbow of colors?

- Stare at colors, then stare at a white screen
- Prism: separates white into various wavelengths

7. Show how the human eye sees.

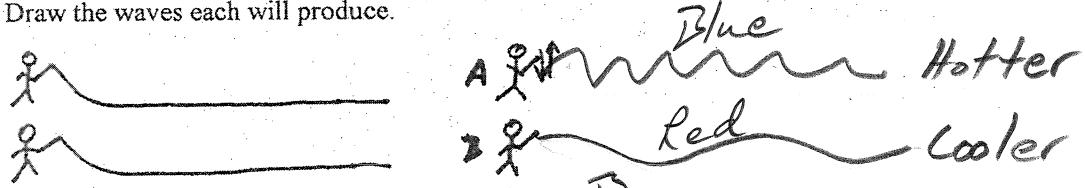
8. Can you find the blind spot created by your optic nerve?



9. Star Colors

Person A and person B are raising and lowering their hands causing series of waves to travel down their ropes. Person A is waving the rope frantically, while person B is waving the rope slowly.

- Draw the waves each will produce.



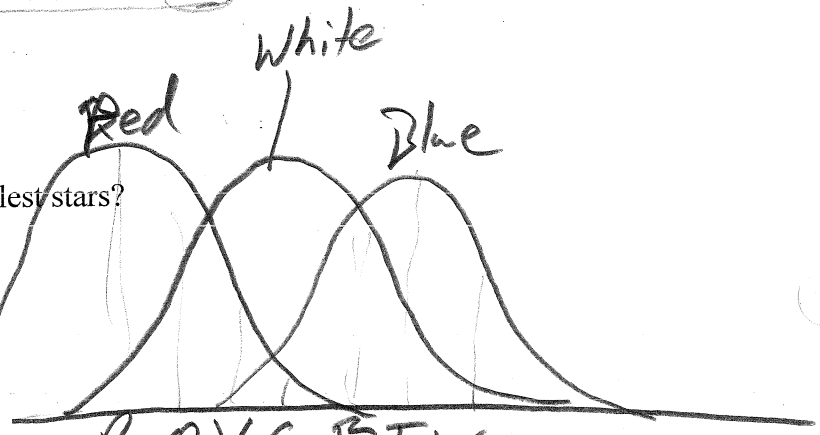
- Who produces waves with the longest wavelength? B
- Who produces waves with the highest frequency? A
- If those waves were waves of light, which waves would be more red, and which would be more blue?
- Which person is more like a hot molecule?

10. What colors are the hottest and coolest stars?

Hottest: Blue
Coolest: Red

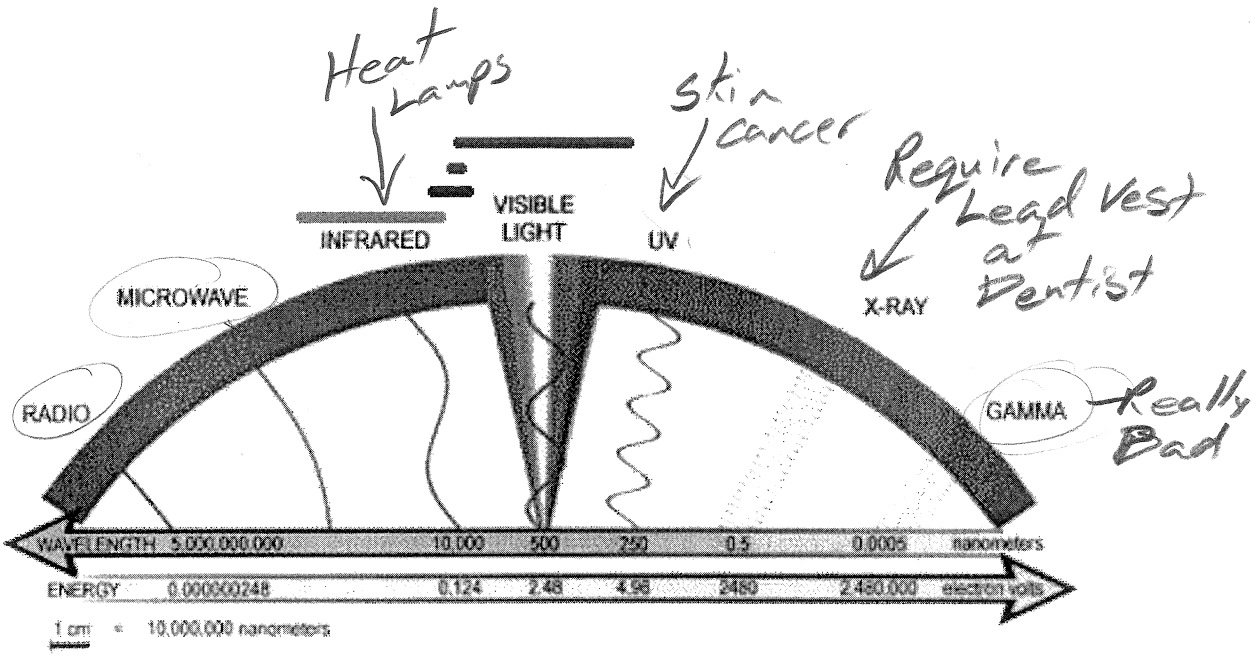
11. Why are there no green stars?

Stars can't have green without having the rest of the colors, so they're white.

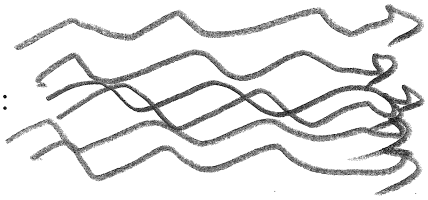


12. All other things being equal (**like number of photons and coherence) what frequencies of electromagnetic radiation most dangerous?

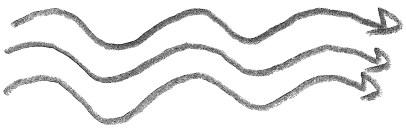
13. Why? High frequency = high energy



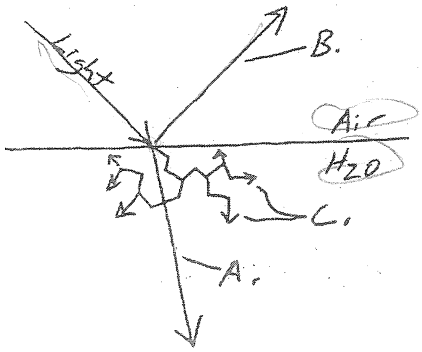
14. Ordinary (incoherent) light waves:



15. *Coherent light waves (found in lasers):



Wave Behaviors:



A. Refraction

B. Reflection

C. Scattering

Refraction (Bending) of Light

16. What is special about the speed of light?

- It's the universal speed limit
* No matter how fast or which direction you're traveling, light always passes you at the same speed

17. One of these properties prompted Einstein to propose the theory of Relativity. Among other things, the theory of relativity states that, when you move faster....

time goes slower (for you)

18. How has that been proven? Clocks on fast jets fall behind

19. What is the speed of light, in a vacuum? 3×10^8 m/s ≈ 670,000,000 mph

20. What is a "light year?"

Distance light travels in one year

21. How long does it take sunlight to reach the Earth? 8 minutes

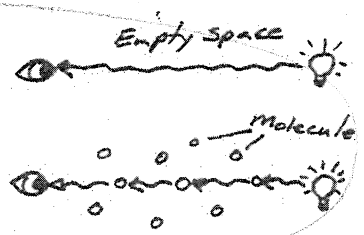
22. If there were a mirror on the moon, and you could use a telescope to look at yourself in that mirror, what would you see?

Yourself, as you were 2.6 seconds ago.

23. If the speed of light is constant, why does it travel more slowly through things like glass?

See below

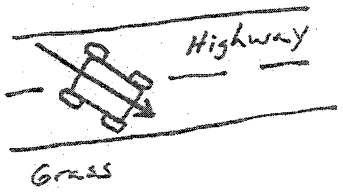
In a vacuum (empty space) electromagnetic waves, including visible (light) waves, travel at 650 million mph. In a vacuum, there are no molecules with which the photons of light can collide.



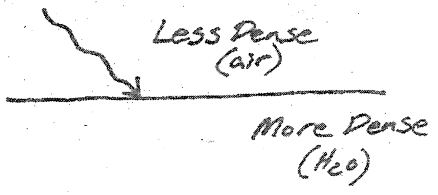
1. When a photon hits a molecule, that molecule can take-in the photon's energy, and then give off another photon. This takes time. When light is travelling through space which is full of molecules, its photons are constantly being absorbed and re-emitted. It travels from one molecule to the next at 650 million mph, but then it has to wait for the molecule to release a photon so that the light can keep going. Do you think light travels faster through a vacuum or through a solid?
2. In general, do you think light travels better through dense things or things which are less dense?

Understanding refraction (bending of light waves) by thinking about cars.

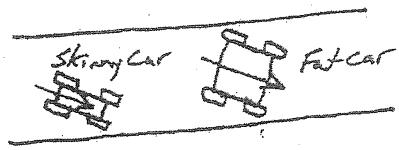
3. Does a car travel faster on a smooth highway or on a grassy surface?
4. The path of a car is shown. As it hits the shoulder of the highway, which front tire will touch the grass first?
5. When that happens, which front tire will begin to move more slowly?
6. Is this going to cause the car to turn to its right or its left?
7. Use an arrow to draw the new path of the car.



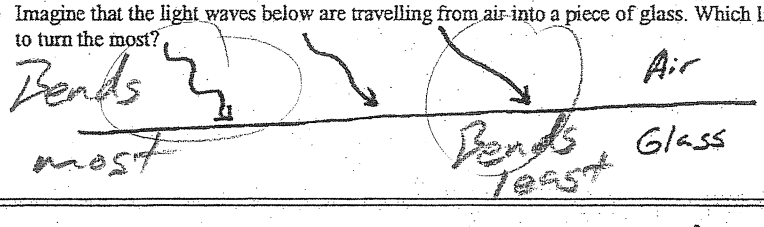
8. Light waves are like that car. The light wave on the right is travelling from air into water. In which substance will it travel faster?
9. Show how entering a more dense substance will affect the path of the light (by drawing the new path on the diagram.)



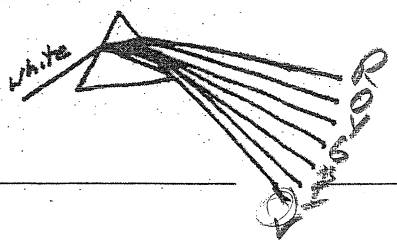
10. The two cars shown on the right are going to turn when they hit the grass because, for a short time, one side will be going faster than the other side. Which car will probably turn the most? Why?



11. Imagine that the light waves below are travelling from air into a piece of glass. Which light waves would you expect to turn the most?

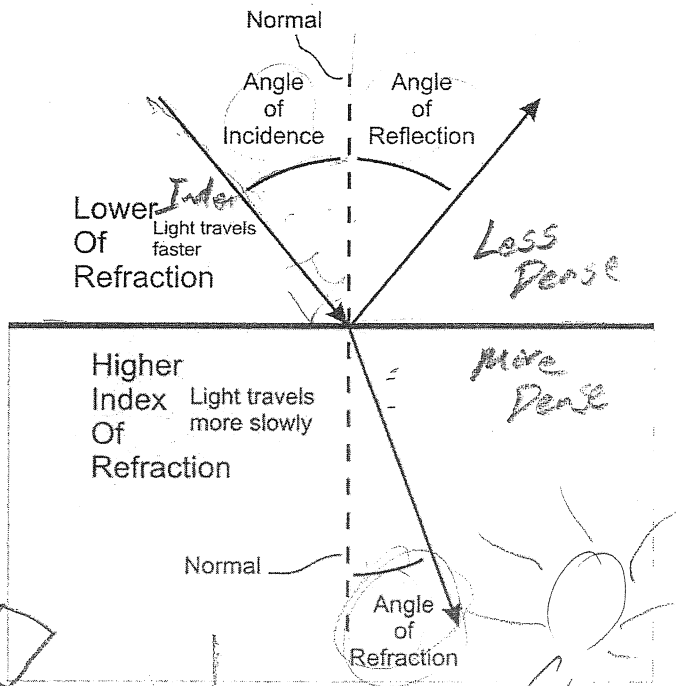


12. The diagram on the rights shows white light hitting a prism. The prism causes the various wavelengths of light to bend. Some bend more than others, so a color spectrum (rainbow) is produced. Label the paths shown with the appropriate colors. [Remember Roy G. Biv. Red has the longest wavelength. Blue has the shortest.]



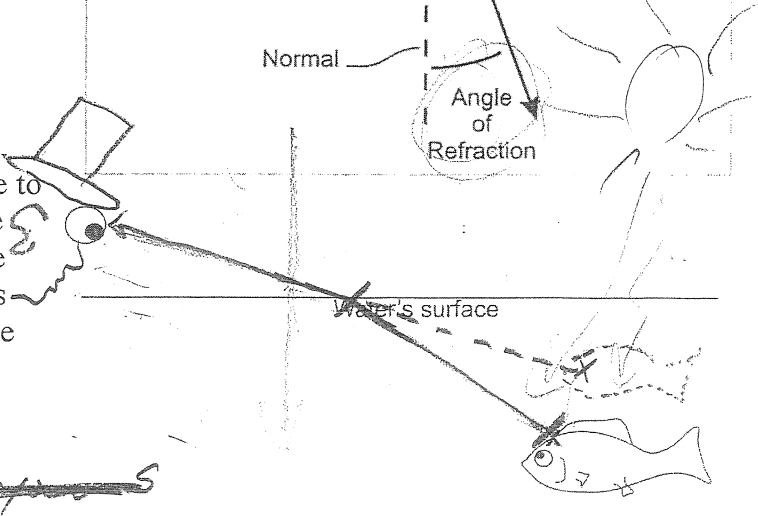
24. When light crosses the boundary between materials, it turns <u>toward</u> the _____ (faster or slower) medium.

25. When a light ray passes from a faster material to a slower material, the angle of refraction is _____ (>,<, or =) the angle of incidence.

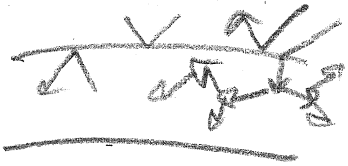


26. If a substance has an index of refraction that is twice as high as air's index of refraction, this means…

27. The eyeball is looking at the fish. It would like to shoot the fish right on the "x." The problem is that the eyeball "sees" the x in a place that really is not the true location of the fish. Draw the x where the eyeball sees it, and show the path of light traveling from the x to the eyeball.

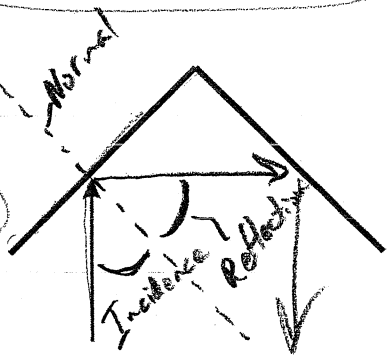


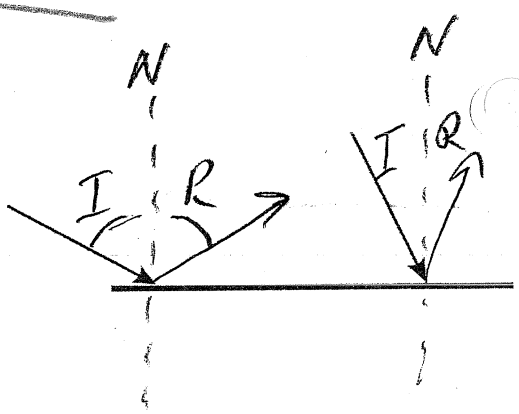
If you want to shoot a fish, where should you aim?



28. Reflection of Light: **Angle of incidence = angle of reflection**

a. Show how the rays are reflected when they hit the mirrors.
b. Draw the "normal."
c. Label the angle of incidence and the angle of reflection.



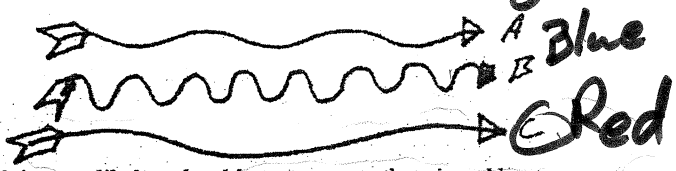


Scattering of Light In Our Atmosphere: The following should be thought of as a mnemonic device to help you remember *which* wavelengths of light get scattered. It is not a real explanation of *why* certain wavelengths get scattered.

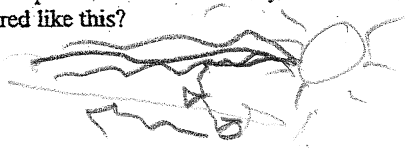
ROY G. BIV

A way to think about scattering of light waves:

1. Imagine that you are shooting arrows at bags of sand. Your arrows are shown on the right. Choose the arrow which will be most likely to penetrate the bag. Choose the arrow which will be most likely to bounce off of the bag.



2. If the air is full of little things, which color of light do you think is most likely to be able to penetrate that air and least likely to be scattered? (red or blue) Which color is most likely to be scattered by bouncing around? (red or blue) The air does contain "little things," such as dust, oxygen molecules, nitrogen molecules, etc. When you look up at the sun, during the day, most of the sun's wavelengths of light reach your eye. All of those colors mixed together look yellowish/whitish. However, some wavelengths bounce off of the particles in the air. They bounce all over the sky before making it to your eye. What color is likely to get scattered like this?



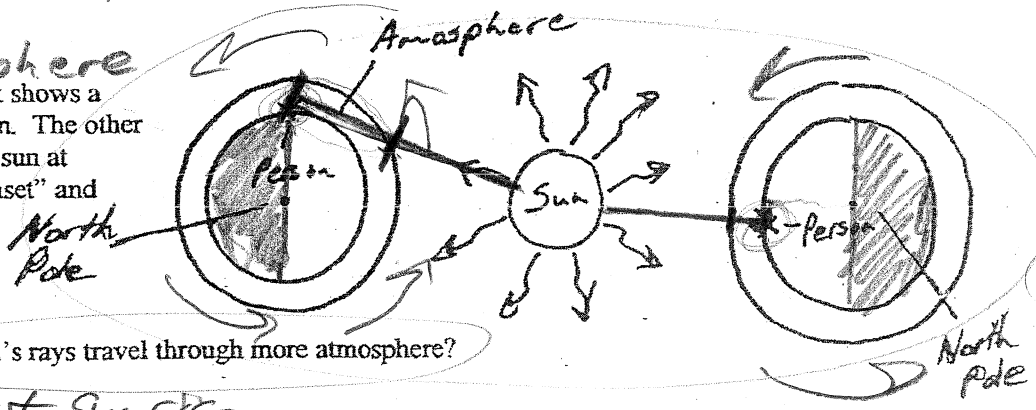
Why is the sky blue? *[On the moon, the sky looks black.]*

When sunlight passes through the atmosphere, the shorter (Blue) wavelengths of light get bounced all over (scattered)

Why does the sun turn red at sunset?

Only the longest wavelengths of light (red) can penetrate the thicker amount of atmosphere

One of the drawings on the right shows a person looking at the sun at noon. The other shows the person looking at the sun at sunset. Label the drawings "sunset" and "noon."



At which time of day do the sun's rays travel through more atmosphere?

Sunset & Sunrise

Physics 100
Refraction and Reflection Practice

Name: Answers

Directions: Anticipate how the laser rays will refract and reflect in the situations below. Draw what you expect to see. Then draw what actually happens when you try this for real. **E = expected. A = actual**