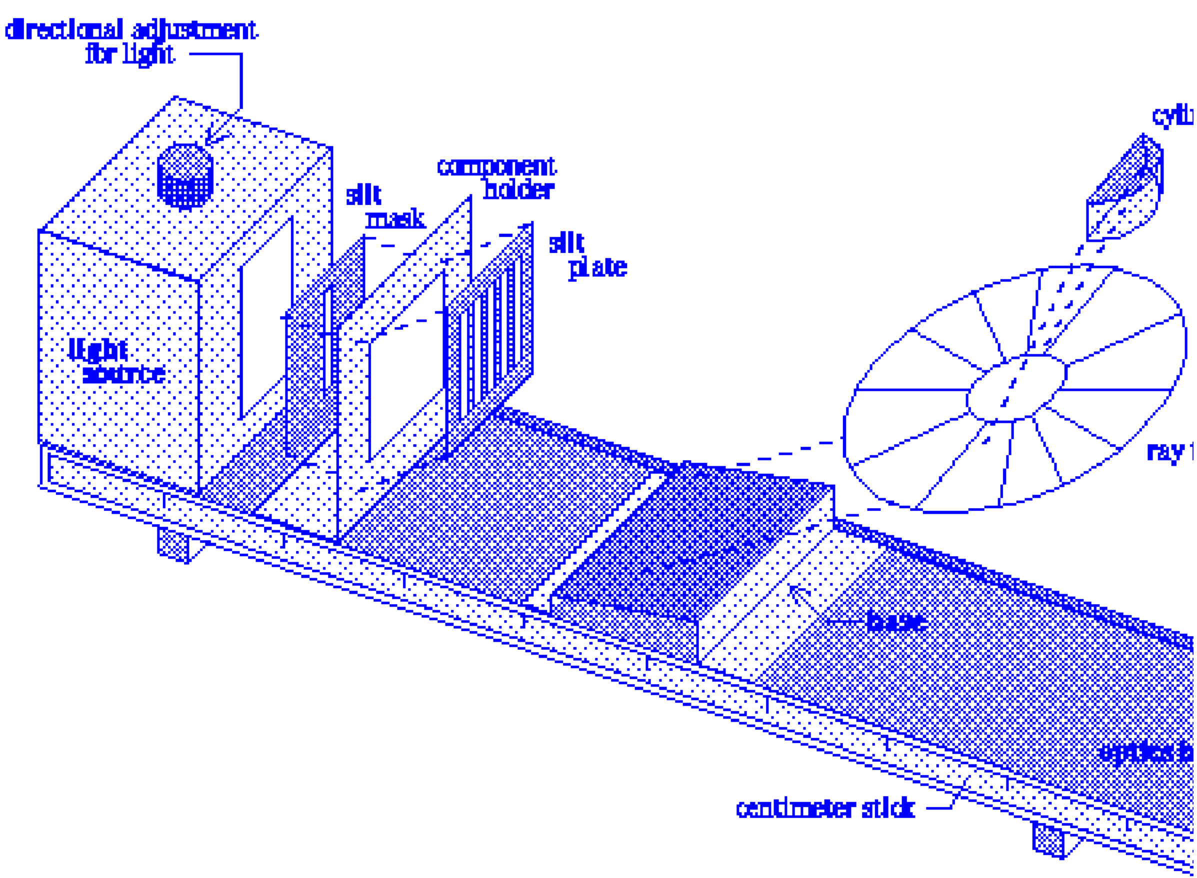
OPTICAL POTPOURRI

(L-21)

What you are about to experience is really five mini-labs in one: an exploration of *refraction*, *total internal reflection*, *dispersion*, *color mixing*, and *mirages*. Note that an illustration of the setup is shown below. There will be variations of this setup in different parts of the lab--all you are seeing below is a GENERAL representation.

GENERAL SKETCH OF RAY TABLE AND COMPONENTS



PROCEDURE--DATA

Part A: (refraction--less dense to more dense)

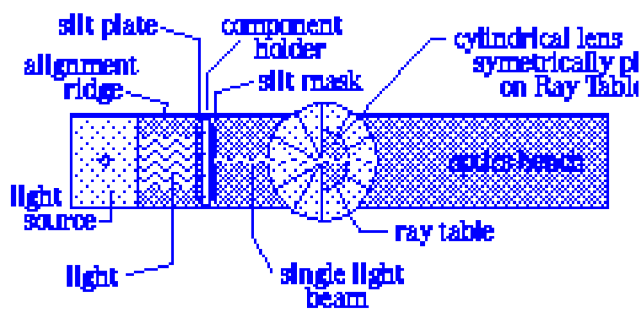
a.) When a ray of light passes from one medium into another, it changes direction. This phenomenon is called REFRACTION.

Snell's Law relates a ray's incoming *incident* angle θ_1 and its outgoing *refracted* angle θ_2 (both angles measured in *degrees* relative to the NORMAL). Snell's Law states that $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$, where n_1 is the *index of refraction* of *medium 1*, etc.

This section will allow you to verify Snell's Law.

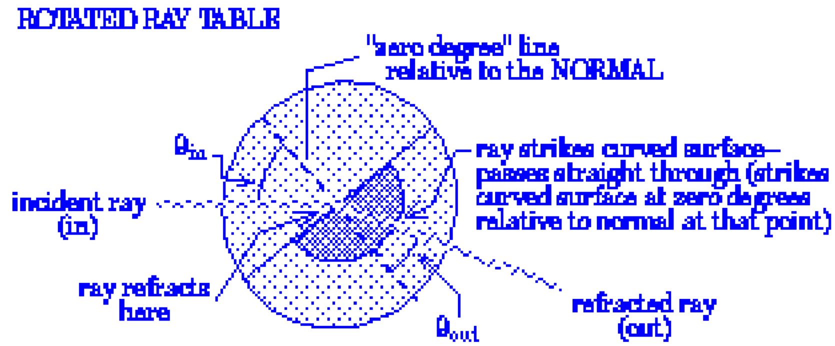
Note: The index of refraction of a medium is defined as the ratio c/v_1, where c is the speed of light in a vacuum and v_1 is the effective velocity of light in *medium 1*.

INITIAL SET-UP LOOKING FROM ABOVE



b.) The OPTICS BENCH in this section should be set up as shown in the sketch to the right (the sketch shows the BENCH as seen from above). Note that there is an *alignment ridge* on one side of the BENCH--make sure all pieces placed on the BENCH are positioned snugly up against that ridge. Note also that the RAY TABLE has a protractor face inscribed on it.

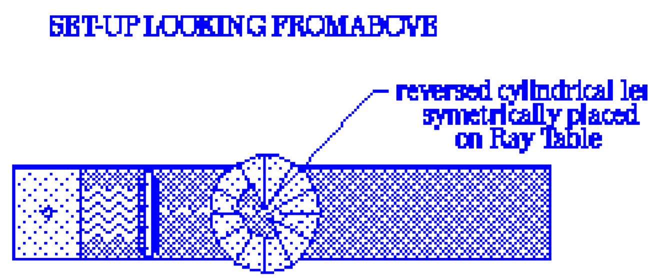
c.) BEFORE putting the CYLINDRICAL LENS on the RAY TABLE, position the COMPONENT HOLDER, SLIT PLATE, and SLIT MASK (see sketch) on the *20 cm* mark on the RAY TABLE (the MEASURE is on the side of the TABLE and is in *millimeters*). Orient the SLIT MASK so that a *single, thin ray of light* runs along the *zero degrees line* marked on your TABLE (you'll find that your LIGHT SOURCE can be rotated--doing so will help with this alignment).



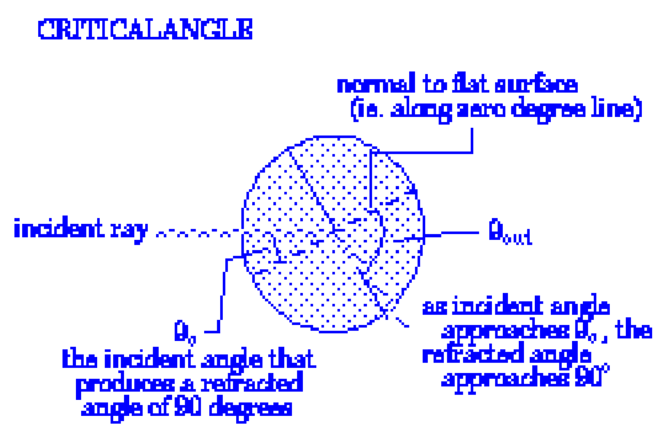
d.) With the RAY TABLE oriented as outlined above, position the CYLINDRICAL LENS symmetrically on the RAY TABLE so that the LENS'S *flat side* both faces the LIGHT SOURCE and sits directly on top of the "Components" line of the RAY TABLE. *Precision is crucial*. If aligned correctly, your single ray should pass through the LENS *without deviation*.

e.) With everything in position, gently rotate the RAY TABLE so that the *incident ray* strikes the CYLINDRICAL LENS at 20^o relative to the normal (see sketch). Use the protractor on the RAY TABLE to determine the *angle of refraction* to the nearest *tenth of a degree*. Record it. Continue this process for incident angles of 30^o, 40^o, 50^o, and 60^o, approximating each to the nearest *tenth of a degree*.

Minor Note: Why is it so important that the LENS be centered on the TABLE? If it is not, refraction will occur not only at the first, flat surface, it will also occur at the *curved surface*. The only way we can keep the ray from refracting at that curved surface is to make the ray strike that surface *square on* so that it passes straight through, That will occur only if the ray follows a radius line, and that will occur only if the ray enters the LENS at its *center* (i.e., where radii originate).



Part B: (total internal reflection--more dense to less dense refraction)



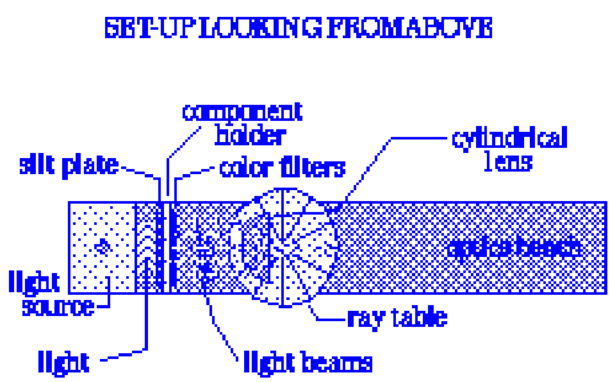
f.) The OPTICS BENCH in this section should be set up exactly as was the case in the previous section *with one exception*. The CYLINDRICAL LENS has been re-versed (see sketch) so that when symmetrically placed, the single incoming light ray will ALWAYS strike the curved surface square on, passing straight through that surface without deviation. The refraction occurs when the ray passes from the plastic back into air on the LENS'S flat side.

g.) With the setup appropriately positioned, gently rotate the RAY TABLE. Notice that at some *critical incident angle* θ_c the <u>refracted light</u> disappears (i.e., all of the light is reflected off the surface and θ_{out} goes to 90^o--see the sketch on the previous page). Determine and record that *critical angle*. Note what happens to the light ray when the incident ray comes in at an angle *greater* than the *critical angle*.

<u>Part C:</u> (dispersion)

h.) For anyone who has ever played with a prism, it is obvious that white light is really made up of the colors of the rainbow. Though it probably isn't obvious at first glance, this prism effect is the consequence of the fact that the *refraction of light* is *color dependent* . . . red light refracts at a different angle than blue light (the difference is quite small, but it is there). Split-ting light into its constituent colors via refraction is called DISPERSION.

i.) With the RAY TABLE set up as in *Part B*, rotate the TABLE until the *incident angle* is exactly *40°*. You should see that the *refracted ray* has spread out with colors showing at its edges. Record: a.) which color refracts the most and which the least; and b.) the refraction angles for both blue and red light. Label these clearly.



<u>Part D:</u> (color mixing)

j.) The DISPERSION section showed that white light can be broken up into its constituent colors via refraction. What happens when those individual colors are recombined?

The setup is shown to the right. Note that the SLIT MASK has been re-moved allowing the SLIT PLATE to produce *seven rays of light* (see sketch). Put the LIGHT SOURCE as close to the SLIT HOLDER, etc., as possible.

Position the BLUE/GREEN FILTER and SLIT PLATE so that *green light* proceeds out of the SLIT PLATE'S <u>*central slit only*</u> , and so that blue light proceeds out of the three other slits to the left of the central green ray. The RED FILTER should be placed next to the BLUE/GREEN FILTER so that red light proceeds out of the three slits to the *right* of the central green ray.

Using the CYLINDRICAL LENS, focus one *red ray* and one *blue ray* so that the two cross the *green ray* at the same place. Use the VIEWING SCREEN (a piece of frosted glass) to observe the three rays as they intersect (you'll have to hand-hold the VIEWING SCREEN to do this--move it back and forth until you find the optimal position). Observe and record the *color* you get when the three rays superimpose.

<u>Part E:</u> (mirage)

k.) At the front of the room you will find a LASER with its light beam just grazing horizontally across the initially cold surface of a HOT PLATE. The beam will strike the CHALKBOARD at some point. Put a mark at that point for future reference.

After the HOT PLATE has been turned ON for a few minutes, you will see that the position of the beam will have moved as it strikes the blackboard. In what direction did the beam diverge from its original path?

<u>CALCULATIONS:</u>

<u>Part A:</u> (Snell's Law)

1.) Assuming an incident angle of 20^o, use Snell's Law and the data you took in *Procedure e* for that situation to determine the *index of refraction* for plastic. Show your work for this part, and give your answer to three decimal places.

Note: If you get an index of refraction that is *less than <u>ONE</u>*, you have goofed!

2.) Repeat *Calculation 1* for the other incident angles listed in *Procedure e*. You should find that they all predict approximately the same *index of refraction* for plastic. If they don't, worry. If they do, take an average. For the rest of the lab, you will use this average value whenever asked to do anything that requires the *index of refraction* of plastic.

Part B: (internal reflection and critical angle)

3.) Use Snell's Law to determine the *critical angle* for plastic.

Note/Hint: When light traveling in plastic strikes a plastic/air interface at the critical angle, the refracted light will leave the plastic at an angle of 90^o relative to the *normal*.

4.) Do a qualitative comparison between the *critical angle* measured in lab and the *critical angle* determined from Snell's Law (i.e., were they only a few degrees from one another or was the variation great). Comment.

Part C: (index of refraction and color)

5.) Use Snell's Law and your data from *Part C*:

a.) Determine the *index of refraction* for red light as it passes through an air/plastic interface;

b.) Determine the *index of refraction* for blue light as it passes through an air/plastic interface;

c.) Do a qualitative comparison of the two indices of refraction calculated above;

d.) From your observations, why is *dispersion* not normally taken into consideration when the *index of refraction* of a material is being deduced?

Part D: (color mixing)

6.) What color did you observe when you mixed red, blue and green light during lab? (impressed?)

Part E: (mirage)

7.) When LASER LIGHT is passed over an initially cold HOT PLATE that has subsequently been heated, it does something unusual.

a.) What, specifically, does it do?

b.) *Why* does it do what it does?

c.) How is this related to mirages?