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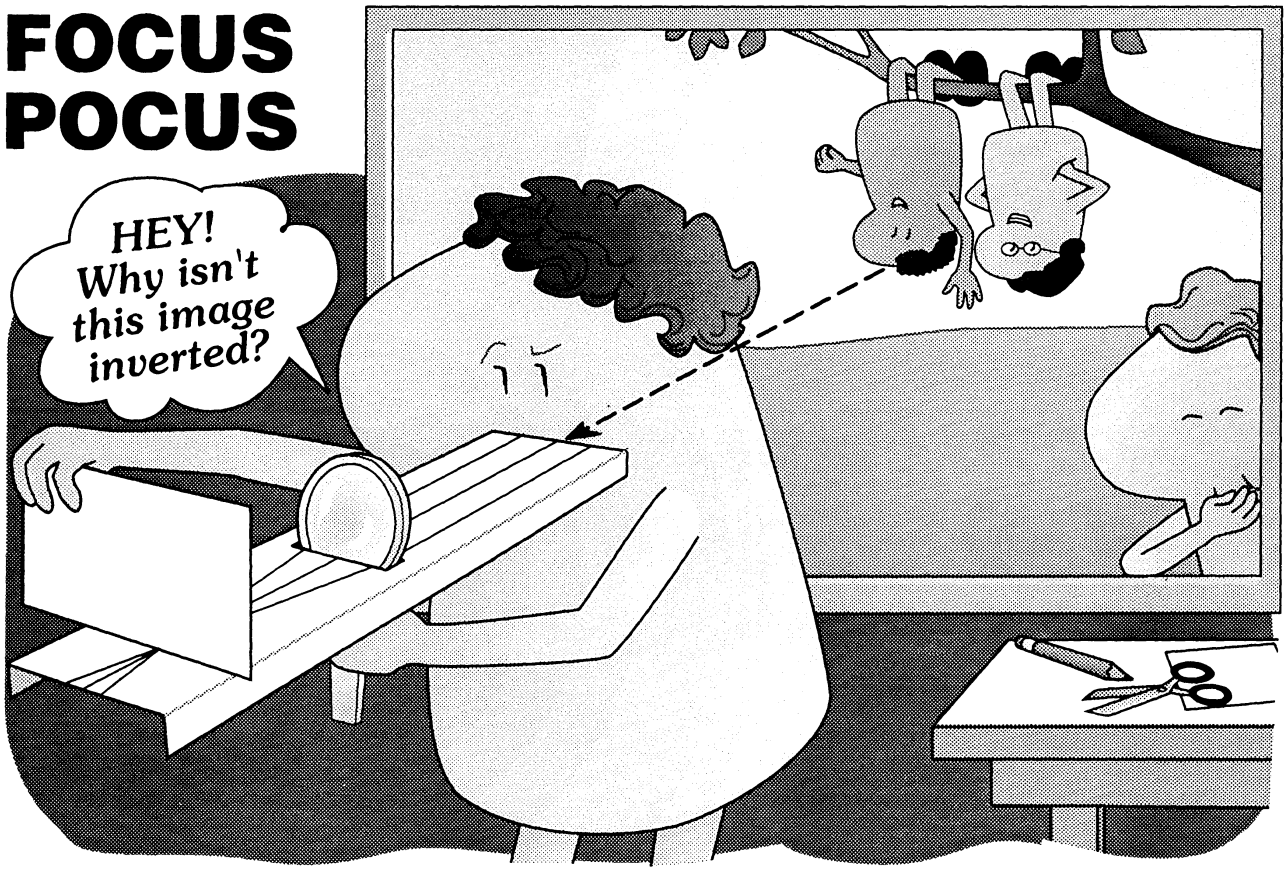

SCIENCE WITH SIMPLE THINGS SERIES

Conceived and written by

RON MARSON

Illustrated by

PEG MARSON

With special thanks to
Zander Willis and Chanelle Willis

TOPS LEARNING SYSTEMS

10970 South Mulino Road
Canby, Oregon 97013

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Gathering Materials

Listed below is everything you'll need to teach this module. Buy what you don't already have from your local supermarket, drugstore or hardware store. Ask students to bring recycled materials from home.

Keep this classification key in mind as you review what's needed.

general on-the-shelf materials:	*special in-a-box materials:*
Normal type suggests that these materials are used often. Keep these basics on shelves or in drawers that are readily accessible to your students. The next TOPS module you teach will likely utilize many of these same materials.	Italic type suggests that these materials are unusual. Keep these specialty items in a separate box. After you finish teaching this module, label the box for storage and put it away, ready to use again.
(substituted materials):	*optional materials:
Parentheses enclosing any item suggests a ready substitute. These alternatives may work just as well as the original. Don't be afraid to improvise, to make do with what you have.	An asterisk sets these items apart. They are nice to have, but you can easily live without them. They are probably not worth an extra trip to the store, unless you are gathering other materials as well.

Everything is listed in order of first use. Start gathering at the top of this list and work down. Ask students to bring recycled items from home. The Teaching Notes may occasionally suggest additional *Extensions*. Materials for these optional experiments are listed neither here nor under *Materials*. Read the extension itself to determine what new items, if any, are required.

Quantities depend on how many students you have, how you organize them into activity groups, and how you teach. Decide which of these 3 estimates best applies to you, then adjust quantities up or down as necessary:

$Q_1/Q_2/Q_3$

- **Single Student:** Enough for 1 student to do all the experiments.
- **Individualized Approach:** Enough for 30 students informally working in pairs, all self-paced.
- **Traditional Approach:** Enough for 30 students, organized into pairs, all doing the same lesson.

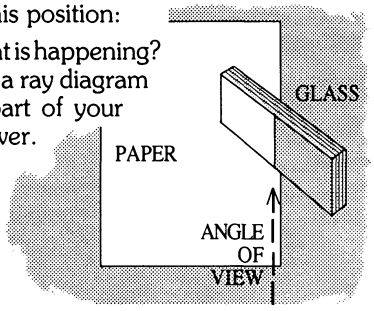
KEY: *special in-a-box materials* (substituted materials) general on-the-shelf materials *optional materials

$Q_1/Q_2/Q_3$	
1/15/15	scissors
4/60/60	microscope slides
.1/1/1	cups modeling clay
6/90/90	straight pins, about 1 inch long
1/5/5	rolls ½ inch clear tape
1/5/15	metric rulers
1/8/15	sets assorted coins: 4 pennies, 1 nickel, 1 dime, 1 quarter
3/45/45	straight plastic drinking straws – see Teaching Notes 6
1/5/5	rolls ¾ inch masking tape
2/30/30	TOPS hand lenses or equivalent – see Teaching Notes 3
2/30/30	glass soda or beer bottles, about 20 cm tall – see Teaching Notes 14
1/15/15	index cards
1/15/15	regular canning rings, not wide-mouth
1/1/1	roll plastic wrap
1/15/15	heavy rubber bands
1/15/15	dropper bottles of fresh water
1/15/15	metal washers, ¾ inch (19 mm) wide with a 5/16 inch (8 mm) hole
1/1/1	box facial tissue (roll toilet paper)
4/60/60	paper clips
2/30/30	wooden clothespins
1/3/15	hand mirrors
1/15/15	empty cans – see Teaching Notes 8
1/1/1	roll wax paper
1/1/1	roll aluminum foil
1/5/15	candles with drip catchers
1/2/5	pkgs matches
1/10/15	meter sticks
1/1/1	roll adding machine tape
1/1/1	pencil sharpener
1/8/15	*hand calculators
1/5/15	sets of nails: three medium, about 4 cm long; one large, about 8 cm long; one finishing nail 4.5 cm long; one framing nail 6.5 cm long – see Teaching Notes 20
1/15/15	palm-sized pieces, clear, flat #6 polystyrene plastic from deli/bakery "clamshells" or lids
1/2/5	hole punch tools
1/1/1	jar petroleum jelly
1/1/1	pkg each: granulated sugar, table salt, pepper, whole poppy seeds
1/1/1	**bottle glycerin*
1/3/15	dark crayons or marking pen
1/5/15	*sets printed matter – see Teaching Notes 18*
1/15/15	wooden toothpicks

Review / Test Questions

activity 1-2

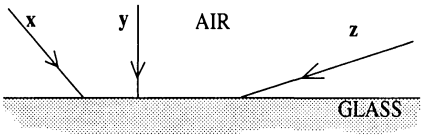
The edge of a straight piece of paper seems to shift inward when viewed through a glass block resting in this position:



What is happening? Use a ray diagram as part of your answer.

activity 1-3 A

Light rays x, y, and z pass from air into glass like this:



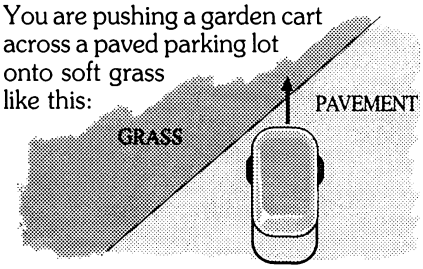
a. Copy and finish this diagram to show how each light ray refracts.
b. Draw and label the angle of incidence (∠i) for light rays x and z.

activity 1-3 B

Suppose light waves did <u>not</u> slow down as they passed through a hand lens. Would the lens still focus light? Explain.

activity 2

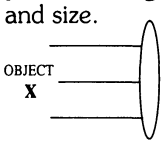
You are pushing a garden cart across a paved parking lot onto soft grass like this:

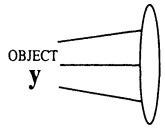


a. In which direction (right or left) will the cart naturally turn when it leaves the pavement? Why?
b. Can you push the garden cart from pavement to grass in a direction that will not turn it? Explain.

activity 3, 8-10

Light reflected from objects **x** and **y** passes through lenses of equal shape and size.





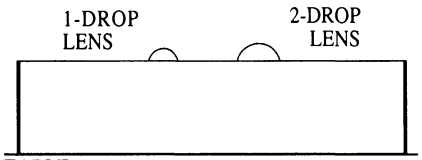
a. Copy and complete these diagrams to show how each lens focuses its light.

b. Which object is closer to its lens? How do you know?

activity 4-6

Use a metric ruler to answer this question:

A 1-drop and a 2-drop water lens rest on a plastic window over a canning ring. A high ceiling light shines through both lenses, but only the 2-drop lens casts a focused image on the table top.

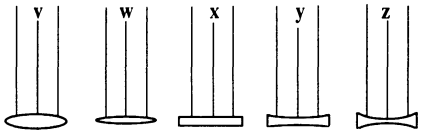


a. Draw a labeled diagram of equal size that shows how light rays refract through each lens.
b. Why does the 2-drop lens form an image of the light, but the 1-drop lens does not?

activity 4-7

Parallel rays from an overhead sun fall on each lens shape as shown.

a. Copy this drawing. Extend the sun's rays through each lens to show how they refract.
b. Describe the shape of each lens, using correct vocabulary.



activity 5-7 A

Circle or *box* all words that belong together:

positive curvature
convex lens
diverging lens
flat
converging lens
reduces
negative curvature
magnifies
neutral lens
concave lens

activity 5-7 B

Connect the correct lens shape with its best description.


You see the greatest magnification through this lens.

A hand lens has this shape.


Window glass has this shape.

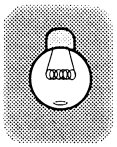

Parallel rays that pass through this lens diverge slightly.

You see the greatest reduction through this lens.

activity 8 A

You are given these 5 materials:
(1) a can with both ends removed,
(2) wax paper,
(3) aluminum foil,
(4) a pin, and
(5) tape.

a. Explain how to build a pinhole projector with these items.



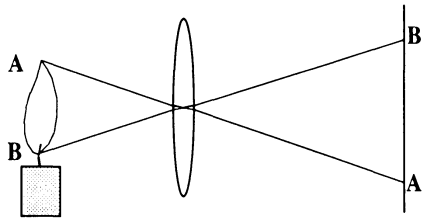
b. When you aim your pinhole projector toward a bright light bulb, its image appears inverted. Draw a diagram that explains why.

activity 8 B

Would you poke a *larger* or *smaller* pinhole in a pinhole projector to make...
a. a brighter image? Why?
b. a better focused image? Why?

activity 8-9

Light rays from points A and B on a candle flame focus on a screen like this.



a. Draw 4 more light rays focusing from point A.
b. Draw 4 more light rays focusing from point B.

activity 9-10 A

When looking through a hand lens, distant objects look blurry, but very close objects are in sharp focus. Why is this so?

activity 9-10 B

People with normal vision can see objects in focus from infinity to a near point of 25 cm.

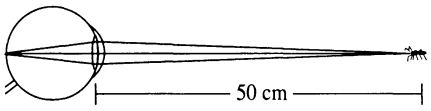
a. Why can't the average eye see closer than this?

b. How might you use a book, a piece of string, and a ruler to compare your own nearest point of clear vision to the normal near point?

Review / Test Questions (continued)

activity 9-10 C

Toby is watching an ant walk across his desk. At 50 cm his eye focuses like this:



a. Draw a similar diagram that shows Toby's eye focusing on the same ant at 25 cm.

b. How does Toby's eye accommodate to see the ant clearly at closer and closer distances?

activity 11

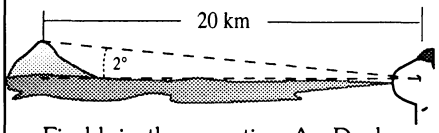
The sun and the moon both subtend about ½° in our field of view. Do the sun and moon have...

a. the same apparent size? Explain.

b. the same actual size? Explain.

activity 11-13 A

A mountain peak 20 km away subtends a 2° angle from your horizon.



a. Find k in the equation A x D = k.

b. How big does the mountain look at 4 km? 40 km?

activity 11-13 B

You are traveling in a spaceship on your way to the moon. At a Distance of 200,000 km, the moon subtends an Angle of about 1° in your field of view.

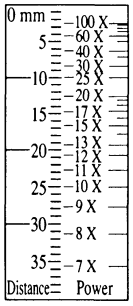
a. A and D are inversely proportional. What does this mean?

b. Find k in the equation A x D = k.

c. Use this equation to estimate your distance to the moon when it subtends 4° in your field of view.

activity 12-13

This Powers Ruler has 2 sets of numbers: what do the numbers on the left measure? The numbers on the right?



a. Show that these numbers are inversely proportional.

b. How far from your eye must you hold a paper clip to see it at 50X? Show your math.

activity 13-14

How close should you hold your eye to the lens of a magnifier to see...

a. the largest possible field of view?

b. the greatest possible magnification?

activity 14-15

Use a hand lens to answer this question.

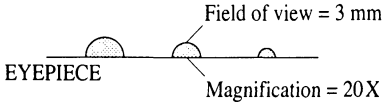
Study this grey square with a hand lens. Make an enlarged drawing of what you see. ⟶ ▫

a. How would the dots look if you placed a drop of water on the center of the hand lens and looked through that?

b. Would the small drop focus at the same distance as the larger hand lens?

activity 15-16

A large, medium and small water drop rest on the eyepiece of your microscope like this. The medium drop has a 3 mm field of view and magnifies at 20X.



What can you say about the field of view and magnification of the largest drop? The smallest drop?

activity 15-16, 20

The maximum power of a "suspender lens" that you can hang from your microscope is about 25X.

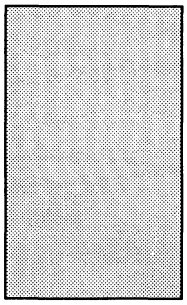
a. How would you physically modify your microscope to make a suspender lens that magnifies higher than 25X?

b. Are "sitting lenses" that rest on top of the eyepiece also limited to 25X? Why?

activity 13, 17 A

Use a metric ruler to answer this question.

The post office has issued a new stamp with this actual size:



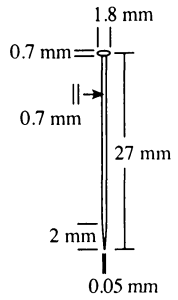
a. Make a scale drawing of this stamp that is 5 times actual size.

b. Your drawing appears 5X larger than actual size when viewed at near point. At what distance from your eye does it appear actual size?

activity 13, 17 B

Use a metric ruler to answer this question.

This straight pin is drawn actual size:



a. Make a scale drawing that is 8 times actual size.

b. Your drawing appears 8X larger than actual size when viewed at near point. At what distance from your eye does it appear actual size?

activity 18 A

A company wants to use three different grey tones (light, medium, and dark) in a printed black and white advertising flyer. What ink color(s) should a printer use to produce this flyer? Explain.

activity 18 B

Spectra Paints, Inc., uses a full-color paint palette in their company logo, printed with black, yellow, blue and red ink. How are blending colors created? Give an example.

activity 19

A secret message is printed on a bright electric light bulb, but the type is too small to read without optical aid. How would you use a piece of foil and a pin to read this message?

activity 8, 10, 19

Look at this paper through half-closed eyes.

a. Why can't you see your eyelashes immediately in front of your eyes?

b. What optical aid would you use to see them? Explain why your method works.

activity 4, 6, 20

Your van Leeuwenhoek microscope has eyepiece holes of 2 different diameters.

a. Which eyepiece hole supports the more powerful water lens?

b. Explain your answer in terms of lens curvature and refraction.

activity 13, 20

A tiny, round lens in your van Leeuwenhoek microscope allows you to focus clearly on a human hair at a distance of 3.8 mm. Derive its power of magnification from near point, based on this inverse equation:

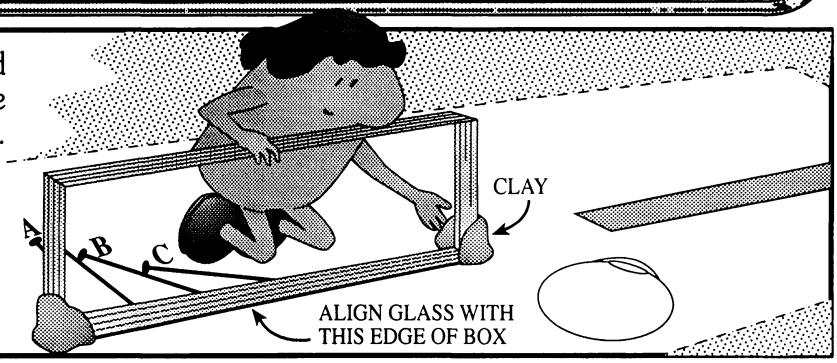
Power x Distance = k

PIN RAYS

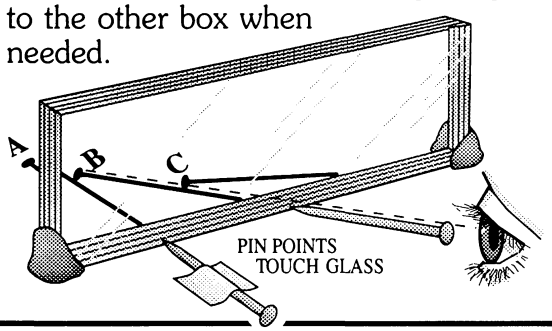
1. Cut the supplementary sheet labeled Pin Rays apart on the dotted line. Use the top now — save the bottom for later.

a. Stand enough microscope slides on edge to cover the *left* grey box.

b. Hold them upright with grape-sized balls of clay pinched around each end to create a glass "block."

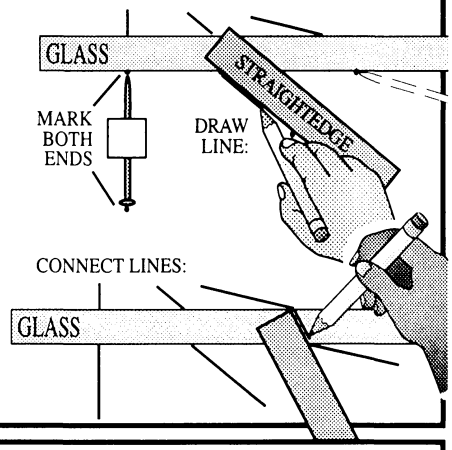


2. Look through the glass at "pin" A. Aim a real pin (point touching glass) so it lines up, then hold it with a bit of tape. Repeat for "pins" B, C, D, E, F, moving the glass to the other box when needed.

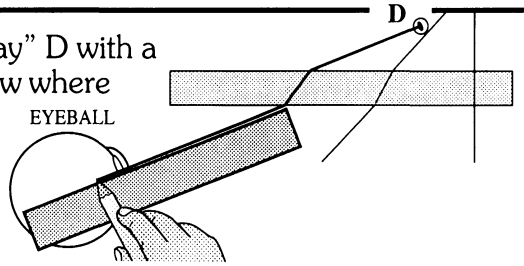


a. Check that each pin appears accurately lined up, then remove the glass, and mark each pinhead *and* point with a dot. Remove each pin and draw a straight line in its place.

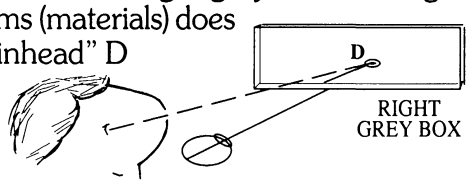
b. Now show the paths of 6 "light rays." Join each "pin pair" with another short, straight line.



3. Extend "light ray" D with a straight line to show where it strikes the *retina* in the back of the eyeball on your paper.

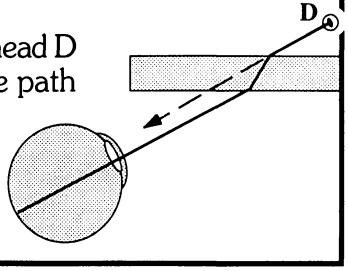


a. Set your glass block on the right grey box. Through what series of mediums (materials) does the light ray from "pinhead" D (circled behind the glass) travel to reach your eye?

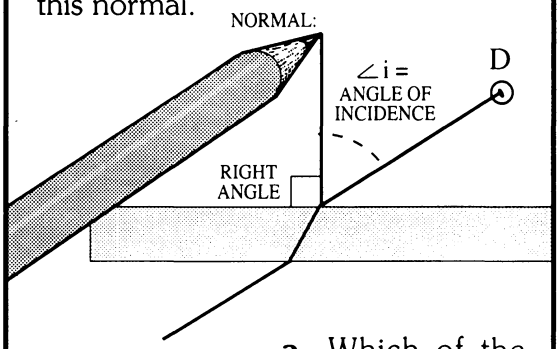


b. Light ray D appears straight until you take away the glass. Describe its actual shape. Label 2 points where it *refracts* (bends).

c. Draw a dashed line from pinhead D to the eye's retina, showing the path light takes without glass in between. Why does pinhead D seem to jump when you replace or remove the glass?



4. Draw a *normal* (a perpendicular line) where ray D meets glass at a right angle. Mark and label the *angle of incidence* (∠ i), between ray D and this normal.



a. Which of the other 5 light rays has the same angle of incidence as ray D? Draw and label this angle.

b. Draw and label other angles of incidence.

c. Does a light ray's angle of incidence affect how much it refracts? Explain.

Objective

To track the path of light as it refracts through glass. To recognize that light bends more sharply as its angle of incidence increases.

Extra Help

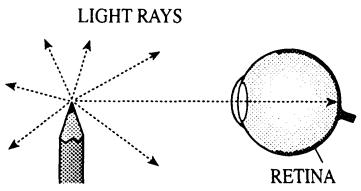
Let me introduce this new section, Extra Help, by telling you about my first bicycle. I remember finding it one year behind our Christmas tree. My father assembled it for me, replete with training wheels. I happily rode this four-wheel contraption up and down my driveway for some time, quite unconsciously learning the balance and skills I would need later to ride on two wheels.

One day my father unbolted those training wheels from my bike and told me to ride without them. I was afraid, but he ran along behind, holding onto the seat in case I should fall. As my self-confidence increased, his firm hand grew lighter and lighter. Soon I was riding solo – and loving it.

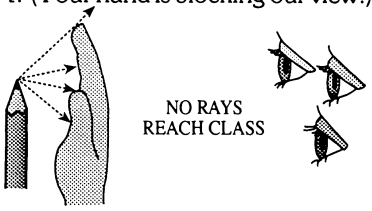
Activity sheets in this TOPS module, like my childhood bicycle, are meant for solo riding. Extra Help, like training wheels, provides teaching strategies to help those younger, less experienced scientists stay in balance. Use this section as needed, but with the gentle touch of my wise father – lighter and lighter, until not at all.

Demonstration: Review, as necessary, the key ideas underlined below. Use simple blackboard diagrams, where possible, for visual reinforcement.

a. Hold up a pencil and ask your class to identify it. (A pencil.) How do you know it's a pencil? (Because we can see it.) If the room was totally dark, could you see it? (No.) How does light help you see it? (Light reflects off the pencil, travels across the room and into our eyes. It strikes the retina at the back of our eyes, which then sends an "I see" nerve message to our brains.)



b. Place a hand between the class and the pencil. Why can I see the pencil, but you can't? (Your hand is blocking our view.) What does this suggest about the path that light takes to reach our eyes? (Light reflected from the pencil travels to my eyes in a straight line. It can't curve around your hand.)



c. Look at an object outside a window. Through what sequence of mediums (materials) does light travel from this object to reach our eyes? (Light travels from the object through air/glass/air to reach our eyes.) Is this true for everyone in the room? (Probably not. Light travels through air/glass/air/plastic/air if I am wearing glasses, or air/glass/air/plastic if I am wearing contacts.)

Lesson Notes

1. Notice that "Pin Rays" is both capitalized and underlined. This style is used throughout this module to alert students that supplemental printed materials are required.

2. When they are properly lined up, each real pin in *front* of the glass should appear to rest on the same straight line as its printed counterpart *behind* the glass. Minor alignment error will not spoil the experiment.

3-4. All the step numbers in these both are underlined. This alerts students that some kind of written response is required, either on notebook paper, or on a cutout that will become part of their write-ups.

4. Though not specifically directed to do so, students should write their names on their Pin Rays sheets (and all supplementary materials) to use again. Equipment that students construct should likewise be labeled and saved for future use, unless otherwise directed. Because the glass blocks in this activity will not be used again, the microscope slides and clay can be pulled apart at this time.

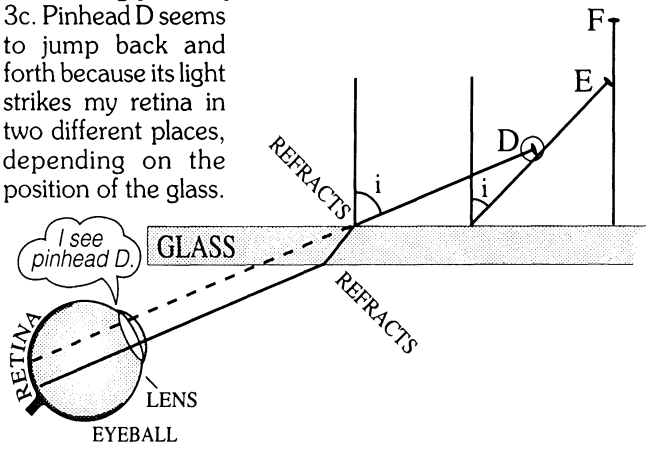
Answers

3-4. Students should draw rays, normals and angles as illustrated on both diagrams below.

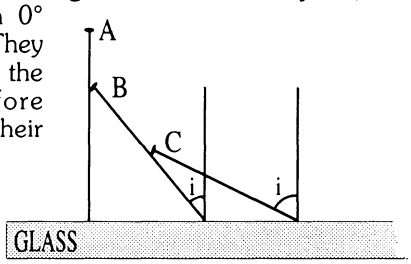
3a. Light reflected from pinhead D travels through air, then through glass, then through more air before entering the eye.

3b. Light ray D bends in 2 places: where it enters and exits the glass. (Sophisticated observers may notice that these entering and exiting rays, though no longer in line with each other, still move along parallel paths.)

3c. Pinhead D seems to jump back and forth because its light strikes my retina in two different places, depending on the position of the glass.



4a. Ray C has the same angle of incidence as ray D. (Pins A and F both have a 0° angle of incidence. They are perpendicular to the glass, and therefore superimposed on their normals.)



4c. Yes. As a light ray's angle of incidence increases, so does its tendency to refract or bend as it enters and exits the glass.

Materials

- ☐ The Pin Rays cutout. Photocopy this from the supplementary section at the back of this book.
- ☐ Scissors.
- ☐ About 4 glass microscope slides, more if they are thin, fewer if they are thick. An approximate match to the thickness of the grey box is OK.
- ☐ A small lump of modeling clay.
- ☐ Six straight pins, about 1 inch (2.5 cm) long.
- ☐ Clear tape.
- ☐ A ruler, index card or other straightedge.