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ABSTRACT

This booklet, one of a series developed by the Frederick County Board of Education, Frederick, Maryland, provides an instruction module for an individualized or flexible approach to secondary science teaching. Subjects and activities in this series of booklets are designed to supplement a basic curriculum or to form a total curriculum, and relate to practical process oriented science instruction rather than theory or module building. Included in each booklet is a student section with an introduction, performance objectives, and science activities which can be performed individually or as a class, and a teacher section containing notes on the science activities, resource lists, and references. This booklet presents an investigation of optical lenses and their use. The estimated time for completing the activities in this module is 2-3 weeks. (SL)

# Lenses

# AIDS TO INDIVIDUALIZE THE TEACHING OF SCIENCE



# MINI-COURSE UNITS

BOARD OF EDUCATION OF FREDERICK COUNTY

1974

Marvin G. Spencer

# LENSES AND THEIR USES

Prepared by

Beverly C. Stonestreet

Estimated Time for Completion

2-3 weeks

Frederick County Board of Education

Frederick, Maryland

Frederick County Board of Education

Mini Courses for

Physical Science, Biology, Science Survey,

Chemistry and Physics

Committee Members

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1974

## FOREWORD

The writing of these instructional units represents Phase II of our science curriculum mini-course development. In Phase I, modules were written that involved the junior high disciplines, life, earth and physical science. Phase II involves senior high physical science, biology, chemistry, physics and science survey.

The rationale used in the selection of topics was to identify instructional areas somewhat difficult to teach and where limited resources exist. Efforts were made by the writers of the mini-courses to relate their subject to the practical, real world rather than deal primarily in theory and model building.

It is anticipated that a teacher could use these modules as a supplement to a basic curriculum that has already been outlined, or they could almost be used to make up a total curriculum for the entire year in a couple of disciplines. It is expected that the approach used by teachers will vary from school to school. Some may wish to use them to individualize instruction, while others may prefer to use an even-front approach.

Primarily, I hope these courses will help facilitate more process (hands on) oriented science instruction. Science teachers have at their disposal many "props" in the form of equipment and materials to help them make their instructional program real and interesting. You would be remiss not to take advantage of these aids.

It probably should be noted that one of our courses formerly called senior high physical science, has been changed to science survey. The intent being to broaden the content base and use a multi-discipline approach that involves the life, earth and physical sciences. It is recommended that relevant topics be identified within this broad domain that will result in a meaningful, high interest course for the non-academic student.

ALFRED THACKSTON, JR.
Assistant Superintendent for Instruction

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CONTENTS

# LENSES AND THEIR USES

Lenses are used in many ways. They are used in our own eyes and in many devices which help us use our sense of sight.

In this series of activities, you will investigate how and why lenses do their jobs. This study is called optics.

## A. Refraction

There is much evidence that light travels in straight lines, but there are also many times when a light ray (a single line of light) changes direction. Many times, this change in direction takes place when light travels from one transparent substance into another. This bending of light happens because light travels at different speeds in different substances.

### OBJECTIVES

After completing the following activities, the student will be able to:

1. define refraction.
2. describe a model of refraction.
3. describe the formation of a mirage.

### ACTIVITIES

a. Read Reference Sheet 8-2, page 238, Behavior of Light and Sound, Cambridge Book Company

b. Read pages 125-127, Pathways in Science, Physics 3, Globe Book Co.

c. Read the following paragraphs.

Bent light rays can fool you. Your eye records the direction from which a light ray enters it but cannot tell if the light has changed direction (been refracted) between the object and your eye. This can cause optical illusions. For example, a pencil in a beaker of water seems to be bent (or broken) at the surface of the water and from above, it seems to be higher than it really is.

A mirage is an optical illusion produced by light traveling faster in hot air than in cooler air. A common mirage is the "pool" of water on the road ahead on a hot, sunny day. Because light travels faster through the hotter air near the road, light coming toward you is bent upward to your eye. This makes the blue light from the sky look the same way it would if it were reflected from a real pool of water on the road.

## OBJECTIVES

After completing the following activities, the student will be able to:

4. determine the pathway of light as it travels from air into glass (or water) and back into air.

5. describe the conditions which cause no refraction of light.

## ACTIVITIES

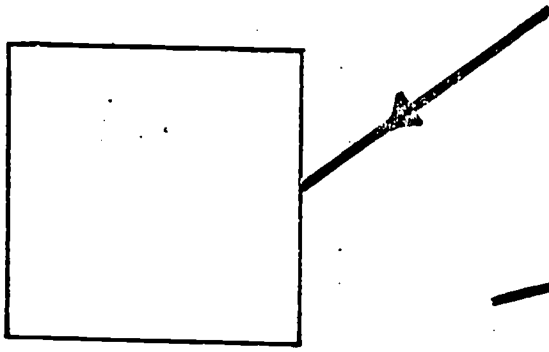
a. Do Investigation 51, "Behavior of Light Passing through Different Substances", page 240, Interaction of Matter and Energy, Rand McNally

or

Do Problem 8-7, "To Determine the Path of Light as It Is Refracted by Glass", page 239, Behavior of Light and Sound, Cambridge Book Company

b. Do the Refraction Worksheet. Do not write in this booklet unless your teacher tells you to. You may be given another copy of the diagrams.

Finish the diagrams to show the path each ray would take through the following shapes of glass (or water) and back into air.



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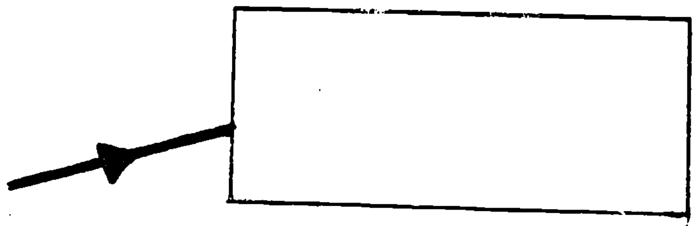

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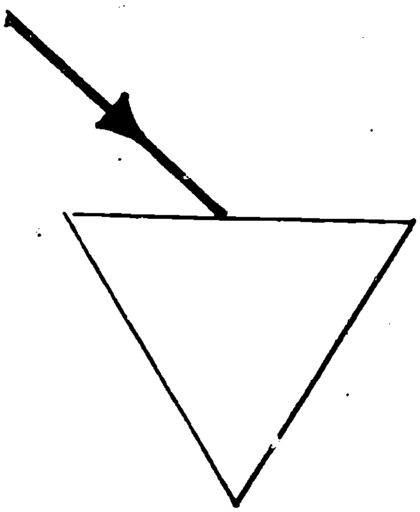

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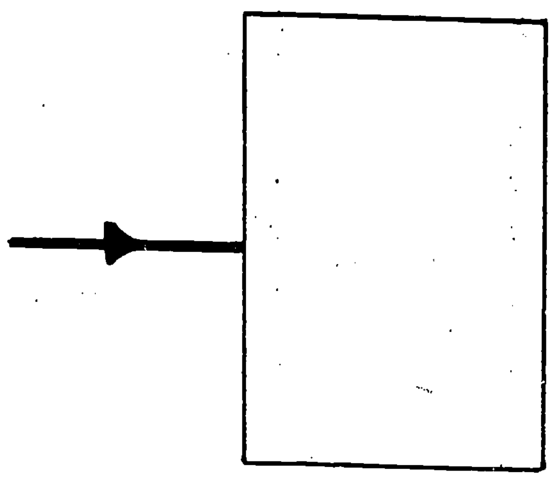

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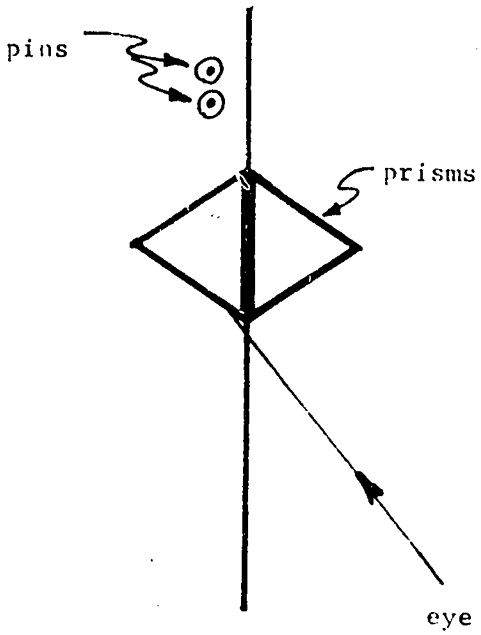



Figure A

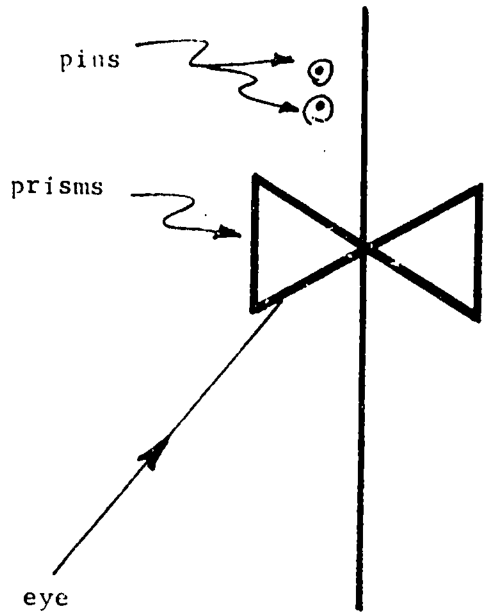
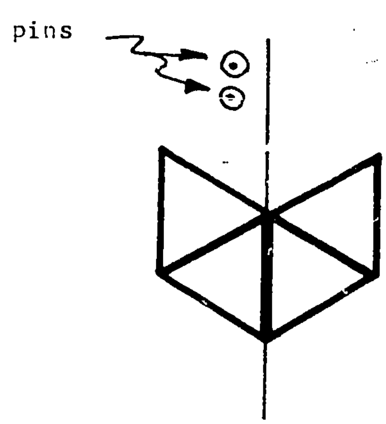



Figure B

Questions

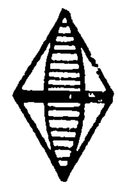
1. How many times is each light ray refracted? Where does this happen?
2. Which prism set-up makes light converge? diverge?
3. Towards which part of the prism is the light bent in both set-ups?
4. Predict the results of using 4 prisms arranged in this way:



C. Types of Lenses and Images

As you have shown, prisms can be used to converge and diverge light rays. A single piece of glass with a shape similar to pairs of prisms can also be used to make light rays converge and diverge.

Imagine that you could smooth the prism edges to form curved pieces of glass like these:



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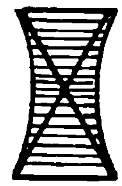


B

Shape A makes light rays converge, since it is thicker in the center. Shape B makes light rays diverge, since it is thicker at the edges. Curved pieces of glass which change the direction of a ray of light are called lenses.

When light rays from an object pass through a lens, they are refracted and form an image of the object. You can see this image by looking through the lens at the object or by shining the image on a screen.

OBJECTIVES

After completing the following activities, the student will be able to:

8. state the purpose of using lenses.

9. identify the type of lens from a drawing of a lens.

ACTIVITIES

a. Read pages 127-130, Pathways in Science, Physics 3, Globe Book Company

b. Read Reference Sheet 8-3, pages 242-243, Behavior of Light and Sound, Cambridge Book Company

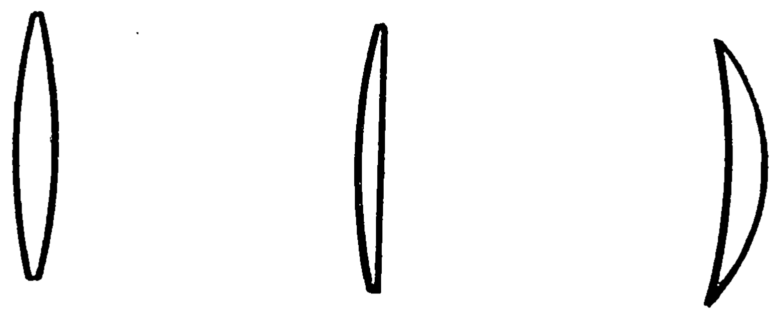
c. Make a collection of as many different lenses as possible.

d. Study the sheet, "Types of Lenses" and self-test yourself on these lens shapes and names.

## TYPES OF LENSES

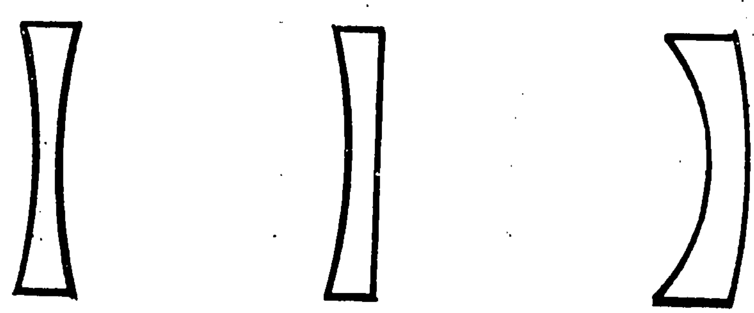
These diagrams are <u>edge views</u> of six different types of lenses.

CONVERGING LENSES - thicker center



double convex    plane convex    concave convex

DIVERGING LENSES - thicker edges



double concave    plane concave    convex concave

OBJECTIVES

After completing the following activities, the student will be able to:

10. identify a given lens as one of six types.

11. describe the image formed by a lens.

12. distinguish between a real and a virtual image.

ACTIVITIES

a. Do the following experiment.

Procedures

1. Examine the lenses which your teacher has given you and identify their type by your study sheet. Place each lens over its picture on the sheet.

2. Copy the following chart and use it to record your observations for Procedures 3 and 4.

| Type of lens | Description of image | | |
|---|---|---|---|
| | 5 cm | 25 cm | across room |
| | | | |

3. Look through each lens at an object 5 cm from the lens. Move the lens toward or away from your eye until you see a clear image. Describe this image as "enlarged" (larger) or "reduced" (smaller) and as "upright" (right side up) or "inverted" (upside down).

4. Repeat Procedure 3, but look at an object 25 cm from the lens and then at an object on the other side of the room.

5. Lay a convex lens over the printing on a page. Observe and describe differences in the letters that you see through the center of the lens and near the edges of the lens. These differences are called <u>distortions</u>. Repeat, using a concave lens.

## Questions

1. How can you identify a convex lens? a concave lens?
2. Which type of lens usually magnifies? reduces?
3. Which type of lens makes light rays converge? diverge?
4. Which part of a lens forms the least distorted image?

b. Copy and complete the following chart:

| Type of lens | Image | Form | Size |
|---|---|---|---|
| concave | ___(1)___ | ___(2)___ | reduced |
| ___(3)___ | real (or) ___(6)___ | ___(4)___ (or) upright | ___(5)___ (or) enlarged |

OBJECTIVES (Optional)

After completing the following activity, the student will be able to:

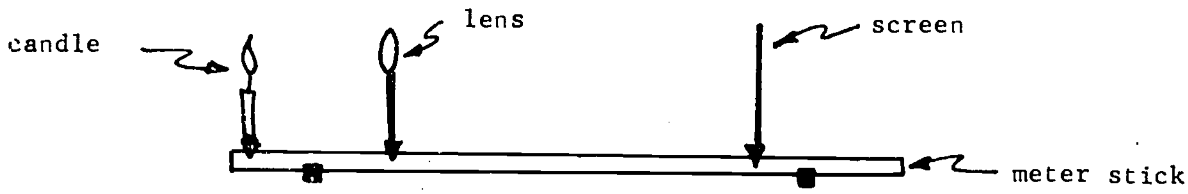
13. assemble an optical bench.
14. adjust an optical bench apparatus to focus a clear image through a convex lens.
15. calculate the ratios $\frac{\text{object height}}{\text{image height}}$ and $\frac{\text{object distance}}{\text{image distance}}$

ACTIVITY

a. Do the following experiment.

Procedures

1. An "optical bench" is a device used in the study of lenses. With it, you can measure the distance between an object, a lens, and the image of the object. Set up the optical bench as directed by your teacher and as shown in the following diagram; use a double convex lens.




2. Move the lens and screen back and forth until a clear image of the flame appears on the screen. Describe the image and measure and record its height in cm and the height in cm of the actual flame. (Remember that a plastic ruler will melt!) Also, record in cm the positions of the candle, lens and screen.

3. Repeat Procedure 2 with a concave lens. Results?

4. Remove the screen and look through the concave lens from where the screen was. Results?

Questions

1. From your measurements in Procedure 2, calculate these ratios:

$$\frac{\text{cm from candle to lens}}{\text{cm from lens to screen}} \quad \text{and} \quad \frac{\text{cm height of flame}}{\text{cm height of image}}$$

Are the two ratios close in value? Careful measurements have shown that they should be equal.

2. A real image is one which can be projected onto a screen. A virtual image is one which cannot be projected onto a screen but which can be seen by looking through the lens. Which type of image is formed by a concave lens?

A convex lens can be used to magnify or make an object larger. The number of times it enlarges the object is its <u>magnifying power</u>.

$$\text{magnifying power} = \frac{\text{size of image}}{\text{size of object}}$$

OBJECTIVES

After completing the following activity, the student will be able to:

16. use a convex lens as a simple magnifier.

17. calculate the magnifying power of a convex lens.

18. describe the conditions for using a convex lens as a magnifier.

ACTIVITY

a. Do the following experiment.

<u>Procedures</u>

1. Place a double convex lens on a piece of graph paper. Do the squares on the paper look any different through the lens?

2. With one eye closed, look through the lens and <u>slowly</u> raise it from the paper. What happens to the size of the squares?

3. Raise the lens from the paper until the lines are as clear as possible. Count and record the number of cross-wise lines which you see through the lens. Count and record the number of cross-wise lines actually on that spot of paper. (You can see these lines beside the lens.)

<u>Questions</u>

1. Divide the actual number of lines on the paper by the number of lines you see through the lens. This tells you how many times larger the lens makes the spaces between the lines.

2. What is the magnifying power of your lens?

3. The image formed by a convex lens may be (a) upright or inverted, (b) larger or smaller than the object, (c) real or virtual. What kind of image is formed if the convex lens is far from the object? if the convex lens is close to the object?

There is a spot on each side of every lens where light from a far away (distant) object is focused. These spots are called focal points or principal focuses (foci). The distance from the lens to either of these focal points is called the focal length of the lens.

OBJECTIVE (Optional)

After completing the following activity, the student will be able to:

19. measure the focal length of a convex lens.

ACTIVITY

a. Do experiment 9-14, "Using a Mirror to Find the Focal Length of a Convex Lens", page 328, Physical Science Investigations, Houghton Mifflin Company

D. Ray Diagrams

You have seen how different lenses can form different types of images and in some activities, you have made drawings to show the refraction of a ray of light. It is possible to diagram the refraction through a lens without actually using the lens and making experimental measurements. These drawings are called "ray diagrams" and predict the formation of images.

OBJECTIVES

After completing the following activities, the student will be able to:

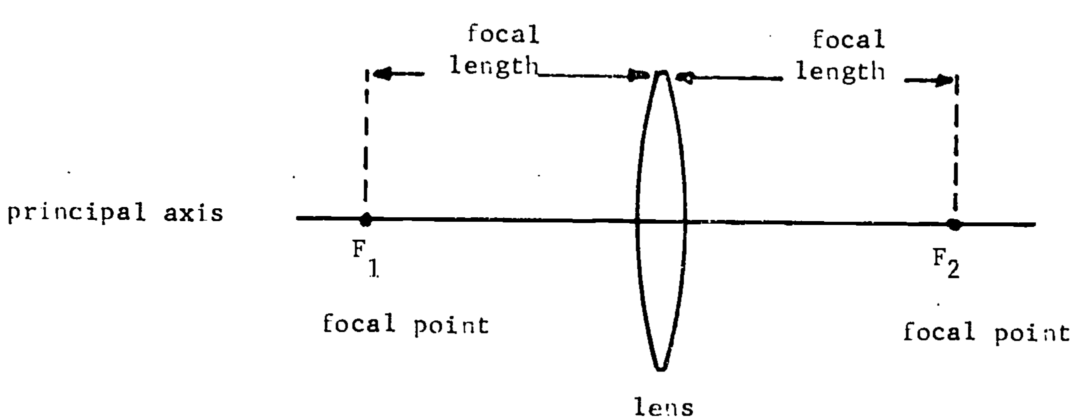
20. identify the principal axis, focal points, and focal length in a ray diagram.

21. complete a ray diagram to locate the image formed by a convex lens.

ACTIVITIES

a. Study the following paragraphs.

There is a certain spot on each side of every lens where parallel rays of light are focused (or seem to be focused) together into a point. These points are called focal points or principal focuses (foci). A straight line drawn through the lens and these focal points is called the principal axis of the lens. The distance from the lens to the focal point is called the focal length of the lens.



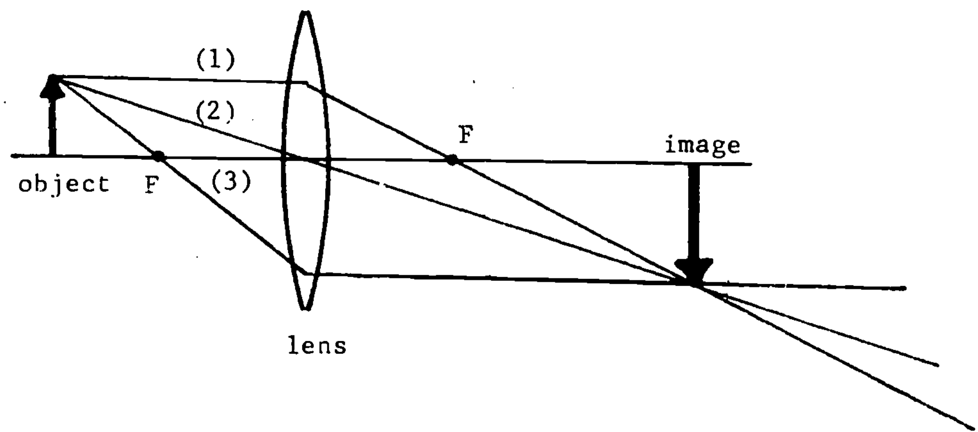
Any object gives off rays of light in all directions, but to diagram the image formed by a lens only two specially chosen rays need to be drawn. Since these rays of light come from the same spot on the object, they will form that spot on the image when they come back together after being refracted through the lens.

To construct the image formed by a convex lens, draw from the tip of the object, any two of these lines:

(1) parallel to the principal axis, through the lens and through the focal point;

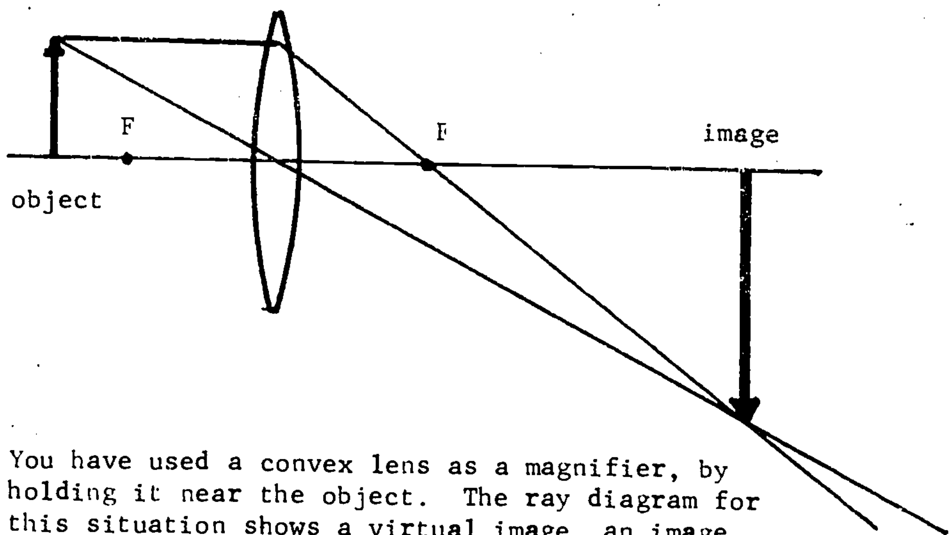
(2) through the center of the lens (no refraction);

(3) through the focal point, through the lens and parallel to the principal axis.

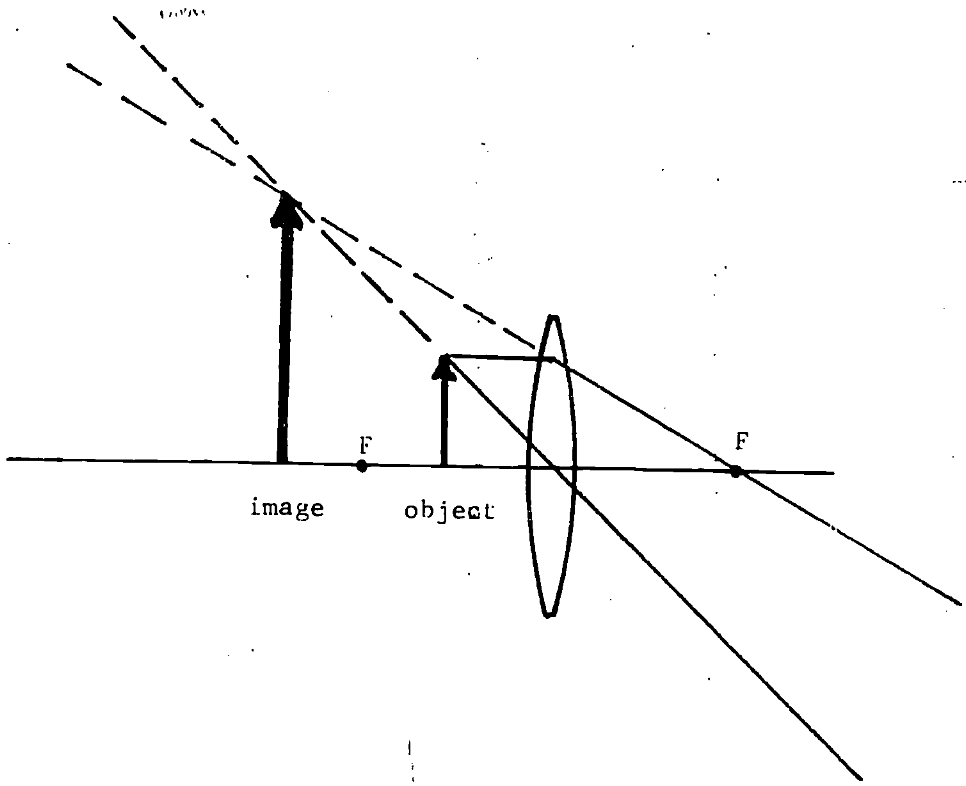



In the diagram, lines (1), (2), and (3) show three rays of light from the tip of the object arrow. Where these rays come together again forms the image of the tip of the arrow. (An object is usually drawn as an arrow because it is easy to tell when its image is inverted.) This particular image is enlarged and inverted.

The following ray diagrams show only 2 of the 3 rays since only 2 rays are really needed to locate the image.




You have used a convex lens as a magnifier, by holding it near the object. The ray diagram for this situation shows a virtual image, an image which seems to be on the same side of the lens as the object.



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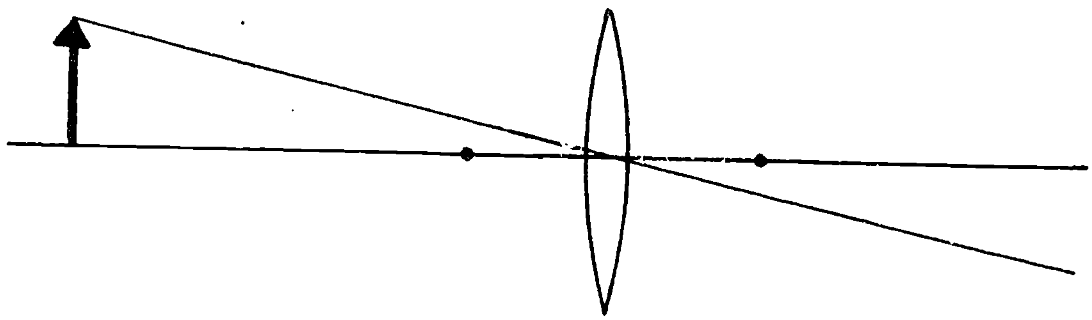
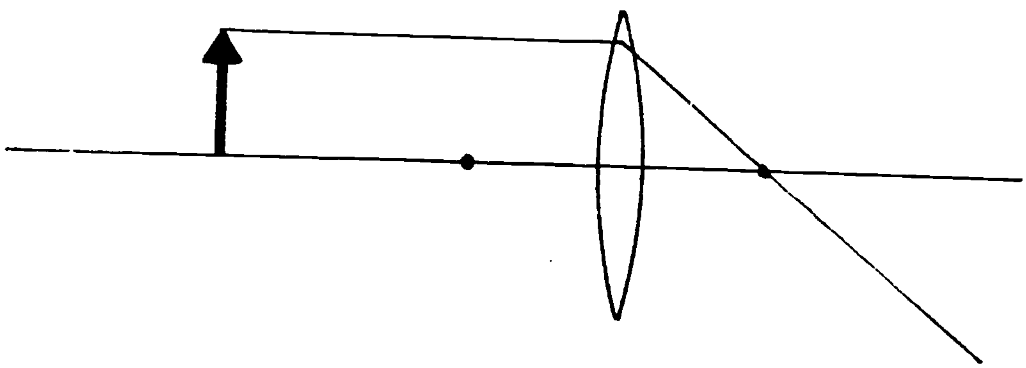
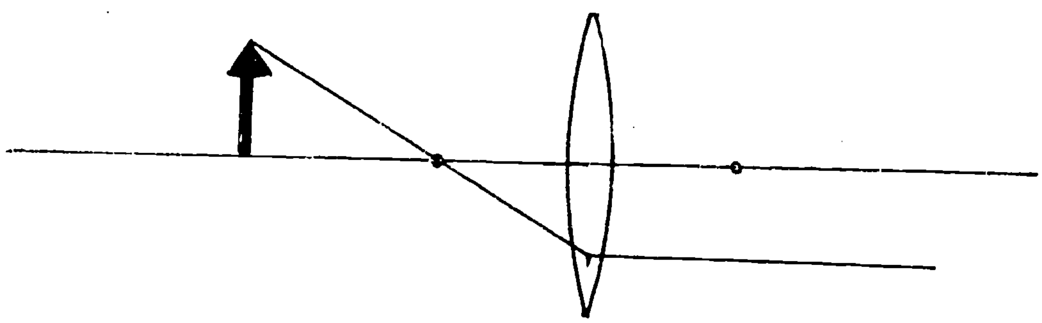
Complete each of the following diagrams to show the image formed by the lens. Label the focal points, the principal axis, the object, and the image.







OBJECTIVES

After completing the following activities, the student will be able to:

22. construct a ray diagram to locate the image formed by a convex lens.

23. construct a ray diagram to locate the image formed by a concave lens.

ACTIVITIES

a. Draw a ray diagram by following these steps:

   1. Draw a straight line long-ways in the center of your paper. Label it "principal axis".

   2. Two centimeters from the left end of this line, draw an upright 2 cm tall arrow. Label this "object".

   3. 14 cm to the right of the object, draw the edge view of a double convex lens 5 cm high (2.5 cm above and below the principal axis).

   4. Measure the focal length, 5 cm on each side of the lens; label these focal points $F_1$ to the left and $F_2$ to the right.

   5. Draw a line (light ray) parallel to the principal axis from the top of the arrow to the lens. Continue the line from the lens through focal point $F_2$.

   6. Draw another line (light ray) from the top of the arrow through focal point $F_1$ to the lens. Continue the line through the lens so that it is parallel to the principal axis on the right side of the lens.

   7. Draw the image at the point where the two lines (light rays) cross.

b. (Optional) Draw and label other convex lens ray diagrams, with different distances between the object and lens and with different focal lengths.

c. (Optional) Draw a ray diagram to show the image formed by a concave lens with a 4 cm focal length if the object is 15 cm from the lens.

E. Human Eye and Vision Correction

Whenever you see anything, you are using a lens in your eye. Anyone who wears eyeglasses is using a combination of lenses (eyeglasses and eye lens) to refract light so that it focuses clearly.

OBJECTIVES

After completing the following activities, the student will be able to:

24. identify the iris, lens, cornea, pupil, retina, and optic nerve in a diagram or a model of the human eye.

25. describe the causes of "near-sightedness" and "far-sightedness" and the uses of lenses to correct these defects.

ACTIVITIES

a. Read pages 103-104 and pages 133-135, Pathways in Science, Physics 3, Globe Book Company

or

Read pages 331-332 and pages 344-347, Physical Science Investigations, Houghton Mifflin Company

or

Read pages 282-288, Physical World, Harcourt, Brace and Jovanovich

b. Examine a model of the human eye and identify these parts: iris, lens, cornea, pupil, retina, and optic nerve. Make a drawing to illustrate these parts.

c. Read the following paragraphs.

As people grow older, their eye-focusing muscles become weaker and it is harder to change the thickness of the eye's lens to focus on objects at different distances. Some people need glasses with a combination of 2 lenses called bifocals. The upper part is for looking at distant objects and the lower part is for looking at close objects. Glasses with a combination of 3 lenses are called trifocals. The middle part is for looking at middle distances.

Some people wear another kind of lens called contact lenses. These lenses are carefully shaped to fit directly on the person's cornea and under the eyelid. The outer surface is shaped to form a concave or convex type lens for vision correction.

d. Draw diagrams to describe how the proper lenses can correct near-sightedness and far-sightedness.

OBJECTIVES

After completing the following activities, the student will be able to:

26. identify the type of lens in a pair of eyeglasses.

27. describe the formation of an image and the brain's function in seeing.

28. determine the horizontal angle of vision.

ACTIVITIES

a. Use your own or a friend's eyeglasses to look at the print on a page. Do this by holding the glasses near the page, not by wearing them. Describe what the lens does to the words. What type of lens is in the glasses? What vision defect is corrected?

b. Do the following experiment to study how the lens of your eye forms an image on your retina.

The eye makes use of a convex lens and you have seen that this type of lens forms an inverted image on a screen. If this is true, the image which forms on the retina of your eye must be upside down. If you see things "right side up", does this mean that the objects are really upside down?

It would be easy to find out if the image formed on the retina is upside down if you could look inside the eye and see the image, but this can be done only with very special equipment. You can use indirect evidence to answer the question.

Face a brightly lighted window (or a light bulb) and hold a card with a pinhole an inch or two away from your eye. In your other hand, hold a straight pin so that the head is very close to your eye, but not quite touching it. (BE CAREFUL!)

When you get the pinhead and the pinhole in line with the pupil of your eye, describe what you see. Do you see a blurred image of the pinhead? What is its position?

How did the image appear? The pin was much too close to your eye for the lens to focus on it. The head of the pin simply formed a shadow on the retina. The shadow would be almost the same if the lens were not there.

Actually, the shadow of the erect pin is an erect shadow on your retina. It appears to be inverted. This must mean that your brain inverts any image that forms on the retina.

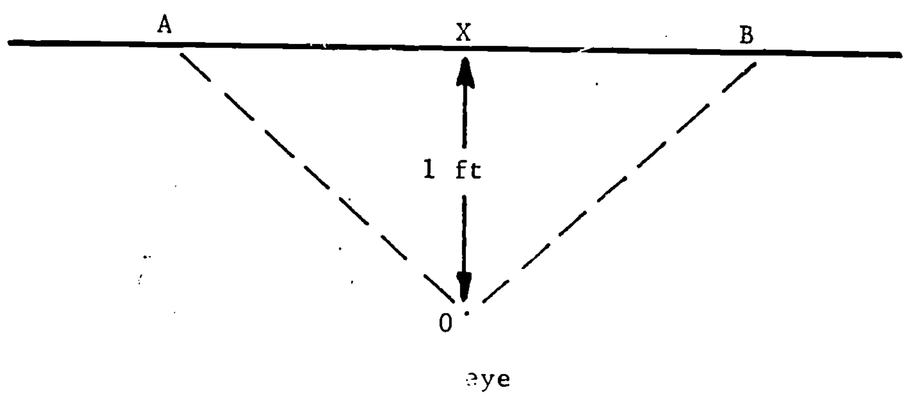
c. (Optional) Do this experiment to study your field of vision.

Procedures

1. Cover one eye and stand so that your face is one foot from an eye-level spot (x) on the chalkboard.

2. Look steadily at the spot. Put your fingers at eye-level on the chalkboard and then slowly move your arms outward until you cannot see your fingers. (You may need to wiggle your fingers to make them more visible.)

3. The points that are farthest apart, but still let you see your fingers while staring straight ahead at (x), mark the limits of your field of vision. Mark these points A and B. This is shown in the following sketch that is a view from over your head.




4. Make a scale drawing of your experiment, using the scale 1 in. = 1 ft., and measure angle AOB. This is your horizontal angle of vision.

Questions

1. How does your angle of vision compare with that of other students?

2. List as many examples as you can where having a wide angle of vision is useful.

## F. Optical Instruments

Optical devices such as telescopes, microscopes, binoculars, projectors and cameras are useful to us only because light can be refracted by lenses. These instruments use different arrangements of lenses which have different focal lengths. In this way, they can do different jobs of refracting the light and forming images.

### OBJECTIVES

After completing the following activities, the student will be able to:

29. identify an optical instrument from a ray diagram showing its image formation.

30. describe the image formation by a camera, microscope, and telescope.

### ACTIVITIES

a. Collect advertisements for optical instruments that use lenses. Post them on the bulletin board which your teacher has provided.

b. Read pages 135-137, Pathways in Science, Physics 3, Globe Book Company

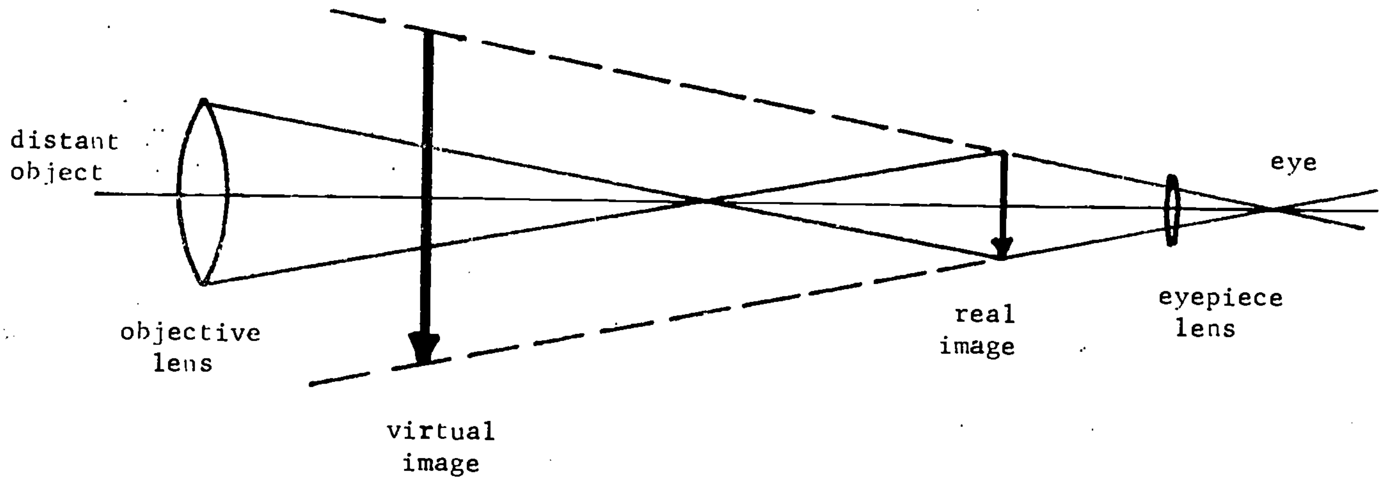
or

Read pages 291-303, Physical World, Harcourt, Brace and Jovanovich

c. Complete the Optical Instruments Worksheet.

Study the following ray diagrams and identify the instrument that uses each arrangement.

A

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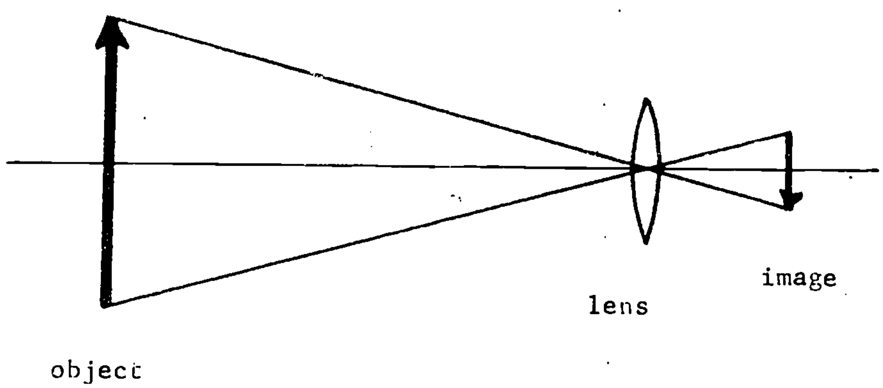
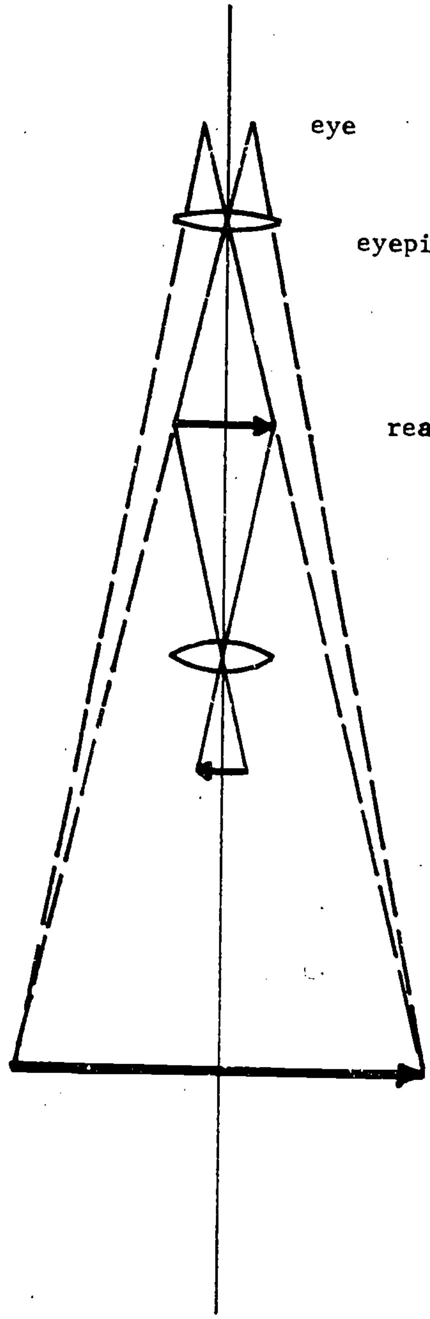


C


eye
eyepiece lens
real image
objective lens
object
virtual image

d. (Optional) Examine the lenses in a camera, projector, microscope, or telescope. Make a diagram of the arrangement and identify each lens as convex or concave.

## OBJECTIVES

After completing the following activity, the student will be able to:

31. construct a pinhole camera and use it to observe an image of an object.

32. describe the relationship between the object and its image formed by a pinhole camera.

33. describe the method of image formation by a pinhole camera.

## ACTIVITY

You may have heard of a "pinhole" camera, which is a very simple camera that focuses light without even using a lens. Construct one by following these directions.

<u>Procedures</u>

1. Cut a 6 cm x 6 cm square hole in the center of one end of a shoebox or other small cardboard box.

2. Tape a piece of waxed paper over the opening. Make a smooth pinhole in the center of the opposite end of the box.

3. Hold the box at arm's length with the pinhole facing a window or other bright object. Describe what you see on the waxed paper.

4. Using melted wax, fasten a short candle to a file card or petri dish so that it will stand up on your table.

5. Put your pinhole camera on the table and aim the pinhole at the candle flame so that it is about 8 cm away. With your eye at the level of the box, observe the image of the flame on the waxed paper. Describe the image.

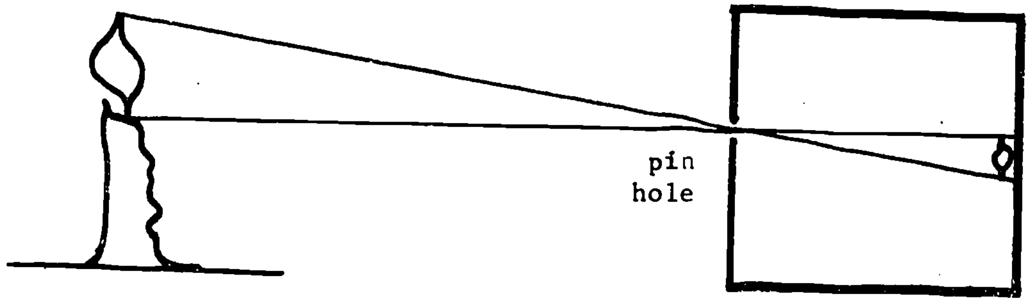
6. While you are watching the image on the waxed paper, move the candle away from the hole. What happens to the size of the image?

7. While you are watching the image on the waxed paper, move the candle to the left, then to the right, and then up. Which way does the image move?

Questions

1. How is the image formed by a pinhole camera different from the object that is being "photographed"?

2. Explain this diagram:




3. What type of lens would form this same kind of image?

OBJECTIVES

After completing the following activities, the student will be able to:

34. describe the image formed by a camera and by a filmstrip projector.

ACTIVITIES

a. Open a camera that does not contain any film. Look through the lens from the place where the film should be and "take a picture". (If there is a "time exposure" setting on the camera, use it to slow the shutter speed.) Describe what you see. How do the direction and size of the image compare to the object?

b. Draw an arrow 4 cm long with a "tail" thickness of 0.5 cm. in the center of a 10 cm square piece of cardboard. Cut out the arrow with a knife or razor blade and throw the arrow away. Put the cardboard in a filmstrip projector, with the filmstrip mechanism removed. Project the image of the arrow on a screen. Compare the direction and size of the arrow in the projector with the direction and size of the image on the screen.

G. Summary and Review

You have studied many different ideas about lenses and probably need to review them.

ACTIVITIES

a. Complete Worksheet 8-2, page 251, Behavior of Light and Sound, Cambridge Book Company

b. Complete the Crossword Puzzle Review Worksheet.

# CROSSWORD PUZZLE REVIEW

ACROSS

1. the bending of light as it passes from one transparent substance into another
5. the vision problem which is corrected by convex lenses
8. a single line of light
9. an optical instrument which enlarges distant objects
11. the colored part of your eye
13. the picture of an object formed when light from the object is refracted
14. your personal optical instrument
15. the part of your eyeball where the image is focused
16. smaller
18. a type of lens which fits over the cornea and under the eyelid
19. a curved piece of glass used to refract light
21. a lens with a thick center
22. clear; a substance which light can pass through
23. the lower lens of a microscope
26. eyeglasses with a combination of 2 lenses
27. the opening which lets light into your eye
28. spread apart
32. a very simple camera (2 words)
34. an optical instrument which magnifies close objects
35. right side up
36. the number of times a lens enlarges an object (2 words)

DOWN

2. the point at which rays of light meet after being refracted (2 words)

3. transparent covering on the front of the eye

4. the vision problem which is corrected by concave lenses

5. the distance from the center of a lens to its focal point (2 words)

6. upside down

7. magnified

10. a triangular shaped piece of glass

12. a 90° angle

16. an image which can be shown on a screen

17. a lens with thick edges

20. light rays which are side by side and do not cross

23. not clear; a substance which blocks light

24. come together

25. an optical illusion caused by layers of hot and cold air

29. the upper lens of a microscope

30. an image which can be seen through a lens, but which cannot be shown on a screen

31. a drawing which shows how lenses refract light rays (2 words)

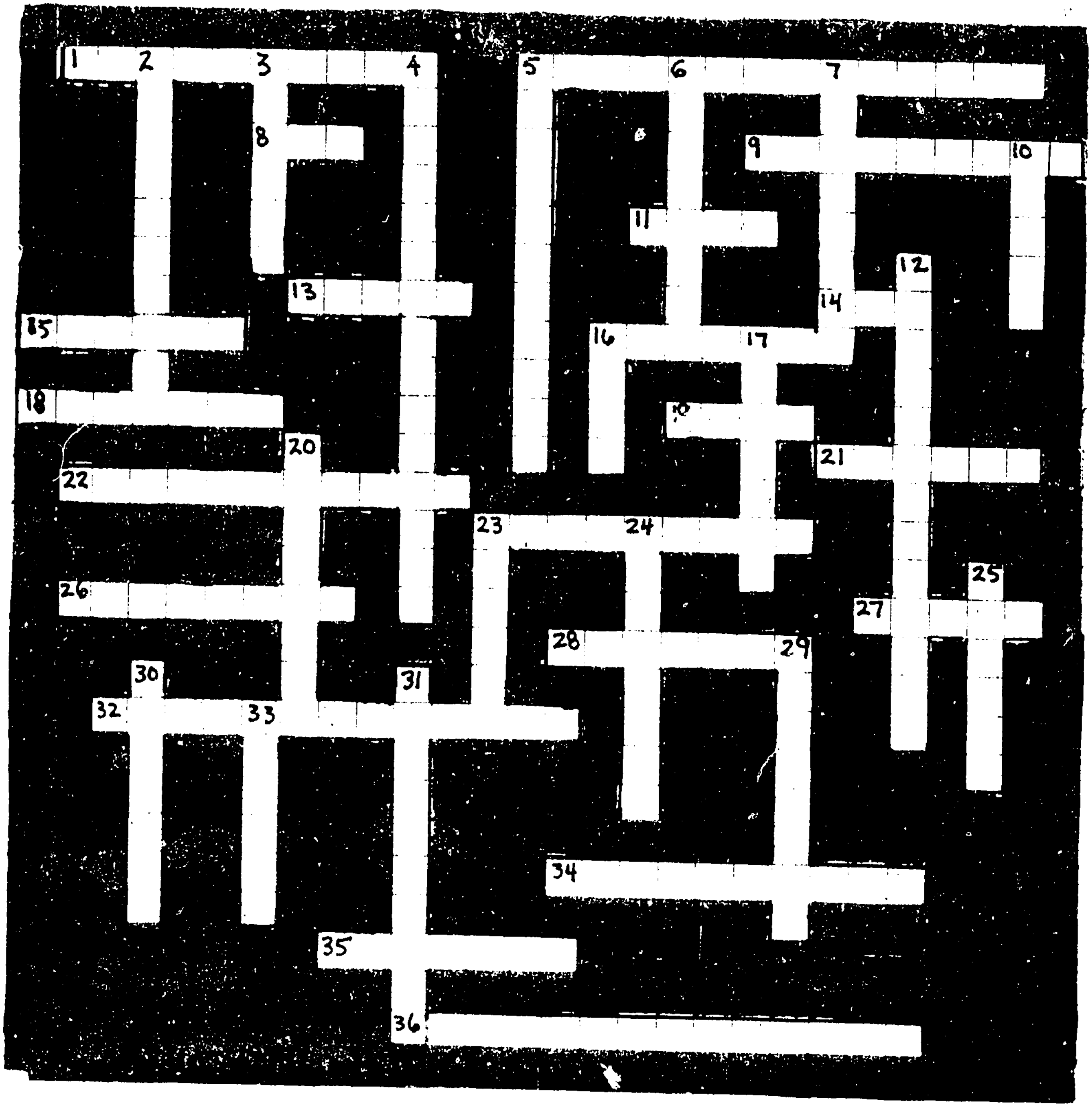
33. something which is looked at

CROSSWORD PUZZLE REVIEW - HINT

You will need to use these terms in solving the crossword puzzle:

bifocals
cornea
concave
convex
contact
converge
diverge
enlarged
eyepiece
eye
focal length
farsightedness
focal point
iris
image
inverted
lens
mirage
microscope
magnifying power
nearsightedness
object
opaque
objective
pinhole camera
pupil
perpendicular
parallel
prism
refraction
retina
real
reduced
ray
ray diagram
transparent
telescope
upright
virtual

CROSSWO[illegible]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c. (Optional)

There are many doctors, called opthalamologists, who specialize in the care and treatment of the eyes. Other doctors, called optometrists, have the training and equipment to measure ordinary vision defects. Opticians actually make the lenses for correcting vision problems.

Find out what training is necessary and what principles of optics are used for each of these careers.

## UNIT OBJECTIVES

After completing the specified activities, the student will be able to:

1. define refraction.
2. describe a model of refraction.
3. describe the formation of a mirage.
4. determine the pathway of light as it travels from air into glass (or water) and back into air.
5. describe the conditions which cause no refraction of light.
6. demonstrate and describe an arrangement of glass prisms to converge or diverge light.
7. distinguish between "converge" and "diverge".
8. state the purpose of using lenses.
9. identify the type of lens from a drawing of a lens.
10. identify a given lens as one of six types.
11. describe the image formed by a lens.
12. distinguish between a real and a virtual image.

*13. assemble an optical bench.

*14. adjust an optical bench apparatus to focus a clear image through a convex lens.

*15. calculate the ratios

$$\frac{\text{object height}}{\text{image height}} \quad \text{and} \quad \frac{\text{object distance}}{\text{image distance}}$$

16. use a convex lens as a magnifier.
17. calculate the magnifying power of a convex lens.
18. describe the conditions for using a convex lens as a magnifier.

*19. measure the focal length of a convex lens.

20. identify the principal axis, focal points, and focal length in a ray diagram.

21. complete a partially drawn ray diagram to locate the image formed by a convex lens.

22. construct a ray diagram to locate the image formed by a convex lens.

*23. construct a ray diagram to locate the image formed by a concave lens.

24. identify the iris, lens, cornea, pupil, retina, and optic nerve in a diagram or a model of the human eye.

25. describe the causes of "near-sightedness" and "far-sightedness" and the use of lenses to correct these vision defects.

26. identify the type of lens in a pair of eyeglasses.

27. describe the formation of an image on the retina and the brain's function in seeing.

*28. determine the horizontal angle of vision.

29. identify an optical instrument from a ray diagram showing its image formation.

30. describe the image formation by a camera, microscope, and telescope.

31. construct a pinhole camera and use it to observe an image of an object.

32. describe the relationship between the object and its image formed by a pinhole camera.

33. describe the method of image formation by a pinhole camera.

34. describe the image formed by a camera and by a filmstrip projector.

*indicates objectives related to optional activities

Activities include readings, experiments and worksheets. References are made to specific resources for some activities and, in other cases, directions and worksheets are included in the minicourse.

Worksheets are printed on separate pages so that you can make "ditto" masters from them and print additional copies for your students.

A. Refraction

Objectives 1-3:

Several simple and quick demonstration-experiments are suggested in the readings.

Objectives 4 & 5:

Two references are listed. Specify either, depending on availability of materials and directions.

Similar experiments are included in Physical Science Investigations, Houghton Mifflin, experiments 9-7, 9-8, 9-10, 9-11

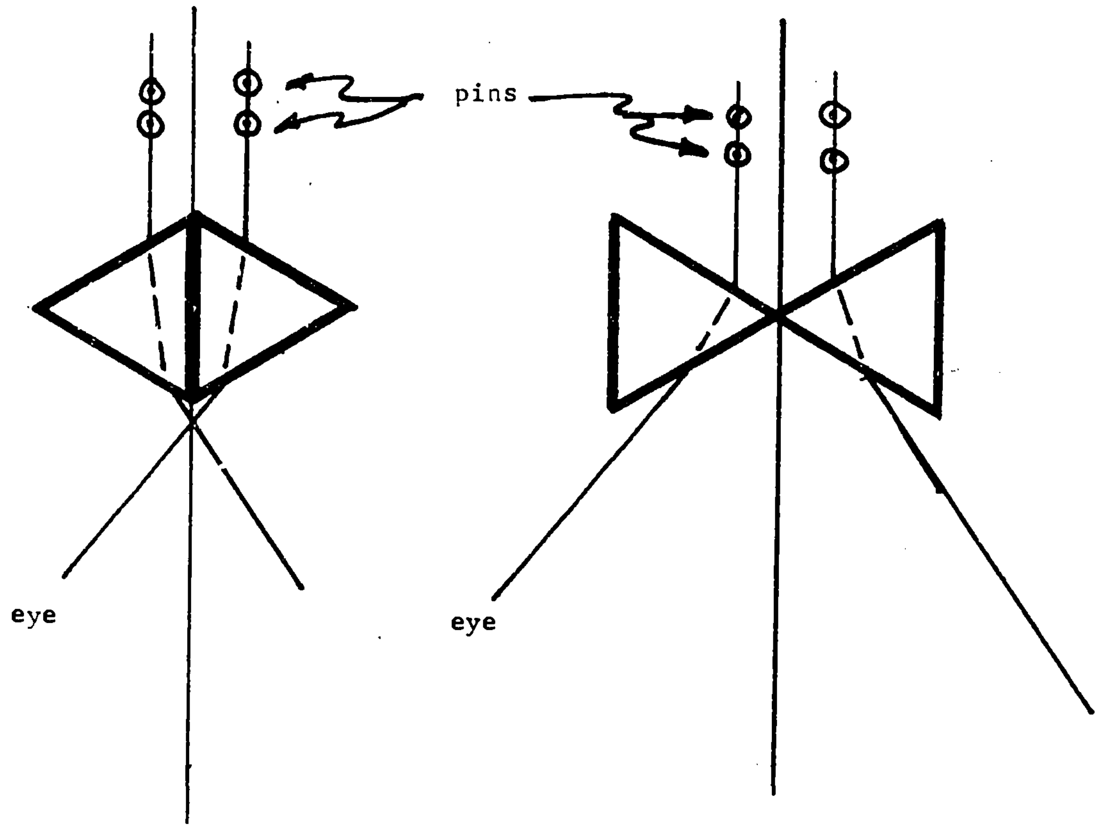
B. Converging and Diverging Light Rays

Objectives 6 & 7:

Materials: cardboard, unlined paper, straight pins, equiangular prisms, tape, rulers

Students may have problems sighting through the prisms and seeing the actual pins, not the reflection of the pins. In Procedure D, they must look through the inner right side of the left prism to see the pins on the left side of the line. Viewing the pins on the right side of the line must be done through the inner left side of the right prism. In the diverging set-up, viewing must be from the outer edges of the prisms.

Final diagrams should be similar to these:




C. Types of Lenses and Images

Objectives 8 & 9:

d. Students will probably need help pronouncing the names of the lenses. You may want to quiz students on this sheet.

Objectives 10-12:

a. Materials: lenses, ruler

Provide as many types of lenses as possible.

b. Blanks should be completed as: (1) virtual, (2) upright, (3) convex, (4) inverted, (5) reduced, (6) virtual

Objectives 13-15(optional):

Materials: convex lens, concave lens, candles, meter stick with support, screen, holders for candle, lens, and screen

An optical bench may be constructed from a meter stick, using lens holders and other physics equipment. An index card may be used for the screen.

An optional assembly, using simpler equipment can be made using Play Dough to hold the lens and screen, with the meter stick lying flat on the table.

Objectives 16-18:

Materials: convex lens, graph paper

A similar experiment is described on page 301, The Physical World

Objective 19 (optional):

A similar experiment is described in Physical Science, A Modern Approach, Laboratory Experiments, Van Nostrand Co.

D. Ray Diagrams

You can find additional drawings in most physics texts.

Objectives 20 & 21:

b. Materials: unlined paper, metric ruler

All three cases should form inverted, reduced images.

You may want to have students measure distances and heights to test the ratios:

$$\frac{\text{image height}}{\text{object height}} = \frac{\text{image distance}}{\text{object distance}}$$

Objectives 22 & 23:

a. Materials: unlined paper, metric ruler

Student diagrams should locate an inverted 1.2 cm arrow 7.8 cm to the right of the lens.

b. Optional

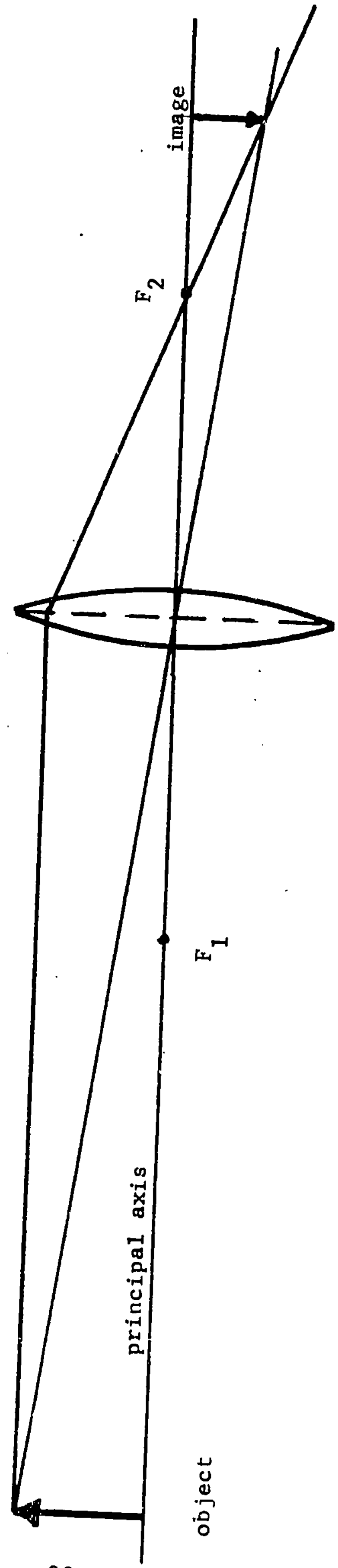
Materials: unlined paper, metric ruler

c. Optional

Materials: unlined paper, metric ruler

Objectives 22 & 23:

a.



E. Human Eye and Vision Correction

Objectives 24 & 25:

a. Any one of these sources provides adequate background material.

b. Materials: model of human eye

Check with the biology or life science teacher for the eye model.

You may want to examine actual eyes, such as cow's eyes. Possible sources are: Frederick Produce, Hemp's and Burtner's.

c. If possible, have bifocals and trifocals available for class examination. Perhaps a student in the class wears contact lenses and will describe or show them to the others.

Objectives 26-28:

a. Materials: eyeglasses

b. Materials: light source, straight pin, cardboard

Caution the students about holding the pinhead close to their eye, but not touching (or poking) the eye.

c. Optional

Materials: ruler

F. Optical Instruments

Objectives 29 & 30:

a. You will need to provide bulletin board space.

b. In spite of its age, Physical World is the better resource.

c. A. telescope
   B. camera or eye
   C. microscope

d. Optional

Materials: camera, microscope, telescope, projector

Objectives 31-33:

Materials: shoebox, waxed paper, razor blade, tape, straight pin, candle and support

Suitable containers for a pinhole camera include: shoeboxes, oatmeal boxes and coffee cans.

Objective 34:

a. Materials: box camera

Try to provide a camera with some means of slowing the shutter speed.

b. Materials: cardboard, razor blade, metric ruler, filmstrip projector

Instead of using a cut out arrow, you may wish to paint an arrow on a glass plate.

G. Summary and Review

b. Crossword Puzzle Review

Across

1. refraction
5. farsightedness
8. ray
9. telescope
11. iris
13. image
14. eye
15. retina
16. reduced
18. contact
19. lens
21. convex
22. transparent
23. objective
26. bifocals
27. pupil
28. diverge
32. pinhole camera
34. microscope
35. upright
36. magnifying power

Down

2. focal point
3. cornea
4. nearsightedness
5. focal length
6. inverted
7. enlarged
10. prism
12. perpendicular
16. real
17. concave
20. parallel
23. opaque
24. converge
25. mirage
29. eyepiece
30. virtual
31. ray diagram
33. object

c. Optional

## Materials

One of the most useful devices for demonstrating refraction by lenses is an optical disk, such as the one available from Sargent-Welch Company and shown on page 450 of A Sourcebook for the Physical Sciences, Harcourt, Brace, and Jovanovich. With it, you can actually see a ray of light bend and change direction as it passes through a cross-section of a lens. Check with the physics teacher in your school to see if a disk and accessory kit are available.

If you do not have complete sets of various types of lenses in your school, major activities can be done by using only a single type of convex lens and a single type of concave lens.

## Printed Materials

Several commonly available textbooks are specified in the student activities. Be sure to check page numbers in case you have a different edition of the book. In some cases, substitutions can be made if you do not have the listed book. The following list includes specified books, possible alternates, and additional teacher references.

*Abraham, N., Interaction of Matter and Energy, Rand McNally and Co., 1969

Bickel, C.L., Physical Science, a Modern Approach, D. Van Nostrand Co., Inc., 1966
with accompanying "Laboratory Experiments in Physical Science"

*Bickel, C.L., Physical Science Investigations, Houghton Mifflin Co., 1973

Brandwein, P.F., Energy, Its Forms and Changes, Harcourt, Brace, and Jovanovich, 1968
with accompanying "Searchbook" and "Lab Experiences"

Brinkerhoff, R., The Physical World, Harcourt, Brace and Jovanovich, 1963

Carter, J.L., Physical Science, a Problem Solving Approach, Ginn & Co., 1971

Diamond, S.R., Fundamental Concepts of Modern Physics, Amsco School Publications, Inc., 1970

Dull, C.E., Modern Physics, Holt, Rinehart & Winston, Inc.

Eckert, T.E., Discovery Problems in General Science, College Entrance Book Co., 1960

*Eisler, S.M., Lab Inquiry Text, Physical Science, Behavior of Light and Sound, Cambridge Book Company, 1972

Esler, W.K., Modern Physics Experiments for the High School, Parker Publishing Co., 1970

Goehring, H.J., Demonstrations and Experiments for General Physical Science, J. Weston Walch, 1971

Heimler, C.H., Focus on Physical Science, Charles E. Merrill Publishing Co., 1969

Joseph, A., A Sourcebook for the Physical Sciences, Harcourt, Brace and Jovanovich, 1961

Kutliroff, D., Physics Teacher's Guide, Parker Publishing Co., Inc., 1970

*Oxenhorn, J.M., Pathways in Science, Physics 3, Sound and Light, Globe Book Company, 1970
with accompanying "Laboratory Workbook"

Weisler, J.J., Physical Science Workbook, Amsco School Publications, Inc., 1971

*indicates references cited in student activities; all are not required

## Audio-Visuals

These materials are available from the IMC:

| | |
|---|---|
| F31000 | Light: Lenses and Optical Instruments |
| Tr 530 | Heat, Light and Sound |
| Tr 534 | Light and Sound Energy |
| SP 535 | Light and Sound |
| SP 536 | Heat, Light and Sound |

These filmstrips are available from Governor Thomas Johnson, through Mrs. Neufeld, Senior High Science:

| | |
|---|---|
| H-48b | Light and How It Is Refracted |
| H-50 | Refraction of Light |
| H-53 | The Story of Lenses |

Evaluation Form for Teachers

Name of mini-course ____________________

| Evaluation Questions | Yes | No | Comments |
|---|---|---|---|
| 1. Did this unit accomplish its objectives with your students? | | | |
| 2. Did you add any of your own activities? If so, please include with the return of this form. | | | |
| 3. Did you add any films that other teachers would find useful? Please mention source. | | | |
| 4. Were the student instructions clear? | | | |
| 5. Was there enough information in the teacher's section? | | | |
| 6. Do you plan to use this unit again? | | | |

7. Which level of student used this unit? ____________________

8. How did you use this unit - class, small group, individual? ____________________

PLEASE RETURN TO SCIENCE SUPERVISOR'S OFFICE AS SOON AS YOU COMPLETE THE COURSE.

# SCIENCE MINI-COURSES

| PHYSICAL SCIENCE | Prepared by |
|---|---|
| ELECTRICITY: Part 1<br>(Types of Generation of Electricity) | Marvin Blickenstaff |
| ELECTRICITY: Part 2<br>(The Control and Measurement of Electricity | Marvin Blickenstaff |
| ELECTRICITY: Part 3<br>(Applications for Electricity) | Marvin Blickenstaff |
| CAN YOU HEAR MY VIBES?<br>(A Mini-course on Sound) | Charles Buffington |
| LENSES AND THEIR USES | Beverly Stonestreet |
| WHAT IS IT?<br>Identification of an Unknown Chemical Substance | Jane Tritt |
| **BIOLOGY** | |
| A VERY COMPLEX MOLECULE:<br>D.N.A. The Substance that Carries Heredity | Paul Cook |
| Controlling the CODE OF LIFE | Paul Cook |
| Paleo Biology – BONES: Clues to Mankind's Past | Janet Owens |
| A Field Study in HUMAN ECOLOGY | Janet Owens |
| Basic Principles of GENETICS | Sharon Sheffield |
| HUMAN GENETICS – Mendel's Laws Applied to You | Sharon Sheffield |
| **SCIENCE SURVEY** | |
| WEATHER Instruments | John Fradiska |
| TOPOGRAPHIC Maps | John Geist and John Fradiska |
| **CHEMISTRY** | |
| WATER | Ross Foltz |
| **PHYSICS** | |
| PHYSICAL OPTICS | Walt Brilhart |