CENTRAL SCIENTIFIC COMPANY

OPERATING INSTRUCTIONS

Big Little Ray Box Kit
No. 32302

1. Introduction

The Big Little Ray Box Kit consists of a light source with assorted optical accessories. In experimental practice, it is a useful apparatus for demonstrating simple principles of light wave behavior. Because you can produce parallel, converging and diverging rays of light with its components, you can do experiments which might normally require a more expensive light box.

2. Description

The switch-operated light box of The Big Little Ray Box Kit produces 7 lumens with its 2.5V, 0.4A linear-filament, tubular point light source.

The small black box that holds the light source also holds a 3-slit or a 1-slit tabbed slide that fits in a slot in the box. You will have to supply two D-cell batteries.

The light from the box falls on a white resin plate. We include a variety of accessories with the kit:

- Glass cylindrical lens (focal point 4 x 2.5cm)
- Concave lens (focal point 15cm)
- Trapezoid prism tank with white resin bottom
- Three strips of colored cellophane
- Resin mirror (concave or convex)
- Plane mirror
- Extra lamp

A white resin “Sun Ray Plate” with three slits is included in the kit. You use the sun as a light source for experiments with the Sun Ray Plate and some of the other accessories in the kit.

It will be helpful to use our No. 30078 Mirror Supports (package of six) to place and hold the resin light plate.

3. Operation

Work in a darkened room; your experiments are more clearly seen. It’s helpful to keep a flashlight or a small lamp handy.

Put a large sheet of white paper under the ray box and use it to mark measurements. Mount two D-cell batteries in the box. Make sure the **+** terminal of the battery is placed by the **+** metal strip in the light box. You may choose to use a piece of cellophane taped to the inside of the light door of the box for many of the experiments in this instruction to increase clarity and to soften glare. Place the light box on the paper surface positioned with the batteries on top. Turn on the light switch.

Experiment Series 1: Focal Point (See Fig. 4):

A. Set the white resin screen into two Mirror Supports and position it about 20cm from the light source. Insert the single-slit plate into the opening of the box. Place the cylindrical lens (the one with a flat side) with either side arbitrarily facing the screen. Place the screen at different distances from the light source: say at 20cm, 25cm and 30cm. Each time you change the position of the screen, adjust the position of the lens until you perceive the sharpest image of the slit. Notice that this distance is the same for every experiment. This is the focal distance of the lens. Turn the lens around so that the other side is facing the screen. Do you notice a difference in the focal distance or not? You might have thought that the focal distance of the lens is affected by whether the light enters the curved or the flat face of a lens, but that doesn't seem to be so. Change the single-slit tab to the three-slit tab. The diverging rays emanating from the box become parallel after passing through the lens, regardless of which side of the lens is turned to the light.

B. You may have had some trouble in experiment A determining the exact focal point of the lens — it isn't always easy to work with a single diverging ray, because clarity is lost as the ray diverges. The following experiment will help you further define the focal point. Use the three-slit tab. Set the cylindrical lens on its flat edge about 6cm from the light source. Begin with the screen about 11cm from the light source and slide the screen away from the lens. At what distance do you see a single ray of light? Do the outside rays of light seem to cross one another as they meet at this point?

Attach a piece of cellophane to the three-slit tab and repeat the positioning. Do you perceive that the outside "rays" of light do indeed cross one another as you move the screen through the focal point? The cellophane can add to the clarity of your experiments.

Repeat Experiments A and B, if you wish, using the convex lens.

Experiment Series 2— Law of Reflection: (See Fig. 1,2, & 3):

A. Position the plane mirror, the white screen (on supports) and the light box with the single-slit tab on the drawing paper until the mirror catches a ray of light from the ray box and reflects it onto the screen. The ray reflected onto the screen is quite wide. Place the cylindrical lens between the mirror and the light source to narrow the ray. This action is called *condensing* the ray. Now you can easily trace the incident ray, or the ray approaching the mirror, and the reflected ray onto the drawing paper. Trace a line perpendicular to the mirror onto the drawing paper. How large is the angle between the perpendicular line and the incident ray? How large is the angle between the perpendicular line and the reflected ray? Repeat the procedure, changing the angles of incidence.

Fig. 1 Reflection by a Plane Mirror
Law of Reflection

B. Repeat the above experiment using a concave mirror. Bend the resin mirror into a concave shape and hold it in your hand in the path of a single light ray that you have condensed with one of the lenses. Trace the mirror location and the incident and reflected ray paths. In order to ascertain the perpendicular to the mirror, bisect the angle formed by the incident and reflected ray and extend the bisecting line through the traced mirror location. Set a compass point on the bisector and trace an arc that follows the circumference of the traced mirror location. Draw the perpendicular to the bisector that touches this arc or mirror edge. As in the above experiment, you will find that *the angle of incidence equals the angle of reflection*. Repeat, using the resin mirror bent into a convex shape. *The law of reflection holds for all surfaces.*

Fig. 2 Reflection by a Convex Mirror
Law of Reflection

C. Change the single-slit to a three-slit tab and place the concave resin mirror in the paths of the three rays. (Don't forget to shine the rays through one of the lenses so they are parallel.) Reflect the rays off the mirror so that the rays converge on the center ray at a single point.

Place a compass on any point on the center ray and draw a circle through the point of convergence. What is the ratio of the radius of the circle to the distance between the point of convergence and the mirror? The radius is twice the focal distance. Repeat this experiment using the resin mirror in convex form.

Fig. 3 Reflection by a Convex Mirror
Ratio of Radius to Focal Distance

Experiment Series 3 — Lens Refraction (See Figs. 4 & 5):
A. Use the three-slit slide. Place the cylindrical lens at one-half of its focal distance from the light source box. The three rays of light become parallel.

Now that you have the rays parallel, use the convex lens to experiment. Move it along the path of the parallel rays and mark the distance from the lens to the point where the rays converge. Again, you have found the focal distance that you discovered in your first experiment.

Set a compass point on the point of convergence and draw a circle through the lens location. How does the radius of the circle compare to the focal length of the lens? Unlike the reflected ray, the radius is equal to the focal distance.

Fig. 4 Refraction by a Convex Lens
Ratio of Radius to Focal Distance

B. Repeat the above experiment, tracing the rays, but without drawing the circle. Clearly mark the point of convergence $\mathbf{F_A}$.

Put the plane mirror anywhere between the point of convergence and the lens and reflect the rays to a new point of convergence. Clearly mark this point $\mathbf{F_B}$. Join the two points with a line. Extend the line of the mirror location to intersect the line joining the two points of convergence. What can you say about the point's locations? (They are an equal distance from the mirror's extended bisecting line.)

Fig. 5 Refraction and Reflection
Using a Convex Lens

Experiment Series 4 — Prism Refraction (See Fig. 6):
CAUTION! In any of the experiments using the Sun Ray Plate, and whenever you are experimenting out-of-doors — **DO NOT LOOK DIRECTLY AT THE SUN.**

A. The rays that you can “catch” from the sun using the Sun Ray Plate are even brighter than those from the light source box. The resin mirror can be bent into a concave or convex shape and held in that position. Using the Sun Ray Plate, hold the resin mirror first in a convex and then in a concave shape. Draw a picture of the rays in each case.

Put the white resin shaped-to-fit plate inside the trapezoid tank. Fill the tank with water and secure the top with some cellophane tape. Place the tank right next to the slits of the Sun Ray Plate to see how the sun’s rays travel through the prism tank. Draw diagrams for study.

The trapezoid tank has quite a few different angles that the rays can be refracted through. By drawing the diagrams and measuring the angles of the refracted rays you can observe the phenomenon of *total internal reflection.*

At what angles of entry are the incident rays refracted? At what angles are they not? Incident angles greater than forty-nine degrees are reflected back.

B. You have seen that refracted rays do not follow the Law of Reflection. What rule would you expect a refracted ray to follow? Did you get any clues working with the Sun Ray Plate and the prism? (You should have seen that rays entering the prism bend toward the perpendicular, or the normal, and that the rays exiting the prism bend away from the normal) To see what relationship there is between the angle of incidence and the angle of refraction, work in a dark room with the light box. Fill the prism tank with water, or better yet, mineral or uncolored vegetable oil. (The tank will not leak if you handle it carefully and keep it more or less upright. Tape the tank shut with cellophane tape for added security against spills. Have some paper towels nearby.)

Set the cylindrical lens a little beyond its focal distance from the light source. Place the trapezoid prism just beyond the lens and shine the light through the prism.

Trace the angles of incidence and refraction. Draw the perpendicular to the boundary (the point where the light enters the prism): Draw a circle through the boundary point and draw the perpendicular to a tangent line running through this point.

Fig. 6 Total Internal Reflection

Measure the angles formed by the incident and the refracted rays: Are they equal? Repeat this experiment many times, using different angles of incidence. Are you able to determine a relationship between the angles of incidence and refraction? [Hint: Draw full triangles with the rays from the same point on the perpendicular.] If you see no relationship refer to Snell's Law,

$$n = F(\sin i, \sin r)$$

where, **n i**s the index of refraction, **i** is the angle of incidence, and **r i**s the angle of refraction.

Does Snell's Law support your expectations at the beginning of this experiment?

The index of refraction is higher for more optically dense materials, which is why it was preferable to fill the tank with oil rather than water.

Experiment Series 5 — Dispersion (See Fig. 7):
Use the trapezoid prism with the light source box to see the full spectrum of white light. It's necessary to work in a dark room for this experiment.

Again, use the prism tank filled with oil. Set the cylindrical lens a little beyond its focal distance from the light source. Place the trapezoid prism just beyond the lens and shine the light through the triangular portion of the prism at the white screen. The convex lens may be used to condense the rays leaving the prism. Move the screen away as you play with the prism to catch the light on the screen. Adjust the screen's position to get a clear view of the spectrum.

Fig. 7 Light Dispersion

Experiment Series 6— Color Mixing:
Remove the slides from the light door. Use the plane mirror to reflect the beam of light onto the screen. Insert pieces of cellophane into the supports and position them along the path of the beam. Interchange their positions to see the results of different color combinations.

True subtractive color mixing involves a complementary secondary pigment mixed with a primary pigment, so it is not *theoretically* possible to achieve black by mixing the cellophanes in this kit. However, because the cellophanes are not absolutely true to primary and secondary pigments, you will get somewhat different results than normally expected. For instance, the red cellophane masks the others and produces black. If you wish to pursue this subject further, we would like to suggest that you purchase our Catalog Nos. 46616 and 46615, Additive Color Mixing and Subtractive Color Mixing demonstrations.

4. Maintenance

The Big Little Ray Box Kit requires no special maintenance. If you should experience any difficulty with a kit, please contact Central Scientific Company, giving details of the problem. To ensure better service, please do not return any apparatus to Central Scientific Company until we have sent you authorization.

5. Accessories

Description	Catalog No.
Protractor (Pkg. 12)	72985-11
Mirror Supports	30078
Heavy Duty Flashlight	84461-24
Gooseneck Lamp	66141-01
Cellophane, Green	88039-01
Cellophane, Blue	88039-02
Cellophane, Red	88039-04
Cellophane, Clear	88039-05

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