GENERATION SCIENCE

LED Ray Box

SE1021-00

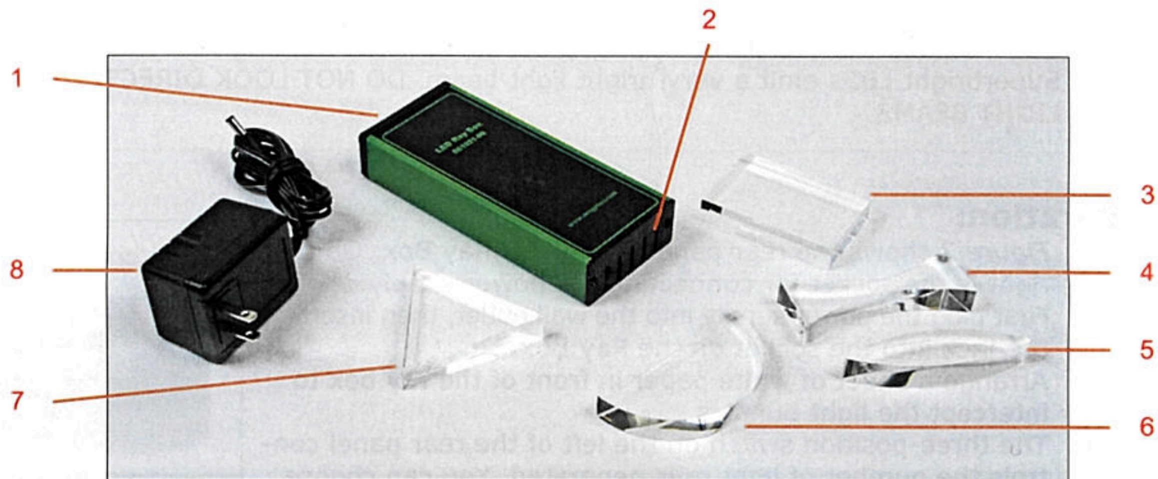

Figure 1

Description:

The LED Ray Box set is used for demonstrating the paths of light rays through various optical elements such as blocks, lenses and prisms.

The LED Ray Box consists of a sturdy extruded aluminum box (1, *Figure 1*) with five openings (2) at one end, containing five individual superbright white light LEDs and a collimator block. A switch on the rear panel allows the user to select 1, 3 or 5 narrow rays for experiments with the five included models of optical elements: rectangular block (3), concave lens (4), convex lens (5), semicircular lens (6), and equilateral prism (7). A wall-mount power supply (8) provides the low voltage needed to drive the LEDs. The low current consumption of the LEDs allows the LED Ray Box to run much cooler that the traditional version with a filament lamp, while providing comparable brightness in the rays, so that experiments can be carried out in a moderately darkened room.

Specifications:

LEDs:	Five white superbright LEDs, power consumption:6W
Optical Elements:	Rectangular block, semicircular block, equilateral prism, biconvex lens, biconcave lens. All acrylic, n =1.49, 15mm thick, typical long dimension 90mm.
Dimensions:	(Ray Box): 16 cm x 7 cm x 3 cm Weight (Set) 850 g.
Power Supply:	Wall mount, Input 110VAC/60 Hz, Output 12VDC/500mA

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Safety
- The LED Ray Box is a low voltage device, but the power supply connects to 110VAC. Observe laboratory electrical safety procedures when working with this unit.
- Superbright LEDs emit a very bright light beam. DO NOT LOOK DIRECTLY INTO THE FIVE LIGHT BEAMS.

Operation:

- *Figure 2* shows the rear panel of the LED Ray Box. On the right is the socket for connecting the power supply.
- First plug the power supply into the wall outlet, then insert the jack into the socket on the Ray Box.
- Arrange a sheet of white paper in front of the ray box to intercept the light bundles.
- The three-position switch on the left of the rear panel controls the number of light rays generated. You can choose one, three, or five parallel rays (*Figure 3*).

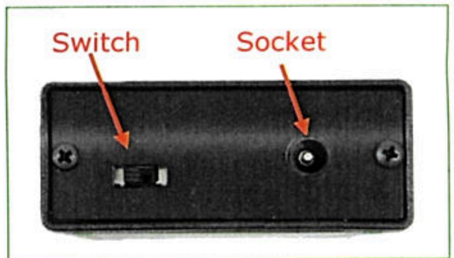

Figure 2

Experiments:

General

A single ray is most appropriate for experiments to measure the refractive index with the semicircular or rectangular blocks and for showing dispersion with the equilateral prism.
Three or five slits are more useful for tracing ray paths through the lens models and for demonstrating total internal reflection.

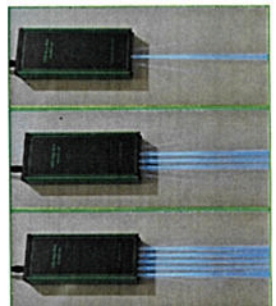

Figure 3

Measuring the Refractive Index

You will need a protractor, ruler, pencil and a sheet of paper

Rectangular block method:

- Choose a single ray straight across the paper
- Place the rectangular block on the center of the paper and angle it to give a deviation of 1-2cm between the incident and exit rays
- With a pencil, trace around the outline of the block, holding it firmly in place.
- Mark two widely spaced points each on the midline of both the incident and exit rays
- Remove the block and ray box, and construct the complete ray path with a ruler.
- Use a protractor to erect perpendiculars to the entry and exit sides of the block at the points where the rays intersect the edges.
- Measure the incidence angles i and the refraction angles r with the protractor and calculate the refractive index n from Snell's Law: $n = \sin i / \sin r$.

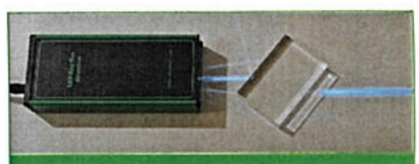

Figure 4

Semicircular block method:

- Place the semicircular block on the center of the paper, and holding it firmly in place, trace around the outline of the block.
- Remove the block. Find and mark the center of the straight edge using a ruler.
- Using a protractor, mark off a perpendicular and incidence angles of 20°, 40°, 60°, and 80°. Draw incident rays striking the block at the center of its straight edge (*see Figure 5*).
- Choose a single ray straight across the paper.
- Replace the semicircular block exactly on its outline on the paper.
- Turn the paper so that the light ray from the box falls exactly along the 20° incident ray line and mark two widely spaced points on the midline of the exit ray.
- Repeat this procedure for the 40°, 60° and 80° incident rays
- Remove the block and draw in the refracted rays. Note that they should all end at the midpoint of the straight edge, since all the rays from the center of the circle strike the circular edge normally, and are not refracted.
- Measure the refraction angles r with the protractor for each incidence angle i and calculate four estimates of the refractive index n from Snell's Law: $n = \sin i / \sin r$.

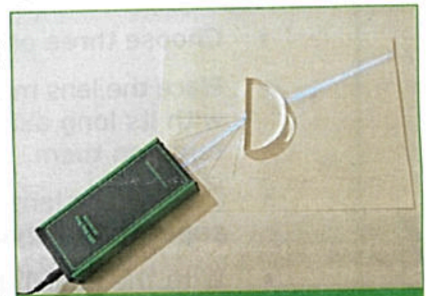

Figure 5

Demonstrating Dispersion

You will need a sheet of paper and a small piece of card to act as a screen

- Choose a single ray straight across the paper
- Place the equilateral prism on the paper 5—7 cm from the ray box with one of its sides parallel to the direction of the light ray. Position it so that the light ray strikes the prism about the middle of the angled side.
- Fold a small piece of card in half and open it about 20°. Place it on the paper to intercept the refracted light ray 5—7 cm from its exit point on the prism.
- Observe the dispersed light produced on the card. One side contains more blue light, the other more red. Rotate the prism carefully in each direction to find the position that produces the best dispersion.
- *The "white" LEDs do not have the same smooth spectrum that "white" filaments lamps produce. The "white" color is produced by combining a lot of blue with some red and a little yellow. Green is largely missing.*
- Note how the angle through which the ray is deviated from its original direction changes as the prism is rotated. Note that there is a position where the deviation is a minimum and rotating the prism either way from this position increases the deviation.

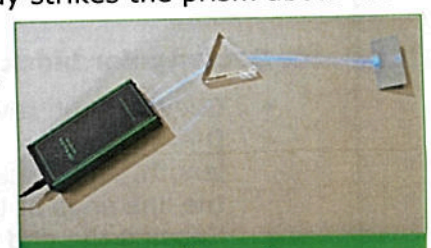

Figure 6

Tracing Ray Paths through Optical Elements

You will need a pencil, ruler, protractor, and a sheet of paper

Biconvex and Biconcave Lens Models

- Choose three or five rays straight across the paper
- Place the lens model on the paper 6—8 cm from the ray box with its long axis perpendicular to the incoming rays and centered on them.
- Holding the lens model firmly in place, trace its outline on the paper with a sharp pencil.
- With the pencil, mark two widely separated points on each of the incoming and exiting rays.
- Remove the lens model, and connect the dots with a ruler to show the ray paths outside the lens. Join the entry and exit points of the rays with straight lines to show the ray paths inside the lens models. Observe that refraction takes place at both lens surfaces.
- Mark the position of the center of the lens and measure the focal length of the biconvex lens from the lens center to the focus point with a ruler.
- For the biconcave lens, project the diverging exit rays back to their intersection in front of the lens and measure the focal length similarly, noting that it has a negative value.

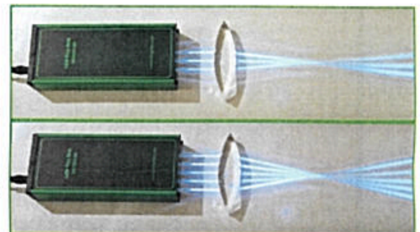

Figure 7

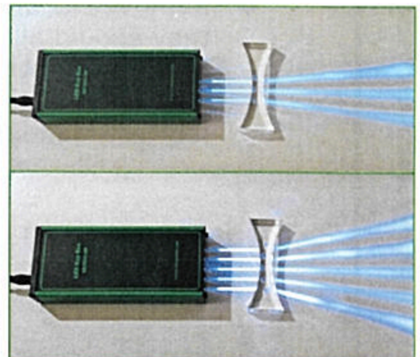

Figure 8

Rectangular block

- Choose three rays projected directly across the paper.
- Draw a line across the paper about a third of the paper length, and place the rectangular block on the paper so that the line ends at the middle of one of its long sides.
- Keeping the end of the line at its surface, rotate the block through an arbitrary angle of 30° - 40°, and holding it firmly in place, trace its outline on the paper.
- Line up the center ray from the ray box along the line on the paper and mark two widely separated points on the corresponding exit ray with pencil dots.
- Remove the block, and using a ruler, join the dots to mark the exit ray. Join the entry and exit points of the ray to show the ray path inside the block.
- Project the exit ray back to the ray box end of the paper, and measure the separation of this line from the entry ray at two points, to show that the entry and exit rays are parallel.
- Note that the three parallel rays remain parallel after refraction.
- Repeat the procedure for several angles of the block to investigate how the offset of the exit ray varies with the block angle.

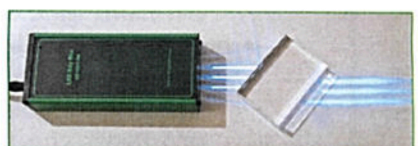

Figure 9

Semicircular Block

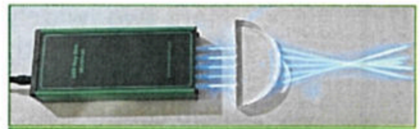

Figure 10a

- Choose five rays.
- Draw a straight line across the middle of the paper and, with a protractor, erect a perpendicular to it about a third of the way across the paper from the ray box end.
- Measure the length of the straight side of the semicircular block and mark two points on the perpendicular so that the original line across the paper will meet the block exactly at its center.
- Place the block on the paper with the straight side on the perpendicular, lined up with the centering marks, and the circular side facing away from the ray box. Holding the block firmly in place, trace around its outline with a sharp pencil.

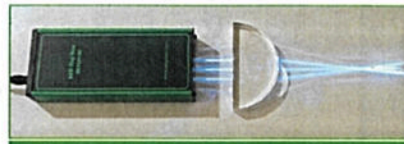

Figure 10b

- Line up the ray box so that the incoming rays are parallel to the line across the paper and symmetrically disposed about it.
- With a sharp pencil, mark two widely separated points on each of the incoming and exiting rays.
- Remove the block, and connect the dots with a ruler to show the ray paths outside the lens. Join the entry and exit points of the rays with straight lines to show the ray paths inside the block. Observe that refraction takes place only at the exit surface.

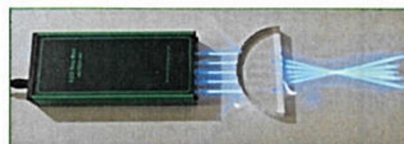

Figure 11

- Note that the inner and outer pairs of rays focus at different points. This is called *spherical aberration*. Mark these two points and also the center of the lens. Measure the focal lengths of the two pairs of rays. Use the switch to flip between three and five rays to make the spherical aberration easier to see.
- Repeat the procedure, this time with the circular side of the block facing the ray box. Note that refraction now takes place at both surfaces, the focal length is shorter than before, and the amount of spherical aberration is less.

Demonstrating Total Internal Reflection

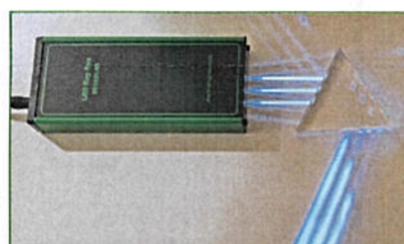

Figure 12

You will need a pencil, ruler, protractor, and a sheet of paper

- Choose three rays.
- Draw a straight line across the middle of the paper and, with a protractor, erect a perpendicular to it about a third of the way across the paper from the ray box end.
- Place the equilateral prism on the paper with one of its sides along the perpendicular .
- Line up the ray box so that the center ray falls along the original line drawn across the paper.
- Adjust the position of the prism so that all three rays exit on the same side of the prism. Note that each ray is reflected inside the prism at its side, and does not exit as a refracted ray. This is called *total internal reflection*. It takes place when the angle at which the internal ray meets the prism surface is greater than a certain critical value.
- With your finger, block one of the outer incoming rays. Note which reflected ray then disappears; the order of the exiting rays is reversed after reflection.
- Holding the prism firmly in place, trace its outline on the paper with a sharp pencil.

- Mark two widely separated points on the centers of each of the incoming and exiting rays. Also mark the three points on the third prism side where each of the rays is reflected.
- Remove the prism, and connect the dots with a ruler to show the ray paths outside the prism. Also connect each entry end exit point to the corresponding reflection point on the third prism side to show the internal reflection ray paths.
- You can check that for total internal reflection the incidence and reflected angles are equal by erecting perpendiculars to the prism side at each of the reflection points and measuring the angles with a protractor.

Maintenance and Storage:

The LED Ray Box does not require any routine maintenance and will not need repair in normal use. Store it in a dry place away from strong sunlight and high temperatures. In case of malfunction, contact your distributor.