



LASER OPTICAL DISK SET

LODS01

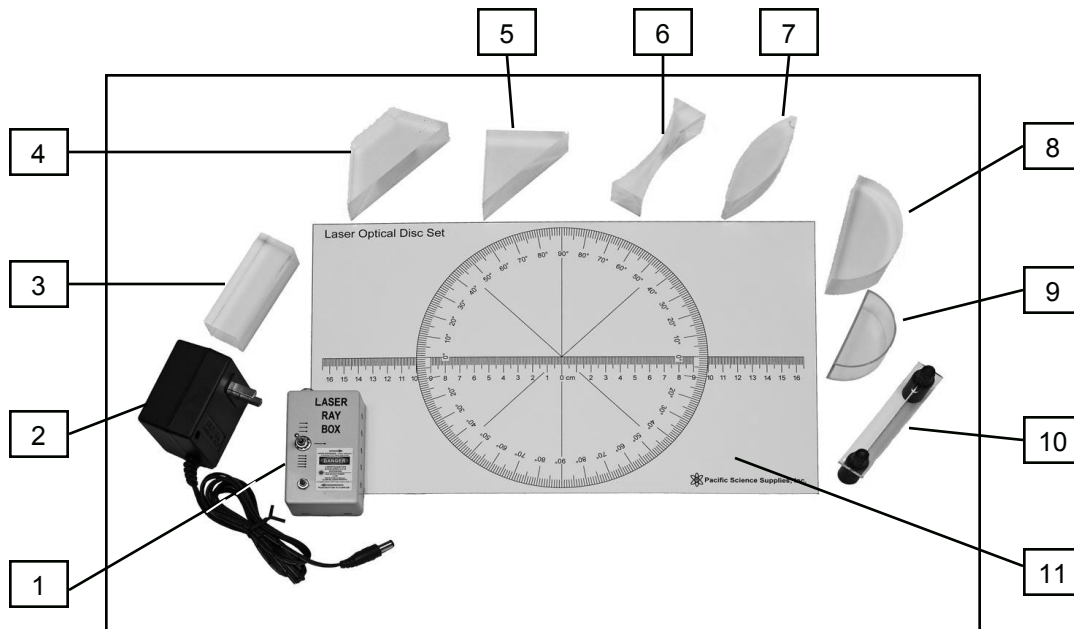


Figure 1

1. Description

The laser Optical Disk Set includes a Laser Ray Box powered by a low voltage wall-mount power supply, a set of eight ray optics elements (three lenses, two prisms, a block, a hollow cell and an adjustable mirror), and a heavy duty vinyl template with a ruler scale and a large protractor printed on it for easy measurements. The Laser Ray Box includes five parallel-mounted low power red diode lasers and a built-in cylindrical lens to fan out the laser beam for ray optics work. A selection switch allows one, three, or five beams to be used, and a momentary switch turns the lasers on only when held down, for safer operation. A storage case and operating instructions are also included.

2. Components and Specifications

Components

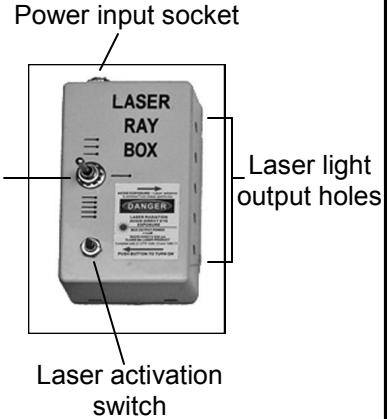
Refer to *Figure 1*

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|------------------------------------|--|
| 1. Laser Ray Box (1, 3, or 5 rays) | 7. Biconcave Lens |
| 2. Wall-mount Power Supply | 8. Semicircular Lens (solid) |
| 3. Parallel-sided Block | 9. Semicircular Cell |
| 4. Trapezoidal Prism | 10. Adjustable Mirror (plane/concave/convex) |
| 5. Right Angle Prism | 11. Template (ruler/protractor) |
| 6. Biconcave Lens | 12. Operating Instructions (not shown) |

Specifications

Laser Ray Box:

Diode lasers:	5 lasers, $\lambda = 650 \text{ nm}$, $<1\text{mW}$ each
Power supply:	Input: 110VAC/60 Hz Output: 6VDC/350mA max
Controls:	Ray selection switch 1, 3 or 5 rays Momentary switch for laser activation
Dimensions:	Ray box: 8.5 cm x 5 cm x 3.5 cm Weight 58 g Power supply: 6 cm x 5 cm x 4 cm Weight 220 g



Optical Elements:

All 19 mm high (except mirror, 25 mm high)	
Biconvex lens:	80 mm wide, f approx. 80 mm
Biconcave lens:	80 mm wide, f approx. -100 mm
D lens (semicircular):	Radius 40 mm
Semicircular cell:	Radius 30 mm
Rectangular block:	78 mm x 26 mm
Right angle prism:	Side: 55 mm, hypotenuse: 79 mm
Trapezoidal prism:	Sides: 90 mm, 36 mm; Width: 35 mm; Base angles: 45° , 60°
Adjustable ("flexible") mirror:	60 mm wide, plane, convex, or concave. Minimum radius: approx. 110 mm

Template:

Heavy duty magnetic backed white vinyl sheet, 38 cm x 21 cm, with printed scale (cm and mm, $\pm 19 \text{ cm}$, center zero) and $360^\circ \times 1^\circ$ protractor, 20 cm diameter.

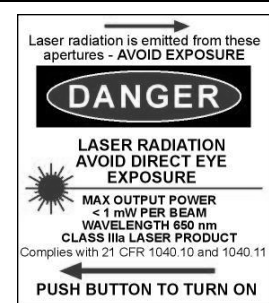
Storage Box:

Heavy card stock box 40 cm x 22 cm x 5.5 cm with molded insert to accommodate all set parts.

3. Safety

Use of most of the components of the Laser Optical Disk Set does not present any safety hazards. However, **special care should be taken with the use of the Laser Ray Box:**

- NEVER allow anyone to look directly into the laser beams.
- Do not allow the laser beams to be projected in an uncontrolled direction—operate the Laser Ray Box only on the bench with the beams horizontal.
- Do not allow the laser beams to be reflected by any shiny surface that would take them out of the experiment area.
- Confine the laser beams to the area of the experiment—place a blocking object (such as a thick book) at the end of the experimental area.
- The laser beams are turned on by pressing and holding the laser activation switch on the lower left corner of the Laser Ray Box. Only turn on the laser beams for as long as is needed to make observations or measurements.



4. Setup

- Plug the wall-mount power supply into a 110VAC outlet.
- Plug the round connector into the power input socket on the Laser Ray Box.
- Place the template on the bench and position the Laser Ray Box at the center of the left hand edge of the template with the laser light output holes facing across the template.

5. Sample Activities

5.1 Ray paths in a convex lens

Tip: For a number of experiments, a simpler template with two perpendicular rulers and no protractor can be advantageous.

- Place the biconvex lens at the center of the template with its long axis aligned with the 0—90° line of the protractor.
- Select three rays using the switch on the Laser Ray box and turn on the laser beams.
- Adjust the position of the Laser Ray Box so that the center beam lies along the top line of the ruler and passes straight through the lens.
- Observe that the upper and lower rays are brought to a focus and measure the focal length f from the center of the lens to the focus point.

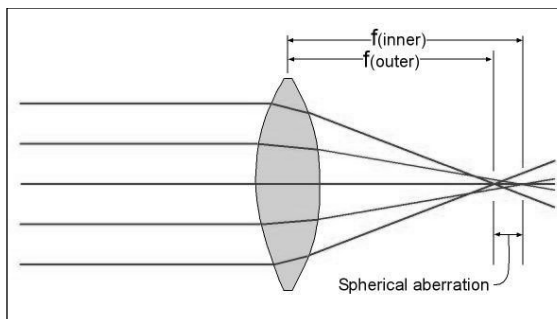


Diagram 5.1

- Now select five rays and repeat the observation. Note that the outer rays are brought to a focus a shorter distance from the lens than the inner rays (see Diagram 5.1). Measure f for the outer rays. The difference between the two focal points is due to *spherical aberration*, a geometric effect of lenses whose surfaces are part of a sphere. To correct this in practical lenses, they must be ground with the outer areas at a different radius than the central area.

5.2 Image formation in a convex lens

- Using the single ray setting, the method for locating the real image of a convex lens with two rays can be demonstrated.
- Place the biconvex lens at the center of the template with its long axis aligned with the 0—90° line of the protractor.
- Choose a point a little more than $2f$ in front of the lens and 20—25mm away from the axis to represent the tip of an object. Mark the point.
- Select a single ray using the switch on the Laser Ray Box and turn on the laser beam.
- Adjust the position of the laser beam so that it is parallel to the axis and passes through the object point. Mark the position on the axis where the refracted beam crosses it (the focus) after passing through the lens.
- Now readjust the position of the Laser Ray Box so that the beam passes through the object point and is aimed at the center of the lens. Fine-adjust the position until the beam can be seen to pass straight through the lens without deviating. Mark a point on the beam after the lens.
- Remove the lens and construct the beam paths as shown in Diagram 5.2 to reveal the position of the image.

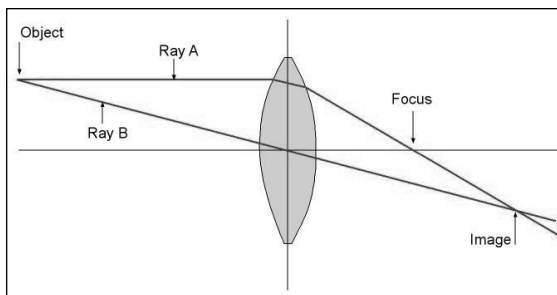


Diagram 5.2

5.3 The semicircular lens

The semicircular, or “D” lens is an extreme example of the type of plano-convex lens often used as a condensing lens in optical instruments. Its characteristics are different for the different directions of light passing through it.

- Set up the semicircular lens with its straight edge facing left and positioned at the center of the ruler scale.
- Select five rays on the Laser Ray Box and turn on the laser beams
- Note the very different focus points of the inner and outer rays, and that the light is only refracted at one surface (see *Diagram 5.3a*)
- Measure the focal lengths of the inner and outer rays.
- Now turn the lens around so that the curved surface is facing left, with the straight edge on the center of the ruler scale as before.
- Note that now both surfaces contribute to the refraction, and the focal points of the inner and outer rays are much closer together (see *Diagram 5.3b*). Measure the focal lengths and compare them with the previous measurements.
- Which orientation of the lens would be more advantageous for an optical instrument?

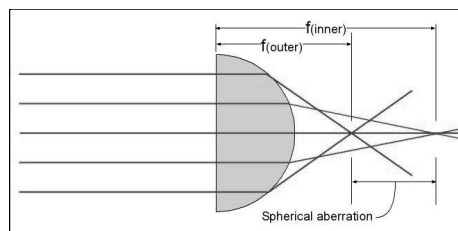


Diagram 5.3a

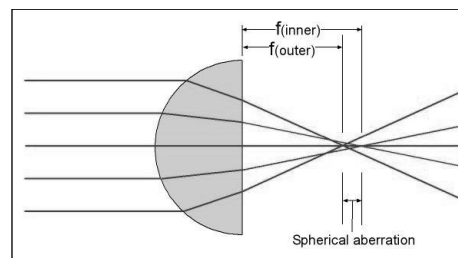


Diagram 5.3b

5.4 Refractive Index measurement

Tip: A template with several lines parallel to the axis at different distances is advantageous in this experiment. The semicircular lens can be used to easily determine the refractive index of its material.

- Place the semicircular lens centrally on the template with its straight side facing left.
- Carefully draw around its outline without moving the lens.
- Select a single ray with the switch on the Laser Ray Box and turn on the laser beam.
- Adjust the Laser Ray Box so that the beam is parallel to the axis, but offset from it by 10—15 mm. (see *Diagram 5.4*)
- Mark two positions on the incoming ray and two positions on the refracted ray.
- Remove the semicircular lens and use the marked points to construct the ray path through the lens.
- Draw the normal to the exit point of the ray from the center of the lens's diameter and measure the incident angle θ_i and the refracted angle θ_r with a protractor.
- The refractive index, n , is given by Snell's Law: $n = \sin(\theta_i)/\sin(\theta_r)$.
- Repeat the measurement for several different offsets from the axis and compare the results

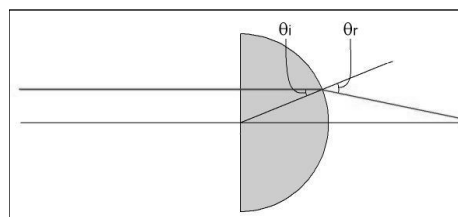


Diagram 5.4

for n

5.5 The right angle prism

Prisms are frequently used in optical instruments to change the path of a bundle of light beams. The right angle prism illustrates how this works.

- Set up the right angle prism on the template with the hypotenuse perpendicular to the axis.
- Select three rays using the switch on the Laser Ray Box and turn on the laser beams.
- Adjust the Laser Ray Box so that the three rays are parallel to the axis and all strike the prism above the axis.
- Note that the directions of the rays are reversed with an offset. Place your finger over one of the exit holes on the Laser Ray Box and identify the order of the exit rays compared to their entry order (see *Diagram 5.5a*)
- Although the order of the rays as shown appears to have been reversed (ABC becomes CBA), this is not so if viewed against the direction of the oncoming light. To confirm this, view an identifiable object through the prism from two directions as indicated in *Diagram 5.5a*
- Now place the prism on the template so that one of the sides is perpendicular to the axis, as shown in *Diagram 5.5b*.
- Turn on the laser beams and observe that the rays are now diverted through 90°. Identify the order of the beams in front of and behind the prism, as before.
- This time, the order ABC appears to have been preserved, but viewing a recognizable object through the prism from two directions as shown in *Diagram 5.5b* demonstrates that the image is actually reversed when viewed against the direction of the oncoming light.
- Now replace the prism on the template with the hypotenuse along the axis and turn on the laser beams.
- Note that only the lower half of the prism is useful, because rays in the upper half are reflected at the side of the prism before reaching the hypotenuse and exit in a different direction from the lower rays.
- The lower rays are preserved in direction but reversed in order (BC becomes CB).
- View a recognizable object through the prism as indicated in *Diagram 5.5c* and note that the image is indeed inverted, but only top to bottom, not left to right.

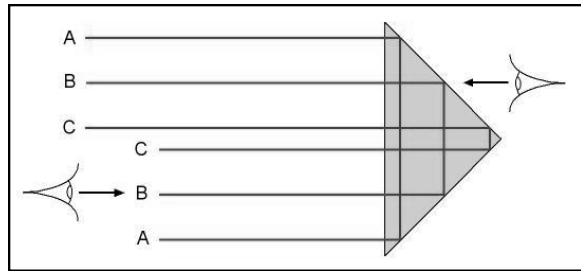


Diagram 5.5a

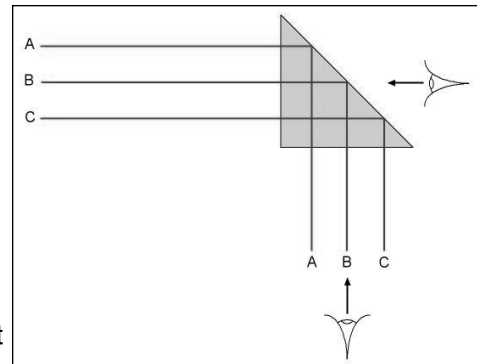


Diagram 5.5b

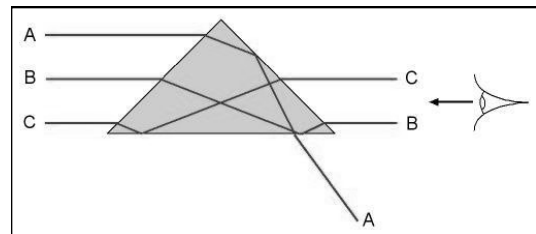


Diagram 5.5c

5.6 The Adjustable Mirror—Plane mirror

The adjustable mirror contains a flexible piece of polished metal supported by two plastic pillars at the ends. The pillars can rotate to force the mirror into a circular curve, and are fixed in the desired position by thumbscrews.

- Loosen the thumbscrews and allow the mirror to relax to a straight configuration. Retighten the thumbscrews and place the mirror on the template at an arbitrary angle to the axis.
- Select three rays using the switch on the Laser Ray Box and turn on the laser beams.
- Adjust the Laser Ray Box so that the central beam lies along the axis, and view the regular reflections.
- Identify the orders of the incident and reflected beams as shown in *Diagram 5.6* and recognize that when viewed against the direction of the oncoming light, the order is reversed left to right.
- Use the protractor to rotate the mirror through an angle of 10° , and note that the reflected beams rotate through 20° .

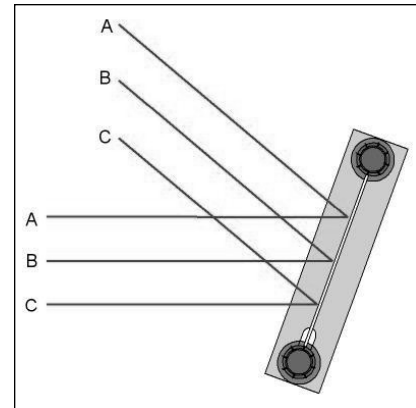


Diagram 5.6

5.7 The Adjustable Mirror—Concave Mirror

- Loosen the thumbscrews and push the center of the mirror into a curve. Holding the mirror in the curved position, tighten the thumbscrews so that the mirror remains curved when released.
- Place the mirror centrally on the template with the long axis of its holder perpendicular to the axis and the center of the mirror at the center of the ruler scale.
- Select five rays using the switch on the Laser Ray Box and turn on the laser beams.
- Measure the focal length f and note that for a circular mirror profile, there is no spherical aberration (see *Diagram 5.7*). Mirrors are used as the primary image forming elements in large telescopes.

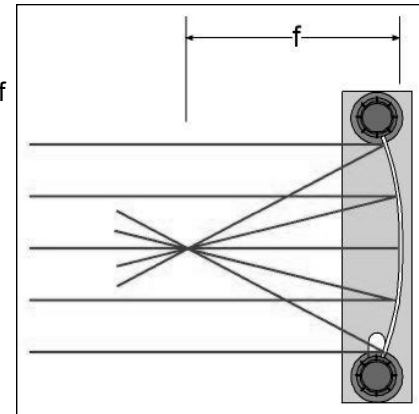


Diagram 5.7

5.8 The Adjustable Mirror—Convex mirror

- Reverse the orientation of the curved mirror so that the convex side faces the incoming light and position it as shown in *Diagram 5.8*.
- Mark two points on each of the reflected rays, then remove the mirror and project the lines joining the exit rays backwards to their meeting point, the focal point. Measure the focal length, f .
- Note that if the light rays were reversed, incoming light from a wide range of angles would be delivered into a narrow bundle after reflection. This effect is used in “wide angle” mirrors, such as automobile side mirrors, to give a wider field of view to the observer.

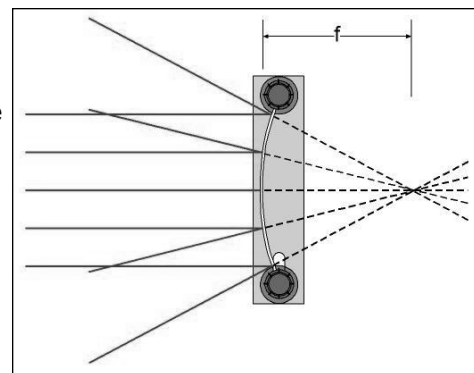


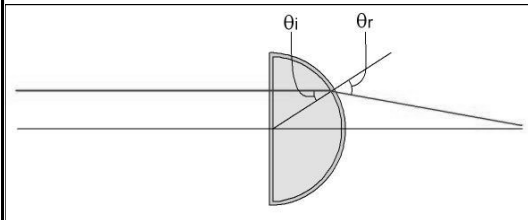
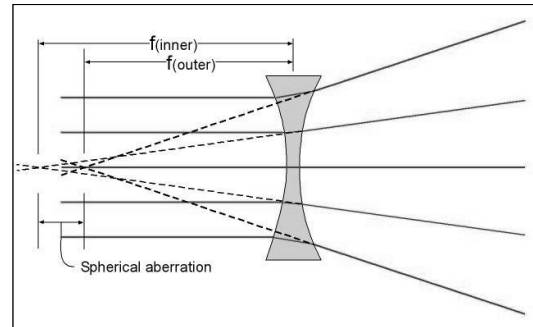
Diagram 5.8

6. Additional Materials

The other optical components include:

Biconcave Lens:

- Diverging exit rays, so no real images, only virtual ones
- Shows spherical aberration by comparing the foci of inner and outer rays

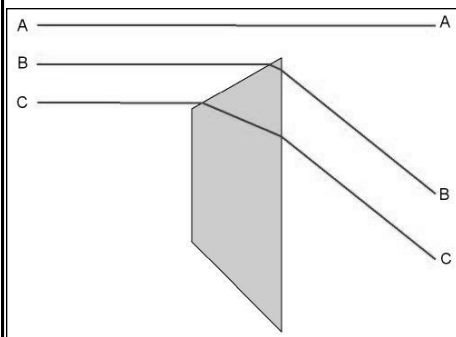
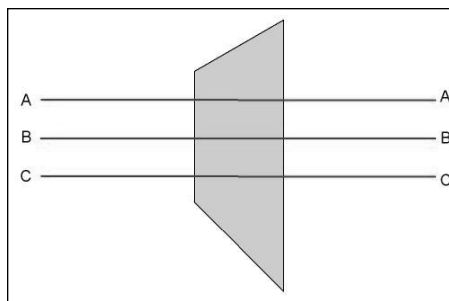
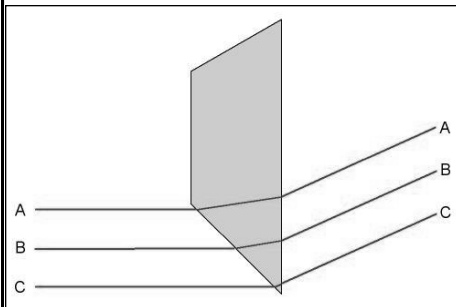
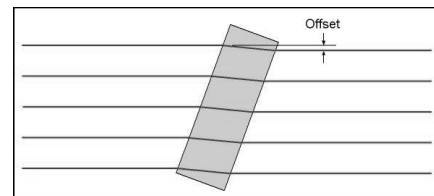


Semicircular Cell:

- Used to find the refractive index of water (procedure as in 5.4 for acrylic material. The acrylic walls do not affect the measurement)

Parallel-sided Block:

- Deviates rays sideways while preserving direction
- Can be used to measure refractive index using the offset



Trapezoidal Prism:

- Compares the deviations produced by equilateral and right angle prisms and a parallel block