12. Replace the 7-slot plate and remove the convex lens. Attach the concave lens perpendicular to the 90-90 axis of the disk after placing a sheet of paper between the disk and the lens. Trace the position of the lens on the paper. Position the disk so that the rays are parallel to the 90-90 axis and trace the rays on the paper (both the incident and transmitted). Remove the lens and paper, and continue the diverging rays back to locate the focal point of the lens. Do the rays appear to have come from a single point?

8. Insert the 90° prism as indicated on the optical disk; rotate the disk until the right angle of the prism points directly away from the illuminator. Cover the middle slot of the 3-slot plate and observe the path of the two rays. Cover the two slots with difference colored filters and observe that the rays are totally internally reflected.

9. Attach the trapezoidal glass plate to the disk, and adjust its position so that a single ray enters through one flat surface and emerges from a different, but parallel surface (see drawing #11 on the chart). Comment on the angle between the incident and transmitted ray. Repeat for several angles of incidence.

angle of incidence	comments

10. Attach the convex "lens" to the disk perpendicular to the 90-90 axis of the disk (see drawing #15 on the chart). Send a single ray along the 90-90 axis of the disk passing through the center of the lens. Rotate the disk slightly and observe the angles of the incident and transmitted rays. Comment on your observations in regards to the ray-tracing rules discussed in lecture.

11. Replace the 3-slot plate with the 7-slot plate and send the rays in parallel to the 90-90 axis of the disk (see drawing #15 on the chart). Comment on the location of the focal point of the lens. Remove the 7-slot plate; is the light sharply focused?

Snell's Law and the Index of Refraction for Glass

angle of incidence	angle of refraction	index of refraction

6. Rotate the disk through 180° so that the incident ray strikes the curved surface of the glass plate (see drawing #8 on the chart). Compare the angles of incidence and refraction with those on from step **5**. Comment on any difference.

7. Vary the angle of incidence and note that as the angle increases, the intensity of the refracted ray decreases. Carefully adjust the disk so that the angle of refraction is 90° (*i.e.* the refracted ray is parallel to the flat edge of the glass plate as in drawing #9 on the chart). What is your measured value of the critical angle for total internal reflection? Compare this value to what you expect based upon the average value of the index of refraction of the glass you obtained in step **5**. (Remember that when the angle of incidence is the critical angle, the angle of refraction is exactly 90°; therefore, $n_1 \sin\theta_c = n_2 \sin 90°$, or $\sin\theta_c = n_2/n_1$.

Data Testing the Law of Reflection

angle of incidence	angle of reflection

Q1. From your observations, what appears to be the relationship between the angle of incidence and the angle of reflection?

3. Replace the 3-slot plate with the 7-slot plate, and check to see that the outgoing rays are parallel (see drawing #2 on the chart). Remove the planar mirror.

4. Attach the concave mirror, and replace the 7-slot plate with the 3-slot plate. Rotate the **screen** slightly without moving the disk. The outgoing rays should all pass through a particular point on the axis of the disk, called the focal point of the mirror (see drawing #3 on the chart). Replace the 3-slot plate with the 7-slot plate; the position of the focal point should be apparent (see drawing #5 on the chart). Remove the concave mirror.

5. Attach the semi-cylindrical glass plate to the disk so that the straight edge lies on the 90-90 diameter of the disk (see drawing #7 on the chart). Replace the 7-slot plate with the 3-slot plate. Adjust the screen so that the single ray touches the flat edge of the glass plate at the 0-0 axis of the disk. Sketch the incident, reflected, and refracted rays. Compare the angles of incidence, reflection, and refraction. Record angles of incidence and refraction for several angles of incidence (*e.g.* 30°, 45° and 55°). Compute the corresponding index of refraction of the glass for each of your measurements from Snell's Law ($n_1 \sin\theta_1 = n_2 \sin\theta_2$).

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Experiment 19
Reflection and Refraction

Objective

In this experiment, we are going to study the fundamental principles of reflection and refraction of light with the help of the optical disk.

Equipment

- Hartl optical disk and accessories.
- Illuminator.
- Ruler.
- Quad ruled paper.

The Hartl optical disk consists of a metal disk with a graduated scale. The disk is partially shielded by a sheet metal screen. The disk and screen are free to rotate about a common axis. Thumb screws can be used to attach lenses and mirrors to the disk. The attached chart shows sketches of some of the experiments that can be performed with the disk. Please refer to it when directed to do so by the instructions.

Theory

Various planar and curved objects, some of which only reflect light while others refract as well, are placed on the optical disk. Single light rays, or parallel combinations of rays, are incident on the various optical components. The rays can be followed, allowing for the study of reflection and refraction.

Procedure

1. First, prepare the optical disk for use. Place the illuminator so that the beam covers most of the opening of the screen. Adjust the position of the optical disk until the light beam traces its path across the face of the disk. Place the 3-slot plate over the opening in the screen, and cover the outer slots with the rectangular metal pieces. Rotate the disk until the beam of light falls on the zero axis of the disk.

2. Attach the plane mirror to the disk so that its front face lies on the 90-90 diameter line of the disk. The light beam should strike the mirror at exactly the center of the optical disk (see drawing #1 on the chart). Record the angle of incidence and the angle of reflection for several different disk positions.