Assignment 1
Due September 6, 2011

Text readings

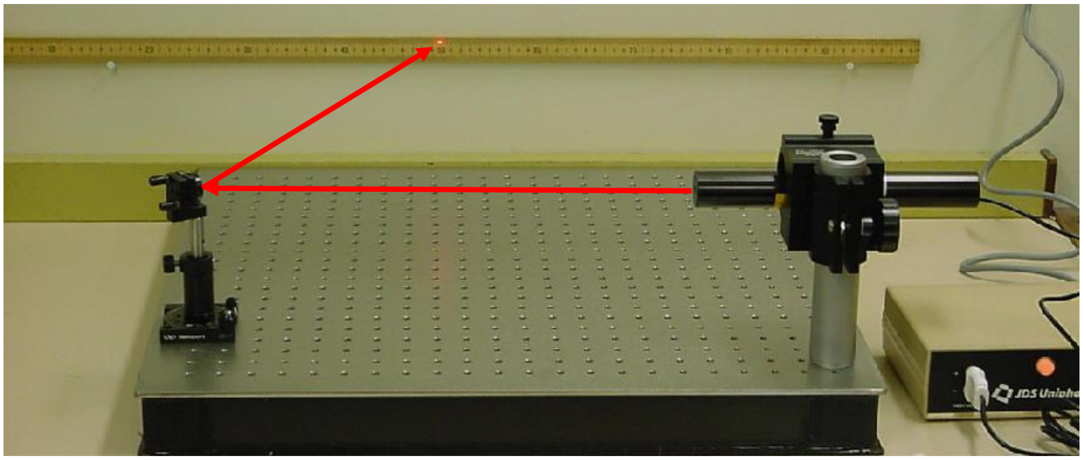
A brief history of optics [Pages 1-9]
Reflection and refraction [Pages 95-104]
Huygen's principle [pages 104-106]
Fermat's principle [Pages 106-111]
Total internal reflection [Pages 122-124]
Images produced by a mirror [Pages 175-178]

Problems

The equipment will be available in Room 1212B. Please work on these problems right away, so we can discuss your conceptual understanding, any needed theory and work out any problems.

Problem 1

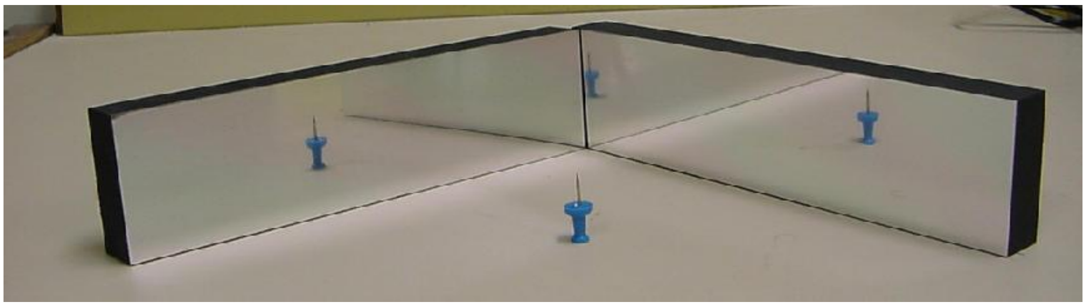
(a) Law of Reflection: Use a He-Ne laser and a mirror mounted on a rotation stage to verify the law of reflection. Rotate the mirror such that the laser beam is reflected on itself. Consider this angle as the reference angle that defines the normal to the surface of the mirror. Now rotate the mirror to see the reflected spot on a meter stick as shown. Record the location of the spot and determine the angle of incidence. Repeat this for two more angles of incidence. Determine the angles of reflection using the perpendicular distance between the wall and the center of the mirror and the distance between the perpendicular line and the location of the spots. Verify that the angle of incidence equals that of reflection. You must draw a clear diagram that shows all the parameters involved in determining the angle of reflection.

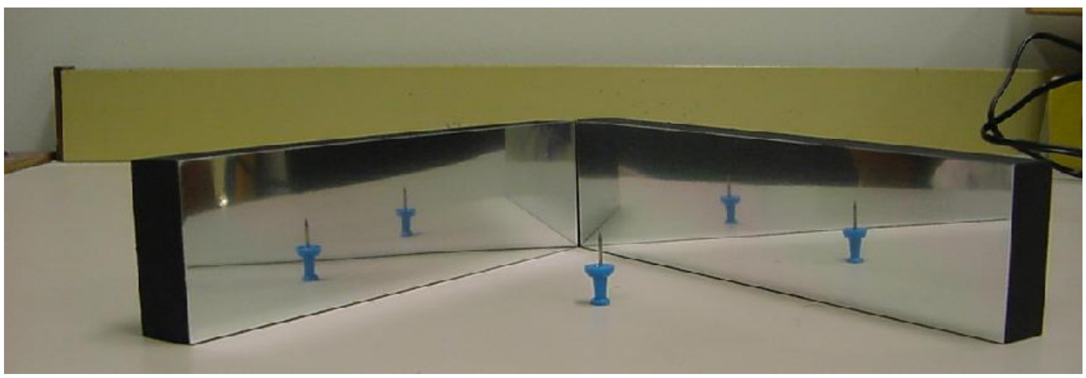


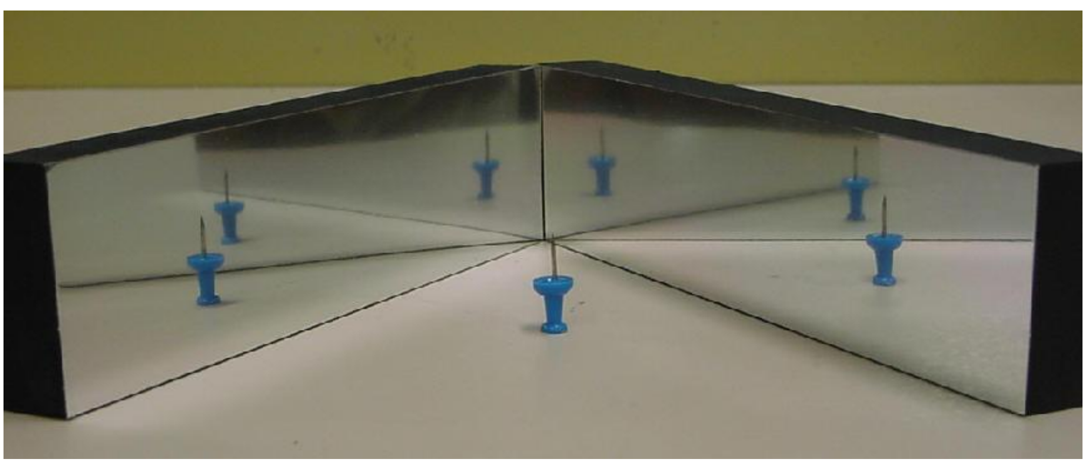
(b) Show that when a mirror is rotated by an angle β the reflected beam rotates by and angle 2β. Draw a clear diagram and show your derivation.

Problem 2

Image Formation using Plane Mirrors: The pictures below show the images formed by two plane mirrors. Reproduce these images in class and determine the angle (θ) between the two mirrors in each case (configure the mirrors to see 1, 3, 5, and 7 images). Explain the formation of these images using ray diagrams (show at least two cases). Plot N vs. θ. Then plot N vs. $\frac{1}{\theta}$. Use the plots to find the equation that describes the relationship between the number of images and the angle between the two plane mirrors.

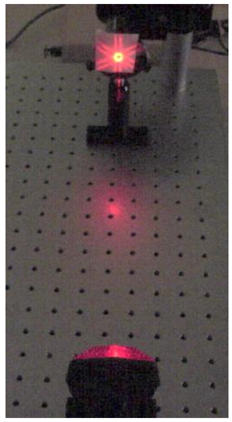
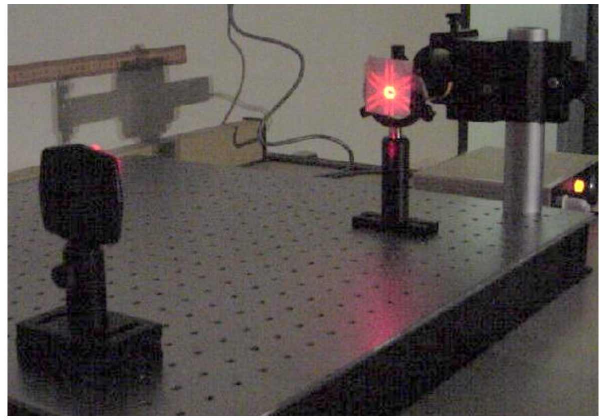






Problem 3

Bicycle Reflector: The first picture (left) shows a bicycle reflector. The other two pictures below show how it retro-reflects the laser beam back directly to the laser (the bright spot). It is also visible in the reflection on the surface of the optical table. Try this reflector and compare its reflection to that of the plane mirror that you did in problem 1. How is this reflector constructed? If you have no idea, don't worry. I will give you hints in class.

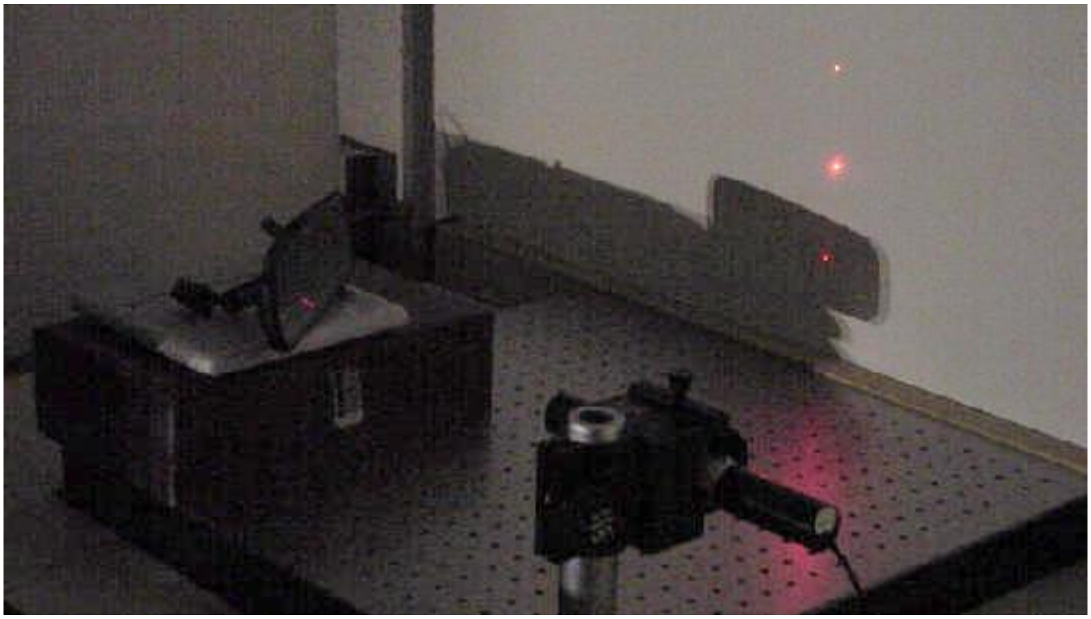




Why when we shine light on the eyes of an animal they appear to glow?

How do most road signs reflect light?

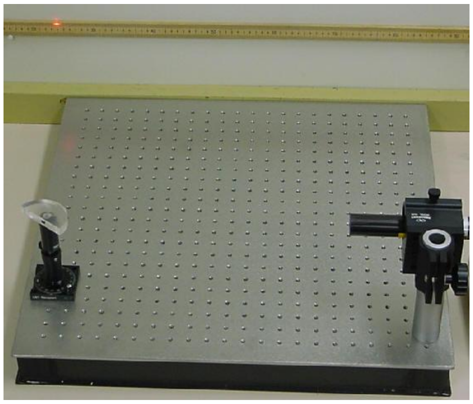
Problem 4

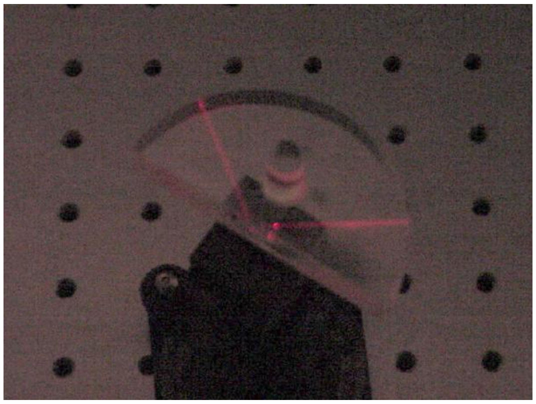
Traditional Car Rearview Mirror: The picture shows the reflection of a laser beam from a car rearview mirror. Based on the reflected beams explain how it works. Support your answer by drawing a diagram. Notice the intensity of the central spot compared to the other two spots. Draw clear diagrams that show both night and day settings.



Problem 5

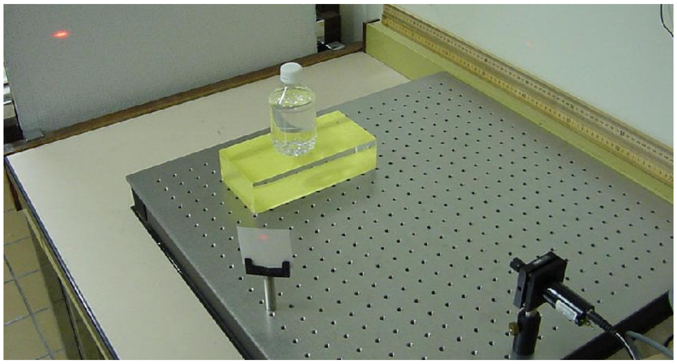
Index of refraction: Use Snell's law to determine the index of refraction of the plastic semi-disk. Draw a ray diagram showing the sample, the path of the laser beam, and the angles. Show the measured quantities on this diagram. Your analysis should include at least 5 different angles of incidence. Plot your data to determine the index of refraction. What angle of incidence produces total internal reflection? Use this angle to directly find the index of refraction. Compare the index you found from the total internal reflection and that from the plot. You will be given a plastic semi-disk container that has the same shape as the plastic semi-disk. Use the cup to measure the index of refraction of water.





Problem 6

Rainbow: The picture at the right shows a plastic bottle filled with water. A helium neon laser shines on the bottle. The red spot on the right results from a reflection of the laser beam from the front surface of the bottle. The red spot on the left results from the incident laser beam refracting twice, once on entering the water bottle and again upon leaving it. It is possible to calculate the angular deflection of the beam using Snell's law. When you observe a rainbow the sun is always behind you. Thus the light coming from the raindrops must be scattering light backwards, unlike the two red spots seen in the forward direction. But there is a backward scattered beam, which results from an initial refraction, followed by a reflection, and finally another refraction on passing from water to air (seen on the white card).

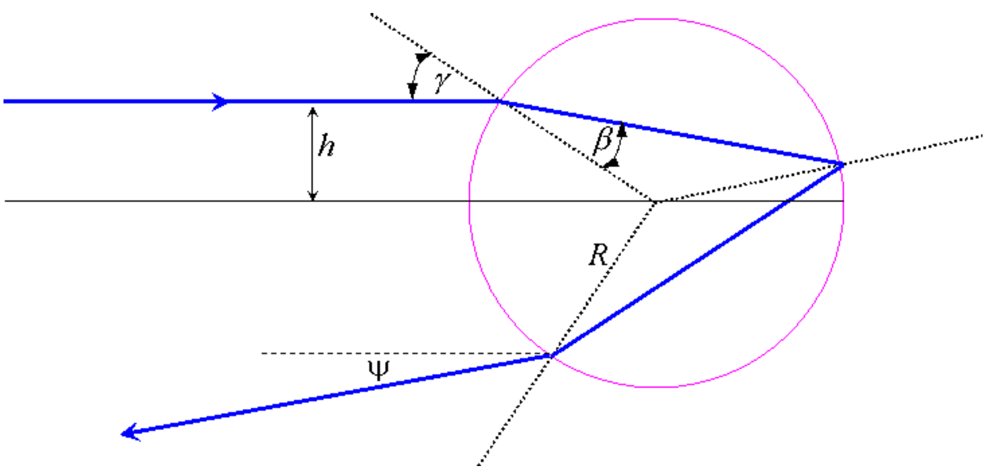


1. Based on your observation explain with the help of ray diagrams how single and double rainbows occur.
2. Consider the rain drop as a sphere of radius R. With the help of the diagram shown below derive an expression for the scattering angle of the primary rainbow and show that it is given by

$$\Psi = 4\sin^{-1}(h / nR) - 2\sin^{-1}(h / R)$$

where *n* is the index of refraction of the drop and *y* is measured relative to the horizontal line.

3. Plot the scattering angle as a function of the h/R ratio.
4. From your plot you see that the raindrop backscatters light over a whole range of angles, however the rainbow occurs at only one angle (for a given color). What angle is that? Why?



Required for Graduate Students
And
Bonus for Undergraduate Students

Problems 4.21 and 4.34