Experiment 1
Spherical, Parabolic and Ellipsoidal Mirrors

Introduction

The objective of the experiment is to learn how spherical, parabolic and ellipsoidal mirrors function as optical elements employed in image formation and in collecting radiation as in astronomical telescope or a spectrometer. [Review Chapter 6 (Sections 6.1-6.4 and 6.8) as well as Section 1.9 pp14-18 in Jenkins and White; in particular see Fig. 1J p16].

1 Spherical Mirrors

Use Cartesian sign convention, distances being measured from the position of the spherical mirror as the origin. The relation between \( u \) (object distance), \( v \) (image distance) and the focal length, \( f = \frac{1}{2} \) (Radius = R) is

\[
\frac{1}{u} + \frac{1}{v} = \frac{1}{f}.
\]  

(1)

Make sketches as in Fig. 6A - 6F for the different measurements you make.

Procedure

Make several measurements of the image and object distance for the spherical mirror supplied.

- As a quick measurement for \( f \), let light from a distant source be reflected off the spherical mirror. With \( u \sim \infty \), the image plane is essentially \( f \) cm from the mirror.

- Set up the spherical mirror on the optical bench. Place the plastic rod in the holder in front of the mirror, with \( u > 2f \) reflection in the mirror. By moving the object towards the mirror, you will observe that the image moves towards the object. Until the object and its inverted image coincide, you will see a parallax between them (See Appendix 1). When the object and the image coincide (\( u = v = 2f \)), you will notice there is no parallax. This method is called auto-collimation. The image is real and inverted.

- Repeat the measurement five times. Note the object and the image have the same size and the magnification is unity.

- Measure \( v \) for several values of \( u > f \) and deduce \( f \) from Eq. (1). Repeat each measurement of \( v \) for a given value of \( u \) several times. Note the nature of the image (magnified or diminished, erect or inverted, real or virtual).

- With \( u < f \), you will notice that the image is erect, virtual and magnified. With a second plastic rod held behind the mirror so as to be seen by the observer, locate the position of the image by parallax. Again deduce the focal length from Eq. (1).
• Observe the real image of an object with length markings and a scale beside the image, having no parallax with it. From the ray diagram as in Fig. 6E, p101 (Jenkins and White≡ JW, shows that the magnification, \( m \) is

\[
m = -\frac{v}{u}.
\]

• In all of the above measurements make a number of observations and estimate the error.

2 Parabolic Mirrors

Procedure This section deals with a mirror that has been cut from a section of a larger parabolic reflector. A parabolic mirror has the property that all light rays impinging on it parallel to the axis of the parabola will converge to its focal point on reflection.

• The set-up for this experiment is in the main room of the laboratory.

• Place a piece of frosted glass directly in front of the laser. This makes the highly collimated light of the laser into a point source with diverging rays.

• Use the +30 cm lens to collimate this light into a uniform beam.

• The beam should impinge directly onto the mirror.

• Slowly rotate the mirror stage and observe the reflected image with a white card.

• At one particular angle the image will focus most sharply without distortion. Note the angle.

Analysis This known as an off-axis parabolic mirror. The angle found above represents the angle between the axis of the full parabola and the line connecting the mirror to the focus. Notice that for other angles the beam does not come into sharp focus and there is lateral distortion of the image.

3 Ellipsoidal Mirrors

Procedure An ellipsoidal mirror has two foci (all three mirrors follow simple geometry, a circle has one focus, an ellipse has two foci, and a parabola also has two foci but one is at infinity) and light emanating from one focus, after a single reflection will be focussed at the other. In this section of the lab the positions of the two foci will be found and the eccentricity of the ellipse calculated.
• Make sure that the laser is on-axis.

• Once again, a piece of frosted glass will be used as a point source. Place the glass and a small white screen on the bench, the glass (hereafter referred to as the source) close to the laser and the screen facing and close to the mirror.

• The mirror should be evenly illuminated with diffuse laser light.

• Bring the source in approximately halfway.

• Move the screen back and forth until the best focus is obtained.

• Move the source in 2 cm at a time, each time adjusting the screen to produce the best image.

• Eventually the final position of the screen should stop deviating for changes in the position of the source. This is the first focus \( f_1 \).

• Now clamp down the stands and reverse the positions of the screen and the source.

• Bring the laser slightly off-axis and realign the beam on the source.

• Move the screen slightly to get as sharp a focus as possible. This is the second focus \( f_2 \).

• Measure the distances from the mirror \( f_1 \) and \( f_2 \).

• Comment on the magnification of the image when the screen is at \( f_2 \).

• From the sum of the distance of \( f \) and \( f_2 \) i.e. \( 2a \), calculate the eccentricity of the ellipsoid.