Paraxial Properties Measurement

PP-1

A Geneva gauge calibrated for a refractive index of 1.523 is used to measure the curvature of a lens having a refractive index of 1.5. The distance between the two end pins on the Geneva gauge is 2 cm. The Gauge measures a power of 2 diopters. How many microns of sag is the Geneva gauge measuring?

Solution

$$\text{Power} = \frac{n-1}{R} = 2\ \text{Diopters}$$

$$\frac{1}{R} = \frac{\text{Power}}{n-1} = \frac{2\ m^{-1}}{1.523-1}$$

$$\boxed{\text{Sag} \approx \frac{y^2}{2\,R} = \frac{\left(10^{-2}\ m\right)^2}{2}\ \frac{2\ m^{-1}}{1.523-1} = 191.2\ \mu m}$$

PP-2

I have a 6 inch diameter, approximately 24 inch focal length lens, and I want to measure the back focal length and focal length to an accuracy of 0.001 inches. Give a method for performing the measurement. Justify whether the desired accuracy can be obtained or not.

Solution

For the given lens the depth of focus ($\lambda/4$ wavefront error) at λ = 0.5 μm is ±2 λ (f#)^2 = ±16 μm = ±0.0006 inches. Thus it is difficult to get the desired accuracy. However, there are several ways of measuring the back focal length and focal length of the lens.

One way to measure the back focal distance is with an autostigmatic microscope. A "fast" objective can give surface position with better accuracy than the focal point position can be measured. The distance the microscope is moved can be measured with a scale or a distance measuring interferometer.

The focal length can be measured with a high quality focal collimator. A second possible technique is to time the drift of a star image over an accurate reticle in the focal plane. The more accurate the measurement time, the smaller the drift time and field necessary. Making incremental timings across a grid reticle can reduce inaccuracy due to distortion.

PP-3

Given the measured total object-to-image distance and measured image magnification for two different object-to-lens distances, derive a formula for the focal length of a thick lens under test. How is this test similar to that using reciprocal magnification? What additional information is needed to obtain both focal length of the lens and principal plane locations?

Solution

Let L be the distance between the principal planes.

Case I

Let d_1 be the distance between the object and image.
Let p_1 be the distance between object and first principal plane.
Let q_1 be the distance between the second principal plane and the image.
Let m_1 be the magnitude of the magnification.

Case II

Let d_2 be the distance between the object and image.
Let p_2 be the distance between object and first principal plane.
Let q_2 be the distance between the second principal plane and the image.
Let m_2 be the magnitude of the magnification.

We measure the d's and the m's.

$$d_1 = p_1 + q_1 + L; \qquad q_1 = m_1\, p_1;$$

$$d_2 = p_2 + q_2 + L; \qquad q_2 = m_2\, p_2;$$

$$d_2 - d_1 = (m_2 + 1)\, p_2 - (m_1 + 1)\, p_1$$

$$\frac{1}{f} = \frac{1}{p_1} + \frac{1}{q_1} = \frac{1}{p_2} + \frac{1}{q_2}$$

$$f = \frac{p_1\, q_1}{p_1 + q_1} = \frac{m_1\, p_1}{(1 + m_1)} = \frac{m_2\, p_2}{(1 + m_2)}$$

Substituting into $d_2 - d_1$ yields

$$d_2 - d_1 = \frac{(m_2 + 1)^2\, f}{m_2} - \frac{(m_1 + 1)^2\, f}{m_1}$$

$$f = \frac{d_2 - d_1}{\frac{(m_2+1)^2}{m_2} - \frac{(m_1+1)^2}{m_1}} = \frac{d_2 - d_1}{(m_2 - m_1) + \left(\frac{1}{m_2} - \frac{1}{m_1}\right)}$$

This is similar to reciprocal magnification where $d_1 = d_2$ and we measure the distance the lens is shifted between Case I and Case II.

We know the magnitude of the magnifications and focal length so

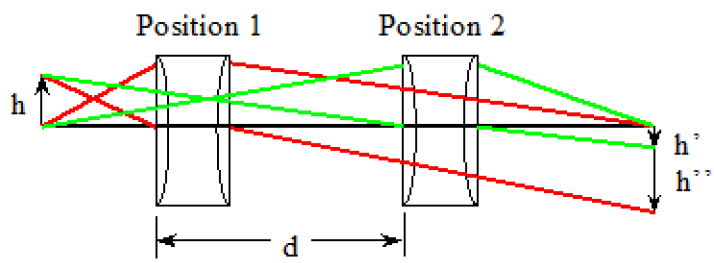
$$p_1 = \frac{(1+m_1)\,f}{m_1} \quad \text{and} \quad q_1 = (1+m_1)\,f$$

Thus we know the location of the principal points and we know the focal points are a distance f away.

PP-4

The focal length of a thick lens is measured using the reciprocal magnification technique. For the first position of the lens the magnitude of the magnification is 2. The distance between the first position of the lens and the second position of the lens is 10 cm. What is the focal length of the lens?

Solution



Let p be the distance from the object to the first principal plane and q be the distance from the second principal plane to the image.

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$q - p = 10\text{ cm}; \quad \frac{q}{p} = 2;$$

Therefore, $q = 20$ cm and $p = 10$ cm.

$$\frac{1}{10\text{ cm}} + \frac{1}{20\text{ cm}} = \frac{1}{f}$$

$$\textbf{Solve}\left[\frac{1}{10\text{ cm}} + \frac{1}{20\text{ cm}} == \frac{1}{f}, f\right] \text{ // N}$$

$$\{\{f \to 6.66667\text{ cm}\}\}$$

PP-5

A focal collimator with an Fo/A of 1000 is used to measure the focal length of a lens. The image of the reticle is measured to be 2± 0.01 mm.

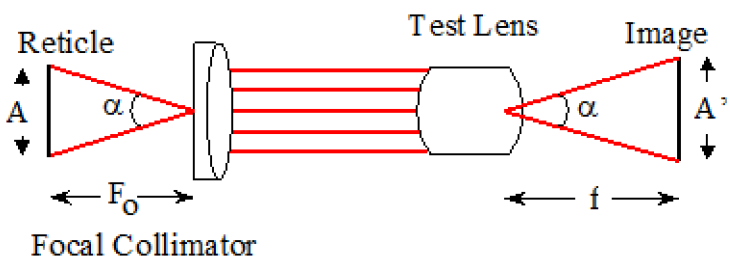
a) Sketch the focal collimator.

b) What is the focal length of the lens?

c) Briefly describe how you would use the focal collimator to measure all the cardinal points of the lens.

Solution

a)



b)

$$f = A' \left(\frac{F_o}{A}\right) = 2\ \text{m} \pm 10\ \text{mm}$$

c)

The image is formed at one focal point and one principal point and one nodal point are a distance equal to the focal length away from the focal point. The lens must be turned around to determine the second focal point position and consequently the second principal point and the second nodal point.

PP-6

A focometer is used to measure the power of a thin lens. What is the location of the lens being tested so the distance the target must be moved to restore focus is linearly proportional to the power of the lens being measured?

Solution

The lens being tested is located at the second focal point of the collimating lens.