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**1. Thin lenses. (20%)**

An optical imaging system as illustrated in Figure 1 consists of two Biconvex thin lenses. The object is 5-mm high. Lens #1: refractive index n1 = 1.50, and the radii of curvature R1=R2=30mm. Lens #2: refractive index n1 = 1.75, and the radii of curvature R1=R2=75mm.

a) Determine the focal length of each lens;

b) Determine the location and size of the image. Make a sketch of proper rays and the image.

Ans:

Part A.

so = 50; % mm

% Lens 1 Parameters

lens\_1\_n1 = 1.5; % refractive index

lens\_1\_R1 = 30; % mm

lens\_1\_R2 = 30; % mm

% Lens 2 Parameters

lens\_2\_n1 = 1.75; % refractive index

lens\_2\_R1 = 75; % mm

lens\_2\_R2 = 75; % mm

% Part a.

% Lens Focal points

% use equation: 1/f = (nl-1)(1/R1 - 1/R2)

% Where R2 is negative because lens is concave

lens\_1\_f = ((lens\_1\_n1-1)\*(1/(lens\_1\_R1) - 1/(-lens\_1\_R2)))^-1;

lens\_2\_f = ((lens\_2\_n1-1)\*(1/(lens\_2\_R1) - 1/(-lens\_2\_R2)))^-1;

So,

f1 = 30 mm

f2 = 50 mm

Part B.

% Part b.

si = 1/( 1/(lens\_1\_f ) - 1/so );

So, Intermediate image at 75mm to right of first biconvex lens and shown in diagram below.

Chart, line chart

Description automatically generated

And the size of the image is

M = -si/so;

So,

M = -1.5

**2. ABCD Matrix. (20%)**

Compute the ray (ABCD) matrix of a thick biconvex lens as shown in Figure 2. The lens is composed of two spherical refractive surfaces of radii R1 and R2, and a thickness of d. The lens is made of glass of refractive index n. The lens is in air (refractive index = 1).

Figure 2

Chart

Description automatically generated with medium confidence

Ans:

Text

Description automatically generated with low confidence

**3. Aberrations. (20%)**

What is spherical aberration? Describe 3 ways to correct the spherical aberration.

Ans:

Spherical aberration is the blurriness at the edge of an image that is caused when we use a ray tracing model, and the peripheral rays are all not focused on our image plane. The exact cause of this phenomenon is parallel rays that strike the edges of our lens are refracted more than rays closer to the central axis.

Here are three basic ways to correct: The use of aspherical lens, optical aperture and lens splitting.

Aspherical lenses correct and compensate for caused by spherical lens that do not let all the rays of the lens converge to a single point. Light rays that pass thru the center must travel a greater distance and “blur”, so a special curvature is created with a kind of notch at the corners of the lens. For many years it was very expensive to manufacture and control the curvatures to make an aspherical lens practical, although the process has been greatly refined by manufacturers such as Canon.

A second way to correct for spherical aberrations and perhaps the most straight-forward is with an optical aperture that just prevents the outer regions of the lens thru. Of course the main drawback with this approach is that less light is throughput.

A final way to solve the spherical aberration problem is with lens splitting. The use of multiple lenses reduces the distortion that would be caused from one spherical lens. Along with using multiple lens, the lenses can have bends that also correct for transverse abberations.

**4. Eye (20%)**

A myopic person (without astigmatism) has a far point of 200 cm and a near point of 20 cm.

(a) What correction should an optometrist prescribe to move the myopic far point out to infinity?

(b) With this correction, can the myopic person also read a book held at the normal near point, 25 cm from the eye?

Ans:

Part A:

%fp = 2 % far point in m

%np = .2 % near point in m

% For Far point

% do = inf

% Use lens equation

% 1/f = 1/do + 1/di;

% and subst. for do eq becomes

% 1/f = 1/di

% P = 1/f

% di is negative so for fp: di = -2

P = -1/2;

Part B:

% Now reshuffle lens eq

% 1/do = 1/f -1/di

% di is negative so for np: di = -.2

% 1/do = -.5 - 1/(-.2)

% 1/do = 4.5

do = .22;

% This means that with correction, the closest is .22m

% which is greater than .025, so No, a person could

% not read book at normal distance with correction,

% which from experience tells us that this is so.

**5. Microscope (20%)**

What is infinity-corrected microscope? Draw diagrams to show the differences between infinity-corrected system and traditional finite tube length microscope. Explain the advantage of infinity-corrected microscope?

Ans:

Here is a drawn diagram of a traditional finite tube length microscope:

Diagram

Description automatically generated with medium confidence

And, here is a drawn diagram of an infinity-corrected system.

A picture containing weapon, projectile

Description automatically generated

An infinity-corrected microscope has a tube that contains another lens between eyepiece lens and the objective lens to produce an intermediate range image inside of the tube.

The advantage of the infinity-corrected microscope is that other optical elements can be placed in the path of the light propagation, polarizers, filters, without refocusing the beam. This makes, for example, fluorescence microscopes which rely on other optical elements, possible with an infinity-correction configuration.