Answer all questions. Show your work. Partial credit will be given. As in class, \( z \) and \( z' \) refer to the object distances measured from the Principal Planes and the Gaussian imaging equation should be used in these cases. The values \( z_F \) and \( z'_R \) are the object and image distances measured from the front and rear focal points and the Newtonian imaging equation should be used in these cases.

1. For an object distance \( z = 150 \text{ mm} \), an object space index \( n = 1.5 \), and a front focal length \( f_F = -100 \text{ mm} \), what is the effective focal length \( f \) and the magnification \( m \)? Is the image upright or inverted?

*The effective focal length is given by \( f = -(-100) / 1.50 = 66.67 \text{ mm} \).*

*The magnification is given by \( m = (-100) / ((-100) - (150)) = 0.4 \).*

*The image is upright since the magnification is positive*

2. For an image distance \( z' = -75 \text{ mm} \), an image space index \( n' = 1.5 \), and a rear focal length \( f_R' = 75 \text{ mm} \), find the effective focal length \( f \) and the magnification \( m \)? The image is at what cardinal point?

*The effective focal length is given by \( f = (-75) / 1.50 = -50 \text{ mm} \).*

*The magnification is given by \( m = ((-75) - (-75)) / (-75) = 0.000 \).*

*The image is located at the rear focal point.*

3. Given the object distance \( z = -200 \text{ mm} \), an object space index \( n= 1.0 \), and a lens of effective focal length \( f = 60 \text{ mm} \), what is the front focal length \( f_F \) and the magnification \( m \)? Draw the system.

*The front focal length is given by \( f_F = -1.00(60) = -60 \text{ mm} \).*

*The magnification is given by \( m = (-60) / ((-60) - (-200)) = -0.429 \).*

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[Diagram showing the system with labeled distances and focal lengths.]
4. Given the image distance \( z'_F = 80 \text{ mm} \), an image space index \( n' = 1.0 \), and a lens of effective focal length \( f = 80 \text{ mm} \), what is the rear focal length \( f'_R \) and the magnification \( m \)? Draw the system.

The rear focal length is given by \( f'_R = 1.00(80) = 80 \text{ mm} \).

The magnification is given by \( m = -(80) / (1.00(80)) = -1.000 \).

5. For an object distance \( z_F = -150 \text{ mm} \), an object space index \( n = 1.33 \), and an effective focal length \( f = -70 \text{ mm} \), what is the front focal length \( f'_F \) and magnification \( m \)? Is the front focal point \( F \) to the left or right of the front principal point \( P \)?

The front focal length is given by \( f'_F = -(1.33)(-70) = 93.1 \text{ mm} \).

The magnification is given by \( m = (1.33)(-70) / (-150) = 0.621 \).

\( F \) is to the right of \( P \) since \( f'_F \) is positive.

6. Given the image distance \( z'_F = 80 \text{ mm} \), the front focal length \( f'_F = 20 \text{ mm} \) and the rear focal length \( f'_R = -30 \text{ mm} \), if we want to shift the image plane by \( \Delta z' = 5 \text{ mm} \), what shift in the object \( \Delta z \) is needed?

Given \( z'_{F_1} = z'_F = 80 \text{ mm} \) and \( z'_{F_2} = z'_F + \Delta z' = 85 \text{ mm} \), we can use \( m_1 = -\frac{z'_{F_1}}{f'_R} = 2.666 \) and

\( m_2 = -\frac{z'_{F_2}}{f'_R} = 2.83 \). Based on the longitudinal magnification \( \frac{\Delta z'}{\Delta z} = \left( \frac{f'_R}{f'_F} \right) m_1 m_2 \Rightarrow \Delta z = 0.443 \text{ mm} \).

7. The figure to the right shows two incident and emerging rays from a black box system. Draw the locations of the front and rear focal point, \( F \) and \( F' \), as well as the front and rear principal planes \( P \) and \( P' \).
The black rays define the rear principal plane and rear focal point of the system. Extend the emerging black ray backwards. Where this extended ray intersects the optical axis is the location of the rear focal point. Extend the incident black ray forward. The point where it appears to intersect the emerging ray defines the location of the rear principal plane. Similarly, the gray rays define the front principal plane and front focal point of the system. Extend the incident gray ray forwards. Where this extended ray intersects the optical axis is the location of the front focal point. Extend the emerging gray ray backwards. The point where it appears to intersect the incident ray defines the location of the front principal plane.

8. The figure to the right shows a ray incident onto a black box system, and three possible emerging rays. Which emerging ray (1, 2 or 3) corresponds to the incident ray? Where is the rear principal plane?

Since the object and image space indices are the same, the nodal points are located at their respective principal planes. The incident ray is passing through the front nodal point, so it must emerge from the system at the same angle. Ray 3 satisfies this requirement. Also, since the incident ray has a height of zero at the front principal plane, it must be mapped to a height of zero at the rear principal plane. Therefore, the rear principal plane is located where Ray 3 crosses the optical axis.