Conventions for applying thin lens formula

Ray diagrams should be drawn with rays travelling from left to right.

The normal situation is for an object to the left of the lens to produce an image to the right of the lens.

Object $\Rightarrow$ Lens $\Rightarrow$ Image

Then:

- Object distance, d_o, is positive for an object to the left of the lens (*real object*), negative otherwise (*virtual object*, multi-lens systems)
- Image distance, d_i, is positive for an image to the right of the lens (*real image*), negative otherwise (*virtual image*)
- Converging (positive) lenses have positive focal length, $f > 0$
- Diverging (negative) lenses have negative focal length, $f < 0$

Ex8

Example: A 1.7 m tall person stands 2.5 m in front of a camera. The focal length of the lens is 0.05 m.

a) Find the image distance

b) Find the magnification and the height of the image on the film.

Thin Lens

Thin lens equation: $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$

Linear magnification: $m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

d_o = object distance

d_i = image distance

h_o = height of object

h_i = height of image

f = focal length of lens

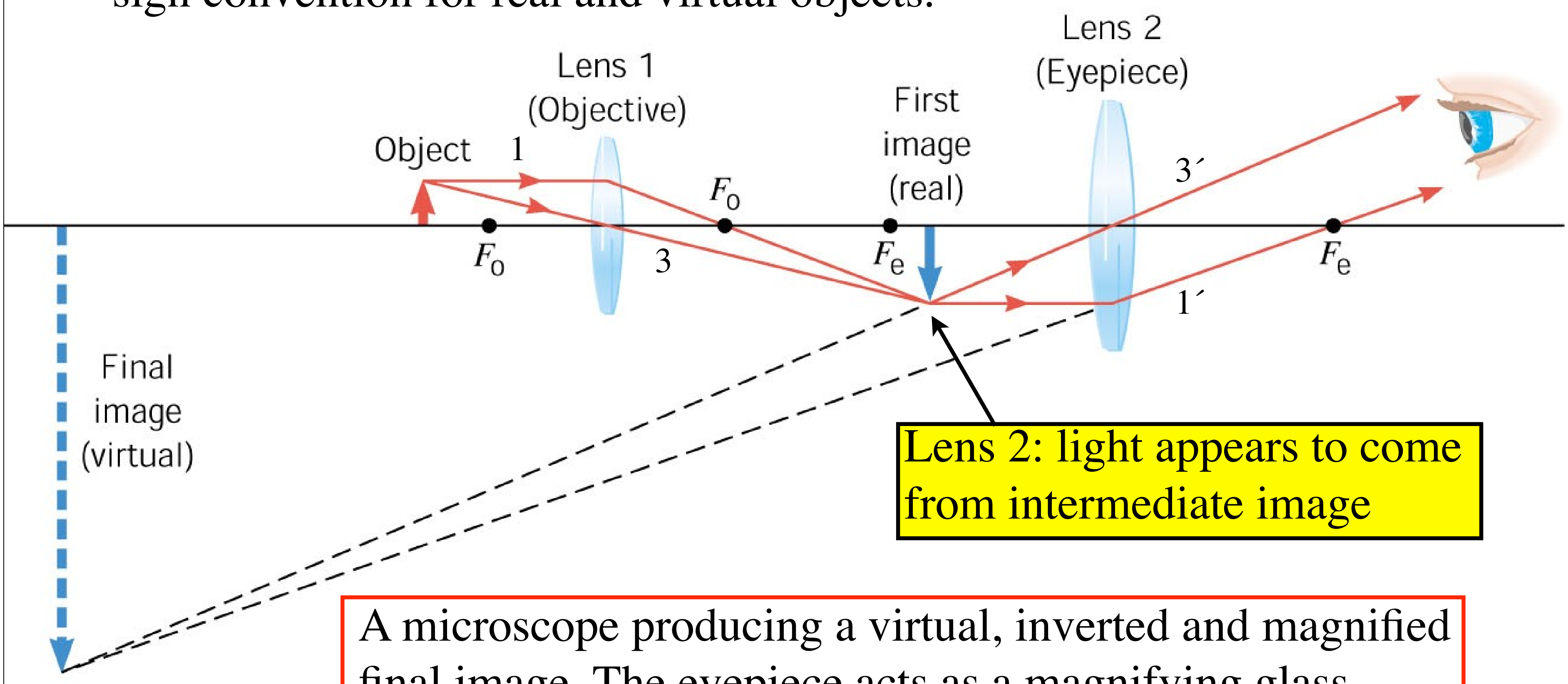
Prob. 26.50: A slide projector has a converging lens of focal length 105 mm.

a) How far from the lens must the screen be if a slide is placed 108 mm from the lens?

b) If the slide measures 24 mm x 36 mm, what are the dimensions of its image?

Combinations of lenses

- Find the location of the image formed by the first lens as if the second lens did not exist.
- Use that image as an object (source of light) for the second lens using the sign convention for real and virtual objects.



A microscope producing a virtual, inverted and magnified final image. The eyepiece acts as a magnifying glass.

Ex 10, a microscope

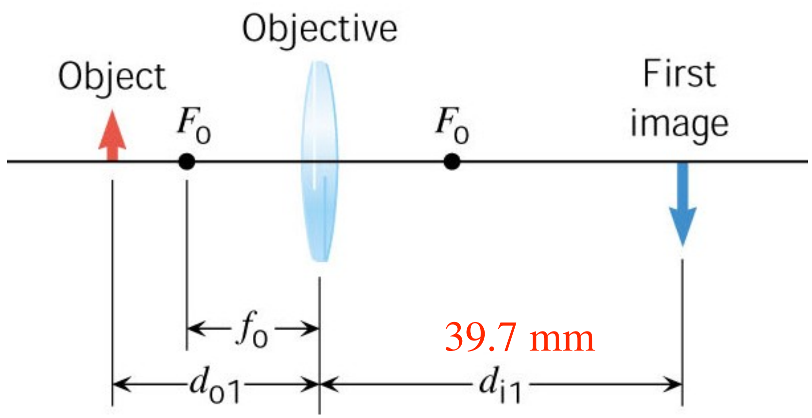
Objective: f_o = 15 mm

Object at d_{o1} = 24.1 mm

Image at d_{i1} = ?

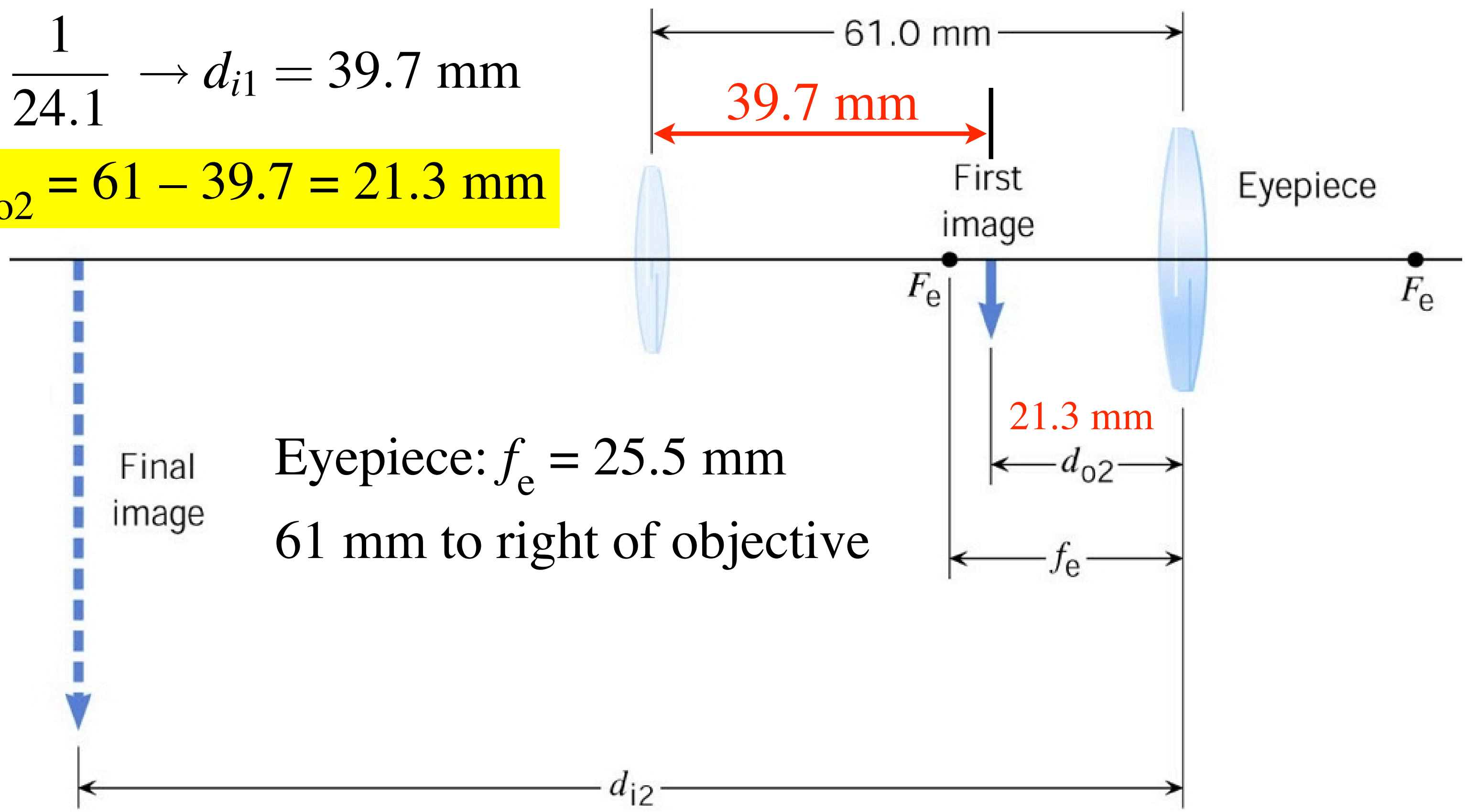
$$\frac{1}{d_{o1}} + \frac{1}{d_{i1}} = \frac{1}{f_o}$$

$$\frac{1}{d_{i1}} = \frac{1}{15} - \frac{1}{24.1} \rightarrow d_{i1} = 39.7 \text{ mm}$$



For lens 2: d_{o2} = 61 – 39.7 = 21.3 mm

Eyepiece:



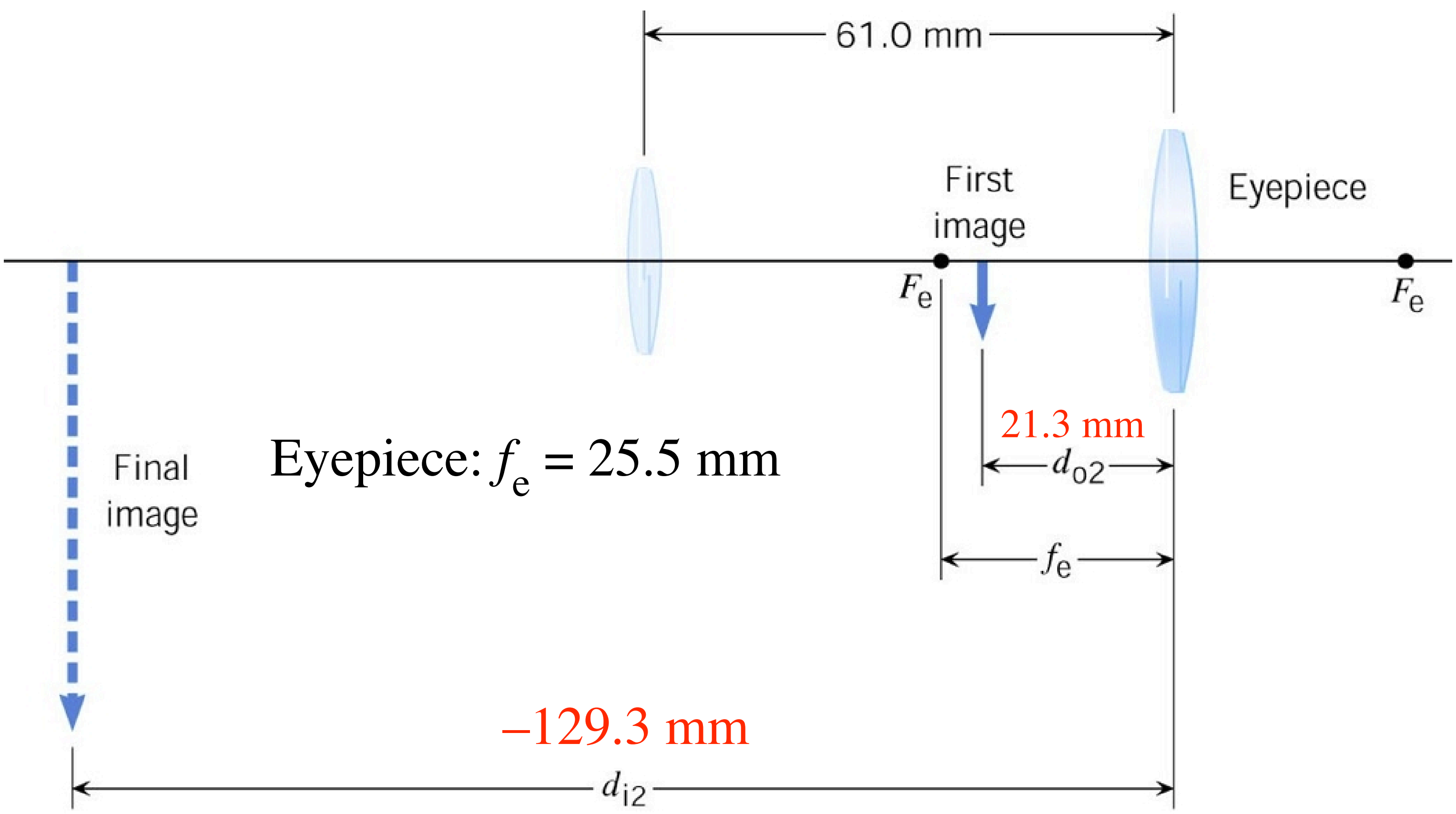
Eyepiece: f_e = 25.5 mm

61 mm to right of objective

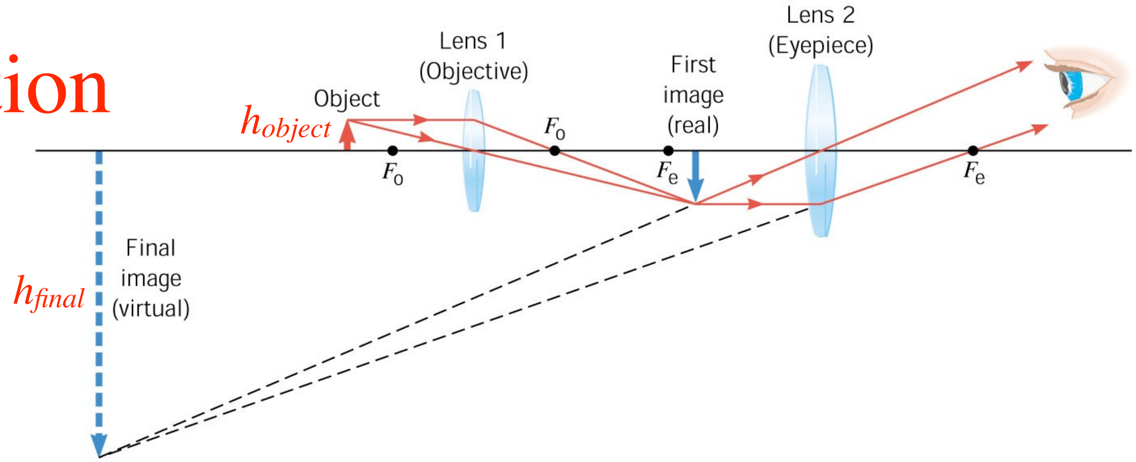
Eyepiece: $d_{o2} = 21.3$ mm, $f_e = 25.5$ mm

$$\frac{1}{d_{o2}} + \frac{1}{d_{i2}} = \frac{1}{f_e} \qquad \frac{1}{d_{i2}} = \frac{1}{25.5} - \frac{1}{21.3} \rightarrow d_{i2} = -129.3 \text{ mm}$$

The final image distance is negative, so the final image is virtual



Linear Magnification



$m = h_{final}/h_{object}$

Two steps:

1) m_1 = magnification of first image relative to object, $m_1 = -d_{i1}/d_{o1}$

2) m_2 = magnification of final image relative to first image, $m_2 = -d_{i2}/d_{o2}$

The overall magnification is $m = m_1 \times m_2$

$$m_1 = -\frac{d_{i1}}{d_{o1}} = -\frac{39.7}{24.1} = -1.647 \qquad \text{lens 1}$$

$$m_2 = -\frac{d_{i2}}{d_{o2}} = -\frac{-129.3}{21.3} = 6.056 \qquad \text{lens 2}$$

$$m = m_1 \times m_2 = -1.647 \times 6.056 = -9.977 \qquad \text{overall}$$

$m < 0$, so the final image is inverted.

Next Week

March 8, 9, 10

Lab: Total Internal Reflection and Geometrical Optics

Final Exam

Thursday, April 21, 6 – 9 pm

Frank Kennedy Brown Gym

The whole course, 30 questions, formula sheet provided

Marks on the Web

Check your marks and inform your TA or Dr. Kunkel of errors

Term test marks should be up ~mid-week

Thin Lens

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Linear magnification: $m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

d_o = object distance

d_i = image distance

h_o = height of object

h_i = height of image

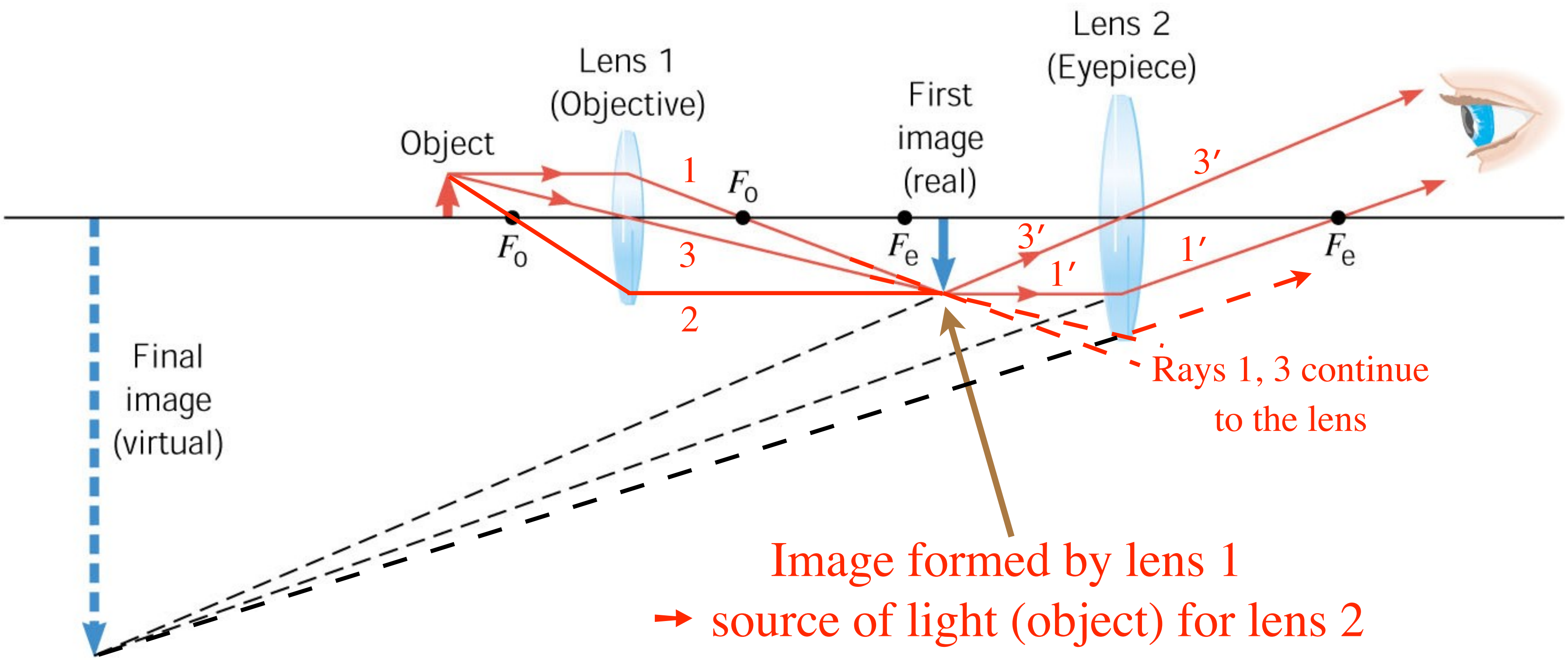
f = focal length of lens

Two Lenses

Overall linear magnification, $m = m_1 m_2$

Combination of Lenses

Consider the lenses separately: the first lens generates an image that is viewed by the second lens.



Prob. 26.60: Two identical diverging lenses are separated by 16 cm. The focal length of each lens is –8 cm. An object is located 4 cm to the left of the lens that is on the left. Determine the final image distance relative to the lens on the right.

Prob. 26.63: A converging lens (f_1 = 24 cm) is located 56 cm to the left of a diverging lens (f_2 = –28 cm). An object is placed to the left of the converging lens, and the final image produced by the two lens combination lies 20.7 cm to the left of the diverging lens.

How far is the object from the converging lens?

Prob. 26.64: A coin is located 20 cm to the left of a converging lens (f = 16 cm). A second, identical, lens is placed to the right of the first lens, such that the image formed by the combination has the same size and orientation as the original coin. Find the separation between the lenses.