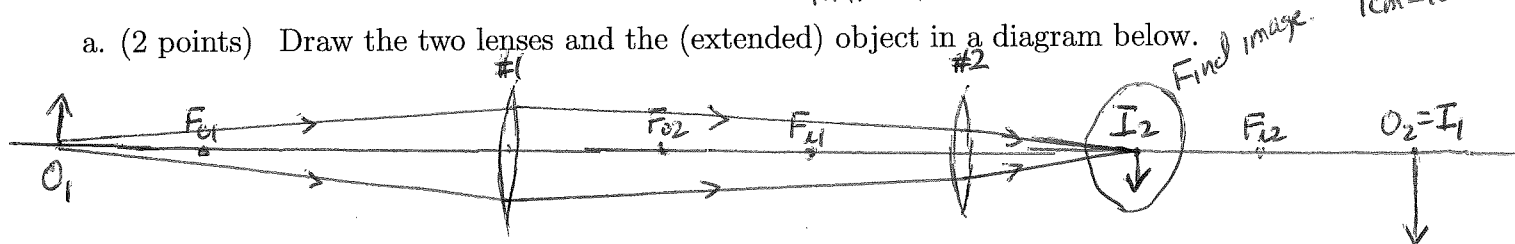


1. (14 points) Two thin lenses, each with a focal length of $+40$ cm, are lined up with a common axis 60 cm apart. An object is placed 60 cm ^{in front of} behind the first lens.

a. (2 points) Draw the two lenses and the (extended) object in a diagram below.



b. (8 points) Calculate the locations of the image from the first lens and the final image from the second lens, along with the final magnification. Draw the two images as extended objects in your diagram above.

$$\begin{aligned}
 f_1 &= f_2 = 40 \text{ cm} \\
 p_1 &= +60 \text{ cm} \\
 \frac{1}{p_1} + \frac{1}{q_1} &= \frac{1}{f_1} \\
 \Rightarrow q_1 &= \left(\frac{1}{f_1} - \frac{1}{p_1} \right)^{-1} = \left(\frac{1}{40} - \frac{1}{60} \right)^{-1} = +120 \text{ cm} \\
 p_2 &= 60 \text{ cm} - q_1 = -60 \text{ cm} \\
 q_2 &= \left(\frac{1}{f_2} - \frac{1}{p_2} \right)^{-1} = \left(\frac{1}{40} - \frac{1}{-60} \right)^{-1} = +24 \text{ cm} \\
 m_1 &= -\frac{q_1}{p_1} = -\frac{120}{60} = -2.0 \\
 m_2 &= -\frac{q_2}{p_2} = -\frac{24}{-60} = +0.4 \\
 m_{\text{tot}} &= m_1 m_2 = -0.8
 \end{aligned}$$

c. (4 points) Keeping the object and first lens in place, where would you need to move the second lens if you wanted the overall magnification to be equal to $+8.0$?

$$\begin{aligned}
 q_1 &= +120 \text{ cm} \\
 m_1 &= -2.0
 \end{aligned}
 \left. \begin{array}{l} \\ \end{array} \right\} \text{regardless of where lens \#2 is located.}$$

$$p_2 = d_{12} - q_1 = \text{adjustably based on } d_{12}$$

$$\frac{1}{p_2} + \frac{1}{q_2} = \frac{1}{f_2}$$

$$m_2 = -\frac{q_2}{p_2}$$

$$m_1 m_2 = +8.0 \Rightarrow m_2 = -4.0$$

$$q_2 = -m_2 p_2$$

$$\frac{1}{p_2} - \frac{1}{m_2 p_2} = \frac{1}{f_2}$$

$$\left(1 - \frac{1}{m_2} \right) \frac{1}{p_2} = \frac{1}{f_2}$$

$$\Rightarrow p_2 = \left(1 - \frac{1}{m_2} \right) f_2 = \left(1 - \frac{1}{-4.0} \right) (40 \text{ cm}) = +50 \text{ cm} \Rightarrow \boxed{d_{12} = 170 \text{ cm}}$$

