26-53

$f = 105.00\,mm$

$o = 108.00\,mm$

$i = ?$

$h_o = 24.0\,mm$

$w_o = 36.0\,mm$

$h_i = ?$ $w_i = ?$

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i} \Rightarrow \frac{1}{i} = \frac{1}{f} - \frac{1}{o}$$

$$\frac{1}{i} = \frac{1}{105.00mm} - \frac{1}{108.00mm}$$

$$= 9.524 \times 10^{-3}\,mm^{-1} - 9.259 \times 10^{-3}\,mm^{-1}$$

$$\frac{1}{i} = 2.65 \times 10^{-4}\,mm^{-1}$$

$$i = \frac{1}{2.65 \times 10^{-4}\,mm^{-1}} = 3.774 \times 10^{3}\,mm$$

$$\boxed{i = 3.77\,m}$$

$$M = \frac{h_i}{h_o} = \left(\frac{-i}{o}\right) \qquad h_i = h_o\left(\frac{-i}{o}\right)$$

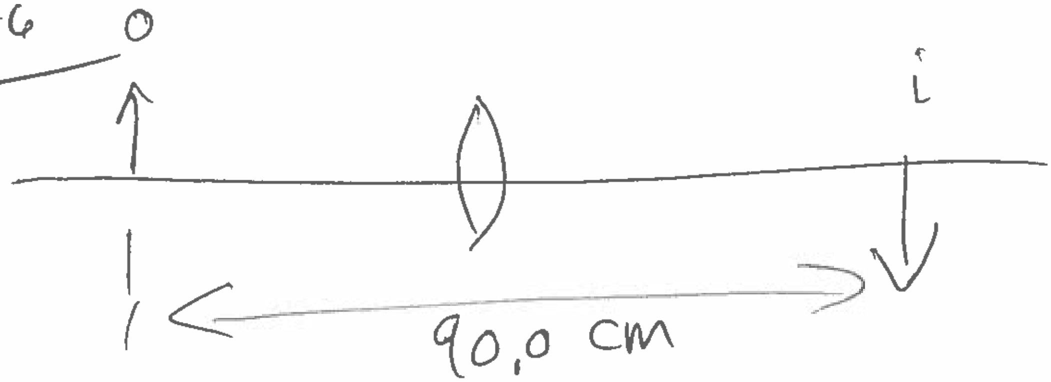
$$h_i = 24.0\,\cancel{mm}\left(\frac{-3.77\,m}{108.0\,\cancel{mm}}\right) = -0.838\,m$$

$$\underline{h_i = 838\,mm} \quad \text{inverted}$$

$$W_i = (36.0\,\cancel{mm})\left(\frac{-3.77\,m}{108.0\,\cancel{mm}}\right) = -1.260\,m$$

$$\underline{W_i = 1{,}260\,mm \quad \text{inverted}}\ (\text{reversed left-right}$$

26-56



$o = ?$

$f = ?$

$h_i = -\frac{1}{2} h_o$

$\frac{h_i}{h_o} = -\frac{1}{2} = -\frac{i}{o}$

$-i = -\frac{1}{2} o$

$i = \frac{1}{2} o$

$i + o = 90.0 \text{ cm}$

$\frac{1}{2} o + o = 90.0 \text{ cm}$

$\frac{3}{2} o = 90.0 \text{ cm}$

$o = \frac{2}{3} (90.0 \text{ cm}) = 60.0 \text{ cm}$

$\boxed{o = 60.0 \text{ cm}}$

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i} = \frac{1}{o} + \frac{1}{\frac{1}{2}o}$$

$$\frac{1}{f} = \frac{1}{o} + \frac{2}{o} = \frac{3}{o}$$

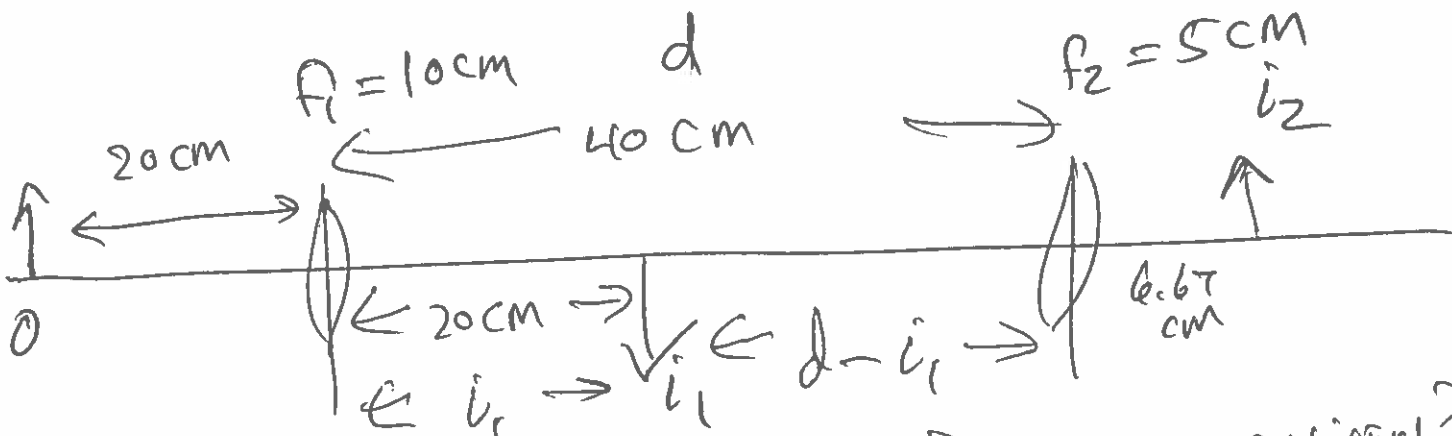
$$f = \frac{o}{3} = \frac{60.0\,\mathrm{cm}}{3} = \boxed{20.0\,\mathrm{cm}}$$

Law of Superposition

When more Then 1 force acts on an object The Net effect is The sum of The forces.

Multiple lens / Multiple optical elements

We find The effect of The first lens and its image becomes object for The next element. And so on.



Where is final image? Real or Virtual?
Larger or smaller?

$$\frac{1}{i_1} = \frac{1}{f_1} - \frac{1}{o_1} = \frac{1}{10cm} - \frac{1}{20cm} = \frac{2-1}{20cm}$$

$$\frac{1}{i_1} = \frac{1}{20cm} \Rightarrow \boxed{i_1 = 20cm}$$

$$O_2 = d - i_1 = 40cm - 20cm$$

$$O_2 = 20 cm$$

$$\frac{1}{i_2} = \frac{1}{f_2} - \frac{1}{O_2} = \frac{1}{5cm} - \frac{1}{20cm}$$

$$\frac{1}{i_2} = \frac{4-1}{20cm} = \frac{3}{20cm}$$

$$i_2 = \frac{20}{3} cm = 6.67 cm$$

final image is located 6.67cm to right of lens 2. It is upright! It is real!

$$h_{i_1} = h_o\left(\frac{-i_1}{O_1}\right) = h_o\left(\frac{-20cm}{20cm}\right) = -h_{o_1}$$

$$h_{i_2} = h_{o_2}\left(\frac{-i_2}{O_2}\right) = -h_{o_1}\left(\frac{-6.67cm}{20 cm}\right) \quad \frac{20}{3}$$

$$h_{i_2} = +h_o\left(\frac{1}{3}\right) \Rightarrow \frac{1}{3} \text{ as large so smaller}$$

Multiple optical elements

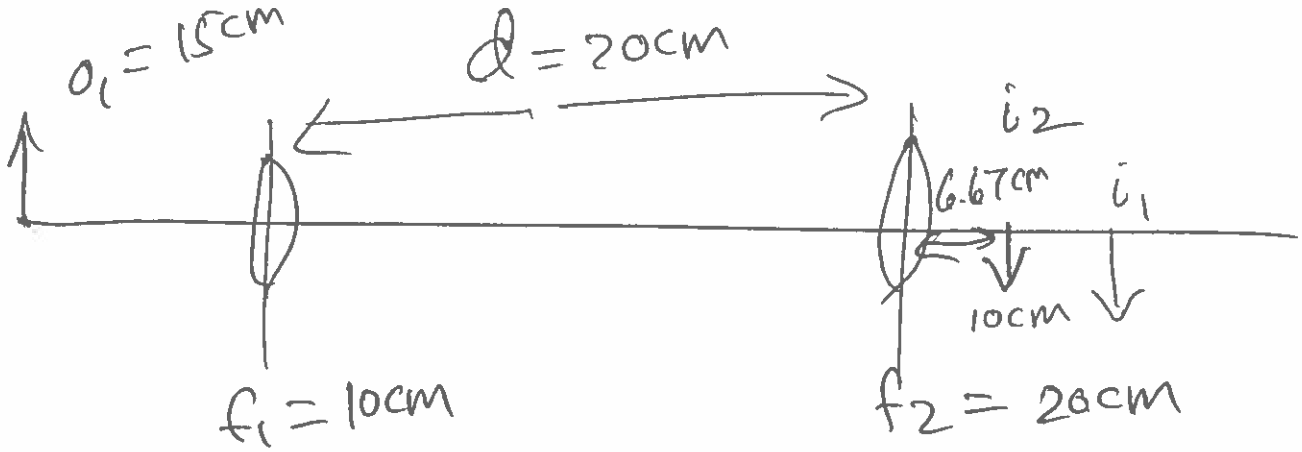
$$M_T = M_1 M_2 \cdots M_n$$

$$h_{i_2} = h_o (M_1)(M_2)$$

$$= h_o (-1)\left(-\frac{1}{3}\right) = \frac{1}{3} h_o$$

$$M_1 = \frac{h_{i_1}}{h_{o_1}} = \left(-\frac{i_1}{o_1}\right)$$

$$M_2 = \frac{h_{i_2}}{h_{o_2}} = \left(-\frac{i_2}{o_2}\right)$$



$$\frac{1}{i_1} = \frac{1}{f_1} - \frac{1}{o_1} = \frac{1}{10\text{cm}} - \frac{1}{15\text{cm}} = \frac{3-2}{30\text{cm}}$$

$$i_1 = 30\text{cm} \qquad M_1 = -\frac{30\text{cm}}{15\text{cm}} = -2$$

$$o_2 = d - i_1 = 20\text{cm} - 30\text{cm}$$

$$o_2 = -10\text{cm} \Rightarrow \text{Virtual object}$$

$$\frac{1}{i_2} = \frac{1}{f_2} - \frac{1}{o_2} = \frac{1}{20\text{cm}} - \frac{1}{-10\text{cm}}$$

$$\frac{1}{i_2} = \frac{1}{20\text{cm}} + \frac{2}{20\text{cm}} = \frac{3}{20\text{cm}}$$

$$i_2 = + \frac{20}{3}\text{cm} = 6.67\text{cm}$$

Final image is real!

Final image is inverted!

it is located 6.67 cm to right of 2nd lens,

$$M_1 = -\cancel{\frac{4}{3}} \; -2$$

$$M_2 = \frac{-\left(\cancel{\frac{-3}{20\,cm}}\right)^{\frac{20}{3}} i_2}{(-10\,cm)\; o_2} = \cancel{-200} \;\frac{20}{3}$$

$$M_2 = \cancel{\frac{2}{200}} \;\frac{2}{3} \Rightarrow \text{No inversion}$$

$$M_T = \left(-\cancel{\frac{4}{3}}^{-2}\right)\left(\frac{2}{3}\right) = -\frac{\cancel{8}^{\,4}}{\cancel{9}\,3} \Rightarrow \text{inverted and Larger } \cancel{\text{smaller}} \; \cancel{\text{(slightly)}}$$