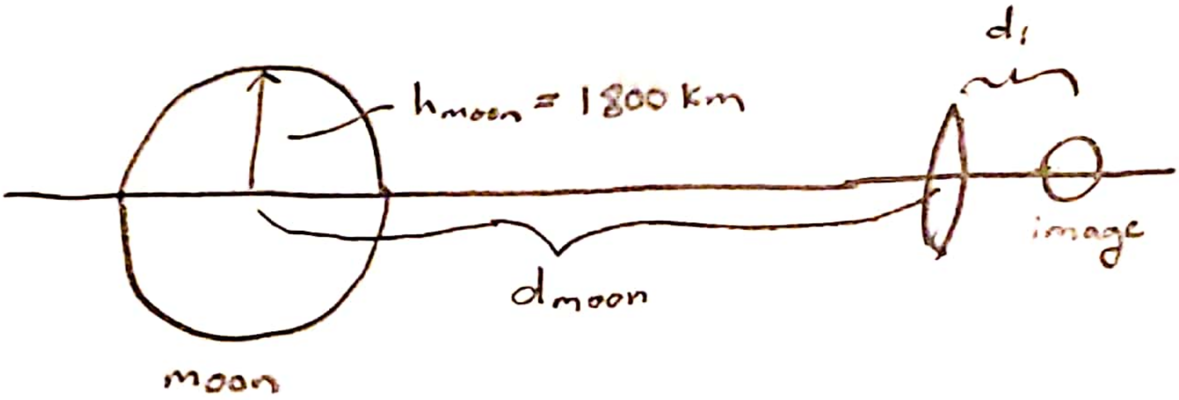
Sol'ns to selected probs (including all optics probs)

3.



$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_{moon}}$$

$$d_i = \frac{1}{\frac{1}{f} - \frac{1}{d_{moon}}} = \frac{1}{\frac{1}{.05\,m} - \frac{1}{3.84\cdot 10^{5}\,m}} = .05\,m$$

$$h_i = -\frac{d_i}{d_{moon}} h_{moon}$$

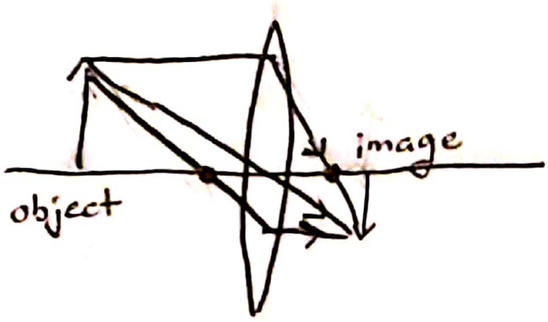
$$= -\frac{.05\,m}{3.84\cdot 10^{8}\,m} \cdot 1.8\cdot 10^{6}\,m = -.000234\,m$$

$$\text{diameter} = 2|h_i| = 2\cdot .000234\,m$$

$$= .000468\,m$$

$$\approx \boxed{.5\,mm}$$

4.

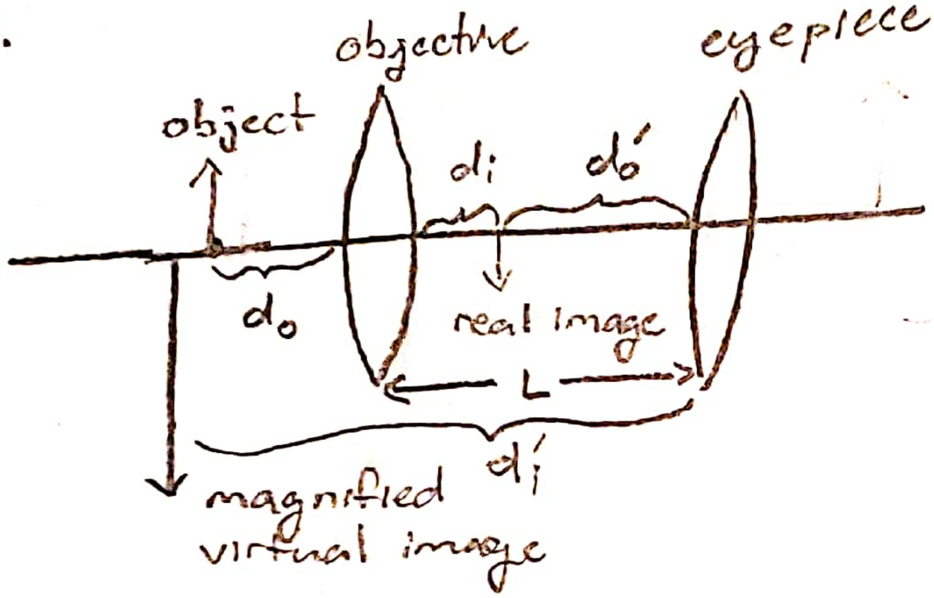


$$h_i = -\frac{1}{2} h_o \Rightarrow -\frac{1}{2} = M = -\frac{d_i}{d_o} \Rightarrow d_o = 2d_i$$

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{d_i} + \frac{1}{2d_i} = \frac{3}{2d_i}$$

$$f = \frac{2d_i}{3} = \frac{2(50\text{ cm})}{3} = \boxed{33\text{ cm}}$$

5.



"focused" = image forms <u>somewhere</u>

$\Rightarrow d_i' = \infty$

Find d_i:

$$\frac{1}{f_o} = \frac{1}{d_o} + \frac{1}{d_i} \Rightarrow d_i = \frac{1}{\frac{1}{f_o} - \frac{1}{d_o}}$$

$$= \frac{1}{\frac{1}{10\text{cm}} - \frac{1}{16.67\text{cm}}}$$

$$= 25\text{ cm}$$

Set up Lens equation for eyepiece:

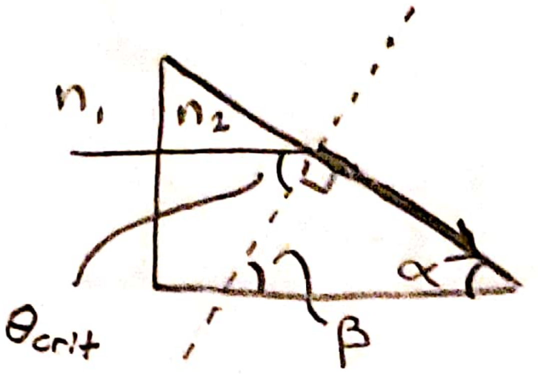
$$\frac{1}{f_e} = \frac{1}{d_o'} + \frac{1}{d_i'} = \frac{1}{L - d_i} + \text{"}\cancel{\frac{1}{\infty}}\text{"}^{0}$$

$$\Rightarrow f_e = L - d_i \Rightarrow L = f_e + d_i$$

$$= 20\text{cm} + 25\text{ cm}$$

$$= \boxed{45\text{ cm}}$$

7. The maximum angle α will occur when the light hits the interface at the critical angle:



From geometry, we know that $\beta = \theta_{crit}$. Since the angles of a triangle add up to 180°, we have

$$\alpha = 180° - 90° - \theta_{crit} = 90° - \theta_{crit}.$$

What is θ_{crit}? By Snell's Law

$$n_2 \sin \theta_{crit} = n_1 \sin 90° = n_1$$

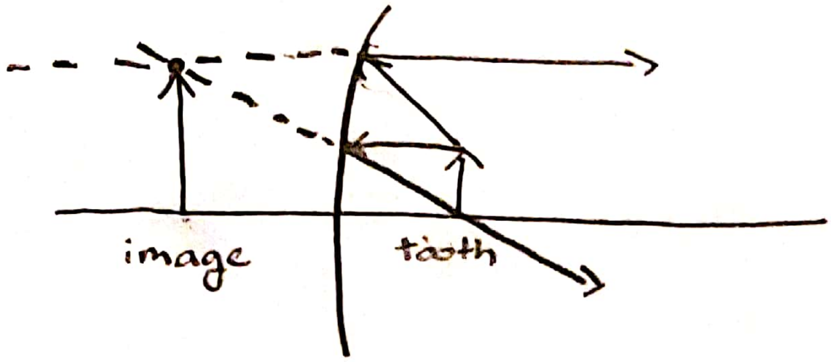
$$\Rightarrow \theta_{crit} = \arcsin\left(\frac{n_1}{n_2}\right)$$

$$= \arcsin\left(\frac{1.333}{1.65}\right) = 53.9°$$

Therefore,

$$\alpha = 90° - \theta_{crit} = 90° - 53.9° = \boxed{36.1°}$$

8.



this makes sense b/c virtual image is "behind" mirror

$$h_i = 3h_o \Rightarrow 3 = M = -\frac{d_i}{d_o} \Rightarrow d_i = -3d_o$$

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} = -\frac{1}{3d_o} + \frac{1}{d_o}$$

$$= -\frac{1}{3d_o} + \frac{3}{3d_o}$$

$$= \frac{2}{3d_o}$$

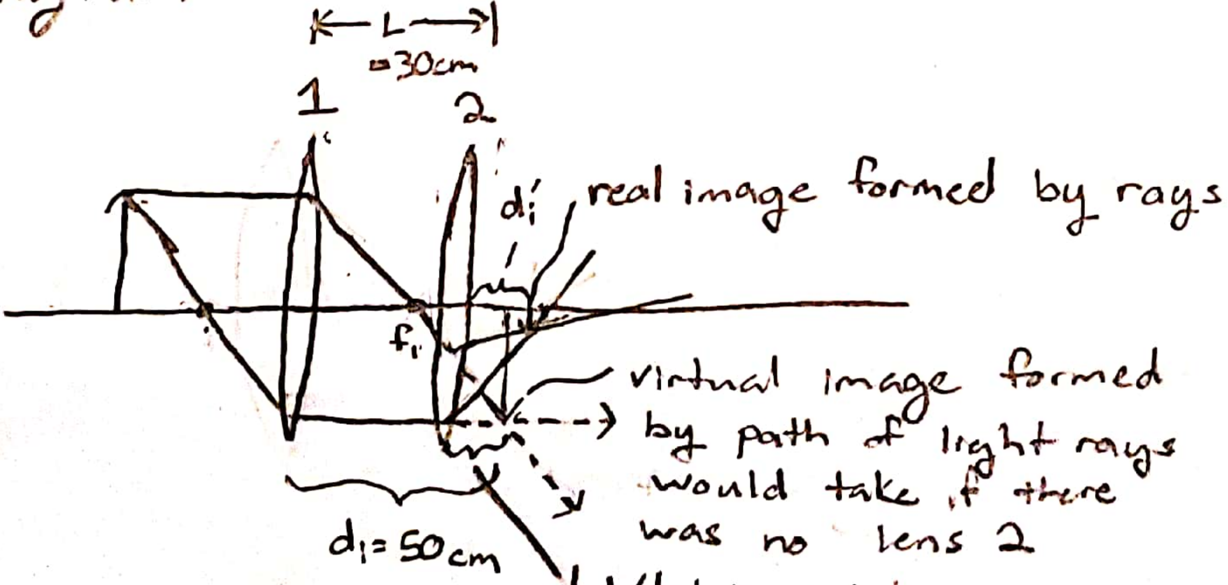
$$\Rightarrow f = \frac{3d_o}{2} = \frac{3(1.5\text{ cm})}{2} = \boxed{2.25\text{ cm}}$$

9. Apply Lens equation to first lens

$$\frac{1}{f_1} = \frac{1}{d_o} + \frac{1}{d_i} \Rightarrow d_1 = \frac{1}{\frac{1}{f_1} - \frac{1}{d_o}}$$

$$= \frac{1}{\frac{1}{25cm} - \frac{1}{50cm}} = 50cm$$

Since $d_i = 50cm$ is greater than the separation $L = 30$ cm between the lenses, we have the following ray diagram



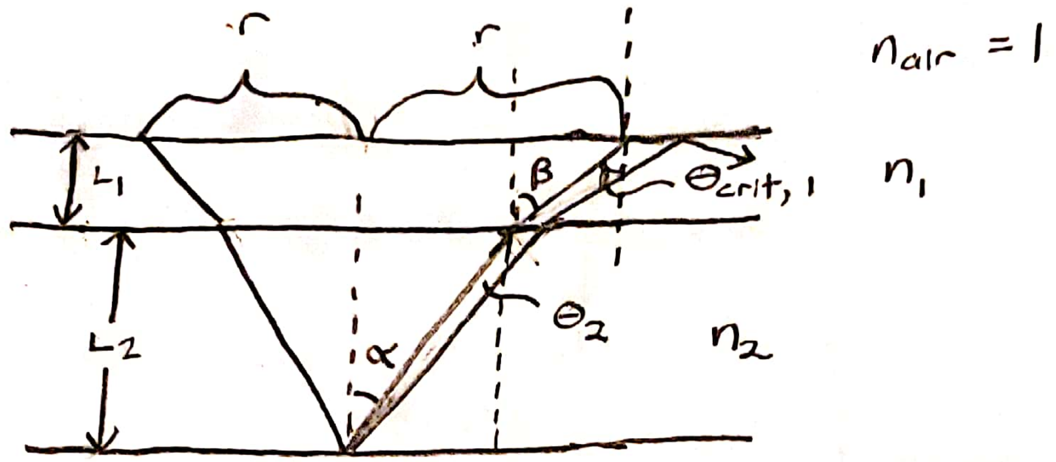
$$|d_o'| = |d_i - L| = 50\text{ cm} - 30\text{cm}$$
$$= 20\text{ cm}$$

Apply Lens equation to lens 2 using position of the virtual image and resultant. Remember, $\underline{d_o' = -20\text{ cm}}$ b/c it is a virtual image.

$$\frac{1}{f_2} = \frac{1}{d_o'} + \frac{1}{d_i'} \Rightarrow d_i' = \frac{1}{\frac{1}{f} - \frac{1}{d_o'}} = \frac{1}{\frac{1}{20cm} - \frac{1}{-20cm}}$$

$$= \boxed{10\text{ cm}}$$

10.



All of the light rays in layer 1 approaching the interface with the air outside the critreal angle for layer 1 will be reflected and will not be part of the circle. So, the radius of the image is determined by α and β, which are equal to $\theta_{crit,1}$ and θ_2. We use Snell's law to find these:

$$n_1 \sin\theta_{crit,1} = n_{air} \sin 90° = 1$$

$$\Rightarrow \theta_{crit,1} = \sin^{-1}\left(\frac{1}{n_1}\right) = 41.14°$$

$$n_2 \sin\theta_2 = n_1 \sin\theta_{crit,1} = 1$$

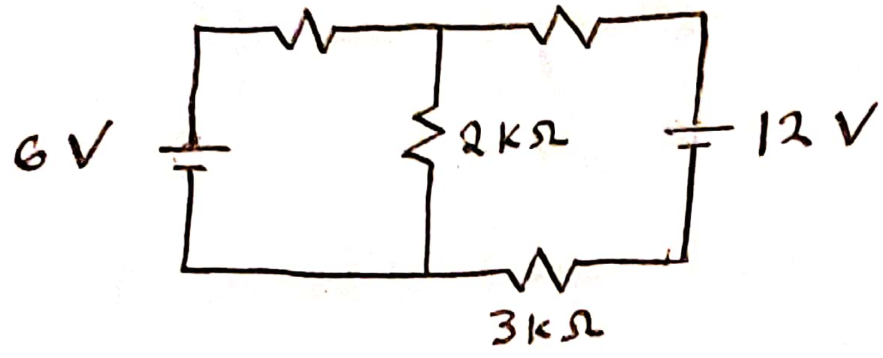
$$\Rightarrow \theta_2 = \sin^{-1}\left(\frac{1}{n_2}\right) = 37.8°$$

$$r = L_1 \tan\beta + L_2 \tan\alpha = L_1 \tan\theta_{crit,1} + L_2 \tan\theta_2$$

$$= (.2\text{ cm}) \tan 41.14° + (3\text{ cm}) \tan 37.8°$$

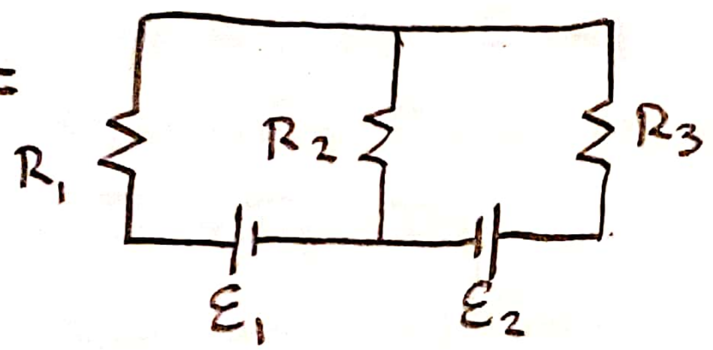
$$= \boxed{2.50\text{ cm}}$$

11.



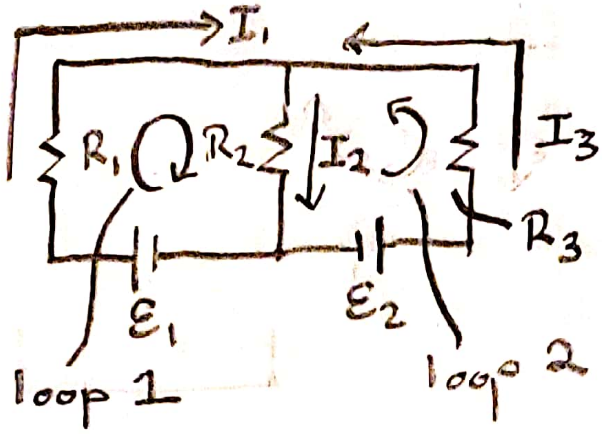
same thing

=



$\mathcal{E}_1 = 6V$, $\mathcal{E}_2 = 12\ V$,
$R_1 = 6\ k\Omega$, $R_2 = 2k\Omega$, $R_3 = 6\ k\Omega$

b/c the 2 3 kΩ resistors are in series



Kirchhoff's Loop Rule:

loop 1: $\mathcal{E}_1 - I_1R_1 - I_2R_2 = 0$ (1)

loop 2: $\mathcal{E}_2 - I_2R_2 - I_3R_3 = 0$ (2)

Kirchhoff's Junction Rule:

$I_1 + I_3 = I_2$ (3)

Subtract (2) from (1) and solve for I_3:

$$\mathcal{E}_1 - \mathcal{E}_2 - I_1R_1 + I_3R_3 = 0$$

$$\Rightarrow I_3 = \frac{\mathcal{E}_2 - \mathcal{E}_1 + I_1R_1}{R_3} \qquad (4)$$

From (3), we get $I_2 = I_3 + I_1$. Plug into (2) and solve for I_3:

$$\mathcal{E}_2 - I_3R_2 - I_1R_2 - I_3R_3 = 0$$

$$\mathcal{E}_2 - I_3(R_2 + R_3) - I_1R_2 = 0$$

$$\Rightarrow I_3 = \frac{\mathcal{E}_2 - I_1R_2}{R_2 + R_3} \qquad (5)$$

Equate (4) and (5) and cross multiply:

$$\frac{\mathcal{E}_2 - \mathcal{E}_1 + I_1 R_1}{R_3} = \frac{\mathcal{E}_2 - I_1 R_2}{R_2 + R_3}$$

$$\Rightarrow (\mathcal{E}_2 - \mathcal{E}_1 + I_1 R_1)(R_2 + R_3) = R_3(\mathcal{E}_2 - I_1 R_2)$$

Solve for I_1:

$$(\mathcal{E}_2 - \mathcal{E}_1)(R_2 + R_3) + I_1 R_1 R_2 + I_1 R_3 R_1$$
$$= R_3 \mathcal{E}_2 - I_1 R_2 R_3$$

$$-(\mathcal{E}_2 - \mathcal{E}_1)(R_2 + R_3) + \mathcal{E}_2 R_3$$
$$= I_1 (R_1 R_2 + R_1 R_3 + R_2 R_3)$$

$$\Rightarrow I_1 = \frac{(\mathcal{E}_1 - \mathcal{E}_2)(R_2 + R_3) + \mathcal{E}_2 R_3}{R_1 R_2 + R_2 R_3 + R_1 R_3}$$

$$= \frac{(6\,V - 12\,V)(2\,k\Omega + 6\,k\Omega) + (12\,V)(6\,k\Omega)}{(6\,k\Omega)(2\,k\Omega) + (2\,k\Omega)(6\,k\Omega) + (6\,k\Omega)(6\,k\Omega)}$$

$$= \boxed{.4\,mA}$$

12. Why (A) is not possible:

real $\Rightarrow d_i > 0$

$\Rightarrow m = -\frac{d_i}{d_o} < 0$ b/c $d_o > 0$

$\Rightarrow$ inverted and never erect

Why (E) is not possible:

virtual $\Rightarrow d_i < 0$

$\Rightarrow m = -\frac{d_i}{d_o} > 0$ b/c $d_o > 0$

$\Rightarrow$ erect and never inverted

Why (B) is possible:

Suppose $d_o > 2f$:

$d_o > 2f \Rightarrow 0 < \frac{1}{d_o} < \frac{1}{2f}$

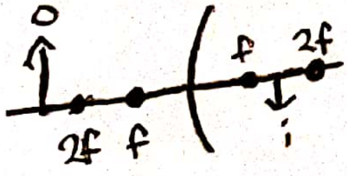
$$\Rightarrow \frac{1}{f} = \frac{1}{f} - 0 > \underbrace{\frac{1}{f} - \frac{1}{d_o}}_{\frac{1}{d_i}} > \frac{1}{f} - \frac{1}{2f} = \frac{1}{2f}$$

$\Rightarrow f < d_i < 2f$, so <u>real</u> b/c $d_i > 0$

$\Rightarrow m = -\frac{d_i}{d_o} < 0$; so <u>inverted</u>

$|m| = \frac{d_i}{d_o} < 1$ (b/c $d_i < 2f = d_o$),

so <u>reduced</u>



why (D) is possible:

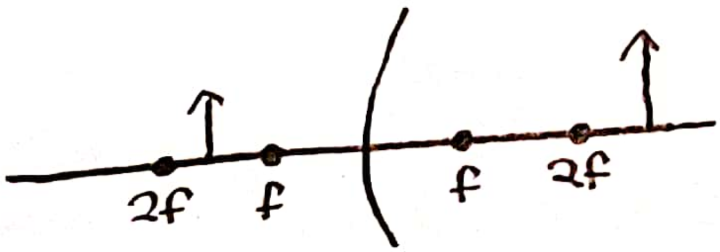
$$f < d_o < 2f \Rightarrow \frac{1}{f} > \frac{1}{d_o} > \frac{1}{2f}$$

$$\Rightarrow 0 = \frac{1}{f} - \frac{1}{f} < \underbrace{\frac{1}{f} - \frac{1}{d_o}}_{\frac{1}{d_i}} < \frac{1}{f} - \frac{1}{2f} = \frac{1}{2f}$$

$$\Rightarrow \frac{1}{d_i} < \frac{1}{2f} \Rightarrow \underline{d_i > 2f}$$

$\Rightarrow m = -\frac{d_i}{d_o} < 0$, so <u>inverted</u>

$|m| = \frac{d_i}{d_o} > 1$ (b/c $d_i > d_o$), so <u>enlarged</u>



why (c) is possible:

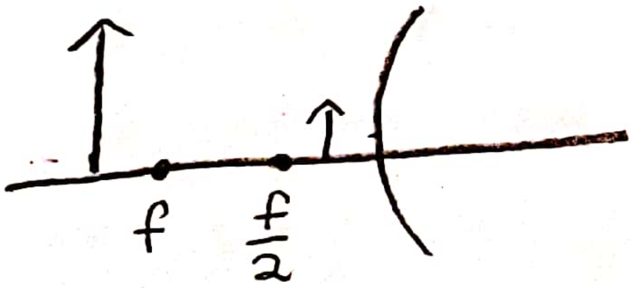
$$d_o < \frac{f}{2} \Rightarrow \frac{1}{d_o} > \frac{2}{f}$$

$$\Rightarrow \underbrace{\frac{1}{f} - \frac{1}{d_o}}_{\frac{1}{d_i}} < \frac{1}{f} - \frac{2}{f} = -\frac{1}{f}$$

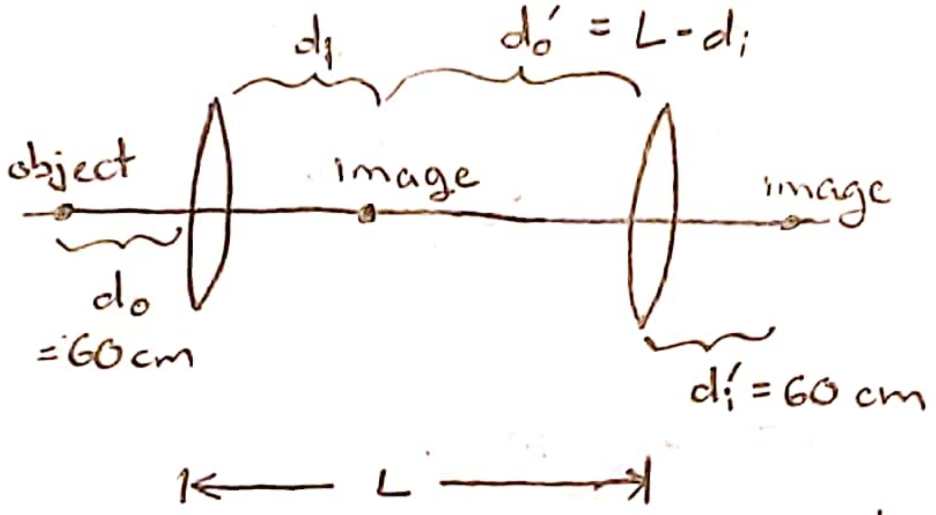
$\Rightarrow d_i < -f$, so <u>virtual</u>

$\Rightarrow m = -\frac{d_i}{d_o} > 0$, so <u>erect</u>

$\Rightarrow |m| = \frac{|d_i|}{|d_o|} > \frac{f}{f/2} = 2$, so <u>enlarged</u>



13.



$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} \Rightarrow d_i = \frac{1}{\frac{1}{f} - \frac{1}{d_o}}$$

$$= \frac{1}{\frac{1}{30cm} - \frac{1}{60cm}} = 60cm$$

$$\frac{1}{d_o'} = \frac{1}{f} - \frac{1}{d_i'}$$

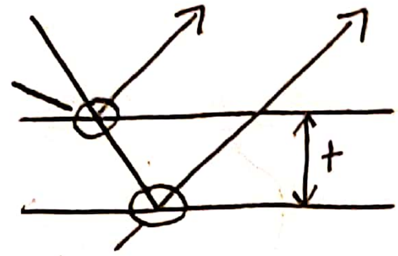
$$\Rightarrow \frac{1}{L - 60cm} = \frac{1}{30cm} - \frac{1}{60cm}$$

$$\Rightarrow L = \frac{1}{\frac{1}{30cm} - \frac{1}{60cm}} + 60 \text{ cm}$$

$$= \boxed{120 cm}$$

15.

phase
change
b/c
1.1>1.0



$n = 1.00$ (air

$n = 1.10$ (oil)

$n = 1.33$ (water)

phase
change
b/c 1.33 > 1.10

Let $\lambda_1 = 458$ nm, $\lambda_2 = 687$ nm. "Enhanced by reflection" means constructive interference. Since we have constructive interf. and 2 phase changes, we have

$$2t = m_1 \frac{\lambda_1}{n_{oil}}, \quad 2t = m_2 \frac{\lambda_2}{n_{oil}},$$

where m_1 and m_2 are integers. Since λ_1 and λ_2 are the only colors for which we have constructive interference, m_1 and m_2 must differ by 1, so

$$m_1 = m_2 + 1 \Rightarrow 2t = (m_2 + 1)\frac{\lambda_1}{n_{oil}}, \quad 2t = m_2 \frac{\lambda_2}{n_{oil}}.$$

Solve the system:

$$m_2 \frac{\lambda_2}{n_{oil}} = (m_2 + 1)\frac{\lambda_1}{n_{oil}}$$

$$\Rightarrow \frac{m_2 + 1}{m_2} = \frac{\lambda_2}{\lambda_1} = \frac{687 \text{ nm}}{458 \text{ nm}} = \frac{3}{2} \Rightarrow m_2 = 2$$

$$\Rightarrow t = \frac{m_2 \lambda_2}{2 n_{oil}} = \frac{2(687 \text{ nm})}{2(1.10)} = \boxed{624 \text{ nm}}$$