1. a. $\boxed{I_A = \frac{1}{2} I_0}$ Unpolarized light equation.

$I_B = I_A \cos^2 60^\circ$

$\boxed{I_B = \frac{1}{8} I_0}$ Rotation of vertically polarized light by 60°.

$I_C = I_B \cos^2 30^\circ$

$\boxed{I_C = \frac{3}{32} I_0}$ Rotation of 60°-polarized light by an additional 30°.

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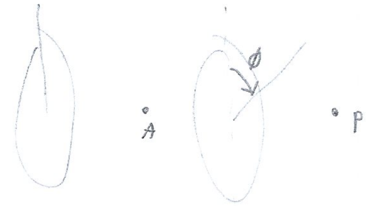
b.

$\boxed{I_C = 0}$ – perpendicular polarizing filters.

2.



a.

$$I_A = \frac{1}{2} I_0$$

Unpolarized light equation

$$I_p = I_A \cos^2\phi = \frac{I_0}{10}$$

Rotating light equation

$$\frac{I_0}{2}\cos^2\phi = \frac{I_0}{10}$$

$$\cos\phi = \frac{\sqrt{5}}{5}$$

$$\boxed{\phi = 63.4^\circ}$$

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b.

$$I_A = I_0 \cos 0^\circ$$

$$= I_0$$

Polarized light equation

$$I_p = \frac{I_0}{10} = I_A \cos^2\phi$$

$$\frac{\cancel{I_0}}{10} = \cancel{I_0}\cos^2\phi$$

$$\cos\phi = \frac{\sqrt{10}}{10}$$

$$\phi = \cos^{-1}\left(\frac{\sqrt{10}}{10}\right)$$

$$\boxed{\phi = 71.6^\circ}$$

3.

$f = 0.120$ m

$h' = 0.00800$ m

$s' = 0.170$ m

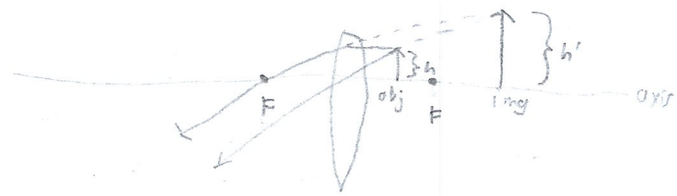
$s = ?$

$m = ?$

$$\frac{1}{s} + \frac{1}{s'} = \frac{-1}{f}$$

$$s = \frac{-1}{\frac{1}{f} + \frac{1}{s'}}$$

$\boxed{s = 0.0703 \text{ m to the right of the lens}}$



$$mh = h'$$

$$h = \frac{h'}{m}$$

$$= \frac{-h's}{s'}$$

$\boxed{h = 0.00331 \text{ m}}$

Erect

Same

4.

$h_0 = 0.0120$ m

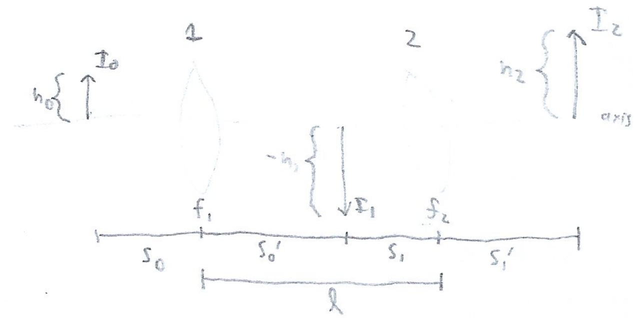
$s_0 = 0.500$ m

$f_1 = 0.400$ m

$f_2 = 0.600$ m

$\ell = 3.000$ m

$s_1 = 1.000$ m



a.

$$\frac{1}{s_0} + \frac{1}{s_0'} = \frac{1}{f_1}$$

$$s_0' = \frac{1}{\frac{1}{f_1} - \frac{1}{s_0}}$$

$\boxed{s_0' = 2.00 \text{ m to the right of lens } 1}$

$$m = \frac{-s_0'}{s_0}$$

$$h_1 = m h_0 = \frac{-s_0' h_0}{s_0}$$

$\boxed{h_1 = -0.0480 \text{ m (i.e., } 0.0480 \text{ m downwards)}}$

b.

$$s_1' = \frac{1}{\frac{1}{f_2} - \frac{1}{s_1}}$$

$\boxed{s_1' = 1.50 \text{ m}}$

$$h_2 = m h_1 = \frac{-s_1' h_1}{s_1}$$

$\boxed{h_2 = 0.072 \text{ m}}$

5.

$V_c = 25$ m/s

$R = 1.50$ m

$V_I = -1.9$ m/s

$s = 2.0$ m

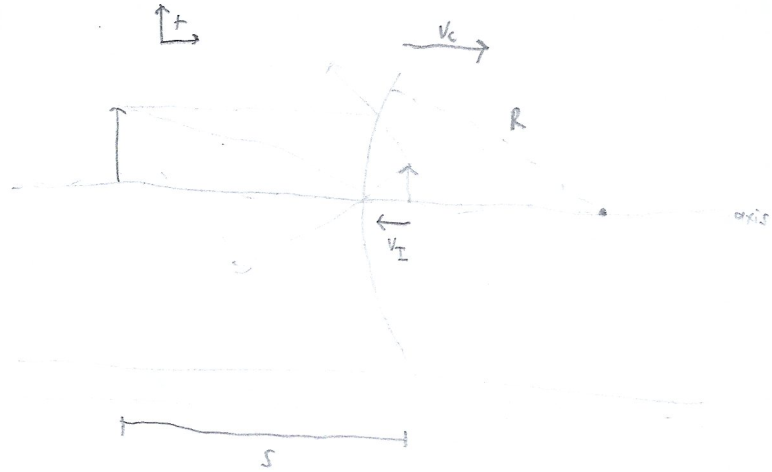
$s' = ?$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$$= \frac{-2}{R}$$

$$s' = \frac{1}{\frac{-2}{R} - \frac{1}{s}}$$

$$= -0.55 \text{ m}$$



$$\frac{d}{dt}\left(\frac{1}{s} + \frac{1}{s'}\right) = \frac{d}{dt}\left(\frac{1}{f}\right)$$

$$\frac{d}{ds}\left(\frac{1}{s}\right) \cdot \frac{ds}{dt} + \frac{d}{ds'}\left(\frac{1}{s'}\right) \cdot \frac{ds'}{dt} = 0$$

$$\frac{-1}{s^2} \cdot \frac{ds}{dt} - \frac{1}{s'^2} \cdot \frac{ds'}{dt} = 0$$

$$\frac{ds}{dt} = \frac{-s^2}{s'^2} \cdot \frac{ds'}{dt}$$

$$= \frac{-s^2}{s'^2} \cdot V_I$$

$$\frac{ds}{dt} = 25.1 \text{ m/s}$$

$$V_T = V_c + \frac{ds}{dt}$$

$$\boxed{V_T = 50 \text{ m/s}}$$

6.

a.

$f = 0.350$ m

$m = \pm 2$

In a mirror, a virtual image is behind the mirror $(s' < 0)$

Thus, in a lens, a real image is behind the lens $(s' > 0)$

$$\pm 2 \stackrel{?}{=} \frac{-s'}{s}$$

$$-2 \stackrel{\checkmark}{=} \frac{-s'}{s}$$

$$s' = 2s$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$$\frac{1}{s} + \frac{1}{2s} = \frac{1}{f}$$

$$\frac{2}{2s} + \frac{1}{2s} = \frac{1}{f}$$

$$\frac{3}{2s} = \frac{1}{f}$$

$$s = \frac{3}{2} f$$

$s = 0.525$ m to the left of the lens.

$\boxed{\text{positive } f \Rightarrow \text{convex lens}}$

b.

$$2 = \frac{-s'}{s}$$

$$s' = -2s$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$$\frac{1}{s} - \frac{1}{2s} = \frac{1}{f}$$

$$\frac{1}{2s} = \frac{1}{f}$$

$$s = \frac{f}{2}$$

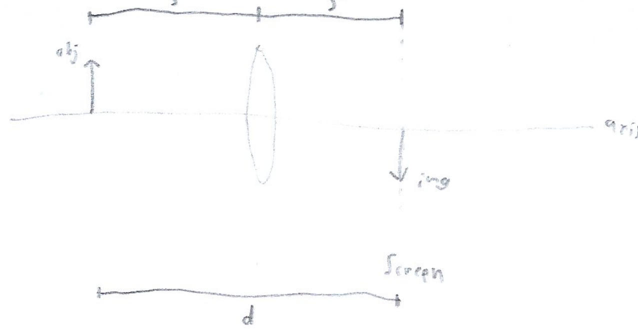
$\boxed{s = 0.175 \text{ m to the left of the lens}}$

positive $f \Rightarrow$ $\boxed{\text{converging lens}}$

7.

$d = 0.220$ m

$f = 0.0300$ m



a.

$$S + S' = d$$
$$S' = d - S$$

$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{f}$$

$$\frac{1}{S} + \frac{1}{d-S} = \frac{1}{f}$$

$$\frac{d}{Sd - S^2} = \frac{1}{f}$$

$$fd = Sd - S^2$$

$$S^2 - dS + fd = 0$$

$$S = \frac{d \pm \sqrt{d^2 - 4fd}}{2}$$

$\boxed{S = 0.184, 0.0358 \text{ m to the right of the object}}$

b.

$$m = \frac{-S'}{S}$$

$$= \frac{S-d}{S}$$

$\boxed{m = -0.195, -5.14, \text{ respectively}}$

8.

a.

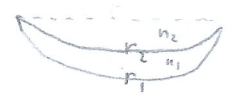
$$\frac{1}{s_0} + \frac{1}{s_1} = \frac{1}{f_1} \qquad -\frac{1}{s_1} + \frac{1}{s_2} = \frac{1}{f_2} \qquad \frac{1}{s_0} + \frac{1}{s_2} = \frac{1}{f}$$

$$\frac{1}{s_0} + \frac{1}{s_1} - \frac{1}{s_1} + \frac{1}{s_2} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{s_0} + \frac{1}{s_2} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\boxed{\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}}$$

b.



$n_1 = 1.55$

$r_1 = 0.0450\ m$

$r_2 = 0.0900\ m$

$n_2 = 1.46$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$= (n_1 - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right) + (n_2 - 1)\left(\frac{1}{r_2} + \frac{1}{\infty}\right)$$

$$\boxed{f = 0.0891\ m}$$

9,

$$I_1 = I_0 \cos^2 \frac{90^\circ}{1}$$

$$I_2 = \left(I_0 \cos^2 \frac{90^\circ}{2}\right) \cos^2 \frac{90^\circ}{2}$$ – For every new screen, we rotate by fewer degrees, but we do so once more, relative to the coordinate system of the prior screen.

$$I_N = I_0 \left(\prod_{i=1}^{N} \cos \frac{90^\circ}{N}\right)^2$$

$$\lim_{N \to \infty} I_N$$

$$= I_0 \left(\lim_{N \to \infty} \prod_{i=1}^{N} \cos \frac{90^\circ}{N}\right)^2$$

$$= I_0 \left(\prod_{i=1}^{\infty} \cos 0^\circ\right)^2$$

$$= I_0 \left(\prod_{i=1}^{\infty} 1\right)^2$$

$$= I_0 \, 1^2$$

$$\checkmark$$

$$= I_0$$