Refraction of Light: Lenses

Problem 1
Light in vacuum is incident on the surface of a glass slab. In the vacuum the beam makes an angle $32.0^\circ$ with the normal to the surface, while in the glass it makes an angle of $21.0^\circ$ with the normal. What is the speed of light in the glass?

$\theta_1 = 32.0^\circ$
$\theta_2 = 21.0^\circ$
$n_1 = 1.0$

Note: We can use Snell's law ($n_1 \sin \theta_1 = n_2 \sin \theta_2$) to calculate $n_2$. From $n_2$, we can calculate the speed of light in the glass ($n = \frac{c}{v}$).

$n_1 \sin \theta_1 = n_2 \sin \theta_2$

$n_2 = \frac{n_1 \sin \theta_1}{\sin \theta_2} = \frac{(1.0) \sin 32.0^\circ}{\sin 21.0^\circ}$

$n_2 = 1.48$

$n = \frac{c}{v} \rightarrow v = \frac{c}{n} = \frac{3.0 \times 10^8 \text{ m/s}}{1.48}$

$\boxed{v = 2.03 \times 10^8 \text{ m/s}}$
Problem 2
Two converging lenses \((f_1 = 9.00 \text{ cm} \text{ and } f_2 = 6.00 \text{ cm})\) are separated by 18.0 cm. The lens on the left has the longer focal length. In object stands 12.0 cm to the left of the left-hand lens in the combination. (a) Locate the final image relative to the lens on the right. (b) Obtain the overall magnification. (c) Is the final image real or virtual? With respect to the original object, is the final image (b) upright or inverted and is it (e) larger or smaller?

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\begin{align*}
\frac{1}{d_0} + \frac{1}{d_i} &= \frac{1}{f} \\
\frac{1}{d_i} &= \frac{1}{9.00 \text{ cm}} - \frac{1}{12.0 \text{ cm}} \\
d_i &= 36.0 \text{ cm}
\end{align*}
\]

Note: in a two-lens system, the image from the first lens serves as the object for the second lens

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\begin{align*}
\frac{1}{d_i} &= \frac{1}{4.5 \text{ cm}} \rightarrow d_i = 4.5 \text{ cm}
\end{align*}
\]

(a) Final image is 4.5 cm to the right of the second lens

(b) \[M = m_1 m_2 = \left(-\frac{d_i}{d_0}\right)\left(-\frac{d_i}{d_o}\right)\]
\[
M = \left(-\frac{36.0 \text{ cm}}{12.0 \text{ cm}}\right)(-4.5 \text{ cm} - 18.0 \text{ cm}) = -0.75
\]

(c) Final image is real (since \(d_i > 0\))

(d) Inverted (since \(M < 0\))

(e) Smaller (since \(|M| < 1\))