1. A thin lens of focal length \( f_1 = 20 \text{ cm} \) forms an image of an arrow which is \( s_1 = 25 \text{ cm} \) to the left of the lens. The arrow is \( h = 10 \text{ cm} \) tall.

(a) Where is the image formed? (2 points)

\[
\frac{1}{s_1} + \frac{1}{s'_1} = \frac{1}{f_1} \quad \text{or} \quad \frac{1}{s'_1} = \frac{1}{f_1} - \frac{1}{s_1} = \frac{1}{20} - \frac{1}{25} = 0.05 - 0.04 = 0.01, \quad \text{so} \quad s'_1 = 100 \text{ cm}.
\]

Since \( s'_1 \) is positive, the image is formed to the right (in the direction the light is going). Altogether, the image is formed 100 cm to the right of the lens.

(b) Is the image **REAL** or **VIRTUAL**? (circle one). **ERECT** or **INVERTED**? (circle one). (2 points)

Rewrite and sign the Honor Pledge: *I pledge my honor that I have not violated the Honor Code during this examination.*

Signature

(OVER—this problem continues on the next page.)
A second lens with focal length $f_2 = 5\text{ cm}$ is positioned $D = 80\text{ cm}$ to the right of the first lens.

(c) Is the image of the arrow formed by the first lens a REAL or VIRTUAL object for the second lens? (circle one) (1 point)

(d) Where is the final image formed? State your answer with respect to the second lens. (2 points)

\[ s_2 = -20\text{ cm}. \text{ It’s negative because it’s a virtual object 20 cm to the right of the second lens.} \]
\[ \frac{1}{s_2'} = \frac{1}{f_2} - \frac{1}{s_2} = \frac{1}{5} + \frac{1}{20} = .2 + .05 = .25, \quad s_2' = 4\text{ cm}. \text{ Altogether it’s 4 cm to the right of the second lens.} \]

(e) Is the final image REAL or VIRTUAL? (circle one). Is the final image ERECT or INVERTED? (circle one). (2 points)

(f) What is the height of the arrow in the final image? (1 point)

\[ H = mh = m_1 m_2 h = (-s_1'/s_1)(-s_2'/s_2) h = (-100/25)(-4/(-20))10 = -8\text{ cm}. \text{ The negative sign indicates an inverted image.} \]