3-1) We have a 100 mm focal length lens (the distance from the rear surface of the lens to the image plane can be assumed to be 100 mm), and we want to place a pentaprism in the path following the lens to bend the optical axis 90°. The index of the prism is 1.5.

a) If the image plane is required to be outside the prism, what is the largest pentaprism that we can use? (Determine the size of the entrance face of the prism.)

b) What is the largest diameter lens that would make sense to use with this prism?

3-2) For a thin lens in air, derive an expression for the overall object-to-image distance D as a function of the focal length and the magnification.
   a) Plot D vs. m for a positive thin lens.
   b) Plot D vs. m for a negative thin lens.
   c) Note that for a given object-to-image distance D, there are two possible values of magnification. Determine these two values of m in terms of D and f. Show that these two magnifications are reciprocals, i.e. \( m_1 = \frac{1}{m_2} \).
   d) For a positive lens with f = 100 mm, sketch the two scenarios for D = 600 mm.

3-3) You have a 100 mm focal length thin lens. For each given object position determine the image position and the image magnification. Note whether the object and image are real or virtual. The object and image locations are measured relative to the lens.

\[ z = \begin{align*}
-10000 \text{ mm} \\
-500 \text{ mm} \\
-200 \text{ mm} \\
-150 \text{ mm} \\
-110 \text{ mm} \\
-90 \text{ mm} \\
-50 \text{ mm} \\
-25 \text{ mm} \\
50 \text{ mm} \\
100 \text{ mm} \\
200 \text{ mm} \\
500 \text{ mm} \\
10000 \text{ mm}
\end{align*} \]
3-4) The following two methods determine the focal length of a positive lens by using two pairs of conjugate locations. In both cases, real objects and images are required (the object to image distance must be larger than 4f).

a) Bessel’s Method uses the two reciprocal magnification positions for a fixed object-to-image distance $D$. The lens is translated between a fixed object and a fixed viewing screen. Two positions of the lens will form an image on the viewing screen (reciprocal magnifications). The separation between these two lens positions is $L$. Derive the following expression for the focal length in terms of $D$ and $L$:

$$f = \frac{D^2 - L^2}{4D}$$

b) In Abbe’s method, the image of an object is formed on a viewing screen. The object position $z_1$ and image magnification $m_1$ are measured. The object is then moved and the new object position and image magnification $z_2$ and $m_2$ are measured. Derive this expression for the focal length as a function of $z_1$, $z_2$, $m_1$ and $m_2$:

$$f = \frac{z_1 - z_2}{1/m_1 - 1/m_2}$$