1 Reflection

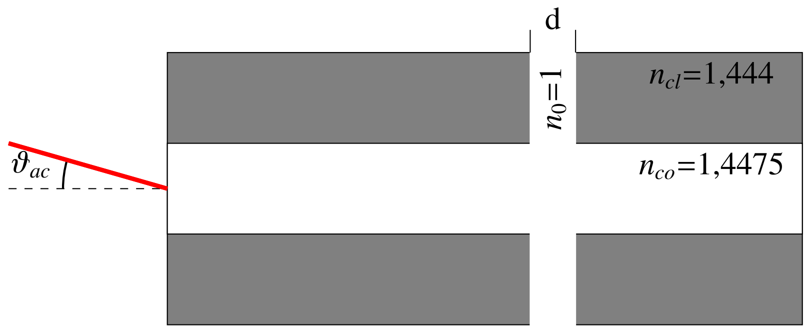

Figure 1: Sketch of the fiber

A Laser ray is coupled into a fiber. The core of the fiber is made of doped silica with a refractive index of 1.4475. The refractive index of the cladding is 1.444.

a) What is the acceptance angle ϑ_{ac} of the laser, so it stays inside the fiber? Derive the formula by completing the sketch in Fig. 1 and calculate the exact value of ϑ_{ac}.

b) Consider that there is a crack in the fiber, which causes a gap in the direction of travel. How does this affect the travel and the angle of the laser ray? How far does the size d of the gap need to be considered?
Assume that the laser ray does not hit the cladding where the crack is.

2 Thin Film Interference

A soap bubble is 100 nm thick and illuminated by white light incident perpendicular to its surface from normal air.

a) What wavelength and color of visible light is most constructively reflected, assuming the same refractive index as water ($n = 1.33$)?

b) When the bubble pops, a film of the same soapy water ($n = 1.33$) with a thickness of 154 nm sits on top of a plastic cutting board ($n = 1.46$). What color is most strongly reflected if it is illuminated perpendicular to its surface?

c) In both cases, if the refractive index is changed to ($n = 1.38$), which colors would not be seen in the reflected light?

3 Ray transfer matrices

Ray transfer matrices (or ABCD matrices) are a useful method for calculating light beam paths in optical systems when angles are small. In ray transfer matrix analysis, all parts of the optical system are modelled as matrices. The most basic matrices are:

Object/image with height h and angle a (radians): $O = \begin{bmatrix} h \\ a \end{bmatrix}$

Light propagating distance d in free space: $D = \begin{bmatrix} 1 & d \\ 0 & 1 \end{bmatrix}$

Thin lens with focal length f: $L = \begin{bmatrix} 1 & 0 \\ -1/f & 1 \end{bmatrix}$

Ray transfer matrix equations have following form:

$$O_{\text{Image}} = D_N \cdot L_N \cdot ... \cdot D_2 \cdot L_1 \cdot D_1 \cdot O_{\text{Object}}$$

Problem:
A simple two lens system is shown in Fig. 2 below.

a) Create a ray transfer matrix equation for this optical system.

b) What is the image height h2?

You can use following assumptions:
Object height $h1 = 5 \cdot 10^{-3}$
Light hits L1 at angle $a1 = 0.5$rad
$d1 = 5 \cdot 10^{-3}$
$d2 = 25 \cdot 10^{-3}$
$d3 = 10 \cdot 10^{-3}$
Lenses L1 and L2 have focal length $f1 = f2 = 6 \cdot 10^{-3}$

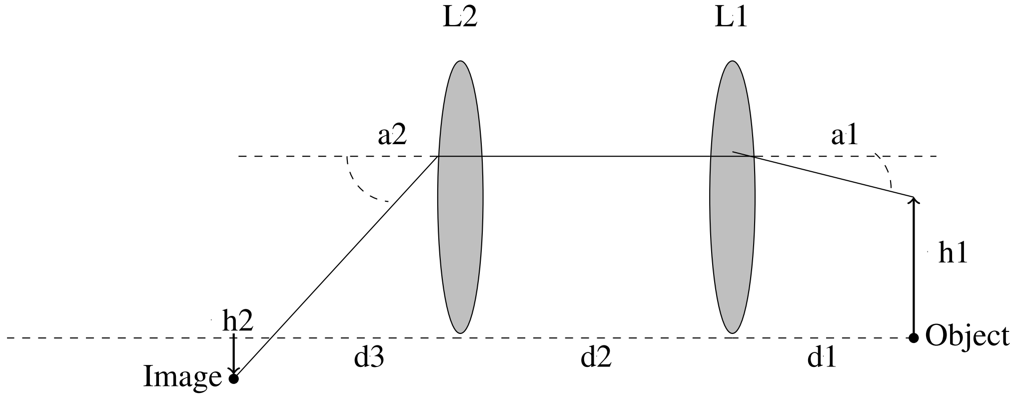

Figure 2: A simple two lens system (not to scale)