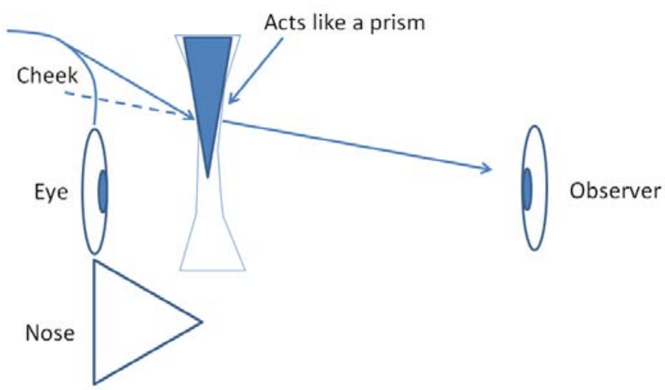
OPTI 415/515 Homework 2

Undergraduates do the first three problems. Graduates Students do all four questions.

1. Does the lens in front of Buddy Holly's left eye have positive or negative power? Explain your answer.

   The lens is a negative lens since the side of his face appears to move in when looking through the glasses as compared to outside the glasses. The drawing below illustrates this effect.



2. You assemble the machine vision system from Homework 1 to inspect a flywheel with diameter 39.6 mm. Your 100 mm focal length lens is at a working distance of 1 meter from the part. The 1/3" CCD camera is at the image plane. You capture the image above and unfortunately, the part doesn't fit on the sensor. The working distance is constrained. Calculate a new lens focal length that will allow the entire part plus 10% to be imaged in the vertical direction. What are the new focal length and image distance?

   In object space, the part size plus 10% is 39.6 + 3.96 = 43.56 mm. In order to get this on the vertical component of the 1/3" sensor, we need a magnification

$$m = \frac{-3.6}{43.56} = -0.0826 = \frac{L'}{L}.$$

Since L = -1000 mm, L' = 82.6 mm. We can then calculate the effective focal length using the following form of the Gaussian imaging equation:

$$L' = (1-m) f_E \Rightarrow f_E = 76.336\ \text{mm}$$

3. Using raytracing code, find the locations of the cardinal points in the following system. Where are the entrance and exit pupils located? If the physical diameter of the aperture stop is 13.4 mm, what are the diameters of the entrance and exit pupil? What is the F-Number of the system?

   I used Zemax with a wavelength of 587.6 nm and BK7 (n = 1.517) and F2 (n = 1.620) for the materials. The locations of the cardinal points are below, as well as F/# and pupil properties.

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CARDINAL POINTS:

Object space positions are measured with respect to surface 1.
Image space positions are measured with respect to the image surface.
The index in both the object space and image space is considered.

Object Space           Image Space
W = 0.587562(Primary)
Focal Length           :         -101.605274          101.605274
Focal Planes           :         -140.486215            0.000407
Principal Planes       :          -38.880941         -101.604867
Anti-Principal Planes  :         -242.091489          101.605681
Nodal Planes           :          -38.880941         -101.604867
Anti-Nodal Planes      :         -242.091489          101.605681
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Image Space F/#           :        5.447628
Paraxial Working F/#      :        5.522031
Working F/#               :        5.522386
Image Space NA            :      0.09017748
Object Space NA           :   9.325644e-010
Stop Radius               :             6.7
Paraxial Image Height     :            7.44
Paraxial Magnification    :               0
Entrance Pupil Diameter   :        18.65129
Entrance Pupil Position   :        23.54995
Exit Pupil Diameter       :        11.55275
Exit Pupil Position       :       -62.93069
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4. *************************Grads Only***********************************

Estimate the diameter of the central hole in the flywheel (the image is available on the course homepage). Point Grey Dragonfly2 cameras have a 1/3" sensor and come with resolutions of 648 x 488, 1036 x 776, and 1296 x 964 pixels. Suppose we can measure the central hole diameter in the image to an accuracy of ½ pixel. What accuracy does this correspond to on the part?

If we analyze the original image, part diameter is 588 pixels and the central hole is 63 pixels. Since the part is 39.6 mm in diameter, the central hole is

$$63\text{pix} \cdot \frac{39.6\text{mm}}{588\text{pix}} = 4.243\text{mm}.$$

The size of a pixel for each of the sensor resolutions is determined by dividing the sensor width by the number of pixels in that direction. For example, for the 648 x 488 resolution, the pixel size is 4.8 mm / 648 = 7.4 μm. The other resolutions correspond to pixel sizes of 4.6 μm and 3.7 μm. To determine the size half a pixel corresponds to in the object plane, we need to divide this dimension by the magnification m = -0.0826 calculated in problem 2. Since we are only interested in absolute size here, we'll ignore the minus sign. For the 648 x 488 resolution,

$$\left|\frac{7.4\mu\text{m}}{2(-0.0826)}\right| = 44.8\mu\text{m}$$

The other resolutions correspond to 28 μm and 22.4 μm, respectively.