Exam: Optical Engineering

Date: 17.03.2016

Examiner: Prof. Stork

1 General Information

The exam started 30 minutes late due to a delay before. It only took 20 minutes however. After he noticed I was German, he proposed to talk German in the exam also. The atmosphere is rather relaxed. He always has a specific answer in mind but does not expect you to get there right away. If you are not sure what he wants, just say what you know about the topic and he will guide you in the right direction. As a general rule, Prof. Stork does not want the details but the general understanding and it is advantageous to know a few parameters by heart for every setup like the size of the eye, the typical magnification of a magnifying glass, etc. .
For me half the exam was about the topic I chose and after that he came to talk about other systems at random. I don‘t think you can influence him in the choice of these . So it is probably good to know one system very well but know the general idea behind other systems as well.
Also try to answer not just by saying the answer but tell him, how you know that and if possible, draw a sketch and write down a formula. This takes time off the clock and shows you know the idea behind something and didn‘t just learn something by heart.
In general: Don‘t panic if you don‘t know something right away.
Best of luck to you.

2 Exam

- **What is the task that optical enigneers deal with?**
  They employ a scientific method to construct and build systems that rely on optical phenomena customized to meet a customer‘s demand.
- **Is there an optical system that you would like to present?**
  The human eye.

2.1 The Human Eye

- **Make a rough sketch of what the human eye looks like?**
  The sketch he has in mind is just the Gullstrand‘s eye model consisting of the cornea and the crystalline lens. He is not interested in the biological details but rather in some numbers like the refractive indices of the different materials, the radii of curvature etc..
- **What is the overall refractive power of the human eye?**
  About 60 dpt. The calculation to get there is the imaging equation:

$$D = \frac{1}{f} = \frac{1}{g} + \frac{1}{b}, \tag{1}$$

with g the object distance and b the image distance. Since the unacommodated eye focusses parallel rays (coming from infinity), $g \to \infty$. The distance b is not the full diameter of the eye but rather the full diameter divided by the refractive index of water in the eye so $g = 24\,\text{mm}/1.33 \approx 17\,\text{mm}$. With these values one gets to 60 dpt.

- **How much of the total refractive power is provided by the cornea?**
  Its about 2/3. The refractive power of one surface is defined as:

$$D = \frac{\Delta n}{R}, \tag{2}$$

  with Δn the difference in refractive indices before and after the surface and R the radius of curvature. This equation is essentially the lens makers equation with the second radius set to infinity and the distance set so zero. With $\Delta n = 0.3$ and $R = 8\,\text{mm}$, one gets to $D \approx 40\,\text{dpt}$.

- **What is the characteristic of the eye, that artificial systems are struggeling with?**
  It‘s the ability to change focus and refractive power and therefore acommodate for different object distances.

- **How does the eye do that?**
  Due to the contraction of the ciliary muscles, the tension from the sclera that usually stretches and flattens the lens is released and the lens gets thicker and rounder due to its own elasticity.

- **How does that mechanism change over the years?**
  Due to protein deposition in the lens, it gradually loses its elasticity and therefore the ability to change refractive power. (Here you should be able to draw the graph how ΔD changes over the years.)

- **What does it mean if you can only change the refractive power by $2\,\text{dpt}$?**
  The change from far point to near point is given by the formula

$$\Delta D = \frac{1}{g_1} + \frac{1}{b_2} - \frac{1}{g_2} - \frac{1}{b_2}, \tag{3}$$

  where the indices 1 and 2 refer to the far and near point. Since the far point of a normal eye is at infinity and the images have to be produced at the same distance this reduces to $\Delta D = -\frac{1}{g_2}$, which means that for 2 dpt, the image has to be 50 cm from your eye which is uncomfortable.

- **What if you have a very long arm?**
  The problem is, that the text also appears half as big as when you hold it at 25 cm, which is the usual near point, so you have trouble reading small print.

- **Why is that good news for the optics industry?**
  Because of the demographic changes in Western Europe a lot of people are around 50 years old and need correction lenses which means a high demand for optometrists and manufacturers for glasses.

2.2 Camera

- **So enough of the eye, lets talk about somehting else. What does a camera look like?**
  Draw a rough sketc of the camera with the lens and the screen.

- **A camera also needs an adjustable focal length, how does this work?**
  Either by adjusting the position of the lens with respect to the screen or by taking two lenses (zoom objective) and adjusting their relative position. (it is always good to have some rough numbers, like how big is the range of magnification for these types of objectives but he did‘s ask them here.)

- **Let‘s assume Nikon wants to manufacture a new camera and uses a pixel size of $2\,\mu$m at their CCD chip. How do you design your camera?**
  (One of those open quenstions where he will gradually guide you to an answer.) Starting from the resolution limit

  $$\delta_{min} = 1.22 \cdot \frac{\lambda}{D}, \tag{4}$$

  with D as the diameter of the aperture you can calculate the size of the Airy disc on your screen with is just a multiplication with the focal length f:

  $$\Delta x_{min} = 1.22 \cdot \frac{f \cdot \lambda}{D} = 2\,\mu\text{m}. \tag{5}$$

  Here you have to see that $\frac{f}{D}$ is the definition of the f-number and so you can calculate that your f-number should be 4.

2.3 Spectrometer

- **What does a spectrometer look like?**
  There are several types like a prism-spectromter and a grating-spectrometer. (He asked wich is more common and went on to ask about the grating spectrometer.

- **Draw the typical setup for a grating spectrometer.**
  I drew one with mirrors and mentioned that this is advantageous to avoid chromatic abberations. The setup is the Cerny-Turner setup. Make sure you include the pinhole at the beginning and know where to put your detector.

- **What determines the resolution of this setup?**
  Firstly the size of the grating (and therefore of the mirrors as well) which is now the D in equation 4. Also the spacing of the slits is important. So the reslution is proportional to the size of the gratings and inversely proportional to the distance of the individual grooves meaning that it is proportional to the number of illuminated slits in the grating.