INF-GEO4310 Imaging
Compulsary Exercise, 2009

Out: 30.10.2009
Due: 15.11.2009, 23:59:59 hrs

Formalities

- The answer should be a text document containing the necessary illustrations.
- The document should be converted into a pdf file.
- Append your answer in an e-mail, and send it to endriasa@ifi.uio.no within the date and time given above.
- The subject field of the e-mail should read INF-GEO4310 – comp.

To create a pdf file, you may first create a postscript file with the print command (but route the output to a file instead of a printer) and then run the program distill on the postscript file. Here an example:

print –o <outfile.ps> <infile.txt>
distill <outfile.ps> (generates outfil.pdf)

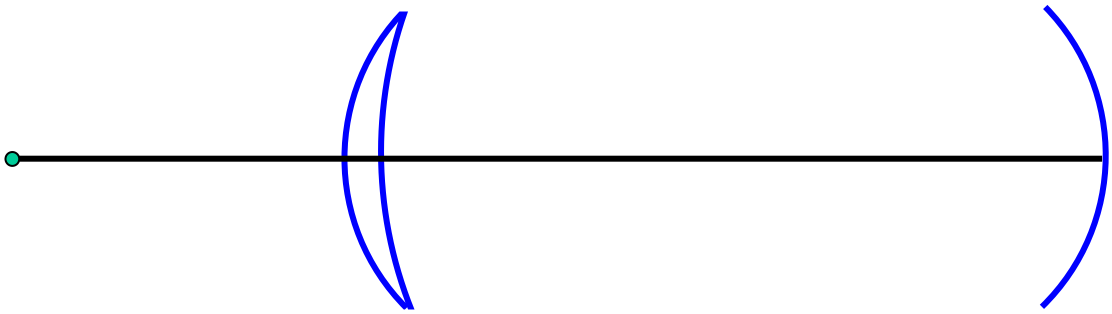
The work may be done in small groups of up to 2 students. The collaboration should be clearly stated on the front page of the document, containing the following clause: "I/we have read and understood the rules given in the document "Departemental guidelines for written assignments" on http://www.ifi.uio.no/studinf/skjemaer/declaration.pdf ."

You may find a lot of background material on the Internet. You may also use material from the lecture foils and from text files on the web page of the course. Remember to include references whenever you quote or build on material published on the Internet or in print. Good and exact references will be evaluated positively. On the other side: Using other peoples material without giving the source is dishonest and in serious cases a crime, and may in connection with work that contributes to a mark be considered as cheating!

If you need help to clarify some questions, please contact Endrias G. Asgedom.

Geometrical Optics

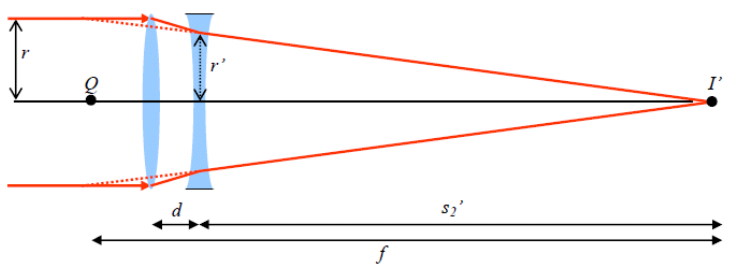
1. Assume that you have a thin convex-concave lens with radii R and 2R. At a distance D to the right of this lens there is a concave spherical mirror having a radius R. To the left of the thin lens, at a distance A, there is an object P. This object is to be images at a distance R/2 to the left of the concave mirror, as shown in the figure below.



a) What is the simplest way of achieving this, and what is then the distance A? Explain how you arrive at your answer using the "object-image relations" for a spherical mirror and a thin lens and the "Lensmaker's Equation", and how you utilize the sigh rules for image formation. You may assume that the refractive index of the lens is 1,5.

b) What is the magnification of this lens-mirror-system if we place them at a distance from each other that is equal to the sum of the two focal lengths?

2. The figure below shows a simple version of a zoom lens. The converging lens has a focal length f1, and the diverging lens has a negative focal length f2. The two lenses are separated by a variable distance d that is alwas less than f1. The magnitude of the focal length of the diverging lens satisfies the inequality |f2| > (f1 – d). To determine the effective focal length of the combination, we consider a bundle of rays parallel to the optical axis of radius r entering the converging lens



a. Show that the radius of the bundle of rays is decreased to

$$r' = r\,(f1 - d) / f1$$

when it enters the diverging lens.

We have seen (in section 2.2.4.14) that the back focal length (BFL) of a combination of two thin lenses, i.e., the distance from the second lens to the focal point of the combined lenses, is given by

$$BFL = f2\,(d - f1) / (d - (f1 + f2))$$

If the rays that emerge from the diverging lens and reach the final image point are extended backward to the left of the diverging lens, they will eventually expand to the original radius r at some point Q. The distance from Q to the final image point I' is the effective focal length f of the lens combination.

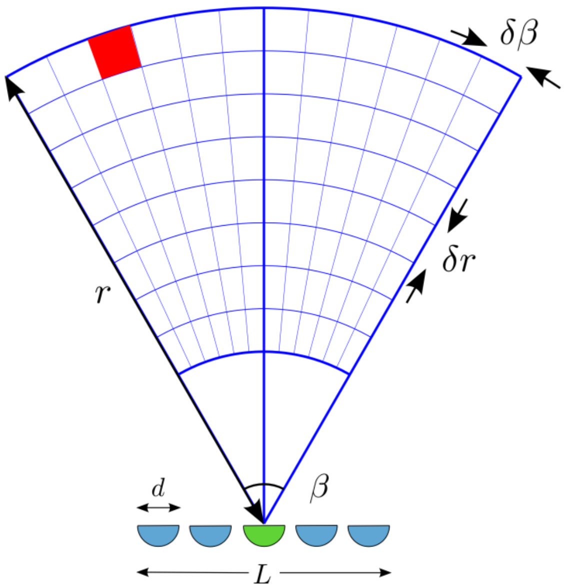
b. Show that the effective focal length is given by

$$f = f1\,|f2| / (|f2| - f1 + d)$$

c. If f1 = 6.0 cm and f2 = -9.0 cm, and the distance d is adjustable between zero and 3.0 cm, what is the minimum and maximum focal lengths of the lens combination, and what is the distance from the first lens to the focal plane for the two cases?

Sonar

1. Assume a sonar transmitter (green) and a receiver array (blue and green). The receiver is a linear array with length L = 120 cm, where each element in the array have size d = 3.75 cm. The sonar system transmits pulses at center frequency f = 100 kHz. The sound speed is assumed to be 1500 m/s.



a) The sonar transmits a pulse each ¼-second. What is the maximum range of the system?

b) In which distance *r* is a pixel in the far field of the receiver array?

c) What must be done to the recorded data in each receiver element for the sonar to image the red pixel in the imaging scene? Draw figure if needed.

d) What is the angular resolution (given as an equation)? What is the angular resolution for this system (given in degrees)? What is the angular resolution of an equivalent system with center frequency of 200 kHz? Is this system better?

Medical ultrasound imaging

1. A 128-element linear array is used for real-time imaging of a fetus in the mother's womb. An uterus (with abdomen) in the final stages of pregnancy can be up to 50 cm thick. Assume that four non-overlapping elements are used to form a group and are fired sequentially to create an image of the fetus.

   a) How many scan lines can you get in each image?

   b) What is the frame rate if one assumes a speed of sound of 1500 m/s and that one need to receive an echo from depth 50 cm, sent from one group of elements before the next group sends out its pulse?

   c) What can be done to increase the frame rate? Please suggest at least two possibilities, and describe briefly what effect the choice one makes will have on the image and image quality.