Note that in many 502 homework and exam problems (as in the real world!!), only the magnitude of the magnification or MP is given. You need to determine the sign based upon the configuration.

10-1) An f/4 reverse telephoto objective is comprised of two thin lenses in air. The system stop is located between the two lenses.

The system is now to be used with a finite conjugate object that is located 150 mm to the left of the first lens. The maximum image size is +/- 20 mm.

Determine the following:
- System focal length and back focal distance.
- Stop size; Entrance pupil and exit pupil locations and sizes.
- Image location.
- Object size corresponding to the image size.
- Required diameters for the two lenses for the system to be unvignetted over the specified maximum image size and conjugate location.

NOTE: This problem is to be worked using raytrace methods only. All answers must be determined directly from the rays you trace; for example, the object size must be determined from the chief ray. Raytraces must be done on the raytrace form. Be sure to clearly label your rays on the raytrace form. Gaussian imaging methods may not be used for any portion of this problem.

10-2) Design a thin-lens telephoto lens with a back focal distance of 50 mm and an effective focal length of 200 mm.
10-3) The goal of this problem is to design a variable focal length lens using a plano-convex lens, a plane parallel plate, and a fluid that has a variable index of refraction. The fluid is placed between the lens and the plane parallel plate to produce a sandwich of thin lenses. There are no moving parts, and the finished system is in air.

Plano-convex lens: focal length = 100 mm, n = 1.517
Plane parallel plate: thickness = 2 mm, n = 1.517

a) Sketch the arrangement of elements and give the equation for the system focal length as a function of the index of the fluid.

b) If the index of this fluid can vary from 1.3 to 1.7, what range of power or focal length can be obtained with the system? Note that this is a fictitious fluid!

10-4) A medium-format digital single lens reflex (DSLR) is to be designed using a monochrome (B&W) image sensor in the DX or APS-C format. The sensor size is 24 x 16 mm.

a) The first task is to specify the focal length of the camera objective. The field of view for distant objects should be equivalent to a 35 mm film based camera with a 38 mm focal length lens. The 35 mm film format is 24 x 36 mm.

b) The next task is to determine the lens focus positions needed to cover a range of object positions from infinity to 500 mm. The camera lens will operate at f/4.

One criteria for good image focus is that the blur diameter due to defocus matches the pixel width on the sensor. For this problem, diffraction and aberrations are to be ignored. (Note that this criterion is very conservative, and significantly more blur may still produce good images.)

The pixels on the image sensor are 10.0 x 10.0 μm.

The first focus zone extends from infinity to its LNEAR. The next zone starts at this position as LFAR and continues to a new LNEAR. The zones continue until the entire object range is covered. At each zone, give the required sensor location relative to the rear focal point of the lens. These values actually provide the amount of lens motion that is required to go from zone to zone (as the lens is actually moved, not the sensor).

This problem is best done by setting up a spread sheet. This also allows the various parameters to be varied to investigate system changes. Examine how does the number of required zones vary with

Focal length?
Blur?
F/#?
10-5) Design a two-element reverse telephoto zoom lens:

Focal length range: 30 to 80 mm
Lens configuration: Two-element zoom lens
Reverse-telephoto configuration (negative-positive)
Element focal lengths: \( f_1 = -50 \text{ mm} \)
\( f_2 = 50 \text{ mm} \)

Assume an object at infinity. Both elements are thin lenses in air.

Provide the equations for the element separation and the back focal distance as a function of the system focal length. Also provide a table giving these two spacings and the total system length at the maximum and minimum focal lengths as well as at regular 10 mm increments of focal length (30 mm, 40 mm, 50 mm, etc.). Plot the lens positions relative to the image plane as a function of focal length (similar to the plot found in the class notes).

Note that the requirement for the two elements having equal but opposite focal lengths is given for computational ease. This is an arbitrary but useful choice.

10-6) A 5X Keplerian telescope has a 200 mm focal length objective.

a) Determine the focal length of the eye lens and the overall telescope length.
b) If the stop of the telescope is the objective, what is the eye relief?

10-7) A pair of 6x30 binoculars (Keplerian) have 150 mm focal length objectives. What is the size of the exit pupil and how much eye relief is obtained?

10-8) Design a Galilean telescope with a magnifying power of 5 and a length of 100 mm. Specify the two focal lengths.

10-9) Design a Keplerian telescope with a magnifying power of 10 and an eye relief of 11 mm. Specify the two focal lengths and the separation.

10-10) Two stars are separated by 2.0 arc seconds. Assuming the eye has a resolution of 1 arc minute, what magnifying power is required for a telescope in order to visually resolve the stars? If diffraction is included, what is the minimum required entrance pupil diameter?
10-11) A magnifier that is marked 10X is used to examine an object. The magnifier lens has a diameter of 10 mm, and the magnifier is used with a relaxed eye. This implies that the eye is focused at infinity, and that the virtual image produced by the magnifier is also at infinity.

a) The magnifier is first used as an eye loupe. The separation between the magnifier lens and the eye is 25 mm. What is the diameter of the half-vignetted field of view (object size in mm) seen through the magnifier? Assume that the eye has a pupil diameter of 4 mm.

b) The magnifier is now used as a magnifying glass by increasing the separation between the magnifier lens and the eye to 250 mm. What is the diameter of the half-vignetted field of view (object size in mm) seen through the magnifier? Once again, assume that the eye has a pupil diameter of 4 mm.

c) What do these results imply about the way a magnifier is best used?

10-12) A Keplerian telescope has the following specifications:

- Magnifying Power = 12 X
- Length = 260 mm (objective to eye lens)
- Unvignetted Field of View = +/- 2 degrees
- Eye Relief = 15 mm
- Entrance Pupil Diameter = 40 mm
- The stop is located at the objective lens of the telescope
- The object is at infinity
- All elements are thin lenses

Design the telescope. How many elements are required? Provide element focal lengths, diameters and spacings. Be sure to verify that all of the above specifications are met exactly.
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