Exercises belonging to lecture Observational Astronomy MKEP5 (SS 2011)

Sheet 3

20 "points" in total

1. **Basic Optics** [5 pt]
   Derive the Law of Reflection and Snell's Law of Refraction from Fermat's principle.

2. **Focal Shift and Aberrations of a Plane-Parallel Plate**
   You have mounted a CCD camera on a telescope and focused the telescope (i.e., the light from a star forms a converging ray bundle intersecting the CCD in a single point). Now you want to insert a filter in front of the CCD. The filter is a colored glass plate (index of refraction n = 1.5) of thickness d = 3mm.

   (a) [2 pt] By how much do you have to adjust the focus of the telescope, in the paraxial approximation?

   (b) [3 pt] At small telescopes, the focus is normally adjusted by moving the eyepiece or camera. However, to mount a large heavy spectrograph or camera at a large telescope, it is frequently more convenient to attach it firmly to a Cassegrain flange, and to adjust the focus by moving the secondary mirror of the telescope in the axial direction. Consider a Cassegrain telescope with transverse magnification of the secondary mirror m. By how much do you have to move this mirror, to get the focus change required when you insert the filter?

   (c) [3 pt] Now go back to the initial problem and consider the exact solution for a ray with angle of incidence i, using Snell's law. Show that the focus shift Δ is given by:
   $$\Delta_{\text{exact}} = d\left(1 - \frac{\cos i}{n\cos i'}\right) \qquad (1)$$

   (d) [3 pt] Show that to second order:
   $$\Delta_{\text{exact}} - \Delta_{\text{paraxial}} \simeq \frac{y_1^2 d(n^2-1)}{2s_1^2 n^3} \qquad (2)$$
   where y_1 is the ray height at the front surface of the filter, and s_1 the distance from the front surface to the nominal focus (i.e., the position of the focus if no filter is present). Interpret this result!

3. **Field-of-View of a Classical Cassegrain Telescope** [4 pt]
   In the lectures we have discussed the field-of-view of a classical Cassegrain telescope, and found out that it is the same as that of a single parabolic mirror of identical focal length. But is this a fair comparison? Compute the total length L of a Cassegrain telescope, as a function of its focal length f, and the parameters m and β. Discuss the result, considering that typically $m \simeq 5$ and $\beta \simeq 0.2$.