A525 - Problem Set # 1

September 8, 2008 Due: September 15, 2008

Please work on this problem set by yourself. The homework assignments will be used as part of your final grade.

1) Derive an expression for the longitudinal magnification, m_L, of a thin lens. m_L is the change in image distance with object distance (e.g. cm/cm). You should find that you are able to express this in a simple form relative to the transverse magnification, m (= i/o).

2) For an aspheric surface we have a set of equations to solve to determine Q' and U' for the outgoing ray, e.g. $Q' = X' \sin U' + Y \cos U'$, $\tan(U+I) = dX/dY$, etc. Taking the surface to be reflective show that the focal distance (distance from the point where the rays cross the optical axis to the vertex of the surface) is independent of the height of the ray, Q, only for a parabolic surface.

3) Consider two thin lenses with focal lengths, f_1 and f_2. They are located a distance d_0 apart such that there optical axes are aligned. The thin lens formula is given by

$$\frac{1}{f} = \frac{1}{i} - \frac{1}{o}$$

where distances are defined relative to the center of the lens, that is, if the object is to the left of the lens, *o* will be a negative number. A positive value of f indicates a "focusing" lens. An object is placed a distance o_1 from the first lens, and the two-lens system forms an image.

   a) Derive and expression for the distance of the image, i_2, from the second lens.

   b) What will be the magnification of this image?

4) Consider a thin lens with a focal length of 3 cm and another one with a focal length of -4 cm. The second lens is located 5 cm to the right of the first lens. Suppose an object is located at 5 cm to the left of the lens and extends from 0 to 0.5 cm above the optical axis.

   a) Using some properties you know about lenses, graphically find the image position and height.

   b) Repeat this analysis using your findings from problem 3 and compare this to your graphical results.

5) Consider a classical Cassegrain telescope. Assume an f/0.6, 25-meter diameter primary, a final focal ratio of f/8, and a back focal distance of 7.5 meters.

   a) Compute the magnification and eccentricity of the secondary mirror.

   b) Compute the primary-secondary distance.

   c) Compute the diameter of the secondary.

   d) Compute the radius of curvature of the secondary.

   e) What is the plate scale?

   f) Make a rough sketch of the system, labeling appropriately.

6) Infrared and submillimeter telescope typically have a “chopping” secondary which allows fast switching between a source and a “blank” sky position. This is done (although not ideally) by tilting the secondary mirror about its vertex. Taking the difference between these two signals makes it possible to eliminate (or greatly reduce) a number of noise sources (sky noise, 1/f detector noise, etc) in the system, since the signal will be modulated with a known frequency. Suppose we have a Cassegrain-type telescope.

   a) What is the relationship between tilt of the secondary and angular change on the sky as seen in the focal plane.

   b) When the secondary is tilted the edge moves by an amount SCA (secondary chop amplitude) and the field seen on the sky is displaced by an angle, θ. Show that the relationship between SCA and θ is $SCA = D\theta/4$ where D is the diameter of the primary mirror.

   c) In question 5 you determined the diameter of the secondary mirror, but this is nominally for an on-axis source. Show that the secondary must be increased in diameter by an amount $2\theta f_{eff}/m$, where θ is the field of view on the sky, f_{eff} is the effective focal length of the telescope, and m is the magnification.