MASSACHUSETTS INSTITUTE OF TECHNOLOGY

2.997 Optical Engineering **Fall '99**

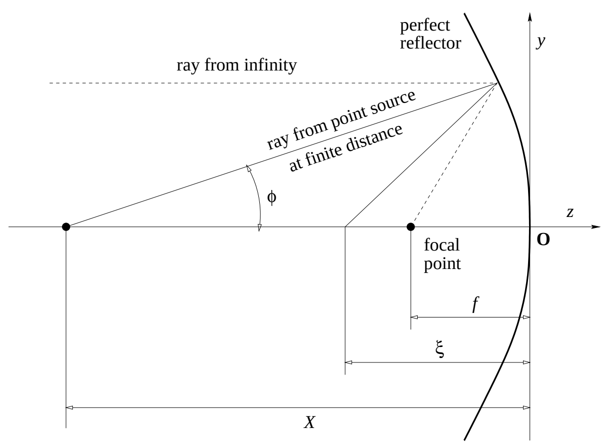
Assignment #2 Posted Sept. 20, 1999 — Due Oct. 4 , 1999

1. WS ch. 2, exercise 5 (p. 55).

2. WS ch. 2, exercise 9 (p. 55).

3. WS ch. 2, exercise 10 (p. 55).

4. **Perfectly focusing reflector at oblique illumination.** We showed in class that a parabolic reflector causes a horizontal (on-axis) ray bundle originating at infinity to focus perfectly at a single point on-axis. However, rays from objects at finite distances do *not* share this property. In the geometry shown below, a point source is located on-axis at distance X and emits a perfect spherical wave towards the reflector. The reflector is designed to have focal length f for on-axis rays.



4.a) Plot the focal distance ξ as function of ray angle ϕ for $-\pi/6 \leq \phi \leq \pi/6$ for the following three cases: $X = 2f$, $X = 8f$, $X = 100f$.

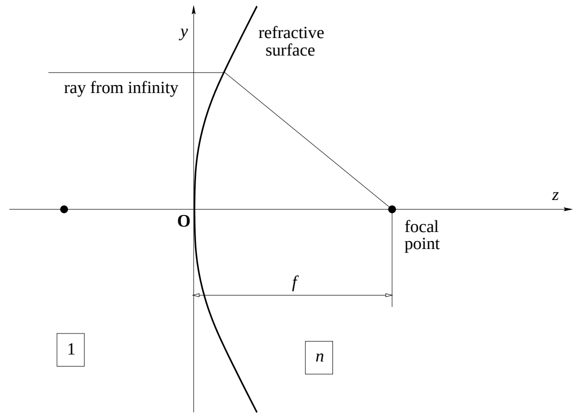
4.b) Find the minimum distance X_{min} such that

$$\left| \xi\left(\frac{\pi}{6}\right) - \xi(0) \right| \leq \frac{|f|}{10}.$$

5. **Perfectly focusing refractor.** This problem demonstrates the subtle differences between reflection and refraction in the non-paraxial regime.

5.a) Derive the shape of the refractive surface shown on the next page that causes a horizontal ray bundle originating at infinity to focus perfectly on-axis at distance f from the origin. What is the paraxial version of your result?

5.b) The incident ray has uniform color distribution between $0.2\mu\text{m} \leq \lambda \leq 0.7\mu\text{m}$. Plot the focal length against wavelength using the exact solution from the previous problem, using the dispersion data for fused silica [WS, Figure 7.6, p. 174]. Your result is referred to as the *dispersion* in the focal length of the refractor.

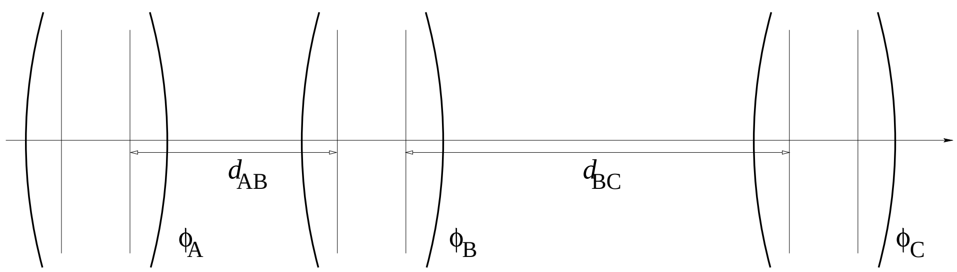


6. Magnification with two elements.

6.a) Derive the magnification produced by the two-element system of [WS Fig. 2.18, p. 46] as function of the parameters ϕ_A, ϕ_B, s, s', d.

6.b) Prove equations (2.49) through (2.53) [WS pp. 46-47].

7. Three-element systems. The system below is composed of three refractive elements with powers ϕ_A, ϕ_B, ϕ_C, respectively. The elements are separated pair-wise by d_{AB}, d_{BC}.



7.a) Derive the power of the composite element as function of the above parameters.

7.b) Let $\phi_A = \phi_C = 5\text{m}^{-1}$, $\phi_B = 2\text{m}^{-1}$, and $d_{AB} + d_{BC} = d = 0.5\text{m}$ (fixed). Plot the power of the composite element against d_{AB} for $0 \leq d_{AB} \leq d$. (You may ignore lens thickness).