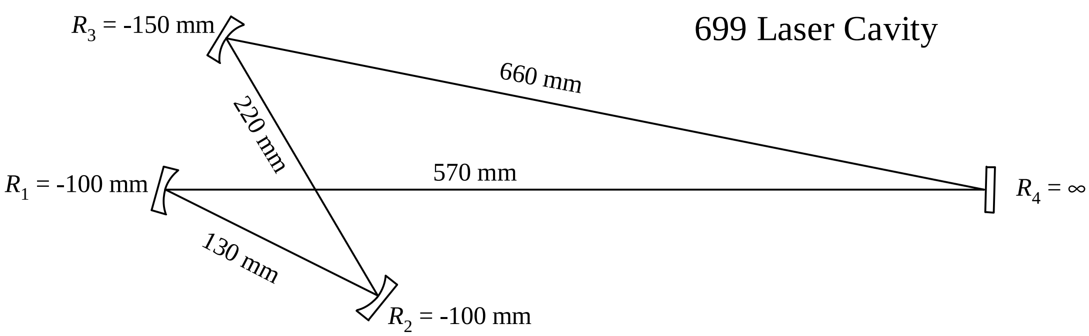
Phys 532 Assignment 1 Due January 23

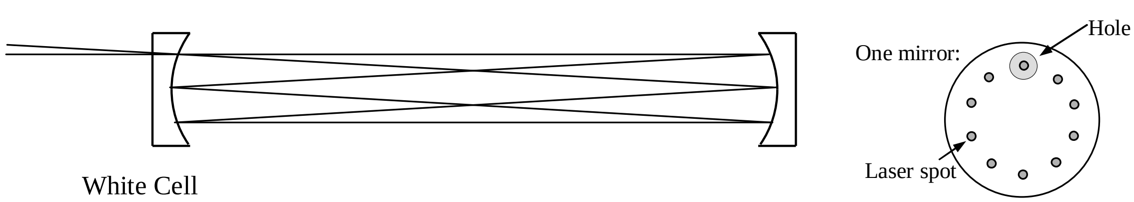
1. **Ray Matrices.** (a) Use Snell's Law to derive the ray transfer matrices for a spherical dielectric surface, Saleh and Teich Eq. (1.4-5).
(b) Using ray matrices, calculate the focal length of a thin lens constructed of a material having index of refraction n. The radius of curvature of the first surface is R_1, and the second surface is R_2. (Note that Eq. (1.2-12) gives the correct answer, but I want you to derive it using the matrix technique.)

2. **699 Cavity Stability.** The Model 699 laser from the Coherent Laser Corporation is a typical commercial ring laser. The cavity in this laser consists of four mirrors in a "bowtie" configuration, as sketched below.
(a) Show that the cavity as shown is optically stable.
(b) Find the range of values R_1 could take such that the the cavity remains stable. You may assume that the angles of incidence on the mirrors are small enough to be paraxial. Suggestion: calculate the required matrices using a computer.



3. **White Cell.** A White cell is an optical cavity consisting of two mirrors, one of which has a small hole through which light can pass unimpeded. It is possible to introduce a laser beam through the hole such that it bounces back and forth between the two mirrors many times before exiting. This is often used for spectroscopic applications to give an increased interaction length. The condition for multiple bounces to occur involves the same considerations as the stability analysis of a closed optical cavity. (Note that the two transverse directions can be treated independently in the paraxial limit.)

If a White cell is constructed with identical mirrors separated by a distance $d = 20$ cm, find all possible values for the radius of curvature R of the mirrors such that the ray trajectory is periodic and the beam hits each mirror ten times before exiting.



4. **Gaussian Beam Waists.** Suppose a Gaussian laser beam with wavelength λ and total power P is focused in the plane $z = 0$ with a waist W_0. The beam is directed at a target a distance d away.
(a) Find the value of W_0 such that the peak intensity on the target is maximized.
(b) Evaluate this W_0 if $\lambda = 532$ nm and for $d = 1$ cm, 1 m, and 100 m.

822 students only:

5. **Ray Matrices for Arbitrary Angle of Incidence.** Ray matrices are only defined for paraxial rays, but their use can be extended to certain non-paraxial situations. To illustrate this technique, consider light incident at arbitrary angle ϕ_1 on a spherical boundary of radius R between materials with indices n_1 and n_2, as shown. Specifically, ϕ_1 is the angle of incidence of the optic axis. The axis itself must be calculated exactly using Snell's Law, but consider nearby rays with with displacement $y \ll |R|$ and angle $\theta \ll 1$, with both y and θ measured from the optic axis. In this case, the deviation of the the output ray can be expanded to first order in the input ray variables, yielding a linear relationship that can be expressed with a matrix.

Use this idea to calculate the ray matrix in the simple case $R \to \infty$, where the boundary is planar. It is easiest to calculate two elements of the matrix at a time: the A and C elements can be determined by setting $\theta_1 = 0$, while the B and D elements can be determined with $y_1 = 0$. This approach is easier than solving the general problem for nonzero y_1 and θ_1.

For your reference, Siegman gives a tabulation of ray matrices for various elements at arbitrary incidence angle, though he uses a slightly different convention than Saleh and Teich.