MASSACHUSETTS INSTITUTE OF TECHNOLOGY

2.710 Optics **Fall '04**

Problem Set #2 Posted Sept. 15, 2004 — Due Wednesday, Sept. 22, 2004

1. **The spoon** Compare the image of yourself that you observe looking at the convex surface of a spoon with the image from a flat mirror. Do some simple raytracing to explain the difference.

2. **Anamorphic demagnifier** Consider the geometry shown in Figure 2, which uses a right-angle prism to laterally translate a horizontal incident ray. The ray experiences TIR at the first two glass-air interfaces and exits at the third interface. The prism has index of refraction n and a tip angle θ.

   a) Show that a horizontal ray bundle is compressed in the vertical direction only. Such optical systems are called anamorphic. Draw a sample input image and how it might look after passing through the anamorphic prism. Is the image erect or inverted?

   b) Show that the ray exits with horizontal orientation if either of the following conditions is satisfied:

$$n = \frac{\cos\theta}{\cos 3\theta} \Longleftrightarrow \cos\theta = \frac{1}{2}\sqrt{3 + \frac{1}{n}}$$

   c) Show that the above conditions are consistent with the ass umption of TIR at the first two interfaces and exit at the third interface.

   d) Show at the vertical demagnification ratio is

$$m = \frac{h_2}{h_1} = \frac{n}{1 + 2n}$$

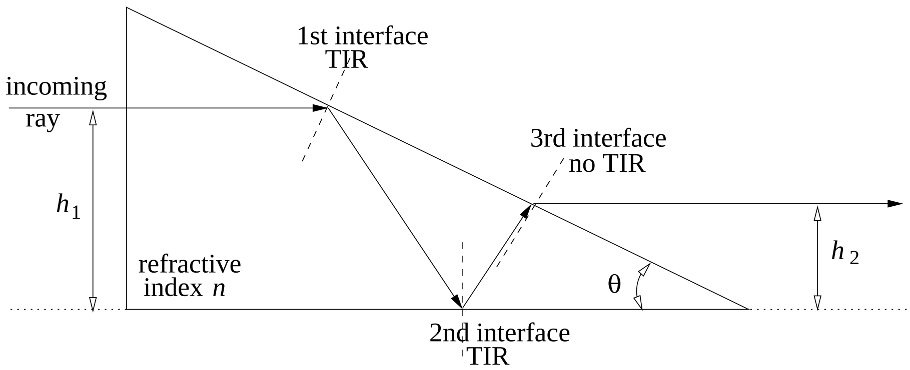

Figure 2

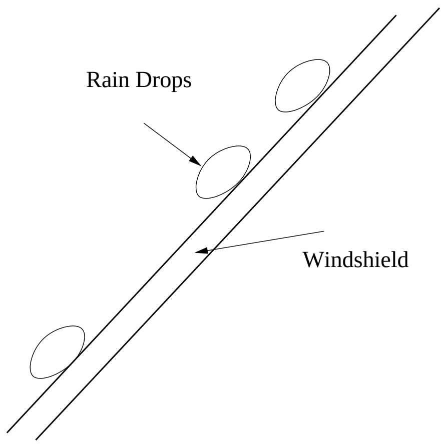

Figure 3

3. Design an optical system which can detect the amount of water present on a car's windshield to adjust the wiper speed.

Hint: indices of refraction $n_{\text{glass}} = 1.5, n_{\text{water}} = 1.33, n_{\text{air}} = 1.0$.

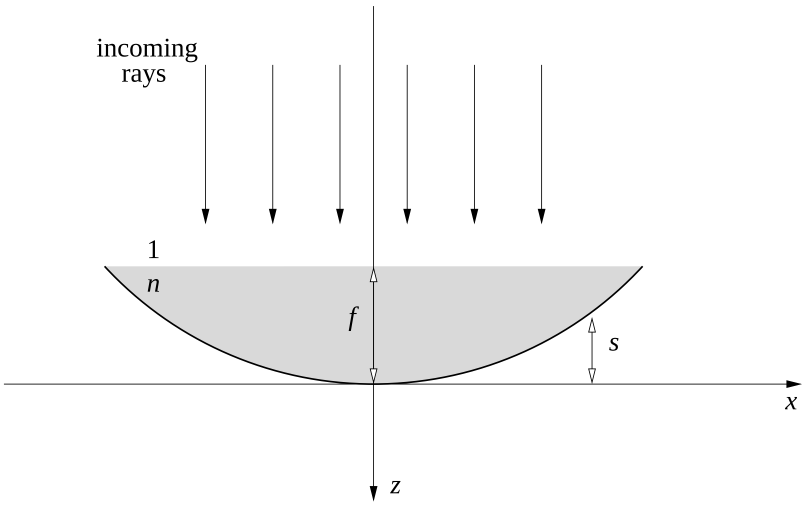

Figure 4

4. Lens-in-a-pool Consider a perfectly focussing one-dimensional paraboloid mirror filled with a fluid of refractive index n. The mirror surface is described by the equation $s(x) = x^2/4f$, where f is the focal length of the mirror. The fluid is present up to a height of f. Light is incident from the top as shown in Figure 4. You may neglect the slight reflection that occurs when the light rays go from the air into the fluid.

a) Calculate the portion of the incoming ray bundle which will exit from the fluid as a divergent ray bundle after focusing.

b) Show that the remaining rays will exit as a parallel ray bundle.

c) Suppose that the incoming ray bundle is shadowed by the letter “A.” If you placed a camera just above the focal point (in air), what would you observe? You need not write any equations, just reason qualitatively.