1/12/15 Ken Intriligator's Phys 4D Lecture outline

⋆ Reading: Volume 1, chapters 26 and 27, of Feynman Lectures (see link on class website). Giancoli chapters 32 and 33.

• Last time: can use Fermat's principle to get Snell's law of refraction: $n_1 \sin\theta_1 = n_2 \sin\theta_2$. Lifeguard analogy example: path of minimum time determined by $v_{sand}^{-1} \sin\theta_1 = v_{water}^{-1} \sin\theta_2$.

• Another way to get Snell's law: light carries momentum proportional to $\vec{k}$ (can be seen either classically, from momentum conservation, or quantum mechanically). Let the interface between n_1 and n_2 be $y = 0$, and the incoming light has $\vec{k}_1 = k_1(\sin\theta_1, -\cos\theta_1, 0)$ and the refracted light have $\vec{k}_2 = k_2(\sin\theta_2, -\cos\theta_2, 0)$. As we discussed last time, $\lambda = \lambda_{vac}/n$, so $k_1 = k_{vac}n_1$ and $k_2 = k_{vac}n_2$. Snell's law is then equivalent to $k_{1,x} = k_{2,x}$, i.e. the x-component of momentum is conserved. This makes sense, since momentum conservation is related to translation symmetry (you'll learn more about that in upper division physics, and the interface at $y = 0$ preserves x-translation symmetry.

• Total internal reflection. Basis of fiber optics, global communication network.

• Chromatic dispersion: smaller λ has bigger n, so different colors of white light get refracted at different angles. Why we see rainbows in Nature, or using prisms.

• Spherical refracting surface. Let object be distance d_0 from interface between index n_1 and n_2, where the interface has radius R. The image location d_i is determined, as before, from the condition that all rays take the same *time* (understand from Fermat), with $ct = n_1L_1 + n_2L_2$. Use same argument as in mirror to find L_1 and L_2

$$L_1 \approx d_o + \delta + y^2/2d_0, \qquad L_2 \approx d_0 - \delta + y^2/2d_i, \qquad \delta \approx y^2/2R,$$

The condition that t is independent of y then determines

$$\frac{n_1}{d_o} + \frac{n_2}{d_i} = \frac{n_2 - n_1}{R}.$$