1. How many Calories do you need in a day to sustain your body temperature? Estimate the number of calories per day that you expend in activity. What is your weight loss if you eliminate 100 Calories from your daily diet?

2. Use the law of least time to show that, when light travels from one homogeneous medium to another in which the speed of light differs, the ray bends in such a way that \( \frac{\sin \theta_1}{v_1} = \frac{\sin \theta_2}{v_2} \). Since the \( \sin \) function is limited to values between 1 and -1 and, if \( v_2 \) is greater than \( v_1 \), you can have situations with \( \frac{v_2 \sin \theta_1}{v_1} > 1 \). What is happening when that occurs?

3. A man is standing on a hot parking lot. The surface of the parking lot is so hot that it heats the air above it so that the air density changes and thus the speed of light varies linearly at a rate of increase of 0.1 times the speed of light in each foot of vertical distance as you move toward the ground from above. The man is six feet tall and is looking toward the ground so that the angle of a ray entering his eye is at \( \frac{\pi}{4} \) up from the horizontal. Opposite from him twenty feet away is a barrier. What height on the barrier is he looking at? Solve this problem by layering the atmosphere in layers that are 6 inches thick and assume that each layer is homogeneous. Hint: note problem #2

4. We want to examine the rays in a spherical mirror. On a piece of graph paper carefully draw a large semi-circle. A radius of 8 cm is a good size. Pick three points on the axis of the semi-circle, the object point is at a distance of 3/2 of the radius, and two potential image points, one at 1/2 of the radius and the second at 3/4 of the radius. For the two pairs, object/image_1 and object/image_2 draw three rays from the object to the image points. Pick the first ray to strike the mirror at the vertex, the second ray to strike a point that is at the mirror 1/4 of the way out from the vertex along the axis and the third that is at the mirror 3/4 of the way out from the vertex along the axis. For all rays, measure the ray path length. Discuss your results in terms of Fermat least time. Also the point at 3/4 is the image point for an object at 3/2 of the radius of a spherical mirror. How is this observation related to your measurements? Discuss these results in terms of Fresnel Theory and Fermat’s Least Time Theory.

5. If you look at the image of an object in a mirror and cover up half of the mirror, only half of the image remains. However, if you project the image of an object on a screen using a lens and cover up half of the lens, you don’t lose half the image; you keep the whole image, although it is dimmer. Explain this using the properties of light rays you’ve learned in class. Does the description of this phenomena work in both Fermat Theory and Fresnel Theory? Does it pick one theory over the other?

6. In Figure 36 on page 58 in QED Feynman says that a lens is an optical system that has the time of the rays through all parts of the lens the same. In other words, you vary the
thickness of the lens so that the off-axis rays take as long as the on-axis ray. For two points separated by 1 m and a lens that is to be 8 cm in diameter, draw 9 equi-spaced rays and find the thickness of glass that has a speed of light that is $\frac{3}{4}c$ that has to placed in each ray to be a lens. Now do this analysis analytically and find the formula for how the thickness of the glass should vary with the distance from the axis. The analysis is a lot easier if you use the approximation from the list of “Things That Everyone Should Know” that $(1 + x)^n \approx 1 + nx$ for $x \ll 1$ for $\sqrt{\frac{D^2}{2} + h^2}$ where $D$ is the distance between the points and $h$ is the distance of the ray from the axis.

7. Draw a diagram like the first one in Fig. 24 on page 43 of QED, but draw in only the light ray that takes the least time path. Call the point where the ray hits the mirror P. Make your mirror 6 inches long and place the points 2 inches above the mirror and 4 inches apart.

(a) Given the frequency of light is $4.5 \times 10^{10}$ Hz, find the point to the left on the mirror closest to P such that the path that reflects from that point and the path that reflects from P are in phase. Then find the next two points to the left of P nearest to P such that the paths reflecting from these points are in phase with the one from P. Now find the next three points to the right of P having the same property.

(b) I have a mirror and two points, at one of which is a light source of a given frequency and at the other is a screen. I also have a quantity of black paper with which I am to cover up half of the surface of the mirror such that the bright spot on the screen becomes brighter than when the mirror is not covered. Where do I put the paper? (The paper doesn’t need to remain in one piece.) By doing this, you have constructed a diffraction grating, as discussed by Feynman in QED. (Look there for hints to this problem.) Compared to the brightness when the mirror is not covered how much more intense is the light after the screen is covered? Elaborate.

8. In the discussion of mirrors and diffraction gratings, Feynman treats the objects as if they were one dimensional, a line. In actuality, they are two dimensional, a plane. How come he does not have to worry about the other dimension? Isn’t the entire surface used.

Home experiment #3 In lecture, we made a sunset. I mixed some sulfuric acid into a beaker of water on the overhead projector with sodium thiosulfate dissolved in it. Describe what happened.