World of Light - Problem Set #4

Assigned April 29, due at start of class on ***Wed. May 6***.

Reading

Light Science chapters 3 and 4.

Topics and equations

This problem set reviews the following topics: reflection, refraction, dispersion, mirrors, lenses, real and virtual images, and Fermat's principle of least time. It requires the use of the following constants and equations:

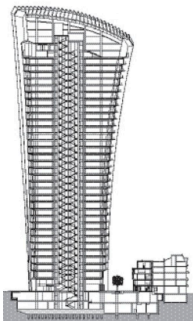
speed of light in vacuum = $c = 3\times10^8$ m/s

$$v = \frac{d}{t} \qquad v = \lambda f \qquad v = \frac{c}{n} \qquad a^2 + b^2 = c^2 \qquad n_1 \sin\theta_i = n_2 \sin\theta_t$$

Problems

Grading scale: basically right = 1 point, basically wrong = 0 points, some right and some wrong = 0.5 points.

1. A new skyscraper in London, called "20 Fenchurch Street" after its address, has a south-facing concave curved exterior. This building has been found to focus sunlight sufficiently well to melt parts of cars that were parked in the wrong places. The building's facade is vertical at the ground and has a radius of curvature of about 540 m. (a) What is the focal length of this mirror? (b) Where is the sun's image, relative to the base of the building, when the sun is to the south and on the horizon? (c) Is this a real image or a virtual image? (d) When the sun is 45° above the horizon (still due south), is the hottest spot on the ground closer to the building or farther away that when the sun was on the horizon?

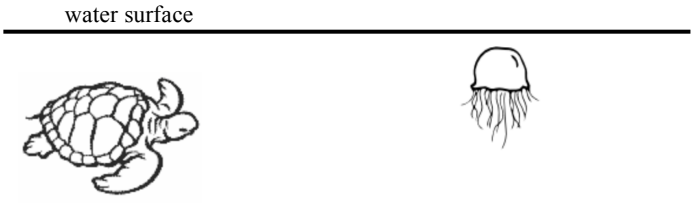


2. Modern car headlights are complex optical instruments, designed to put the right amount of light in the right places. However, for the most part, they aim the light from a small bright halogen lamp filament to a collimated beam. Assume a simple design for this. (a) What shape is the reflector behind the light bulb (e.g. spherical, corner cube, parabolic, flat, convex)? (b) Should the filament be at the focus or elsewhere; if elsewhere, where? (c) There is a separate filament for "high beam" output. Is this high-beam filament above or below the low-beam filament (hint: draw a picture)? (d) The

reflector usually extends out ahead of the light bulb. How much of the light emitted by the filament is directed into the collimated beam (0%, <50%, 50%, >50%, or 100%)?

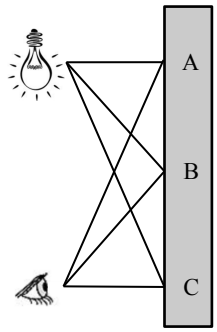
3. A "full-length mirror" is a flat mirror that is large enough so that you can see your entire body in it, from head to toe. Consider a woman who is 170 cm tall (5'6") and whose eyes are 10 cm below the top of her head. (a) What is the minimum length of this mirror (in cm)? (b) How high should the top of the mirror be mounted above the floor (in cm)? (c) Does you answer depend on how far this person stands from the mirror? (Hint: see the book, figure 3.9.)

4. From underwater, the surface of the water can act as a mirror. Consider a sea turtle which is looking at a jellyfish that's near the surface of the water. (a) Will the image that the turtle sees be a real image or virtual image? (b) Will the image of the jellyfish be left-right reversed, up-down reversed, both, or neither?



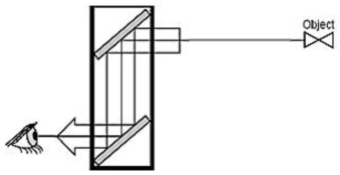
5. (From the book, p. 75). What types of mirrors (flat, convex, or concave) may be used to (a) converge light rays, (b) diverge light rays (more than for no mirror at all), (c) neither converge nor diverge light rays, (d) form a real image, (e) form a virtual image, (f) produce an enlarged image, (g) produce a reduced image?

6. Suppose a room light is 2 m directly over your head and you are sitting 1 m away from a wall. Supposing the wall is a diffuse reflector, calculate the time that the light takes to get to your eye, in ns, for its reflection off of the wall at points (a) A, (b) B, and (c) C in the diagram. (d) Is there any point on the wall where the light takes less time than it does when it reflects at point B (use your intuition, guided by your prior results)? (e) Now suppose the wall is a specular reflector rather than a diffuse reflector. For the light that reflects off of the wall and goes to your eye, which point does it reflect off of?



7. A simple periscope has two flat mirrors that are parallel to each other. Consider a periscope that is 1 m tall, and you're looking at an object that is 5 m from the top

periscope mirror. (a) When you look at that object through the periscope, where is the object's image? (b) is this a real or virtual image? (c) Is the image right-side up or upside-down? (d) If there is text on the image, does it appear to be forwards or backwards? (e) How far away is the object's image? (f) Is the object's image larger, smaller, or the same size as the object?



8. (a) Write down Snell's law. (b) Draw a picture that illustrates Snell's law, with the angles of incidence and transmission labeled. (c) Does light go faster in air or in water? (d) Does red light or blue light travel faster in water?

9. Consider a laser, with a 640 nm wavelength, which is pointed straight down into water. The refractive index of water is 1.33. (a) What color is the laser? (b) What is the laser frequency in air? (c) What is the laser frequency in water? (d) What is the laser light speed in water? (e) What is the laser wavelength in water? (f) What color does the laser appear to be in the water?

10. Suppose you want to focus sunlight to start a fire, using a lens. (a) Do you want a concave or convex lens? (b) Will you be forming a real or virtual image? (c) Do you want a large diameter or small diameter lens?