HW 11 Solutions

Part 1

Ch. 23 P72

a) Image 1: The closest image is the one you see looking in any single mirror. Since you are 1.5 m from the mirror, the image appears 1.5 m behind the mirror. Thus it is *3.0 m* from you.

Image 2: The next closest image is the image of your back. Since you are 0.5 m from the mirror behind you, the image of your back is 0.5 m behind the mirror behind you. That means it is 2.5 m from the mirror in front of you. The image of the image is 2.5 m behind the mirror in front of you, making it *4.0 m* from you.

Image 3: This image is the image in the mirror in front of you of the image in the mirror behind you of the first image of the mirror in front of you. Image 1 we said was 1.5 m behind the mirror in front of you. That means it is 3.5 m from the mirror behind you. Thus the image of this image is 3.5 m behind the mirror behind you. That means that the image of the image is 5.5 m from the mirror in front of you. Thus the image of the image of the image is 5.5 m behind the mirror in front of you. That puts it *7.0 m* from you.

b) The first image is facing you. The second image is of you back, meaning it is facing away from you. The third image is facing you.

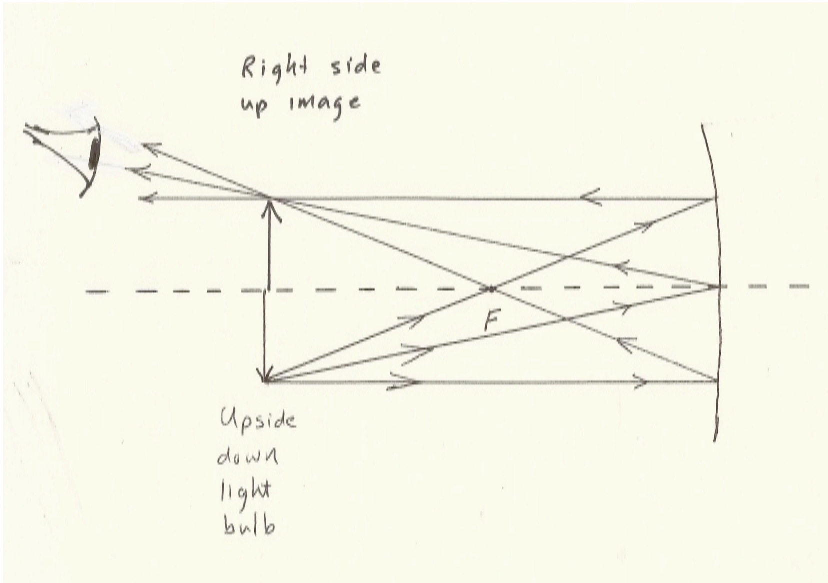
Thank you to Julia for pointing out that this solution ignores the thickness of the person.

Ch. 23 P7

The focal length is 18 cm, and f = R/2, so the radius of curvature of the spherical mirror is *36 cm*.

AP1) If the filament of the light bulb is placed at the focus it will produce an image at infinity, which is equivalent to producing a beam of parallel light rays. Since the radius of curvature is 5.0 cm, the focal length is 2.5 cm. Thus to produce a beam of *nearly* parallel rays, the filament should be *approximately* 2.5 cm from the center of the mirror.

AP2)



The image is inverted relative to the light bulb, which makes it right side up. The image is at the same distance as the light bulb and it is the same size, so to the eye, it looks just like a regular light bulb.

Part II

Ch. 23 P9 The diameter of the ball is 9.0 cm, so the radius is 4.5 cm, so the focal length is 2.25 cm, which is conveniently written as 9/4 cm. The ball is convex, so when using the "mirror equation" ($\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}$) we must put in f = -9/4. We get $\frac{1}{30}+\frac{1}{d_i}=\frac{1}{\left(\frac{-9}{4}\right)}=\frac{-4}{9}$.

A common denominator is 90 so we have $\frac{3}{90}+\frac{1}{d_i}=\frac{-40}{90}$, which says that $\frac{1}{d_i}=\frac{-43}{90}$, and therefore $d_i=\frac{-90}{43}=-2.09$cm.

Using the image distance to find the magnification, we have $m=-\frac{d_i}{d_o}=-\frac{-2.09}{30}=+.070$

Since d_i is negative, the image is 2.09 cm *behind* the lens and is *virtual*. Since the magnification is positive, the image is *upright*.

Ch. 23 P11 The object distance is d_o = 2.20 cm. The desired image is upright, so the magnification must be positive. Thus m = +4.5. Using m = $-d_i/d_o$ to solve for d_i gives d_i = -(+4.5) × (2.20 cm) = -9.9 cm.

Now you can use $\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}$ to find f: $\frac{1}{2.20}+\frac{1}{-9.9}=\frac{1}{f}$. Solving gives f = +2.83 cm.

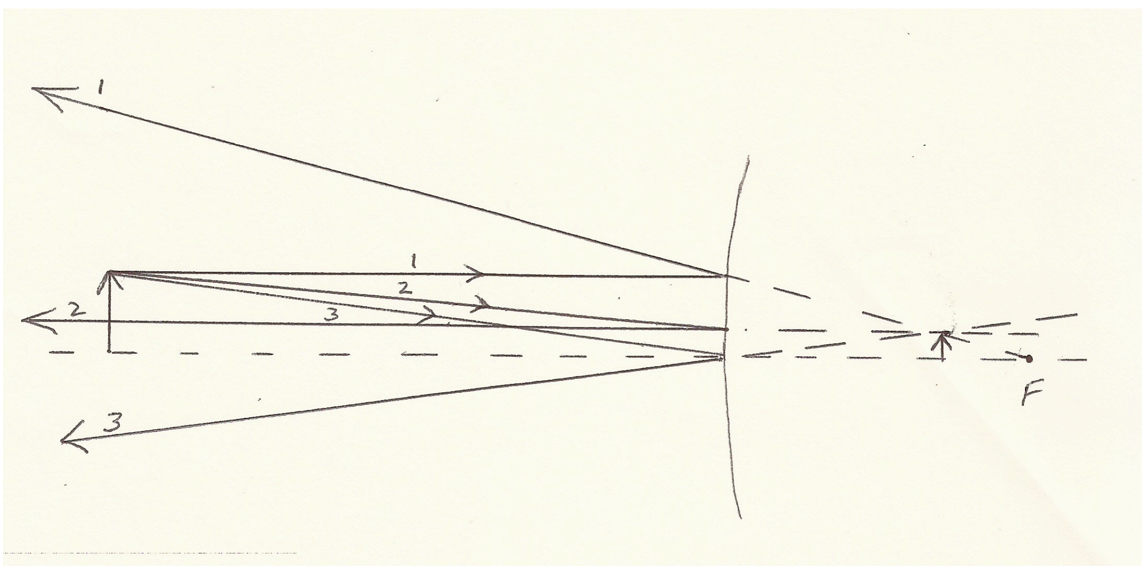
Since f is positive, the mirror must be *concave*. The radius of curvature is twice the focal length, so R = 2 × 2.83 cm = 5.66 cm.

Ch. 23 P12 The mirrors produce upright smaller images, which is enough to tell you that they are convex, but we can show it mathematically too, and we have to do the math to determine the focal length, so here goes.

d_o = 20 m. Magnification = m = +0.33. It must be positive since the image is upright. Using $m = -d_i/d_o$ to solve for d_i gives d_i = -6.6 m. Now you can use $\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}$ to find f: $\frac{1}{20}+\frac{1}{-6.6}=\frac{1}{f}$. Solving gives f = -9.9 mm. Thus the mirror is convex and the radius of curvature is 2 × f = 19.8 m. Notice that this is a very large radius of curvature, meaning the mirror is almost flat. To look at one of these mirrors on your car you would probably not notice that it was at all curved, except for the fact that the image produced is smaller than you would get from a flat mirror.

Ch. 23 P13

a) Since the mirror is convex, the focus is behind the lens. Since the radius of curvature is 20 cm, the focal length is -10 cm. I made the ray diagram at ½ scale in the horizontal direction, but used a different scale for the height of the object, otherwise the image would be so small it would be hard to draw it accurately. There are 3 rays shown. #1 goes parallel to the axis and reflects as if it came from the focus. #2 is aimed toward F and reflects parallel to the axis. #3 is aimed toward the intersection of the mirror and the axis. It reflects below the axis at an equal angle. One could also draw a fourth ray aimed at the center of curvature of the mirror, which is off to the right of the focus. This ray would reflect straight backward. I left this ray out for clarity.



From the diagram, the image is clearly virtual (no light actually emerges from the image). The image distance looks to be about 2/3 of the focal length, so about 6.7 cm behind the lens.

b) Using the mirror equation, $\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}$ gives $\frac{1}{20}+\frac{1}{d_i}=\frac{1}{-10}$. Common denominator is 20, so $\frac{1}{20}+\frac{1}{d_i}=-\frac{2}{20}$, which yields $\frac{1}{d_i}=-\frac{3}{20}$, and d_i = -6.67 cm, as predicted by the diagram.

c) The magnification is $m=-\frac{d_i}{d_o}=-\frac{-6.67}{20}=+.33$. The image size is thus 1/3 of the object size. Since the object size h_o = 3 mm, the image size is 1mm.