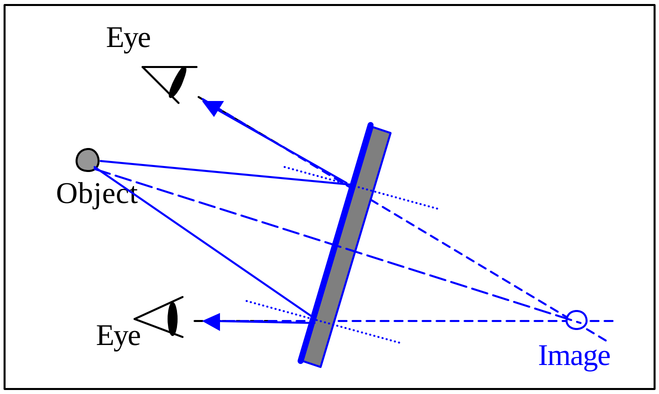
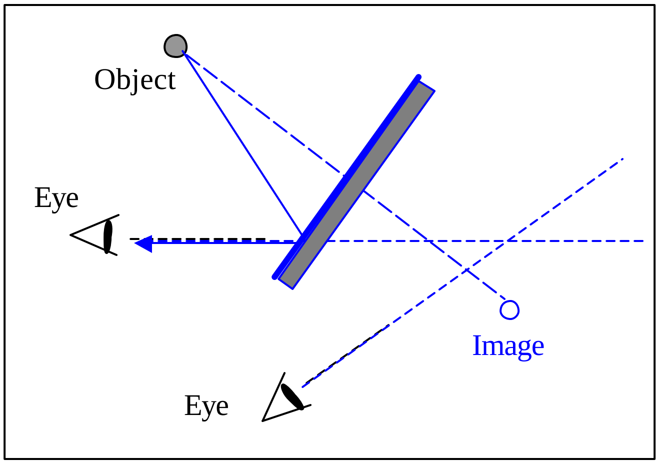
Physics 122, sections 502-4 and 8101 **Assignment 9 Solutions**
Laura Lising

Reference: Cutnell & Johnson, Chapter 25.1-3 and 26.1-2





1) The top view diagrams at right were drawn by a student who is studying image formation by a mirror. Each diagram shows the location of an object and two lines of sight to the image of that object in the mirror.

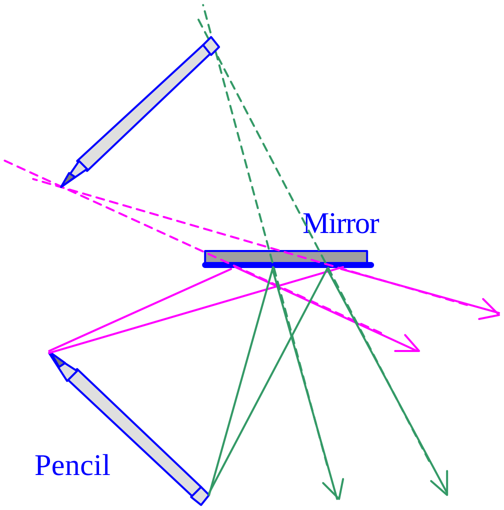
For each diagram, determine whether or not the situation illustrated is possible. If a situation is possible, draw the location and orientation of the mirror. Explain how you reached your conclusions.

The first thing to do is to figure out where the two observers would agree the image is. That's the place their lines of sight intersect. Next, you need to figure out if there is a way to get light from the object to both eyes in the designated directions. There are several ways to go about this, including trial and error.

It gets much easier though if you've done lots of these images in mirror drawings and noticed that for a flat mirror, the image is always an equal distance behind the mirror as the object is in front. In fact, if you draw a line between the object and image, the mirror is perpendicular to that line halfway between.

Once you place the mirror there, you need to check does it make sense with the model. Does the light from the object bounce off at equal angles and hit the observers in the eyes in the specified directions? Drawing little perpendiculars at each point makes it clear that it does work for the first diagram. For the second diagram it works for the upper observer, but not the lower one. The lower observer is on the opposite side of the mirror as the object!

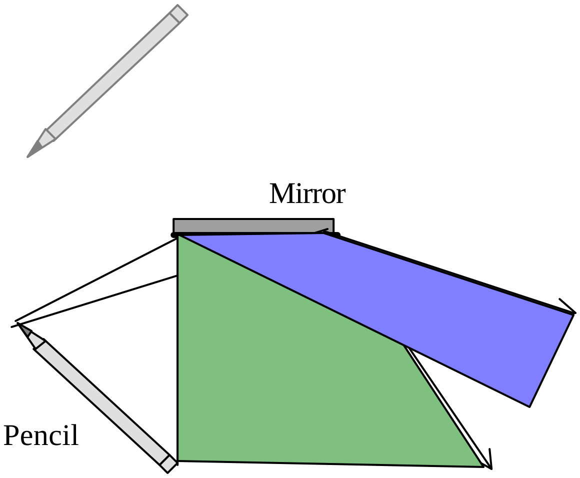
2) A pencil is placed in front of a plane mirror as shown in the top view diagram below.



a) Duplicate this drawing on your paper and use ray tracing to detemine the location of the image of the pencil. Use a protractor and a straightedge to make an accurate drawing. Clearly indicate the entire image on your drawing.

From each point on the pencil, light is spraying out in all directions. First try the point of the pencil. Choose a few rays that will hit the mirror, carefully draw the reflected rays, and then follow those reflected rays back to where they intersect. That is where you'd see the point of the pencil. Now do the same for the eraser. You could do this for every point on the pencil but you don't really need to.

b) Draw a separate diagram and determine the region in which an observer must be located to see (i) the image of the tip of the pencil, (ii) the image of the eraser, and (iii) the image of the entire pencil, if possible. Clearly label each region on your diagram and explain your reasoning.



The question is where the light can hit the observer in the eye. In the one shaded region, light from the tip can hit an observer in the eye, in the other light from the eraser. Where the two overlap is where you could see both ends, and everything in between. (Note that you could answer the question by thinking of the mirror as a window you’re looking through, trying to see the image pencil.)

c) We made a definition of image in class and for a plane mirror, we found that the image is behind the mirror always, as it is in this problem. What does this mean "the image is behind the mirror"?

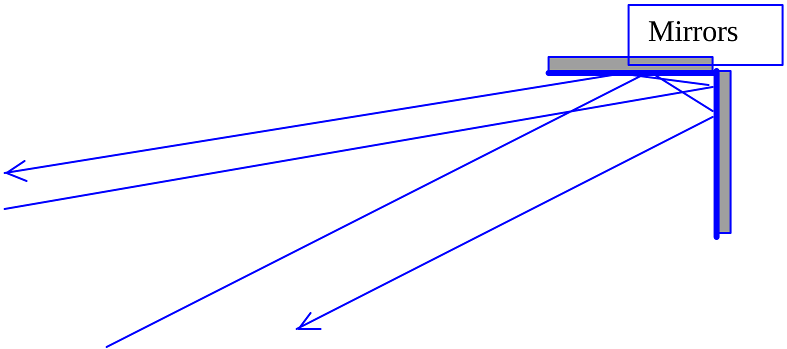
Simply put, this means that your brain thinks that the light is coming from behind the mirror since it expects straight lines. It just looks like there's an actual object there even if the mirror is mounted on a solid object. That's where all observers would agree (if they can see it) that the image is. But it doesn't mean that there's actually light back there. In the case of a flat mirror, no light from the object goes behind the mirror. It bounces off the surface and comes back the other way. So, the image location in this case isn't actually where the light is coming from. (That is true for some images, "real" ones.) Thus this is a "virtual" image.

3) Consider two mirrors arranged at right angles.

a) Imagine shining a flashlight or laser with a fairly narrow beam at one of the mirrors. What happens to the light? To figure this out, choose a location and draw a flashlight there and draw where the light goes. Now choose another location and draw a flashlight there and do the same thing.

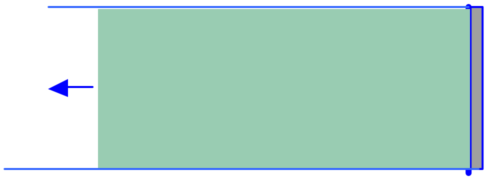
What happens to the light? What can you say about this arrangement of mirrors and what it does to light?

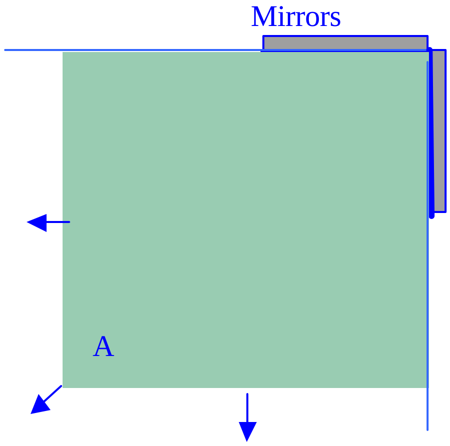
I showed a couple of locations: The light comes out parallel to the direction it went in. The two reflections make for a 180-degree turnaround.



b) If you were looking at the mirrors, where would you need to stand in order to see your reflection?

Any where in the green region you could see yourself, and this extend on to the left and below. Unlike a single mirror where you can only see yourself directly in front of the mirror, with this arrangement you can see yourself at positions like point A because the light will make this 180-degree turn back to you.



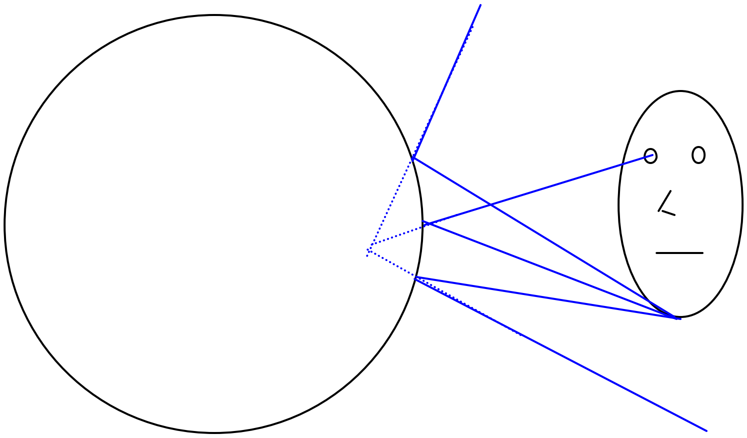


c) Thinking what this arrangement of mirrors does to light, think of two possible applications in real life. (These are actually used for lots of things. More common is the 3-D version, with three mirrors, often quite small, arranged all at right angles to each other like at the corner of a room. This is called a "corner cube.")

Any application that needs light to go back the way it came. Corner cubes are used for bicycle reflectors so that light from car headlights and such goes back toward the car where the driver can see the bicyclist. They can also be used to measure the distance to distant objects like the moon. There is a corner cube array on the moon and when we shine a laser on it the light comes back to us. We can measure the time to get the distance.

6) We did the front of a spoon, now do the back. Or imagine looking at your image in a shiny sphere. Make a sketch that shows how light leaves your face, hits the sphere, and bounces back to your eyes and elsewhere. Use the sketch to show why the image is small and right-side up. Is it a real image or a virtual one (meaning, does the light pass through the location where the image is or not)?

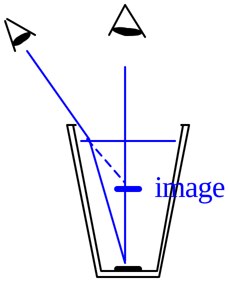
The light bounces off the sphere, out at the same angle it came in (relative to the spot on the sphere it hits). And we see the light as coming from the point where all the lights of sight intersect. So the image of the chin is at the point where the sight lines of the reflected light from the chin intersect behind the mirror; same for the top of the head.



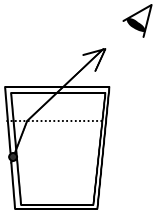
5) Get an opaque cup of some sort - a styrofoam cup or a paper cup. Draw a dot on the bottom of the cup in the center. Get a second cup and fill it with water. Hold your head so that you can see the dot on the bottom of the cup, and then move your head back a little so that you can no longer see the dot on the bottom. (Your eyes should now be in a position like the one shown.) Now, holding your head still, pour the water from the other cup into the one with the dot.

a) Explain what you see and why. Draw a picture of the cup, the water, your eye and the dot, drawing what the light is doing.

Before you pour in the water, the light from the dot can't get to your eye; with the water in, the light refracts at the surface, and then can hit you in the eye. If you actually wanted to find out where the image of the coin is (where your brain thinks the coin is) you can trace the ray into your eye backwards and also look at another one. An easy on is the vertical line, which won't bend. These intersect at a position above the coin. This makes sense because without the water at the angle you were looking you couldn't see the coin, but now it's like it's a shallower cup, so you can see the bottom at that angle. This also explains why pools look shallower than they actually are.

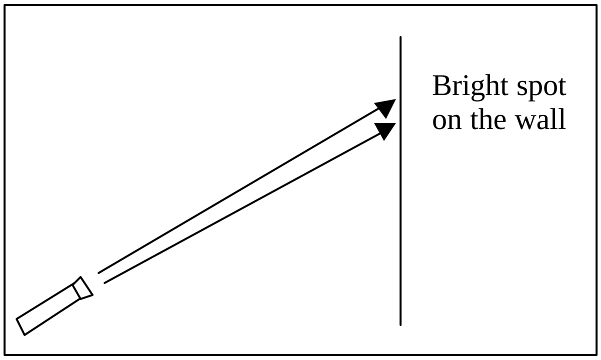


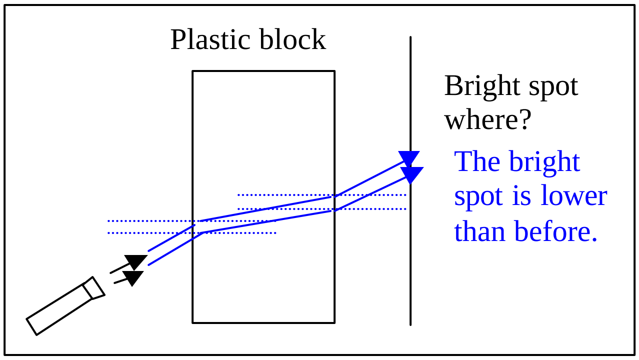
b) Try this again, but this time draw the dot on the side of the cup instead of the bottom. Before you pour the water in, predict what will happen and make a drawing to support your prediction.



Same thing: Light leaving the dot refracts at the surface.

6) Suppose you have a flashlight or a laser and you hold it at some angle and shine it on the wall, observing a bright spot at some height.





a) Suppose you know put a clear plastic block between the flashlight and the wall. Where would the bright spot be? At the same height or different? If different, how? Draw ray diagrams and explain your reasoning.

When the light hits the plastic block it bends (refracts). Since the plastic has a higher index of refraction, the light bends toward the normal (perpendicular) line. Then, when it reenters the air, it bends away from the normal. This bend ends up bending back to the original angle, but now it is lower than before so the spot on the wall is lower.

b) Suppose now you have a triangular shaped plastic block in between the flashlight and the wall. Will the spot be higher, lower, or at the same height as the spot with no plastic? Explain ….

The story is the exact same as before except now the normals are different on the different sides because the surfaces are not parallel The light bends toward the normal upon entry. The normal for the first surface is horizontal since the surface is vertical. But the normals for the second surface are tilted since the surface is. So instead of away from the normal being up as before, away from the normal is down. So the spot is much lower than before.