Tutorial Instructor's Guide

How to tell where things are by looking (Mirrors)

Equipment:

- Short pencils ("golf pencils" are good) or large nails (three or four inches long), with clay blobs or something else that lets them stand on the table without being held up by a person. Two pairs of identical items per table.
- Small mirrors (about 2x3 inches), with stands or binder clips so that they can stand on the table without being held up by a person. The base of the mirror needs to be flush with the table. The mirror needs to be shorter than the pencils or nails you're using. Two per table.
- Butcher paper or 11x17 paper, a plentiful supply.
- An enlargement of the diagram for part II.C (attached). One per table per section (students will draw on them).
- A ruler and a protractor. One each per table.

I. In this part students are introduced to the idea of an image and apply the model for seeing an image to a simple situation.

Go ahead and have all the equipment on the tables at the beginning of tutorial, including clean butcher paper.

A-C. Students usually do fine with these questions. Note the definition of the term *image;* it seems innocuous now, but will become important later.

Students already know that the angle of incidence equals the angle of reflection and usually apply the idea correctly. Sometimes students think the reflected beam always makes a right angle with the incident beam and will draw a little square on their diagram to show this. Question B.2 can help address this (move the card to change the incident angle – at some point the right-angle answer will look clearly wrong).

II. In this part students determine location by crossing lines of sight. They do this in the context of a real but inaccessible object, and then again for a mirror image. The same technique applies to both. This analogy is powerful, and leads to a conclusion that is totally counterintuitive to many students **and some TAs.**

A. This part is so brainlessly easy students wonder why they're being asked to do something so silly. The tutorial acknowledges this and asks for their patience.

Nifty bonus question about the Mel and Taylor technique:
Can you think of any situation in which the Mel and Taylor technique would be used by real people? Hint: You use it yourself. (Answer: Mel and Taylor are your two eyes, and the technique is what gives us stereo vision. Animals whose eyes are on the sides of their head don't use the technique.)

B. This exercise is the first of several in this tutorial in which students try to determine the location of an image in a mirror. Many students **and some TAs** are quite certain that the image is on the surface of the mirror; after all, there's "nothing behind the mirror." These students often need several forms of evidence to decide otherwise. This particular exercise provides one piece of evidence, but if it's not conclusive for some students, that's all right.

1. This is meant to be an elicitation question; if students say the image is on the surface of the mirror, that's okay for now. Those students will claim that the image location changes when they move their heads ("first it's on the left side of the mirror and then it's on the right side of the mirror"). This will seem stupidly obvious to them. TAs should not correct, just elicit.

   TAs should check that students can explain how the Mel and Taylor technique could be applied to this situation by having students actually put the mirror and the pencil on the butcher paper and draw the appropriate lines of sight with rulers. Some students are looking at the wrong pencil (the real one instead of the one in the mirror). Others are just not being careful about lines of sight, assuming they cross at the surface of the mirror rather than actually trying it. Some are not drawing straight lines of sight, which lets them conclude whatever they like.

   Some students still don't believe the image is behind the mirror, even after the evidence of the Mel and Taylor technique. That's fine. There will be other evidence.

2. This question is not meant to ask, "Where is the image really located?" but instead to ask, "What evidence should we use to decide where the image is located?" – which is a softer question, allowing students to cling to their wrong idea a little longer if they want to. ☺

C. Students should use the enlargement of the diagram, not the one in the book, and should use actual rulers and protractors to make appropriate lines.

<u>*Checkpoint*</u>: TAs should check students on how the Mel and Taylor technique could be applied to the pencil situation (see II.B.1 above), and should find out where students think the image of the pencil is located and why. If they still think it's on the surface of the mirror, that's okay for now. If students in a group disagree, that's also okay. Students should, however, be held responsible for *correctly applying lines-of-sight reasoning*, whether or not they think it is the right reasoning for the image location.

III. In this section students learn the method of parallax.

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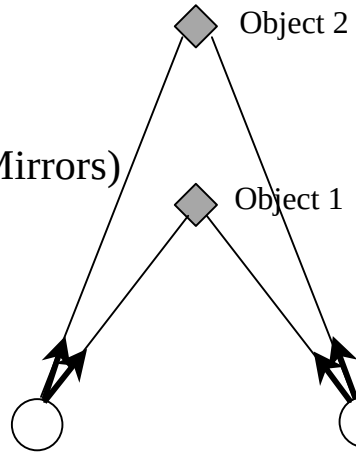

"Mel" (or, head on the left)

"Taylor" (or, head on the right)

A. Students do fine with this part. For question 2, an appropriate answer is something like, "Whichever way you move your head, left or right, the thing that appears to move the same way as your head is in the back." Or, of course, the thing that moves the opposite way is in front. Be careful of "The thing that appears to move is in the front/back," because that depends a lot on what the observer focuses on.

B. This can be a hard question. The first part of the idea is that when you have your head on the left, you're Mel, and when you have your head on the right, you're Taylor. Then, if you draw a "Mel-and-Taylor" diagram of the situation (similar to the one in part II.A), you see that Mel sees the back object as being to the left of the front object, whereas Taylor sees the back object on the right. See the diagram at right. In sum, similarities are that in both cases there are observers in two different positions noting their lines of sight to an object; the differences include that there are two objects, and they're observing the relative positions of the objects rather than prioritizing the place where the lines of sight for one object cross.

C. Sometimes students get confused about which pencil they're supposed to look at or move around; or they just put the second pencil at the place they know the image to be, and don't know what to do after that. Students should follow the following physical steps: (1) Put the "object pencil" in front of the mirror. (2) Stick the other pencil somewhere behind the mirror. (3) Use parallax to figure out whether the second pencil is at the exact same location as the image of the pencil. If it is, you're done. If it isn't, scoot the second pencil in the direction your method of parallax indicated it needed to move (left, right, forward, or backward), and try again.

Nifty bonus question about parallax:
Can you think of any situation in which parallax would be used by real scientists? Hint: Astronomers use it. (Answer: They use it to tell the relative distance of stars. Challenge students to come up with the details. Second-level answer: For this application, it's not enough to move your head from side to side. Students often suggest using telescopes on different sides of the earth, which isn't bad except that it's probably daytime in one of those locations… and we can do better, which is to look at different times of year.)

IV. The idea is that this tutorial helps you to rethink automatic learned processes (locating objects) in terms of the physics principles and rules that supposedly govern those processes. It's interesting how many people initially think that their personal approach is *not* consistent with the physical laws (i.e. they think the Mel and Taylor technique doesn't apply to locating images in mirrors) – but then they find out that in fact the physical laws do apply after all. This is hopefully a valuable lesson, not only about mirror images, but about the relationship of physics to everyday life in general.