# Tutorial Instructor's Guide

## Can an image float in empty space? (Lenses)

<u>Equipment:</u>

- A dark room. (In 0220, remove the security lighting as in the *Model for light* tutorial, but leave the doors to the hall and the cave open for light sources. It should not be completely dark in there, and we need some lit objects to observe.)
- A black box that produces five diverging beams of light (a "beam box"). One per table.
- An assortment of lenses (concave, convex, large, small, one-sided, two-sided, etc) for each table.
- An assortment of mirrors (flat, concave, convex, spherical, semicircular, etc) for each table.
- Rulers, one or more for each table.
- Butcher paper or 11x17 paper for each table (a plentiful supply in the room).

This tutorial is a little different from others in the series in that it is much more open-ended. This is intentional; we want students to start being a little more independent about investigating phenomena, so we give them questions that are larger in scope, and scale back on the detailed instructions. It can be a little rocky for students **and TAs**, because everyone is used to fairly cookbook instructions by now and they tend to treat all questions as deserving only ten seconds of effort. Some of the exercises in this tutorial are quite complicated and challenging. **TAs should tell the students what to expect.**

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

I. In this part students investigate the effect of lenses and mirrors on light beams and account for the location of an image created by a convex lens.

A. This part is pretty observational and students do fine with it. They will need these results for the next part.

B. This part is hard, because students **and TAs** expect this to be a quick question (like most other tutorial questions), and it's actually the most difficult question in the tutorial. The difficulty is mostly in understanding what a useful diagram would be. People tend to just draw a picture of the situation without any careful treatment of the light beams. Tell them this is actually a pretty hard question and they should expect to spend some time on it. Have them make a trial version on their butcher paper using rulers. Tell them that their drawing should show not only why they see what they do, but why they *don't* see something else – that is, it should be good enough to rule out other possibilities, as well as accounting for the thing they do see. Their answer to question 3 should not be an intuitive guess, but rather should be something they can prove based on their diagram. This means they have to be able to interpret some features of their diagram, also. It's hard. Hold them accountable or they'll blow past it with little effort.

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Note: **TAs** (and maybe students as well – I'm not sure) often think the image is at the focal point of the lens. This tutorial doesn't bring up anything about focal point and TAs shouldn't bring it up unless students mention it, but fairly often it comes up on its own during TA preparation. You may want to help the TAs understand what's incorrect about this, in order for them to be prepared should it arise with the students.

Checkpoint: This is to check on their diagram for part B.2. A good diagram should show some specific object in the lit room; multiple beams of light coming from one point on that object, passing through the lens appropriately, and winding up somewhere else (those are enough to show the image location); and beams from some other point on the object, to show whether the image is inverted or not. Helper instructions can be along the lines of: *Pick a specific object in the lit room that you see on your screen. Draw what happens to the light that comes from that object. Use what you know from page 1. Use the Mel and Taylor technique.* Etc.

Possible reflection questions:
*What observations from the first page did you use here?* (How a convex lens bends light)
*What are you using from the tutorial about a model for light to draw this diagram?* (Objects emit light in all directions from every point on the object)
*Where are the techniques from last week coming in to your understanding of this diagram?* (Lines-of-sight reasoning, including the Mel and Taylor technique for locating images) *Where's your eye, in this picture?*

I. In this part students consider an image that isn't on a screen. They tend to see the image as *on the lens* in that case. (Try it yourself to see why someone might think that.) The point of this section is for students to decide that the image is in fact floating in empty space even though there is in some sense "nothing there."

A. Students should just reproduce the diagram from page 2, only with no screen.

1. Students sometimes answer this question correctly. Other times they say, they see the light as "coming from the object." (Okay, the light *is* coming from the object, but they would not *see the light as* coming from there. This can be a weird distinction for students.) If they answer this way, have them actually do it and point to what they see; for at least some directions, they won't be pointing at the object.

   Yet other students say they see the light as coming from the lens. For this answer, more theoretical questions are appropriate, since the image will in some ways look like it's on the lens. Try: *What does where you see something as being have to do with the crossing point? How did that work out for mirrors?*

2. Students are free to insist at this point that the image is really on the lens, or whatever they want. Try to get them to acknowledge their genuine feeling.

3. Students will hopefully be able to use the method of parallax reliably based on the last tutorial. Have them demonstrate to you how they're using it.

B. This question is, again, not meant to be a short question. Instead it is an invitation to explore the issues raised for the concave lens all over again for a convex lens. Students may need prompting to conduct this new investigation. We're trying to encourage independence, but we find we have to push them out of the nest a little.

*End of tutorial:*
Students who didn't recognize how hard some of these questions really are are likely to finish early for the wrong reasons. Hold them accountable for the ideas outlined above. Here are some questions for TAs to keep handy.

- *Where did you think the image formed by a flat mirror would be? Why? Where was it really? How did you decide? How is this like that? How is it different?*

- Pick an object from the assortment on the table (a mirror or lens of some kind) and ask: *Does this make an image? If so, where is it? If not, why not? Call me back when you can explain with both observations and a diagram of the light beams.*