Bizarre behavior with light

I have observed people with cameras undergoing some strange behavior.

a. When I was at a conference in North Carolina, one of the physics graduate students (who should have known better!) was trying to take a picture of the overheads projected on a white screen. Since the room was darkened, he used a flash. Explain why this is a bad idea and what his pictures are likely to show.
b. I mentioned to him that he probably should not be using his flash so he turned it off. He then proceeded to try and take pictures of the participants in the darkened room! Explain why this is a bad idea and what his pictures are likely to show.
c. I once observed a woman on an airplane at night with a camera. As we flew low over Washington DC she was impressed with the view of the city lights in the dark. She stood back in the aisle and tried to take a picture through the window using her flash. Explain why this is a bad idea and what her pictures are likely to show.

Measuring the speed of light a la Galileo

Galileo tried to measure the speed of light by having two people stand on hills about 5 km apart. Each would hold a shuttered lantern. The first would open his lantern and when the second saw the light, he would open his lantern. The first person would then measure how much time it took between the time he first opened his lantern and when he saw the light returning.

a. How much time would it take the light to travel between the two hills?
b. Is this a good way to measure the speed of light? Support your argument with a brief explanation that includes some quantitative discussion of the uncertainty in the measurement.

Speed of light and the GPS system

Although light appears to travel at a speed that is for all practical purposes infinite, for some modern purposes the time delay due to light travel time is of great importance. The Global Positioning System (GPS) allows you to determine your position from comparison of the time delays between radio signals from 4 satellites at a height of 20,000 km above the surface of the earth. (There are actually 24 of these satellites. Your GPS picks out the closest 4 to your current position.) In order to get some idea of how important the speed of light is in establishing your position with one of these gadgets, let's make some simple assumptions. Assume a satellite is almost directly overhead. Then let's figure out how far the satellite will move in the time it takes light (the radio signal) to get from the satellite to your GPS receiver. This estimates how far off the reading of your position would be if your device didn't include the speed of light in its calculations. To do this:

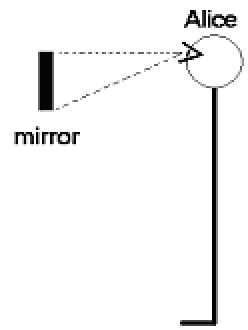
a. Figure out what speed the satellite must be going in to be in a circular orbit.
b. Estimate the time it would take for a radio signal to get from the satellite to your receiver.
c. Estimate how far the satellite would move in that time. If you ignored light travel time, this tells about how wrong you would get the satellites position (and therefore how wrong you would get your position).

Alice and the looking-glass

Alice faces a looking glass (mirror) and is standing at a level so that her eyes appear to her to be right at the top of the mirror as shown in the figure. At the position she is standing, she can just see her belt buckle at the bottom of the mirror. If she steps back far enough

a. she will be eventually able to see all of herself in the mirror at the same time.
b. she will see no change in how much of herself she can see.
c. she will see less of herself as she steps back.
d. some other result (explain)

Put the letter of the choice that completes the sentence correctly in the box at the right below and explain why you think so with a few sentences and some rays on the diagram.

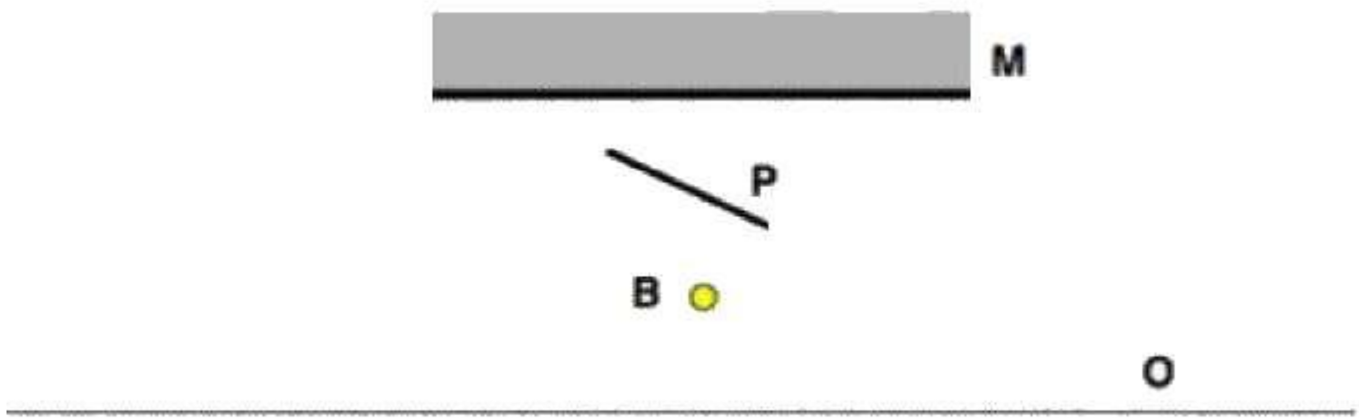


On the mirror

While doing a tutorial lesson on "How to find out where something is by looking," two students, Ethelred and Guinivere, answered the question, "Where does the image [in the mirror] appear to be located?" by saying "On the mirror." Do you agree with them or not? If you disagree, where would you say the image is and how would you justify your answer to them? If you agree, propose a different plausible position for the image in the mirror and explain why you prefer Ethelred and Guinivere's answer.

One more mirror

In the diagram below, M is a plane mirror, B is a very small bulb that can be treated as a point source, and P is an opaque plate that does not transmit light. O is a line anywhere along which an observer can stand to try to see the image of the light bulb in the mirror. By using relevant rays of light, determine the locations along line O from which the image of B is visible in the mirror and the locations from which it is not visible. Mark these regions accordingly along line O and explain your reasoning.



Bending Light – *PhET Simulation*

In the PhET sim *Bending Light*, there are two mystery materials, Mystery A and Mystery B. These materials appear in both the "Inro" and the "Prism Break" tabs. Determine what the index of refraction is for each of these materials and propose substances that fit these values. Describe clearly how you determined the two values of n including all calculations.

Snell's law for ultrasound

a. Snell's law correctly predicts the refraction (bending) of light as it moves from one homogeneous medium into another where the speed of light differs from the speed in the first medium. Discuss what has been assumed about the speed of light in a more dense medium in order to describe experimental observations.

b. We typically deal with sound that has wavelengths comparable to the objects it interacts with (on the order of a few centimeters to a few meters) so we don't usually talk about "sound rays" or Snell's law for sound. But if we are working with high frequency ultrasound, as is used currently in many medical probes, it would be appropriate to consider it. We are pretty certain of a couple of relevant facts about sound:
   - Sound propagates as a wave.
   - The speed of sound is greater in a dense medium.

   Discuss what this would means for Snell's law for sound. Do you expect a ray of sound coming onto a denser medium to bend towards the normal (like light) or away from the normal? Explain your reasoning.

c. Can we have the analog of total internal reflection for sound? If so, this could have severe implications for imaging using ultrasound. The speed of sound for some relevant media are given below. Determine which boundaries between two media could lead to total reflection of sound rays. Describe the configuration (entering from which medium) and find the angle above which total reflection occurs.*

Material	*Speed of Sound*
Air	330 m/s
Muscle	1600 m/s
Bone	4000 m/s

* Data taken from J. R. Cameron and J. G. Skofronick, *Medical Physics* (John Wiley & Sons, Inc., 1978) p. 255.