Creating An Inverting Lens from Water (Refraction)

Materials:
Paper
Marker/Pen/Pencil
Glass Cup or other Cylindrical Transparent Jar
Water
Flat-sided glass or transparent container (optional)

Instructions:

1. Fill the cylindrical jar halfway with water so that when you look through the side, you can see all the way through both the air and water portion.

2. Draw a horizontal arrow (pointing right) on a piece of paper that is shorter than the diameter of the jar.

3. Put the paper standing upright behind the cylindrical jar, with the arrow above the water. What do you see when you look through the air portion of the jar at the arrow on the other side?

4. Without changing the direction of the arrow, move the paper down so that the arrow can be viewed through the water portion of the jar. What do you see when you look through the water portion of the jar at the arrow on the other side? What happened? *(Optional: repeat this procedure 1-4 for the flat-sided container. Do you observe a different result than from the cylindrical container?)*

5. Draw other arrows going different directions, such as a pair of horizontal arrows where one goes left and one goes right (opposite directions) and perform the same experiment. What do you see for a pair of vertical arrows? Record what you see through the air and water portions of the jar.

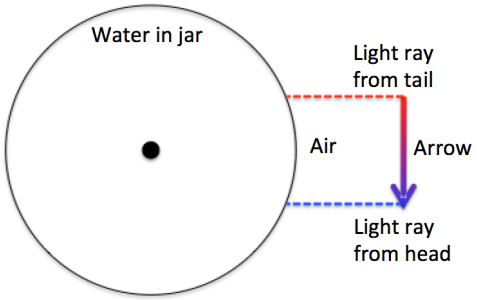
6. Feel free to draw other figures and shapes on the paper and see if you can predict what you will see through the air and water portions of the jar. Draw figures on the top part of the page (the air portion) and the bottom part of the page (the water portion) and look at these simultaneously through the jar.

7. Can you hypothesize why the arrow changes direction? Remember that in a single medium, light travels in a straight line.

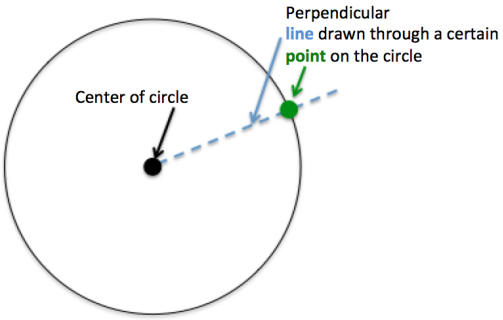
8. At the end of this handout is a top-down view of the jar (the circle) and an arrow at a height within the water portion of the jar. The side of the jar opposite the arrow is the observation side. Draw on that image while following these instructions to demonstrate why the arrow appears to an observer to be inverted through the jar.

    a. Draw two lines: one representing a light ray coming from the arrow head and one representing a light ray coming from its tail, both should be drawn straight to the circle.

These two straight lines should be parallel to each other. We will call these the "incident" rays (illustrated below).

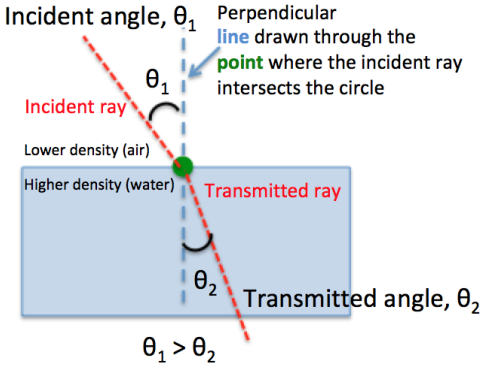


b. Now draw two lines that are perpendicular to the curved surface of the jar at the water/air interface at each point where each light ray intersects the circle. This can be easily done by starting each of these perpendicular lines at the center of the circle and crossing over the point where each light ray intersects the circle (one perpendicular is illustrated below).



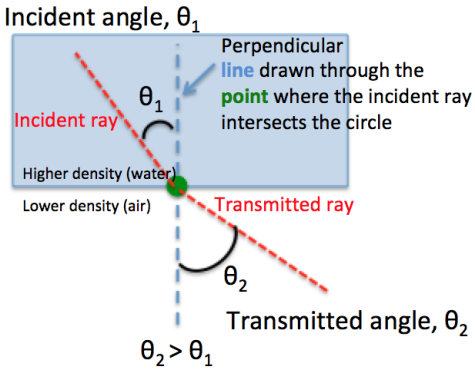
c. When light travels from a less dense medium (air) into a more dense medium (water), its speed slows down and it "bends" toward the perpendicular at the interface. This is called "refraction".

Now, draw an extension of each light ray into the water of the jar (and all the way across to the other side of the jar), making sure that the angle of the transmission ray with the perpendicular at the water entry point is smaller than the angle of the incident ray (illustrated below).



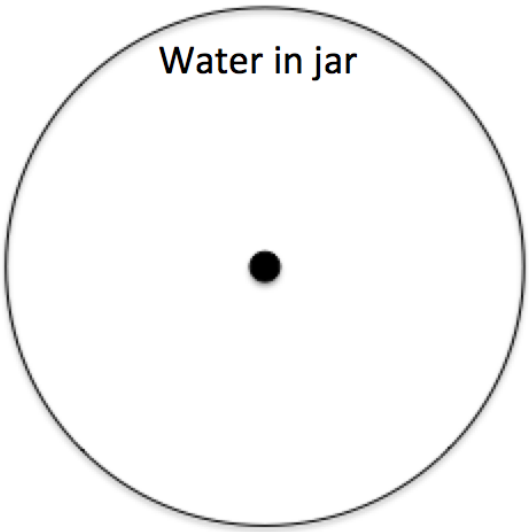
d. When light travels from a more dense medium (water) into a less dense medium (air), its speed increases and it “bends” away from the perpendicular at the interface. This is also called “refraction”.

Now, draw an extension of each light ray back out into the air from the water, making sure that the angle of the transmission ray with the perpendicular at the air entry point is greater than the angle of the incident ray (illustrated below). (Note that we now rename the ray in the water, which is now entering this new water/air interface as the “incident” ray.)

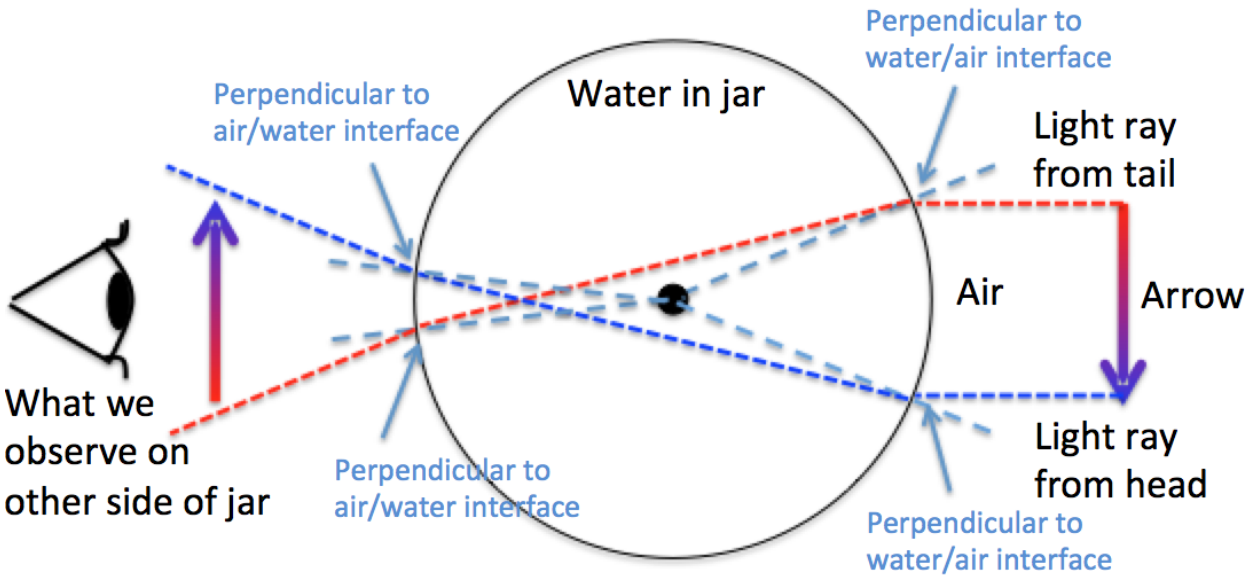


e. Now, you can draw an “image” arrow on the observation side. Put the arrow head at the ray that started at the head of original arrow and put the tail at the ray that started at the tail of the original arrow. Which direction is the arrow pointing? *(Optional: Repeat the procedure 8a-e for the flat sided container filled with water to explain the different results it gives you.)*

What we observe on other side of jar



Answer


Perpendicular to
water/air interface
Water in jar
Perpendicular to
air/water interface
Light ray
from tail
Air
Arrow
What we
observe on
other side of jar
Perpendicular to
air/water interface
Light ray
from head
Perpendicular to
water/air interface