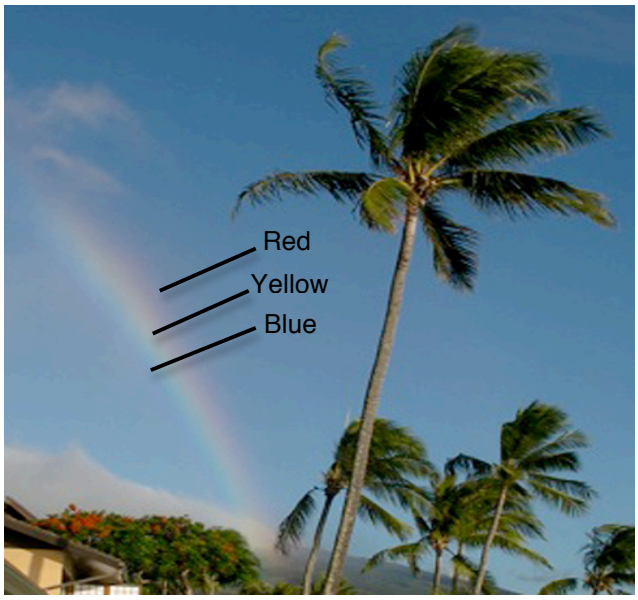
Rainbow Models



This writeup deals with the construction of two physical models intended to aid in understanding two major characteristics of an an ordinary primary reainbow: the order of colors (red on the outside or top, yellow in the middle, blue on the inside or bottom), and the semicircular shape.

There is a wealth of explanation of rainbow formation available in textbooks, articles and on websites. These range from general to extremely detailed, and include secondary bows and other more exotic related phenomena. This is mentioned since it is not the purpose here to provide a comprehensive explanation of rainbows, but rather to show how to make and use the two simple models to understand the two characteristics noted above.

Figure 1

Marble Model of Individual Raindrop

Materials

1-inch diameter glass marble
red, blue and yellow cones (see accompanying templates; can use colored cardstock or colored bond paper)
scissors
hot glue guns and hot glue sticks
transparent tape

Assembly: See instructions on cone templates. Make cones and glue to marble in correct color order. See Figures 2 and 3.

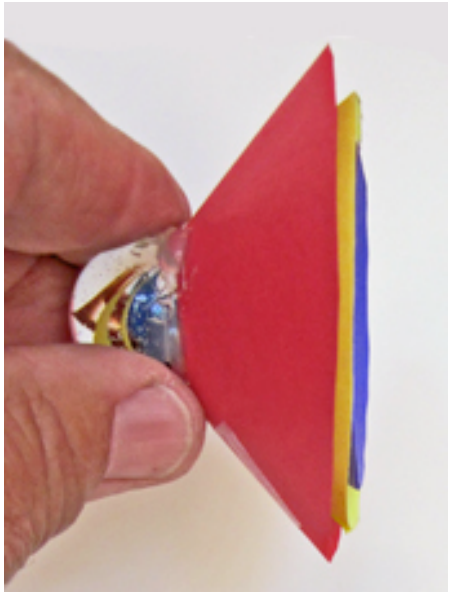


Figure 2

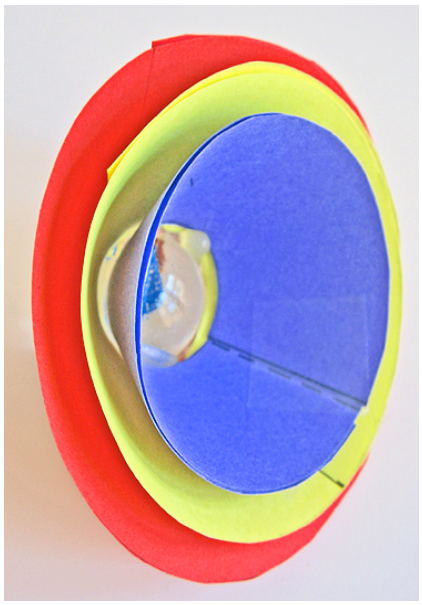


Figure 3

Don Rathjen....Exploratorium Teacher Institute....Pier 15, San Francisco, CA 94111...drathjen@exploratorium.edu

What's Going On?

The diagram in Figure 4 below shows light travelling in a raindrop. White light, composed of all colors enters the drop from the right (represented by the black line with the arrow). When entering the water the different colors bend, or refract, different amounts. Red, yellow and blue are shown, with red bending least and blue bending most. A portion of the colored light bounces, or reflects, off the back surface of the drop (some goes back out into the air, but this light never reaches your eye). Finally, some of the reflected light enters the air again near the bottom of the drop (some also reflects back into the drop but again, this light never reaches your eye).

Everything shown thus far has taken place in two dimensions; the circle is just in the plane of the paper. But an actual raindrop is three dimensional; it is a sphere. So try to imagine what things would look like in that case; each color emerging from the drop actually forms a cone of light, and these cones are responsible for the rainbow that you see.

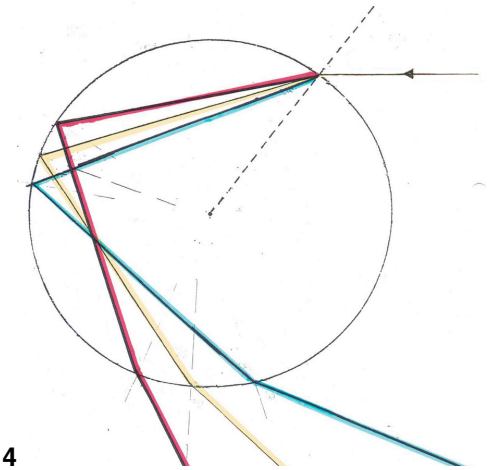


Figure 4

Light from the red cone of the water drop represented by the marble in Figure 5 reaches your eye. But when light from the red cone of a particular raindrop enters your eye, the yellow and blue light arrive above your eye. Yellow light entering your eye must come from a drop lower down, and blue light comes from a drop lower still. This explains why in an ordinary rainbow red light is higher than yellow and yellow is higher than blue. You can check this by looking at the actual rainbow photo in Figure 1.

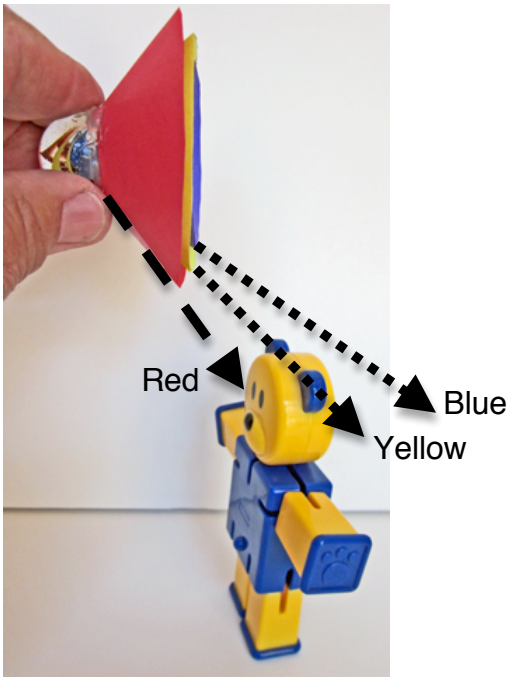


Figure 5

Don Rathjen....Exploratorium Teacher Institute....Pier 15, San Francisco, CA 94111...drathjen@exploratorium.edu

Pegboard Model of Semicircular Rainbow

Materials

pegboard, 3/16 in. thick, 8 in. x 13 in.
pegboard, 3/16 in. thick, 1 in. x 1 in. (with pegboad hole approximately centered)
pine shelving, ¾ in. x 5 ½ in. x 5 ½ in. (this is a 5 ½ in. long piece of what is normally referred to as "1x6" pine shelving
screw, sheet metal, #8 x 5/8", pan head, Phillips
electric drill
drill bit, 1/8 in.
screwdriver, Phillips
wood dowel, 1/4 in. diameter, 6 in. long
yellow cone (see accompanying template; yellow cardstock works well)
scissors
transparent tape
paper clip
masking tape
drinking straw
hot glue gun and hot glue sticks

Assembly:

Slide the small pegboard single-hole flange piece onto the dowel so that about 1/4 in. of the dowel protrudes.
Assemble the cone (see instructions on temp-late page) and hot glue it to the flange and dowel.
Glue the short piece of straw to the inside of the cone so that it is in a plane with the dowel. Insert the long piece of straw into the short piece.
Cut the drinking straw into two pieces, with one about an inch longer than the other; use scissors to make a slit all the way along the length of the longer piece, and then compress it into a smaller diameter that will fit inside the shorter piece; this allows you to set a variable length for the straw by sliding the inner piece
See Figures 6, 7 and 8.

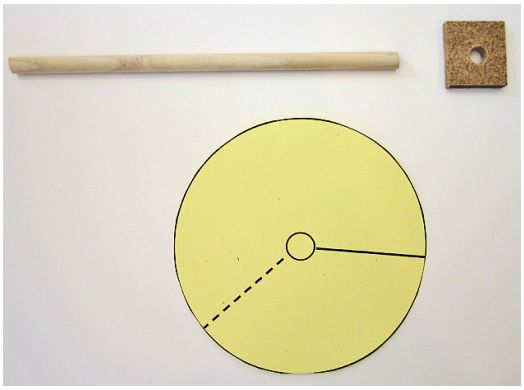


Figure 6

Figure 7

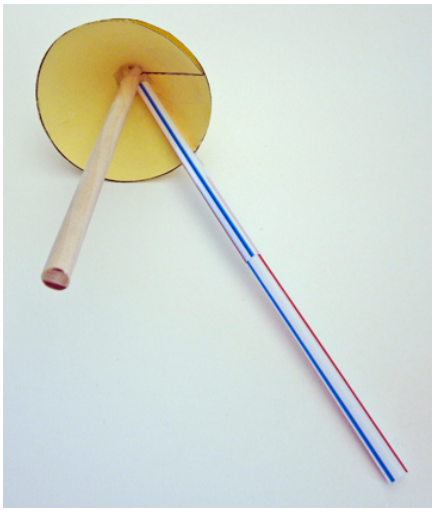


Figure 8

Screw pegboard to wood base so that base is centered on bottom edge of pegboard
Bend paper clip and tape to the base.
See Figures 9 and 10 on next page.

Don Rathjen....Exploratorium Teacher Institute....Pier 15, San Francisco, CA 94111...drathjen@exploratorium.edu

What's Going On?

The pegboard represents a "wall of raindrops." The top of the vertical portion of the paper clip represents your eyes. By experimentally moving the dowel-and-cone assembly to different holes on the pgboard, and rotating it to try to get it the straw to point directly at the top of the paper clip (your eyes), you can find which of the raindrops will actually allow you to see the yellow light. (When you Insert the short end of the dowel into a hole, the small pegboard flange should be esentially flat against the pegboard with the dowel sticking straight out from the pegboard.) You should find that the raindrops (pegboard holes) that meet this condition lie in a semicircle. This semicircle represents the yellow part of the rainbow.

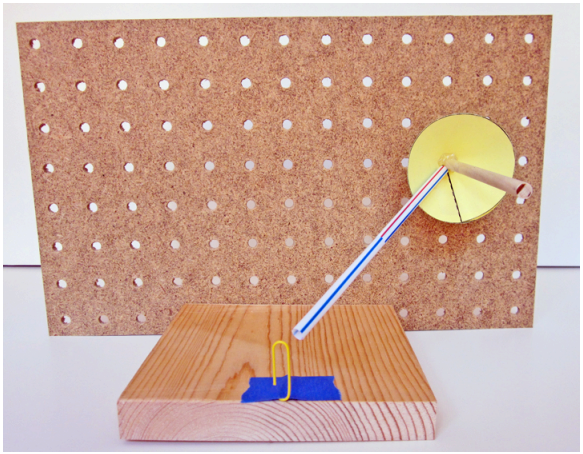


Figure 9

As noted in the Marble Model, the red part will be provided by water drops which are higher and the blue by water drops which are lower.

If the "wall of raindrops" was farther away, your viewing angle to the more distant raindrops would remain the same, but since the drops are farther away the semicircle would be larger; conversely, if the "wall of raindrops" was closer, the semicircle would be smaller. As you should have found on the accompanying diagram for tracing rays through a raindrop, the cone of yellow light has a 42° angle between its axis and its emerging light rays. This then results in a 42° viewing angle for the semicircular rainbow. To see a rainbow, you will be positioned with the sun at your back, and the rain in front of you. If you extend a line between the sun and your head forward to the rain, the yellow part of the rainbow will have an angle of 42° with this line.

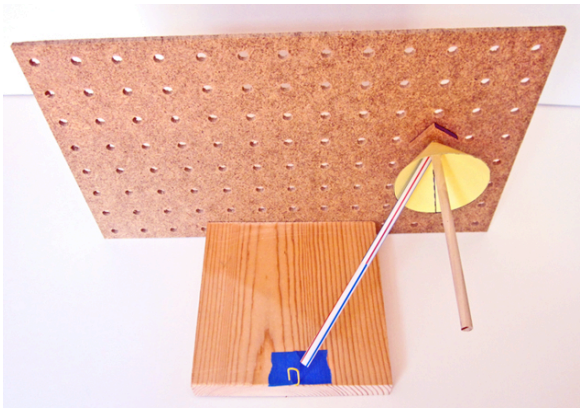
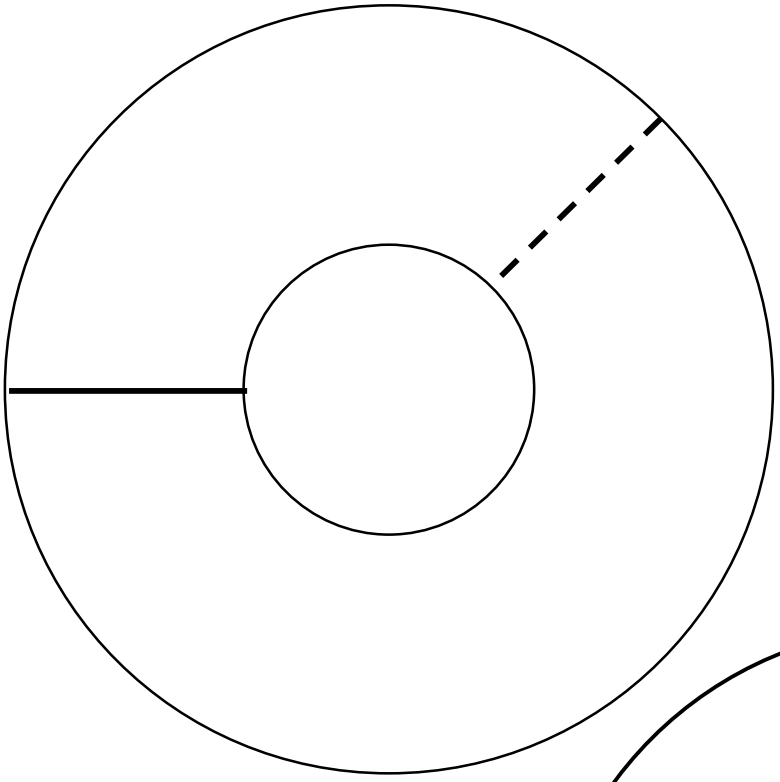


Figure 10

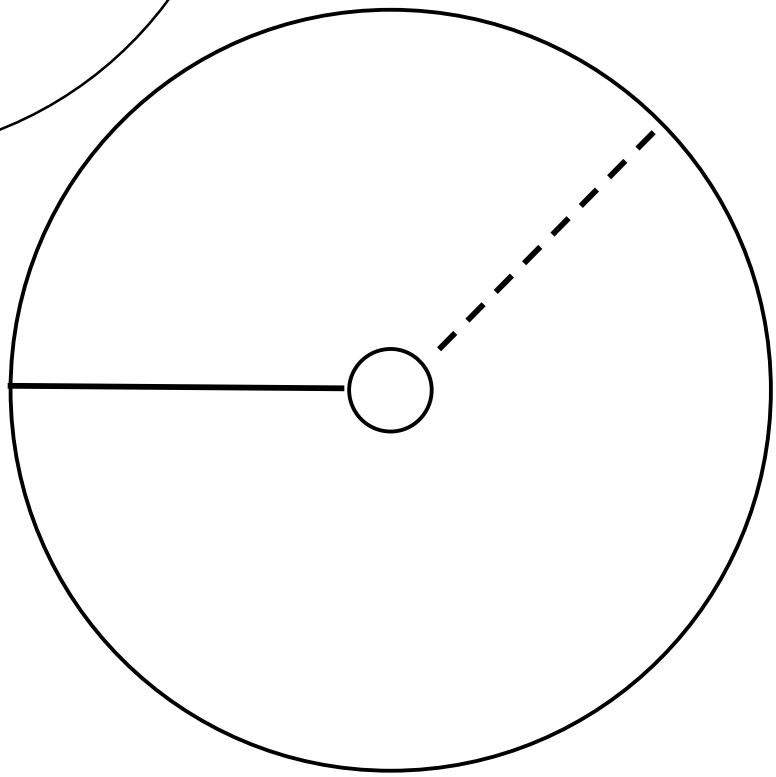
Don Rathjen....Exploratorium Teacher Institute....Pier 15, San Francisco, CA 94111...drathjen@exploratorium.edu

YELLOW Cone Templates. Copy this page on YELLOW cardstock and follow the directions below for each circle.

1. Cut out the entire circle.
2. Cut along the solid line and cut out the center circular area.
3. Bring the cut edge over to the dashed line so that it lies straight along the dashed line. Adjust the overlapping portions very slightly if necessary so that the outside edges are even, and the resulting shape forms a cone with its top cut off.
4. Tape the edges in place on both the inside and outside of the cone.



YELLOW Cone for **MARBLE**

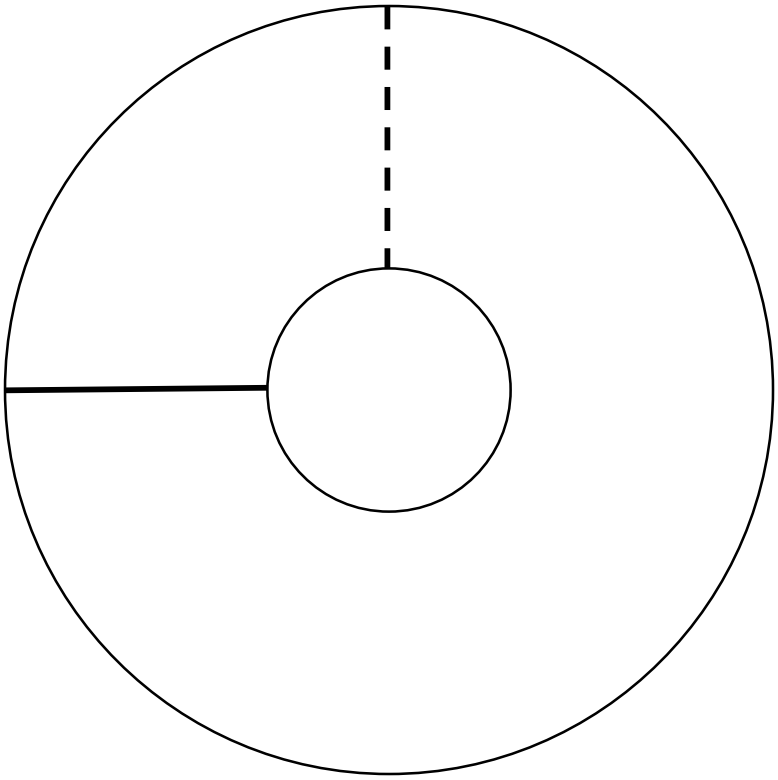


YELLOW Cone for **PEGBOARD**

Don Rathjen....Exploratorium Teacher Institute....Pier 15, San Francisco, CA 94111...drathjen@exploratorium.edu

RED Cone Template. Copy this page on RED cardstock and follow the directions below.
1. Cut out the entire circle.
2. Cut along the solid line and cut out the center circular area.
3. Bring the cut edge over to the dashed line so that it lies straight along the dashed line. Adjust the overlapping portions very slightly if necessary so that the outside edges are even, and the resulting shape forms a cone with its top cut off.
4.Tape the edges in place on both the inside and outside of the cone.

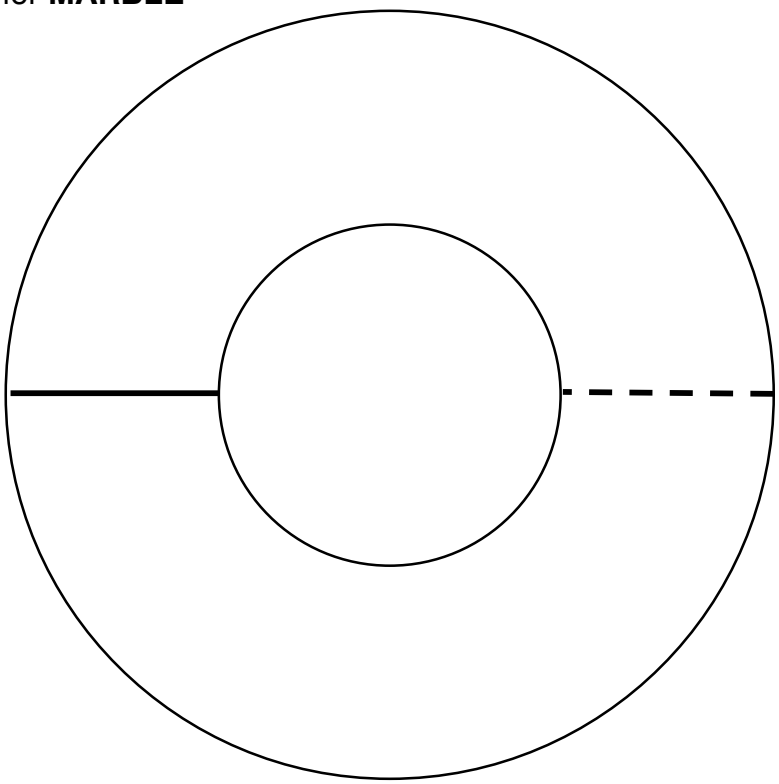
RED Cone for **MARBLE**



Don Rathjen....Exploratorium Teacher Institute....Pier 15, San Francisco, CA 94111...drathjen@exploratorium.edu

BLUE Cone Template. Copy this page on BLUE cardstock and follow the directions below.
1. Cut out the entire circle.
2. Cut along the solid line and cut out the center circular area.
3. Bring the cut edge over to the dashed line so that it lies straight along the dashed line. Adjust the overlapping portions very slightly if necessary so that the outside edges are even, and the resulting shape forms a cone with its top cut off.
4.Tape the edges in place on both the inside and outside of the cone.

BLUE Cone for **MARBLE**



Don Rathjen....Exploratorium Teacher Institute....Pier 15, San Francisco, CA 94111...drathjen@exploratorium.edu