Mystery Box

Overview

A clear, colorless liquid is poured into a funnel at the top of a box, and comes out into a container at the bottom. What happened in the box? The process is repeated, only this time the liquid comes out colored. What's going on? A third repetition gives still another different color! And a fourth trial results in no liquid coming out the bottom at all! What will a fifth trial do? Or a sixth? The challenge to a person observing this behavior is to figure out what's going on in the box, without seeing the inside. This is exactly the sort of problem faced by scientists investigating the nature of the atom, since it is impossible to "open up' the atom and take a look inside. Instead, the process involves a series of observations, hypotheses, predictions, tests, and conclusions, all of which may have to undergo revision as new behavior is observed.

Materials

1 standard cardboard "fold-to-assemble" file/storage box , with lid, approximately 12" wide x 18"long x 10" deep (sold at Office Depot, Office Max and Staples in bundles of 6 or 10)
4 clear plastic water bottles, 500 mL, with caps
1 clear plastic bottle or cup
4 cardboard toilet paper tubes
1 funnel, 3 1/2 in. diameter -- ours is a yellow plastic funnel from True Value hardware, $0.79 at this writing
1 funnel, 5 in. diameter -- ours is a blue plastic funnel from True Value hardware, $0.99 at this writing

2 pieces 1/2 in. PVC pipe, 7 in. long
2 pieces 1/2 in. PVC pipe, 9 in. long
4 pieces 1/2 in. PVC pipe, 12 in. long
8 PVC 90 degree elbows
5 in. Velcro
hot glue gun and hot glue sticks
utility knife
masking tape
electric drill
1/4 in. drill bit
mat board, 3in. x 5 in.
3 cable ties
5 in. length of wooden dowel, 3/16 in.
8 in. length of Tygon tubing, 1/2 in. i.d, 5/8 in. o.d.
scissors

optional: sabre saw or roto-zip saw or Dremel tool (these are to cut holes in 2 layers of cardboard -- alternatively, the utility knife can be used for this)
optional: single-hole paper punch (this is to punch holes in the matboard for the cable ties -- alternatively, the point of the utility knife can be used to poke slits)

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Assembly

1. Assemble the PVC stand as shown in Figure 1. (The four small Velcro pieces shown at the top corners can be applied later. See Step 18.)

Figure 1

2. Assemble the box. After assembly, pull up the inside bottom flap, apply hot glue, and glue it to the outside bottom section. Then pull the two inside end flaps inward , apply hot glue, and glue them to the outside end sections -- NOTE: it is important that these end flaps are glued well, since holes will be cut in them later.

3. Assemble three sides of the lid, but leave one long side andthe small flaps extending from it unfolded, as shown in Figure 2a. Glue the long unfolded edge edge of the lid to the long edge of the box to form a door, as shown in Figure 2b. Fold the small flaps upward, as shown in Figure 2c, and glue them to the ends of the box (a glued tab can be seen at the top of Figure 3).

Figure 2a

Figure 2b

Figure 2c

4. Use masking tape to tape the handhold cutout tabs in place so that they are covering their openings. Use masking tape on both the inside and outside of the box. See Figure 3.

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5. Turn the box so that the ends become the top and bottom, and the door opens out toward you. See Figure 3.

Figure 3

6. Open the door of the box. Turn the **smaller** (yellow) funnel upside down and center its circular opening on the **top** (formerly the end) of the box. Trace a line around it. Turn the box over and, again with the door open, center the circular opening of the **larger** funnel on the **bottom** of the box, and trace a line around it. Cut holes in the top and bottom about 1/4 in. **inside** the funnel outlines. See Figure 4.

Figure 4

Figure 5

7. Place the funnels in their respective holes (see Figure 5). The rims of the funnels should rest essentially on the box surface, and the funnels should not fall through the openings. Additionally, the top funnel (yellow, smaller) should rotate easily when you push on the edge of the small tab on the funnel with your finger. If a hole is too small, carefully cut away additional cardboard. If a hole is too large, build it up with masking tape.

8. Cut four 500 mL water bottles approximately in half. The cut does not need to be exactly halfway(sometimes there's a groove or label location that is convenient to use as a cutting location), but it is **important that all four bottles are cut identically**. The top ends will be used as funnels, and the bottoms as restraints to hold the funnels in place.

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9. Glue the four top ends together to form a 4-bottle "gang" of funnels, as shown in Figures 6a, 6b and 6c.

10. Drill a 1/4 inch hole in the center of three bottle caps. Leave one bottle cap undrilled.
Glue one of the drilled bottle caps in the middle of the "gang" as shown in Figure s 6a, 6b and 6c. Put the other two drilled caps and the undrilled cap on the appropriate bottles as shown in the same Figures.

Figure 6a


Figure 6b

Figure 6c

11. Figure 7a shows the gang of bottles resting in the bottom funnel. Figure 7b shows the addition of four "restraints" which are glued to the bottom of the box and serve to keep the bottles from tipping, wobbling, and moving out of position. The next few steps deal with making and installing the restraints.

Figure 7a


Figure 7b

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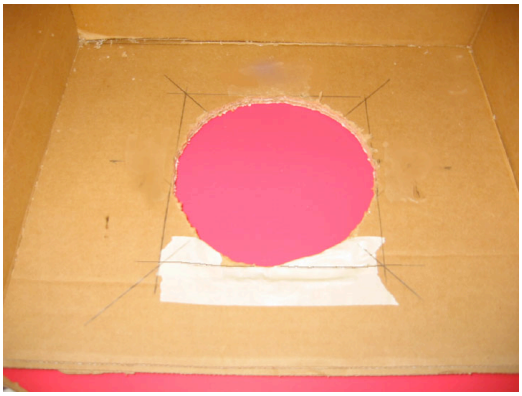
12. Glue a toilet paper tube in center of the bottom of the each of the four bottles. as shown in Figures 8a and 8b.

Figure 8a 

Figure 8b 

13. Draw a square around the hole in the inside bottom of the box. Then draw the diagonals of the square. See Figure 9.

Figure 9 

14. Place the funnel in the inside bottom hole. Glue a toilet paper tube/bottle assembly on each diagonal so that the inside edge of the toilet paper tube is right up against the edge of the funnel . See Figures 10a and 10b.

Figure 10a


Figure 10b

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15. Place the gang of the funnels in position so it is held in place by the four bottle/toilet paper tube restraints, as shown in Figure 11 (this is the same as Figure 7b above). Be sure the uncapped bottle is in the front.

Figure 11 

16. Assemble the Tygon tube and its mat board mount as shown in Figures 12a and 12b. You can use the template in Figure 13 to mark locations on the matboard, but you may have to make some adjustments if the dimensions in your box and funnel gang are significantly different from the prototype used for this write-up. The holes can be made with a paper punch, or you can use the point of a utility knife blade to make slits that the cable ties will fit through (a round hole is not necessary -- in fact a paper punch would not reach the middle hole on the left, and it was made with a utility knife). Secure the Tygon tube with the cable ties, and hot-glue the dowel in place as shown (the template in Figure 13 shows the dowel location).

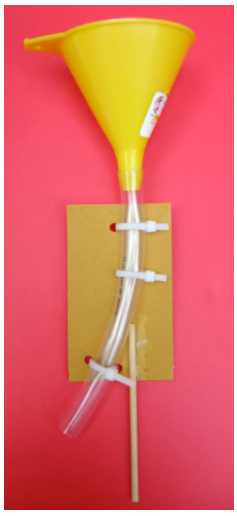
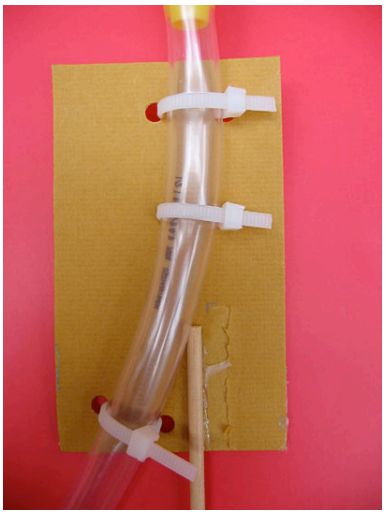
Figure 12a 

Figure 12b 

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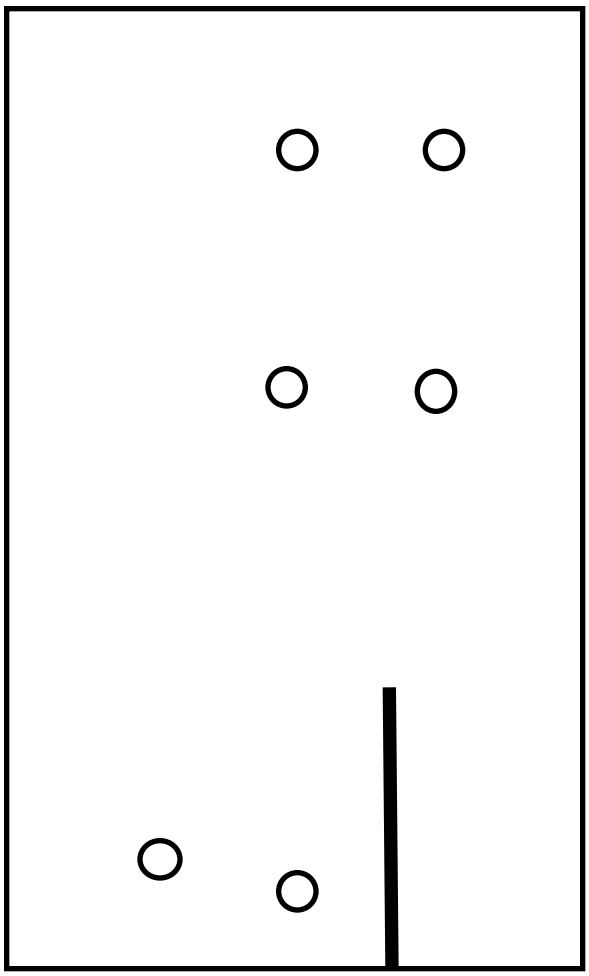

Figure 13

17. Put the Tygon tube on the spout of the yellow funnel so that the handle tab on the funnel points the same way as the outlet of the Tygon tube. Then drop the whole assembly in place through the hole in the top of the box. See Figure 14. The wooden dowel should fit into the hole in the bottle cap in the middle of the funnel gang (this helps prevent the mat board assembly from tipping and wobbling as it turns, which might result in the tube outlet emptying water into the box rather than a funnel!).

Figure 14

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18. Cut four 1-inch pieces of sticky-back Velcro and use them to attach the box to the stand. The four pieces on the stand were shown previously shown in Figure 1. Place the corresponding pieces appropriately on the box. Also use a 1-inch piece of Velcro to make a "lock" to keep the door shut (put one piece on the inside of the outer edge of the door (lid) and one piece opposite it on the box).

To Do and Notice

Call the uncapped funnel at the front funnel #1, and continue the numbering clockwise (funnels #2 and 3 have holes in the cap, and funnel #4 has an undrilled cap).

BEFORE SHOWING THE BOX TO STUDENTS, put a piece of paper towel with a few drops of food color on it in funnel #2. Put another piece of paper towel with drops of a different color on it in funnel #3 (consider using a dark color like blue or green, rather than yellow, so that it will better mask any residue from the previous color when it drains). Nothing goes in funnels #1 or#4.

Show students all sides of the Mystery Box at a distance. Be sure not to let them see the inside of the box, and don't tell them anything about what's in it.

Place the catch container (cup or cut-off bottle) under the bottom funnel.

TRIAL 1

Ask students to observe what happens when you pour water into the top funnel. Pour water in the top funnel, and observe that what appears to be ordinary water comes out the bottom funnel (funnel 1, inside the box, has no cap). Ask the students to draw a picture of what they think the inside of the box might look like, based on their observations.

TRIAL 2

While they are drawing, secretly turn the top funnel by nudging the edge of the tab on the funnel with your finger, so that it will now empty into funnel #2 inside the box. (If you have trouble positioning the funnel correctly, make inconspicuous marks on the top of the box that show the correct positions).

After allowing time for the drawing, ask students to predict what will happen if you pour more water into the top funnel. Do so, and observe that this time a clear but colored liquid comes out the bottom funnel. Ask the students to make a new or revised drawing of what they think might be inside the box.

TRIALS 3 AND 4

Repeat this procedure for funnels # 3 and #4. (funnel #3 releases a different clear colored liquid, and funnel #4 doesn't release anything, since it has an undrilled cap on it).

IF YOU ARE GOING TO DO THIS SEVERAL TIMES IN A DAY, REMEMBER THAT IF YOU SHOW STUDENTS THE INSIDE OF THE BOX, THEY MAY LIKELY TELL THEIR FRIENDS! THIS MAY ALSO EVEN OCCUR FROM YEAR TO YEAR! Depending on you and your students, you may choose to **NEVER** show the inside, to emphasize that there are things in science that can never be "seen." (There is at least one teacher who made an offer that if a student became a science teacher, they would be welcome to come back and see the box, and has actually had this occur!)

What's Going On?

Funnel #1 has nothing in it, so the liquid draining from the bottom will be clear and colorless. When you turn the large funnel on top so that it drains into funnel #2, the water picks up color from the food coloring on the paper towel, and the water draining from the bottom is colored. Funnel #3 will give a different color. Funnel #4 is capped, so the water is held in the funnel and nothing comes out the bottom.

Emphasize that scientists often need to continuously revise and rework their conclusions as new observations are made. Although everyone's drawings may be different, they can all be considered correct if they can be supported by the observations made.

Going Further

The preceding scenario is one way to use the box. You may well come up with variations which better suit your own situation. We would appreciate hearing about other ways you use the Mystery Box.

Credit

Many teachers over several years have built various versions of the Mystery Box during the Exploratorium Teacher Institute's summer programs. The origin of the Mystery Box itself, however, is a mystery. If you have information, let us know!

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