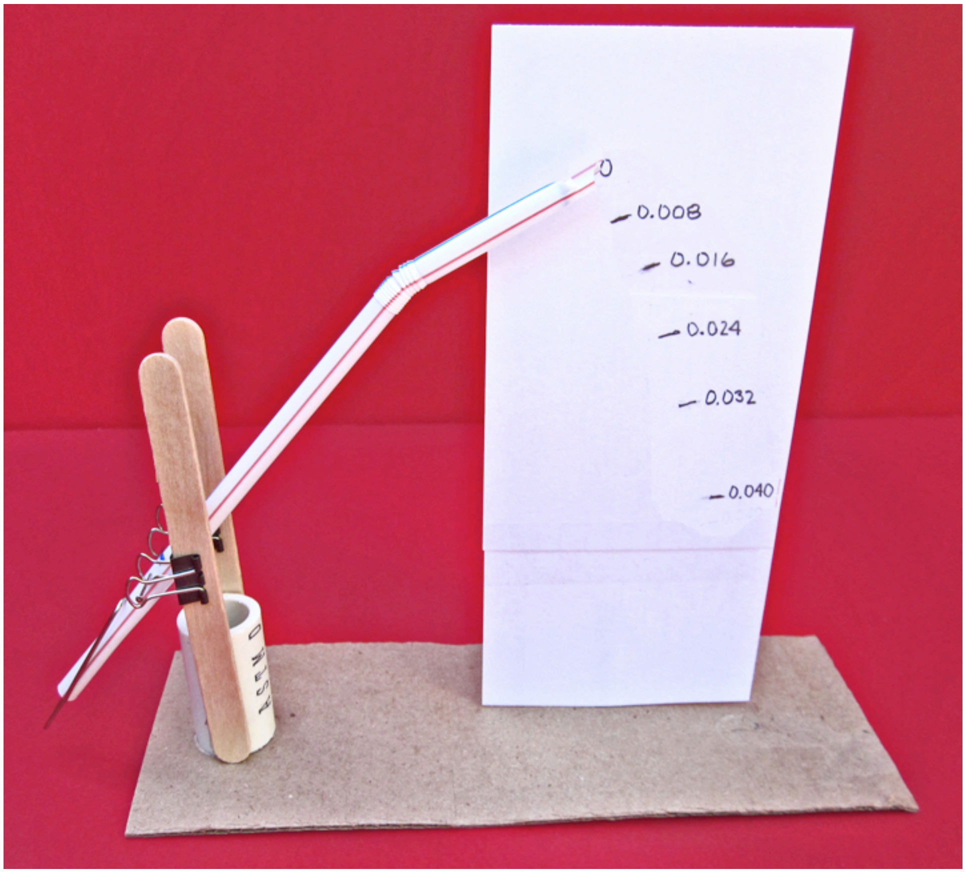
Drinking-Straw Microbalance

For a few hundredths of a dollar, you can weigh a few thousandths of a gram!

Using simple, inexpensive materials, this balance is sensitive enough to weigh items of only a few milligrams. While no claim is made that the balance is accurate enough to be legal for trade (!), it will nevertheless allow you to find approximate masses of things that are too small to even attempt to weigh at all, except with very expensive balances.



Note on Weight vs. Mass: In the use of this balance we will be dealing with mass, in grams. It is realized that the distinction between weight and mass is critical in physics, but my experience has been that even in scientific settings it is sometimes common usage to talk about "weighing" things on an analytical balance, rather than "massing" them. So when that happens here, your forgiveness is appreciated!

Figure 1

Materials

• flexible plastic drinking straw
• straight pin
• base, 3 in x 8 in -- cardboad or matboard
• 2 pieces ½-inch PVC pipe, each 1½ inches long
• 4 wooden craft sticks
• 2 paper clips, jumbo size (or 1 jumbo and 1 regular)
• 2 binder clips, micro size
• 2 index cards, 3 in x 5 in
• hot glue gun and hot glue sticks
• tape, matte-finish (e.g., Scotch brand Magic Tape) or glue stick (regular, not hot glue)
• ruler
• scissors
• several sheets of copy paper (10 is a handy number) -- you only need to actually use a small portion of one sheet, but you will have to weigh several sheets, as noted in the assembly instructions below
• access to a scale or balance that preferably will weigh to the nearest whole gram, e.g., lab balance, kitchen scale, postal scale, etc
• calculator (not necessary if you're willing to do one multiplication and one division by hand)

Don Rathjen....Exploratorium Teacher Institute....3601 Lyon St., San Francisco, CA 94123...donr@exploratorium.edu

Assembly

1. Cut two slits, each about 1.5 cm long, in the flexible end of one of the straws along the side walls . Use a pencil or a straightened end of a paper clip to poke the top flap back into the straw so that it blocks off the tube. See Figure 2. The bottom now forms a small trough or pan to hold the object being weighed, and the portion poked into the tube will prevent it from sliding into the straw.

Figure 2

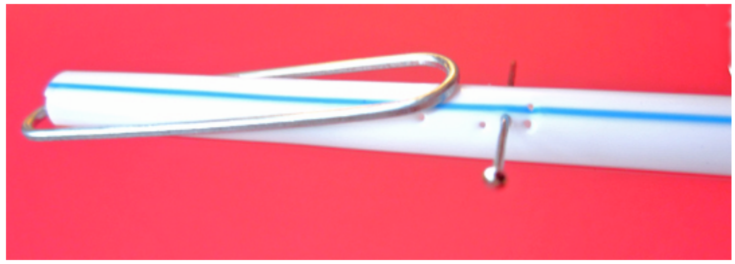
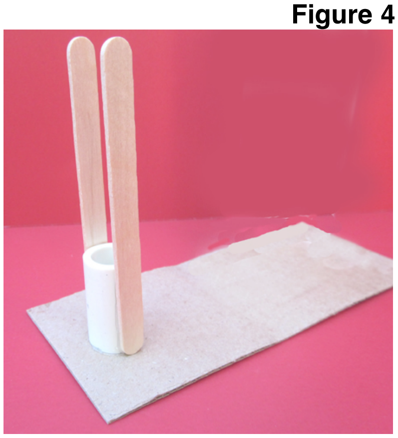


Figure 3

2. With straw horizontal and the trough facing upwards, stick the pin crossways through the straw, about 2 inches away from the non-flexible end**. IMPORTANT NOTE: Stick the pin through so that it is nearer the "top" of the straw.** See Figure 3.

3. Slide the jumbo paper clip onto the end of the straw near the pin, with the small part of the paper clip inside the straw. See Figure 3.

Figure 4

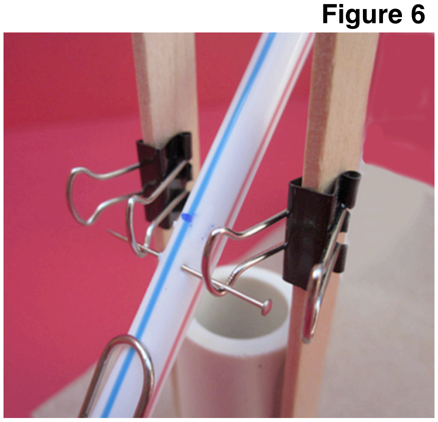


4. Use hot glue to glue create the PVC pipe-craft stick assembly shown in Figure 4. You can either glue the craft sticks to opposite sides of the PVC pipe and then glue the pipe to the cardboard base, or you can glue the pipe to the base first and then glue the craft sticks to the pipe. The edge of the pipe should be about ½ inch from the end of the base and centered between the two sides.

5. Place the two binder clips on the craft sticks as shown in Figure 5. The bottoms Figure 4of the binder clips should be about 2 inches above the base.

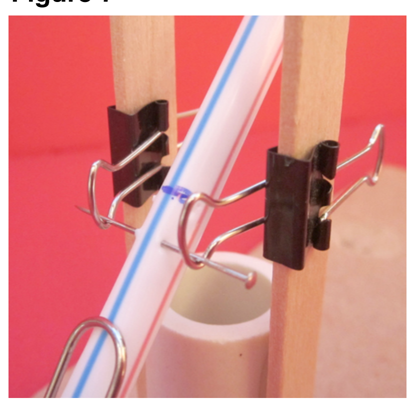
Figure 5

Figure 6



6. Bend the flexible end of the straw to an angle similar to the angle shown in Figures 1, 5 and 9, and then suspend the straw so that the pin rests in the binder clip handles as shown in Figures 5, 6 and 7. The binder clip handles act as very low-friction bearings for the pin, so that it is very sensitive to forces producing rotation of the straw. Note: You may want to flip the outside handles forward so that they are out of the way as shown in Figure 7 -- either way is OK since the outside handles don't support the pin. But don't take them off, since they are necessary in the event the positions of the binder clips need adjustment..

Figure 7



Don Rathjen....Exploratorium Teacher Institute....3601 Lyon St., San Francisco, CA 94123...donr@exploratorium.edu

7. Overlap two of the 3x5 cards by 3 inches, and tape or glue (regular glue stick, not hot glue) them so that you have a single card that is 3x7 (see Figures 1, 8 and 9). This will be the index scale that will display the calibration values such as those in Figure 1.

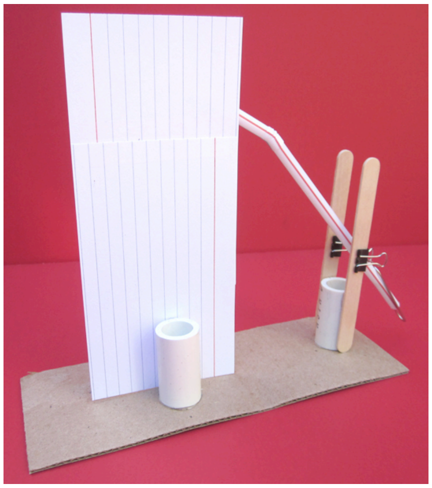


Figure 8

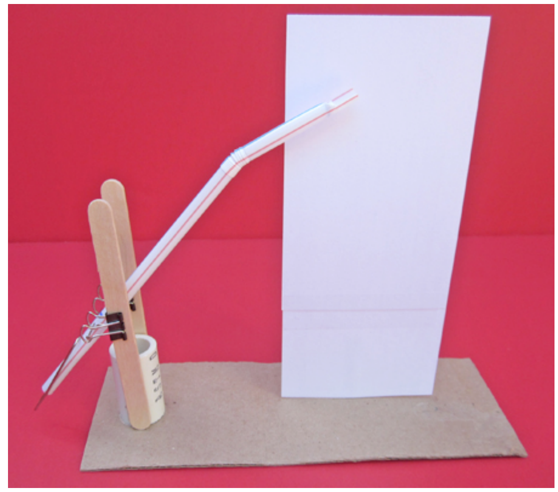


Figure 9

8. Hot-glue the 3x7 card to the remaining PVC pipe (see Figure 8) and position the card-pipe assembly so that the straw swings relatively close to the card but does not hit it at any time, and the location of the tip as it swings will allow calibration marks to be made on the card (the calibration values shown in Figure 1 give an idea of the approximate extent of the swing). Placing the back edge of the pipe approximately ½ inch from the edge of the base as shown in Figure 8 may be a good starting point in the process.
The swing of the straw and position of the tip relative to the card can be adjusted by
- sliding the paper clip counterweight in or out of the straw
- adjusting the bend of the flexible section of the straw section
- adjusting the position of the card-pipe assembly before gluing it to the base
- moving the position of the pin on the straw (see the trial-and-error sets of pinholes in Figure 3)

When the card-pipe assembly is properly positioned, hot-glue it to the cardboard base.

9. When the appropriate adjustments have been made so that the tip of the straw comes to rest somewhere near the top of the 4 x 6 card (see Figures 1 and 9), make a mark on the card alongside the resting point of the end of the straw, and label this mark 0 (see Figure 1).

10. To continue calibrating the balance you will be handling very small pieces of paper, and a pair of tweezers will be very handy. To make the tweezers, tape the ends of two craft sticks tightly together, and insert a paper clip as shown in Figure 10 (either regular or jumbo will work).

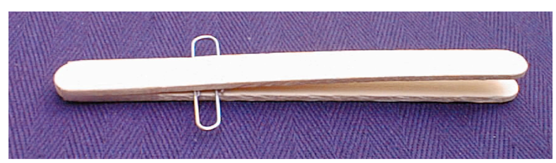


Figure 10

11. Weigh a stack of several identical sheets of paper, in grams. This can be done on a lab balance, a postal scale or a kitchen scale. Then divide the total mass in grams by the number of sheets to find the mass of a single sheet.

14. Measure the length and width of a single sheet, in centimeters, and find the area, in square centimeters.

15. Divide the mass of a single sheet by the area of a single sheet. This will give the mass, in grams, of a single square centimeter of paper.

16. Use scissors to cut out one square centimeter of paper.

Don Rathjen....Exploratorium Teacher Institute....3601 Lyon St., San Francisco, CA 94123...donr@exploratorium.edu

17. Use the tweezers to place this square centimeter of paper on the trough end of the balance (It may be easier if you fold or crumple the paper square). Make a mark on the card alongside the resting point of the far end of the straw, and label this mark with the mass of the square centimeter of paper. See Figure 1.

18. Repeat step 17, using two, three, four and five square centimeters of paper, or however many are feasible with your balance. NOTE: Rather than handling 2,3,4 or 5 individual squares of paper, you may find it easier to cut strips of paper 1 cm wide, and 2, 3, 4 and 5 cm long. These can be folded so that they can be either placed in the trough at the tip or draped over it. Remove any calibration masses and make sure your balance goes back to zero. You have now calibrated the balance.

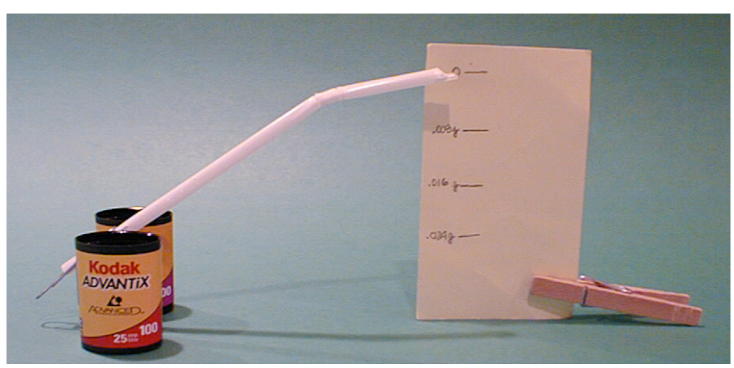
To Do And Notice
Place a small object on the balance, and find its mass. Readings between the calibration marks can be estimated. Spices are often easily available -- a peppercorn, a rosemary leaf, a red pepper flake, a mustard seed, a sesame seed, a sea salt crystal, etc. Other ideas are a dead fly, a small flower petal, a birdseed, -- anything that is within the range of your balance -- it's up to you!

What's Going On
This balance typically allows you to detect the differences in mass between objects whose masses are in the order of several thousandths of a gram. As noted in the overview, it will allow you to find approximate masses of things that are too small to even attempt to weigh at all on ordinary balances -- the balances would just read zero, On the other side of the coin, while the balance may be able to tell the difference between two objects whose masses are only a few milligrams apart, the limitations of the balance and its calibration process put its accuracy in question. That is, you may be able to tell the difference between an object of 4 milligrams and one of 8 milligrams, but you're not really sure how accurate those masses are. But you're definitely in the ballpark, and considering the cost it's still an impressive capability.

Going Further
Use references to learn something about simple error analysis. In particular, familiarize yourself with the following terms: precision, accuracy, and deviation.

Credit
A similar balance, using different materials, appeared as part of the original PSSC Physics in the 1960's, and is the inspiration for the version presented here.

NOTE ON AN ALTERNATIVE VERSION: The photos below show an alternative method of construction. Film cans are a vanishing species, so just look for other suitable objects, e.g., plastic cups, small cans such as tomato paste, tomato sauce, or individual-size pineapple or tomato juice, etc. The original PSSC version noted in the **Credit** immediately above used two microscope slides rubber-banded to a block of wood as a separator. One of the nice features of the device in the write-up is that the entire balance is a single movable unit. To achieve the same thing with film cans or other choices, you could just glue or tape everything to a single base made from cardboard or other suitable material.



Don Rathjen....Exploratorium Teacher Institute....3601 Lyon St., San Francisco, CA 94123...donr@exploratorium.edu