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Microscale Cartesian Diver Activities

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MICROSCALE CARTESIAN DIVER ACTIVITIES

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Because air has weight, it exerts pressure. The air in a room can weigh as much as 100 kilograms, which is the weight of a large person. Air can also be compressed into small containers, such as those used by underwater divers. Teachers can construct several toys called Cartesian divers which will rise and fall exactly as a diving bell does. The toys are called "Cartesian" because the principle of moving diving machines by air pressure was first explained by Rene Descartes, a 16th century mathematician. This exercise is divided up into four parts: "A Cartesian Retriever," "The Cartesian Helicopter," "A Cartesian Counter" and "Cartesian Basketball."

Part One:

An easily adjustable Cartesian diver can be made and then turned into a fun, challenging eye-hand coordination task.

Materials:

two graduated pipets with all but 1 centimeter of the stem cut off
two hex nuts that can screw securely onto the stems of the pipets. These should be made of brass or stainless steel. Either 3/16" or 12/24 metric nuts should fit and will thread themselves on the stem of the pipet.
one 6-7 cm length of stiff nylon fishing line (30-50 lb test)
one 7-8 cm length of insulated copper wire. Speaker wire works well because it can be bent without using pliers, 22 gauge wire will make a stiffer hook, and the pliers can be used to bend it into the proper shape.
one plastic, clean, empty 2 liter soda bottle with cap
water
several containers with colored water
pliers

Tools/Equipment

hot-melt glue gun
candle and matches
one 2 liter bottle with the top cut off at the point where the neck meets the side of the bottle to use as a test tank

Construction of the Retriever:

1. Using pliers, fashion the length of wire into a hook (Figure 1).
2. Pass the cut stem of the pipet through the loop end of the hook; then screw one of the hex nuts over the end of the stem as far up as it will go. The hook should now be held securely in place (Figure 1).

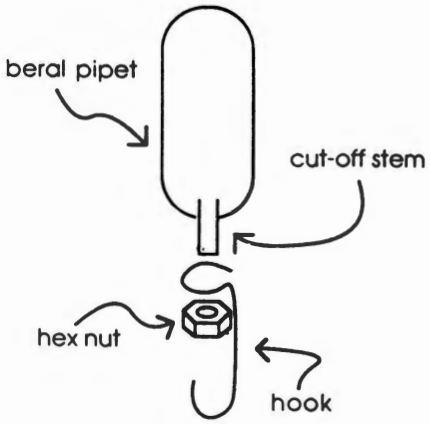

Figure 1

3. Attach another hex nut to a different pipet and fill about 1/2 full of colored water. Take this to the testing tank and squeeze a few drops of the colored water out of the pipet until it barely sinks. This pipet will eventually become the treasure.
4. Light the candle, then bend the length of fishing line into a "U" and hold the ends near the flame until the tips start to melt. Withdraw from the flame and push the two ends together so that they join to form a loop. Hold them together for at least 10 seconds to allow them to fuse securely. If the fishing line should catch on fire, extinguish the flame by placing it in the testing tank (Figure 2).
5. Place the loop on the end of the pipet away from the nut and attach it with a drop of glue from the glue gun. Wait 3-4 seconds for the glue to begin to cool; then push the loop down into the glue so that it completely covers the joint on the loop. This will create a secure bond. Wait for the glue to set for approximately one minute (Figure 3).
6. On the end of the pipet that is covered with the nut, gently squeeze the pipet and place a drop of glue into the opening to seal it. Place this "treasure" in the test tank and remove; gently squeeze the pipet to see if there are any leaks. The "treasure" is now finished.

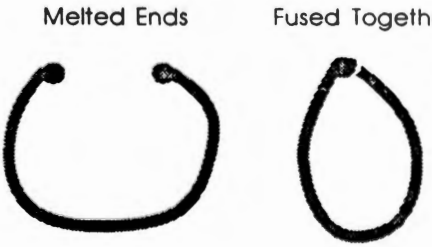

Figure 2

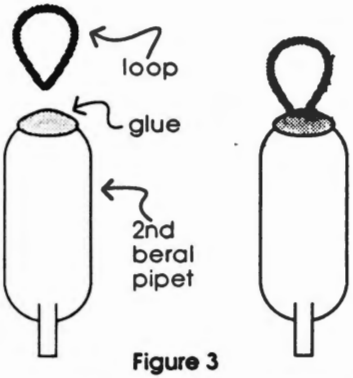

Figure 3

7. Adjust the retriever so that when the treasure is attached, they will both float. If you leave too much air in the retriever, it will be almost impossible to squeeze the bottle hard enough to make it dive. The trick is to adjust the retriever so that it will be easy enough to dive, yet have enough buoyancy to lift the treasure once it is captured.
8. A very challenging secondary puzzle can be made by adjusting the retriever so that when it captures the treasure, both pipets will sink.
9. Fill the plastic soda bottle with water to within about 5 cm of the top; insert the "treasure," then the "retriever" and screw the cap on tightly. The treasure should be upright on the bottom, with the loop on the top; the retriever should be on top, with the hook hanging down (Figure 4).

Tell the students to try to maneuver the retriever down to hook the treasure and bring it back safely to the surface by squeezing and tipping the bottle from side to side. The degree of difficulty can easily be increased by decreasing the size of the loop and/or hook. Another variation can be tried by making a third pipet, with a loop on top and a hook on the bottom, so that it can serve as a "go-between." In order for this to work properly, the loops and hooks must be made smaller to increase the difficulty, and the treasure needs to be heavy enough so that when the first retriever hooks the treasure, it is not buoyant enough to lift the treasure until a second retriever is added.

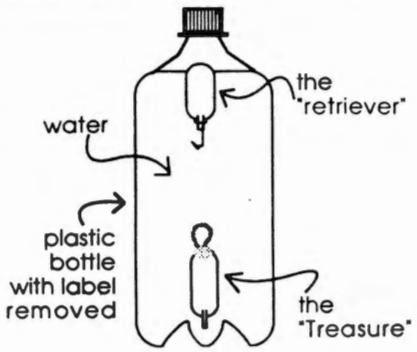

Figure 4

Part Two: The Cartesian Helicopter

In the following manner, connect the pipet, a hex nut and a small pin-wheel propeller constructed from a sheet of plastic or vinyl. ("Hot-ones" report covers work best because of their bright color.)

1. Using a fifty-cent piece as a pattern and a wooden block underneath the sheet of plastic, cut out a circle with an Exacto knife or similar sharp object.
2. Punch a hole in the center of the circle with a paper punch.
3. Place the punched circle on the pipet and secure it with the hex nut.
4. Using a pair of scissors, cut the punched circle to the point on the hex nut where two sides meet. You will be making six cuts.
5. Adjust the density of the pipet with water until it barely floats.
6. The ends of the propeller may be bent so that when the pipet dives, it will rotate on the way down (see Figure 5). It will rotate in the opposite direction on the way back up.

Students can hold a propeller design contest, trying to design a propeller that produces the most rotations as it sinks. If a reference dot is placed on one of the propellers, determining the number of rotations will be much easier. Students should consider the number, size and pitch or angle of the blades. Note the propellers may be larger than the mouth of the bottle, for the plastic will flex back and forth. Another teacher suggested that she could teach fractions by having the students make several propellers and cut them in thirds, quarters, fifths, etc.

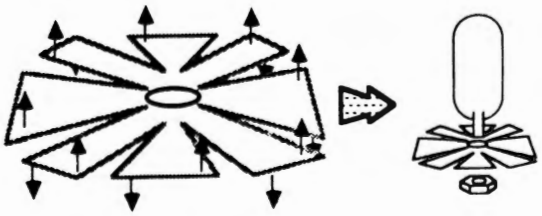

Figure 5

Part Three: The Cartesian Counter

1. Construct seven or more Cartesian Divers using the pipets and hex nuts, adjusting the densities so that they all float with varying degrees of buoyancy.
2. The easiest way to give them all different buoyancies is to number them from one to seven. Leave #7 full of air. While the diver is in the test tank, squeeze two bubbles from #6, four from #5, etc.
3. If you line up the divers in numerical order, #1 should be most deeply submerged and #7 the least.
4. Place all the divers in the same 2-liter bottle, screw on the cap and squeeze the bottle. The divers should descend in order. If they don't, minor adjustments need to be made in the buoyancy by either adding a little more water or squeezing some out.

You can play this up quite a bit by announcing while #4 is descending, "Okay #5, it's your turn...and sure enough, there goes #5." One can also use this as a carnival-type "strength-tester." With my high school classes, it is the "Wimp Tester." Several teachers suggested that their students could use these to add and subtract. If three divers are on the bottom, how many are left on top? With the students' help, several bottles can be used in series. The other students can then add the number of divers on the bottom and the number of divers on the top.

Part Four: Cartesian Basketball

1. Wrap a fishing line around a fifty-cent piece, and cut the line where it meets the other end.
2. Heat the cut ends in the candle, make a loop and join them together.
3. Select another pipet, fill it with colored water and cut off about 1 inch from the bottom. Attach the hex nut, and adjust the buoyancy until this basketball standard is on the bottom and floating upright. Seal the open end with a drop of hot glue.
4. Place the loop on the side of the basketball standard near the middle of the bulb. Glue the loop to the pipet so it is parallel to the ground.
5. A "basketball" can be made from a 2-inch square of aluminum foil that has been rolled into a ball. Some air is trapped in the foil and it will float.

The rules of the game are quite simple. While maintaining a constant pressure, the students try to maneuver the basketball into the loop on the basket. The basketball must go through the loop on its descent to the bottom. Once the basketball passes below the loop it is the other person's turn.

The original idea for the retriever and helicopter was developed by Robert Becker of St. Louis, Missouri. Many extensions have been suggested by teachers who have participated in his workshops. If you have other variations to add to those included here, John Mauch would love to have you share them with him.

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