

Heat or Dye? Building a Convection Cell in a Tank

Investigation question: When colored water is released at the bottom of a tank, what makes it rise, the dye or the temperature difference, and what does the cold side of the loop look like?

Physical model

Groups of 4

1 session

Setup 8 · Activity 35 · Cleanup 7 min

MS-ESS2-1 · practice

Name _____

Group _____

Date _____

Your role today

- ☐ **Tank manager:** Fills and refills the tank, checks the water is still and at room temperature, and holds the ruler against the side during each run.
- ☐ **Releaser:** Lowers the covered vial to the bottom with tongs, slides the cover off on the timer's signal, and places the ice cube on the timer's signal. Never fills the warm or hot vials.
- ☐ **Timer:** Starts the stopwatch at release, calls out 30, 60 and 120 seconds, and records the time the dye first touches the surface.
- ☐ **Observer and sketcher:** Narrates what the dye does, sketches the plume at 60 seconds for each run, and records the written description.

Safety

- Hot water is dispensed only by the teacher, from a kettle or urn kept at or below 60 °C, into a vial that the teacher sets on the group's tray. Students never pour hot water and never touch the kettle.
- The 'warm' vial is about 40 °C, which is bath temperature and safe to handle briefly; the 'hot' vial at about 55 °C is carried on the tray and lowered with tongs, not fingers.
- Use plastic containers, not glass. Wipe spills immediately; wet floors near a kettle are a slip and electrical hazard. Keep the kettle cord away from walkways and water.
- Food coloring stains skin and clothing; wear aprons or old shirts and keep the dye bottle at the teacher station.
- Nothing in this lab is to be tasted, and vials are not reused for drinking.

Procedure

1. Fill the tank with room-temperature water from the refill bucket to a depth of 10 cm. Let it stand for 3 minutes with no one touching the table. Measure and record the tank temperature.
2. Control run: the tank manager fills one vial with room-temperature water from the bucket and adds exactly 3 drops of red dye. Record the vial temperature. Cover the vial with a card, hold the card in place, and use the tongs to lower it upright to the bottom of the tank at one end.
3. When the timer says 'go', slide the card off the vial without lifting the vial. Start the stopwatch. Record the height the dye has reached at 30, 60 and 120 seconds, and the time the dye first touches the

- surface if it does. Sketch the dye at 60 seconds.
4. Empty the tank into the used-water bucket, wipe it, and refill to 10 cm from the refill bucket. Let it settle for 2 minutes.
 5. Warm run: ask the teacher for a vial of water at about 40 °C with 3 drops of red dye. Record its temperature. Cover, lower, release and record exactly as in steps 2 and 3.
 6. Empty, wipe and refill the tank as in step 4.
 7. Hot run: ask the teacher for a vial of water at about 55 °C with 3 drops of red dye. Record its temperature. Cover, lower with tongs, release and record exactly as before.
 8. As soon as the red dye reaches the surface in the hot run, the releaser sets one blue ice cube on the water surface at the opposite end of the tank. Watch for 2 minutes. Record and sketch where the blue goes and where the red goes; draw arrows showing the direction of flow along the bottom and along the top.
 9. Compare the three sketches and the three times. Decide as a group: what moved the water, the dye or the temperature difference? Write the decision and the single strongest piece of evidence on the recording sheet.
 10. Answer the analysis questions individually, then compare within the group. Empty the tank, return vials to the teacher tray, and wipe the table.

Record your observations

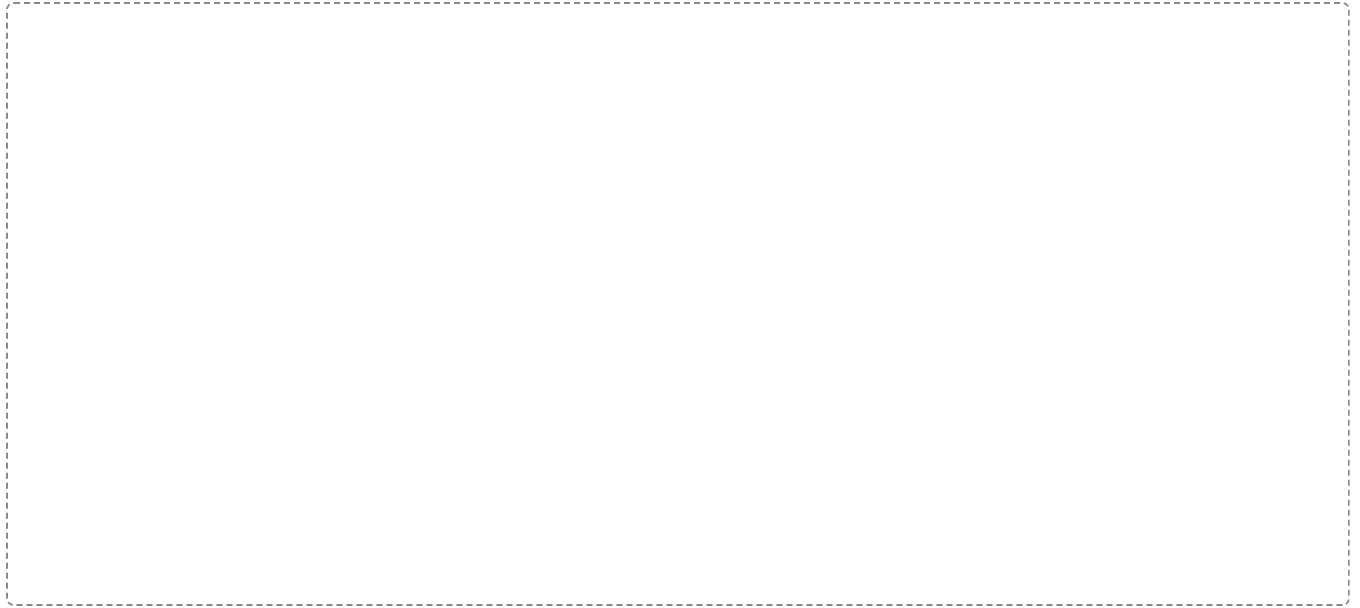
Lab 1 recording sheet: Heat or dye?

Fill in every box for each run. If the dye never reaches the surface within 3 minutes, write 'no' in the time column and record how high it got. Use the ruler taped to the tank; heights are measured from the bottom.

Plume data

Run	Vial water temperature (°C)	Tank water temperature (°C)	Dye height at 30 s (cm)	Dye height at 60 s (cm)	Dye height at 120 s (cm)	Time dye first touched the surface (s)
Control (room temperature)						
Warm (about 40 °C)						
Hot (about 55 °C)						

-  Four panels. Panels 1 to 3: the tank at 60 seconds for the control, warm and hot runs, with the red dye drawn and arrows for its direction; label the vial, the water surface and the dye front. Panel 4: the hot run 2 minutes after the blue ice cube was added, with red and blue arrows along the top, the bottom and both ends, and labels for where water is warming and where it is cooling.



1. Group decision: what moved the water, the dye or the temperature difference? Give the single strongest piece of evidence from your runs.

2. In the ice-cube run, describe the path of the blue water in one or two sentences. Where did it meet the red water, and what happened there?

Analysis questions

3. Compare the control run to the hot run. What did the dye do in each, and why does the control run matter for your conclusion?

4. Use the class data. On average, how many times faster did the hot plume reach the surface than the warm plume? Show the calculation. What does a larger temperature difference do to the speed of convection?

5. Explain why the warm red water went up and the cold blue water went down. Your answer must use the words density and gravity and must say what pushed the red water upward.

6. Suppose you had released the hot vial at the surface instead of the bottom. Predict what the dye would have done and explain using density.

7. Match each part of the tank model to the real mantle: the hot vial, the room-temperature water, the water surface, the red plume and the blue sinking water. Then name two important ways the tank is not like the mantle.

8. Your hot plume crossed the 10 cm of water in the tank in seconds. Mantle rock rises at about 3 cm per year. How many years would mantle rock take to rise the same 10 cm? Then, using your hot-run time and $1 \text{ year} \approx 31,500,000 \text{ seconds}$, calculate about how many times slower the mantle is than your plume. Show both calculations.
