Thermal convection in water

FizziQ activity · High school · 45 min

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Two temperature probes linked to the FizziQ app through FizziQ Connect track water heated from below, revealing convection currents up to boiling. High school.

Learning objectives

- Observe and characterize convection currents in a heated liquid
- Measure temperature simultaneously at two positions in a fluid
- Interpret the temperature difference between upper and lower probes
- Identify the three phases: heating with gradient, simmering, and boiling
- Understand the three modes of heat transfer: conduction, convection, radiation

Instruments and sensors

Dual-channel temperature data logger · Temperature probe (x2)

Materials

- Smartphone or tablet with FizziQ Connect
- M5 Stack module with two temperature probes
- A beaker (200 mL)
- An immersion heater
- Lab stand and clamp
- Optional: aluminum foil insulation
- Note: the protocol remains adaptable to any comparable data acquisition tool.

Protocol

1. Connect the two temperature probes to the M5 Stack module via the multiport hub. Verify both temperatures display in FizziQ Connect.

2. Fill the beaker with cold tap water (about 200 mL). Optional: wrap the beaker in aluminum foil to reduce lateral heat loss.

3. Fix one temperature probe near the bottom of the beaker (close to the heater, without touching it) and the other near the top (just below the surface).

4. Place the immersion heater in the water, attached to the lab stand with a clamp. The heating element must be fully submerged near the bottom.

5. Connect FizziQ Connect via Bluetooth and select dual-screen display to visualize both temperatures simultaneously.

6. Start the recording (REC). Both probes should show similar temperatures (room temperature).

7. Turn on the immersion heater. Observe the temperature gap between the two probes in real time.

8. Continue recording throughout the heating phase (about 15 to 20 minutes), noting the moments of simmering and boiling.

9. Stop the recording when boiling is well established and both temperatures are stable and equal.

10. Export the data and superimpose the two temperature-time curves to identify the three phases: heating with growing gap, simmering (gap narrows), and boiling (gap disappears).

Expected results

From the start of heating, the upper probe warms faster than the lower one, demonstrating upward convective transport. The temperature gap grows during early heating, then narrows at simmering as bubble-driven mixing homogenizes the fluid. At full boiling, both probes read 100°C. Total heating time is typically 15-20 minutes for 200 mL with a standard immersion heater.

Questions

- Why does the upper sensor warm up first even though the heat source is at the bottom?
- How can we explain that the temperatures equalize at boiling?
- What happens if you heat the water from above instead of below?
- Why is convection more efficient than conduction for heat transport in fluids?
- What everyday phenomena involve convection currents?
- How do Rayleigh-Bénard cells relate to atmospheric circulation?

Going further

- Heat the water from above (infrared lamp) and observe the absence of convection (stable stratification)
- Add a few drops of food coloring to visualize the convection currents
- Compare heating rates with and without a lid
- Measure the heat transfer coefficient from the temperature curves and heater power
- Use a larger container and more probes to map the temperature field in 2D