Depressurization by barometer

FizziQ activity · High school · 20 min

Scan to open in FizziQ

A smartphone barometer records the pressure drop when an aircraft toilet flushes; with FizziQ, students apply the Boyle-Mariotte law to estimate the air evacuated.

Learning objectives

- Measure the atmospheric pressure variation in an aircraft lavatory during a flush using the smartphone barometer
- Observe the characteristic pressure drop and recovery caused by the vacuum drainage system
- Apply the Boyle-Mariotte law (PV = constant) to estimate the volume of air evacuated
- Understand the engineering principles of vacuum drainage systems used in aviation
- Connect pressure measurement to practical applications of gas physics

Instruments and sensors

Barometer · Atmospheric pressure sensor

Materials

- Smartphone with the FizziQ app and its built-in barometric sensor
- A plane flight
- FizziQ experiment notebook to record readings and calculations
- Note: the protocol remains adaptable to any comparable pressure data acquisition tool.

Protocol

1. Before the flight, open FizziQ and verify that the Barometer sensor is available and reading the local atmospheric pressure (approximately 1013 hPa at sea level).
2. During the flight, note the cabin pressure reading (typically 750-800 hPa at cruising altitude, equivalent to ~2000 m altitude).
3. Enter the aircraft lavatory with your smartphone. Close the door and wait 10 seconds for the pressure to stabilize.
4. Start recording the atmospheric pressure at the highest available sampling rate.
5. After recording a 5-second baseline, activate the toilet flush.
6. Continue recording for at least 15 seconds after the flush, capturing the full pressure drop and recovery.
7. Stop recording and exit the lavatory.
8. Examine the pressure-time graph. You should see a sharp pressure drop of approximately 0.5-2 hPa at the moment of the flush, followed by a gradual recovery.
9. Measure the magnitude of the pressure drop (ΔP) and the recovery time.
10. Estimate the volume of the lavatory (typically about 1.5-2.5 m³ for a standard aircraft lavatory).
11. Apply the Boyle-Mariotte law: $\Delta V = V \times \Delta P / P$, where V is the lavatory volume, ΔP is the pressure drop, and P is the ambient cabin pressure.
12. Calculate the estimated volume of air evacuated through the drainage system during the flush. Compare with typical values (about 1-5 liters).

Expected results

The pressure drop during a flush typically ranges from 0.5 to 2.0 hPa, lasting 1-3 seconds, followed by a recovery over 5-15 seconds as cabin air seeps back through gaps around the door. For a lavatory volume of 2 m³ at a cabin pressure of 770 hPa, a 1 hPa drop corresponds to an evacuated volume of approximately 2.6 liters using the Boyle-Mariotte law. The barometer's precision (typically ±0.1 hPa) is sufficient to clearly detect this event. Students may also observe smaller pressure fluctuations from the aircraft ventilation system as background. The recovery time depends on how well sealed the lavatory door is.

Questions

- Why do aircraft use vacuum drainage instead of gravity-based toilet systems?
- How does the Boyle-Mariotte law relate the pressure drop to the volume of air evacuated?
- What maintains the low pressure in the aircraft waste tank?
- Why is the cabin pressure lower than sea-level pressure during flight?
- What would happen if the flush valve remained open? Would the cabin depressurize?
- How does temperature affect the Boyle-Mariotte calculation?

Going further

- Compare the pressure drop from flushes in different aircraft lavatory positions (front vs. rear)
- Measure the pressure recovery time and investigate whether it depends on door seal quality
- Record the pressure during door opening and closing to detect ventilation-related pressure changes
- Compare the aircraft lavatory pressure drop with the pressure change when opening a car door at highway speed
- Calculate the air flow rate through the drainage system from the pressure drop and recovery time