Rate of climb in flight

FizziQ activity · High school · 20 min

Scan to open in FizziQ

During a flight, students log GPS altitude with the FizziQ smartphone app, calculate the airliner's rate of climb and compare it with the world's fastest elevator.

Learning objectives

- Measure the altitude change during an aircraft's initial climb phase using GPS
- Calculate the aircraft's vertical speed (rate of climb) from the altitude data
- Compare the aircraft's climb rate with the speed of the world's fastest elevator
- Understand the physical differences between aerodynamic lift and elevator cable systems
- Develop skills in GPS data analysis and unit conversion

Instruments and sensors

GPS altimeter · GPS · Barometer

Materials

- Smartphone with the FizziQ application and GPS reception
- A plane flight
- FizziQ experiment notebook
- Note: the protocol remains adaptable to any device capable of continuous GPS altitude logging.

Protocol

1. Before the flight, open FizziQ and select the GPS Altitude sensor. If available, also select the Barometer (atmospheric pressure) in Duo mode for a cross-check.
2. Ensure GPS reception is working (preferably by a window seat). Note that airplane mode may need to be temporarily disabled for GPS lock, then re-enabled with GPS remaining active on some phones.
3. Once the aircraft begins its takeoff roll, start recording in FizziQ.
4. Record continuously for the first 5-10 minutes of flight, covering the initial climb phase.
5. After the seatbelt sign indicates stable flight, you may stop recording.
6. Examine the altitude-versus-time graph. Identify the linear climb phase where altitude increases steadily.
7. Select a 30-second interval during the steepest climb. Record the altitude at the start and end of this interval.
8. Calculate the rate of climb: vertical speed = (altitude change) / (time interval) in m/s.
9. Convert to other units: km/h (multiply by 3.6) and feet per minute (multiply by 196.85).
10. Compare your measured rate of climb with the Shanghai Tower elevator speed: 20.5 m/s (74 km/h).
11. If barometer data is available, cross-check the altitude using the barometric formula: $\Delta h \approx (P_{ground} - P_{flight}) \times 8.5$ m/hPa.
12. Discuss the fundamental physics differences between lift-based flight and cable-based elevator systems.

Expected results

A typical commercial aircraft climbs at 7-15 m/s (1500-3000 feet per minute) during the initial climb phase. This is comparable to, but often less than, the Shanghai Tower elevator speed of 20.5 m/s. GPS altitude measurements have typical precision of ±5-10 meters, which over a 30-second interval translates to a rate-of-climb uncertainty of about ±0.5 m/s. The barometer provides a more precise altitude measurement (±1 m) if properly calibrated. Students should observe that the climb rate decreases as the aircraft gains altitude, due to decreasing air density reducing engine performance and lift. The aircraft's horizontal speed (typically 200-300 km/h) vastly exceeds the elevator's speed, even though the vertical component may be slower.

Questions

- Is the plane climbing faster or slower than the world's fastest elevator? Does the answer surprise you?
- What is the fundamental physical difference between how an airplane and an elevator gain altitude?
- Why does the rate of climb decrease as the aircraft reaches higher altitudes?
- What forces must be overcome for an airplane to climb? For an elevator?
- Why is the horizontal speed of the aircraft much greater than its vertical speed?
- How do pilots control the rate of climb during flight?

Going further

- Compare the rate of climb during takeoff, initial climb, and cruise climb phases of the same flight
- If possible, measure the vertical speed during descent and compare with the climb rate
- Compare altitude measurements from GPS and barometer during the same flight
- Research and compare the vertical speeds of different transportation systems: elevator, helicopter, rocket, hot air balloon
- Calculate the power required to lift the aircraft versus the power required for the elevator, accounting for their different masses