Variation of g with latitude

FizziQ activity · High school · 30 min

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Using the smartphone accelerometer in FizziQ, students measure g precisely, compare results across latitudes and explain why gravity is weaker at the equator.

Learning objectives

- Measure the acceleration of gravity at your location using the smartphone accelerometer
- Compare your measurement with values from other latitudes (partner schools or published data)
- Understand the two physical causes of g variation with latitude: Earth's shape and rotation
- Calculate the theoretical value of g at your latitude and compare with the measurement
- Appreciate the historical significance of latitude-dependent gravity in shaping our understanding of Earth's shape

Instruments and sensors

Absolute acceleration · Accelerometer

Materials

- Smartphone with the FizziQ application
- A flat and stable surface
- Contact with a class located near the equator (ideally)
- Internet access to check official g values
- FizziQ experiment notebook
- Note: the protocol remains adaptable to any comparable acceleration measurement tool.

Protocol

1. Open FizziQ and select the Accelerometer sensor. Choose absolute acceleration for the most precise measurement.
2. Place the smartphone on a perfectly flat, stable surface (a solid table, not a desk that flexes). Ensure the surface is level.
3. Record the acceleration for at least 60 seconds at the maximum sampling rate. Minimize all environmental vibrations: close doors, avoid walking near the phone.
4. Calculate the average (mean) value and the standard deviation of the recorded data. Record these values.
5. Repeat the measurement three times, removing and replacing the phone each time. Calculate the overall mean and standard deviation.
6. Determine your geographic latitude using a GPS app or online map service. Record it in degrees.
7. Look up the theoretical value of g at your latitude using the International Gravity Formula: $g = 9.7803267715 \times (1 + 0.0053024 \times \sin^2\varphi - 0.0000058 \times \sin^2 2\varphi)$, where φ is the latitude.
8. Compare your measured mean with the theoretical prediction. The difference represents the combined systematic error of the sensor plus local gravity anomalies.
9. If possible, obtain a measurement from a partner school at a different latitude (ideally near the equator or at a significantly different latitude). Compare the two measurements.
10. Calculate the expected difference between the two latitudes using the gravity formula. Is it consistent with the measured difference?
11. Discuss the minimum detectable latitude difference given the precision of your smartphone

accelerometer.

12. Research Jean Richer's historical measurement and compare his observed discrepancy with your theoretical calculation for Paris versus Cayenne.

Expected results

At a mid-latitude location (e.g., Paris at 48.9°N), the theoretical value of g is approximately 9.809 m/s². At the equator (0°), it is approximately 9.780 m/s². The difference of about 0.029 m/s² (0.3%) is small but potentially detectable with a good smartphone accelerometer. However, individual smartphone accelerometers typically have systematic calibration offsets of 0.05-0.20 m/s², which may exceed the latitude-dependent variation. Comparing two different smartphones at the same location will show differences due to calibration, not latitude. The most convincing approach is to use the same phone at two different latitudes, though this requires travel. Students should appreciate that detecting a 0.03 m/s² difference requires measurement precision better than 0.01 m/s², which is at the limit of consumer accelerometers.

Questions

- Why is the acceleration of gravity smaller at the equator than at the poles?
- What are the two main physical causes of this variation, and which one contributes more?
- How did Richer's observation help confirm that the Earth is not a perfect sphere?
- What is the centrifugal effect, and why is it strongest at the equator?
- How precise would a sensor need to be to detect the difference in g between the ground floor and the top of a tall building?
- How do geophysicists measure local variations in g, and what do these variations reveal about underground geology?

Going further

- Compare accelerometer readings at the ground floor and the top of a tall building to detect the altitude-dependent decrease in g
- Research and plot the theoretical variation of g from equator to pole and mark your measured value on the curve
- Use published gravity data from international databases to create a world map of g variations
- Investigate local gravity anomalies by measuring g at different outdoor locations and looking for variations due to underground geology
- Calculate the centrifugal acceleration at your latitude and compare it with the total variation of g