

Magnetic inclination and latitude

FizziQ activity · Middle school · 30 min



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Middle school students record the magnetic dip angle with the smartphone magnetometer and inclinometer in FizziQ Duo mode, then calculate their magnetic latitude.

Learning objectives

- Measure the magnetic field inclination (dip angle) using the smartphone magnetometer
- Apply the dipole formula $\tan(I) = 2 \times \tan(\lambda)$ to calculate the magnetic latitude
- Compare the calculated magnetic latitude with the geographic latitude
- Understand the structure of Earth's magnetic field and the concept of magnetic inclination
- Appreciate the difference between magnetic and geographic coordinates

Instruments and sensors

Magnetometer · Inclinometer · Magnetometer · Accelerometer

Materials

- Smartphone or tablet with a magnetic field measurement application (FizziQ)
- Environment free from magnetic disturbances
- FizziQ experiment notebook
- Calculator for trigonometric calculations
- Note: the protocol remains adaptable to any comparable magnetic field measurement tool.

Protocol

1. Find a location free from magnetic disturbances: away from metal structures, electrical cables, electronic devices, and vehicles. An outdoor location in an open field is ideal.
2. Open FizziQ and select the Duo mode to record both the Magnetometer (magnetic field components) and the Inclinometer simultaneously.
3. Place the smartphone on a flat, non-magnetic surface (wooden table, plastic bench, or directly on the ground away from any metal).
4. Rotate the phone slowly until the horizontal component of the magnetic field is maximized and the phone is aligned with the magnetic meridian (pointing toward magnetic north).
5. Record the values of the horizontal (B_h) and vertical (B_v) components of the magnetic field.
6. Calculate the magnetic inclination I from: $\tan(I) = B_v / B_h$, or read the inclination directly if FizziQ displays it.
7. Record the inclination angle I in degrees.
8. Apply the dipole formula to calculate the magnetic latitude: $\lambda = \arctan(\tan(I) / 2)$.
9. Convert the result to degrees. This is your magnetic latitude.
10. Look up your geographic latitude using a GPS app or map. Compare it with the calculated magnetic latitude.
11. The two values will differ because the magnetic poles do not coincide with the geographic poles (the current magnetic declination and the non-dipolar components of Earth's field cause discrepancies).
12. Research the current position of the north magnetic pole and discuss why geographic and magnetic latitudes differ.

Expected results

At a mid-latitude European location (e.g., Paris, 48.9°N), the magnetic inclination is approximately 64-66°, yielding a magnetic latitude of about 47-49° using the dipole formula, which is close to but not exactly equal to the geographic latitude. The discrepancy (typically 2-5°) arises from two factors: the magnetic dipole axis is tilted about 11° from the rotation axis, and the Earth's magnetic field is not a perfect dipole (higher-order components cause local anomalies). The smartphone magnetometer typically measures the field components with a precision of $\pm 1 \mu\text{T}$, which translates to an inclination uncertainty of about $\pm 1-2^\circ$. Environmental magnetic noise from nearby buildings or vehicles can cause larger errors.

Questions

- Why does the magnetic inclination vary with latitude?
- What is the difference between magnetic declination and magnetic inclination?
- Why do the magnetic poles not coincide with the geographic poles?
- How has the position of the magnetic north pole changed over time, and what causes this drift?
- What would the magnetic inclination be at the magnetic equator? At the magnetic poles?
- How did navigators historically use magnetic inclination to estimate their latitude?

Going further

- Measure the magnetic inclination at several locations in the school and investigate whether local magnetic anomalies affect the result
- Create a map of magnetic field strength and direction across the schoolyard
- Compare measurements taken inside a building versus outside to assess the effect of building materials on the magnetic field
- Research the history of magnetic navigation and the search for a method to determine longitude at sea
- Use published global magnetic field models (like IGRF) to calculate the expected inclination at your location and compare with your measurement