Triangulation with a theodolite

FizziQ activity · High school · 40 min

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Using the FizziQ smartphone theodolite, students measure azimuths between four landmarks and apply the law of sines to compute every distance from one baseline.

Learning objectives

- Use the FizziQ theodolite to measure angles between reference points in a chain of triangles
- Apply the law of sines to calculate unknown distances from one measured baseline
- Chain two triangles together to reach an inaccessible point
- Verify calculated distances by direct measurement where possible
- Understand the historical importance of triangulation in cartography and geodesy

Instruments and sensors

Theodolite · Magnetometer

Materials

- Smartphone with the FizziQ application
- An open space with visible reference points
- A tape measure to measure a reference distance
- Drawing materials to make the diagram
- Calculator
- FizziQ experience notebook
- Note: the protocol remains adaptable to any comparable angle-measurement tool.

Protocol

1. Choose four clearly visible points (A, B, C, D) in an open area, forming two triangles that share a common side (e.g., triangles ABC and BCD).
2. Directly measure the length of side AB with a tape measure. This is your baseline. Record it precisely.
3. Stand at point A and use the FizziQ Theodolite to measure the azimuth (compass bearing) to points B and C.
4. Calculate the internal angle at A in triangle ABC from the difference between the two azimuths.
5. Move to point B and measure the azimuths to points A and C. Calculate the internal angle at B.
6. Calculate the angle at C = 180° - angle_A - angle_B. (Or measure it directly as a check.)
7. Apply the law of sines to triangle ABC: BC = AB × sin(A) / sin(C) and AC = AB × sin(B) / sin(C).
8. Now side BC becomes the baseline for the second triangle BCD.
9. From points B and C, measure the azimuths to point D. Calculate the internal angles of triangle BCD.
10. Apply the law of sines to calculate BD and CD using BC as the known side.
11. If possible, directly measure BD and CD with a tape measure and compare with your calculated values.
12. Calculate the percentage error for each side and discuss the sources of uncertainty.

Expected results

With careful angle measurements (±2-3° with a smartphone theodolite), the calculated distances should agree with direct tape measurements within 5-15%. The accuracy depends heavily on the triangle geometry: equilateral or near-equilateral triangles give the best results, while very elongated triangles amplify angle errors. For triangles with sides of 20-50 meters, errors of 2-5 meters are typical. The sum of angles in each triangle should be close to 180° (within ±5°). The chain of two triangles allows reaching point D, which may be inaccessible for direct measurement, demonstrating the practical power of triangulation.

Questions

- Why is triangulation more practical than direct distance measurement for surveying large areas?
- How does the shape of the triangle affect the accuracy of the calculated distances?
- What is the minimum information needed to determine a triangle completely?
- How did the Great Trigonometric Survey of India use triangulation to measure Mount Everest's height?
- What are the advantages and limitations of using a smartphone as a theodolite compared to professional surveying equipment?
- How has GPS replaced triangulation for most modern mapping applications?

Going further

- Chain three or more triangles to reach a more distant point and evaluate how errors accumulate
- Use triangulation to determine the position of a hidden object visible from two known points
- Compare the accuracy of smartphone theodolite measurements with a physical compass and protractor
- Calculate the area of the triangles from your measured data using the formula A = ½ab sin(C)
- Research historical triangulation surveys and compare their methods with your schoolyard experiment