

MEASURING MOUNT EVEREST

GUIDING QUESTION

How did surveyors measure and map the great mountains of the Himalaya?

Students build an inclinometer, then use triangulation to measure the height of a tree. They compare their process to the work of British surveyors in the 1800s.



Materials

(Provide one each of these items for each group of students)

- small piece of cardboard, roughly 15 x 25 cm
- metal washer or paper clip as weight
- protractor
- 30 cm string
- transparent tape
- drinking straw
- 25-m tape measure
(can be shared among groups)
- calculator
- clipboard

Handouts

- *The India Survey*
- *Build An Inclinometer*
- *How Tall?*

DIRECTIONS

1. Discuss finding your way in an unmapped place.

View with students the film clip “George Mallory’s Wildest Dream.” Help students imagine going someplace not yet explored. Ask: *Can you think of a vast wilderness area nearby? Could you find your way through it without a map? How? What tools do we have today to help us find our way? How does one make a map of a wilderness area?*

Explain that climbers in extreme environments like Mount Everest today can have experienced guides, highly effective clothing, and resources such as detailed maps and global positioning system (GPS) technology. This was not the case in 1921, the year that the first climbers approached Mount Everest. In the 1800s, Sir George Everest and a team of British surveyors spent more than 50 years working on a huge land survey. A land survey is the measurement of distances and elevations on the Earth’s surface. The government of Nepal, however, did not allow the British to enter the country. Surveyors were forced to view and measure Mount Everest from over 100 miles away. When George Mallory attempted to climb Mount Everest in 1921, he used incomplete maps that were drawn from this distance.

2. Model the technology surveyors use.

Distribute **Handout 1: The India Survey**. Have students read paragraph 1, then model the movement of the parts of a theodolite. Explain:

- *Use your arms as the telescope of a theodolite. Point one arm to the first location, such as a bookshelf and move your other arm from there to a second object on the wall or window. How many degrees is this angle? Estimate.*
- *Next, use your arms to estimate a vertical angle. Point to a level spot; now use your other arm to point up to a new location such as a light or clock. How many degrees is this vertical angle? Estimate.*

3. Envision measuring distances in the Himalaya.

Have students read paragraphs 2 and 3. Draw the diagram from the handout on a white board. Mark known locations A and B in the classroom. Have two students stand at locations A and B, then point their arms at each other and at the glacier on the whiteboard. Explain that by measuring these two angles, and by measuring the distance between the locations, surveyors would use trigonometry to determine the distance to a third location, such as a summit or another point on a mountain. Each angle and distance would be calculated before measuring another triangle of land. Finish reading the handout.



MEASURING MOUNT EVEREST

Film Clip

- *George Mallory's Wildest Dream*

VOCABULARY

- coordinates
- elevation
- horizontal angle
- inclinometer
- land survey
- surveyor
- tangent ratio
- theodolite
- triangulation
- trigonometry
- vertical angle

Ask: *Why do you think it took so long to determine the elevation of Mount Everest? What was the India Survey's final measurement for the peak?*

4. Create a tool for measuring the height or elevation.

Students next build an instrument called an inclinometer. They will use this instrument to measure a vertical angle, then calculate the height of a tree or other tall object outside. Grouping students in teams of three or four, distribute **Handout 2: Build An Inclinometer** to each group. Go over materials and procedures and begin.

5. Model the surveyors' technique with a tree or other tall object outdoors.

Before heading outside, distribute **Handout 3: How Tall?** Explain that students will use the inclinometers and a tape measure outside to gather two angles and one distance related to the height of tall objects. More than one group will measure different objects so they can compare their results later. Have students follow closely the directions on Handout 3 and monitor their progress.



6. Calculate using their measurements and the Tangent Ratio Chart.

When measurements are complete and entered in the chart, return to the classroom to calculate the height of the objects. Discuss the process for determining height of the objects, then allow students to calculate the height of their three objects. Consider having each group choose one object they measured, then come to the board to demonstrate how they calculated the height. They can draw the triangle, point out the right angle, the measured angle, and the distance. Together, on the white board, list their results with other results for the same objects, then discuss.



MEASURING MOUNT EVEREST

“I am now in possession of the final values of the peak... it measures 29,002 feet.”

— a letter from Andrew Waugh, 1856

7. Connect students' work with the surveyors' work on Everest.

Talk about how measuring the height of a tree is a simple application of trigonometry, while measuring the elevation of a distant peak is much more difficult. Surveyors spent almost three years using a combination of trigonometric calculations to reach the conclusion that Everest has an elevation of 29,002 feet. This was an amazingly accurate result. Ask: *What was the most challenging part of measuring and calculating?*

Explain that a surveyor's theodolite measures both vertical angles and horizontal angles. The angle students measured with the inclinometer is an example of a vertical angle based on one reading. Ask: *Would this measurement work to figure out the summit of a mountain? Why or why not?* (No, because of lack of information. There is no distance measure or right angle. We only have one angle to work with. Even if we hike to the base of the mountain, there is not a right angle to the summit as with the tree.)

EXTENDING THE LESSON

Read the [article](#) about the 1999 measurement of Mount Everest. Read the excerpt from *Everest: Eighty Years of Triumph and Tragedy* listed below, or research using other sources. Have students compare the challenges that the surveyors faced measuring Everest in 1856 and with those of the 1999 team. Discuss: *How far off was the 1999 measurement from Waugh's number in 1856? What does this say about both technologies used for measurement?* (1856: 29,002 feet; 1999: 29,035 feet)

SUGGESTED RESOURCES

Gillman, Peter, and Leni Gillman, *Everest: Eighty Years of Triumph and Tragedy*, Mountaineers Books: 2001. Pages 10-11.

Millennium Expedition, measuring Everest's elevation with GPS technology: http://www.nationalgeographic.com/features/99/everest/millennium_start.html



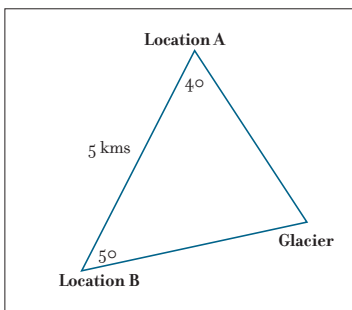
THE INDIA SURVEY

HANDOUT 1

ONE OF THE KEY TOOLS OF THE INDIA SURVEY of the mid 1800s was a **theodolite** (thee-oh-duh-lite). Weighing more than 1,000 pounds, it required 12 men to move this enormous piece of equipment! A theodolite is a type of telescope mounted on a tripod, which surveyors use to view locations in the distance. The surveyor pivots the telescope and measures the angle between the two locations. The telescope also pivots up and down to measure the angle of a slope, or incline.

When marking a location, surveyors identify its **coordinates**, or the location's exact intersection of longitude and latitude. With the India surveys, surveyors began at one location and used huge chains or bars to measure and build a 12-kilometer baseline. Along that baseline, they established observation posts. From the observation posts they were able to observe, measure, and plot triangles across the land, then draw the land in the form of a basic map. A triangle is a helpful shape to the surveyor. Using triangles to identify and measure the land is called **triangulation**.

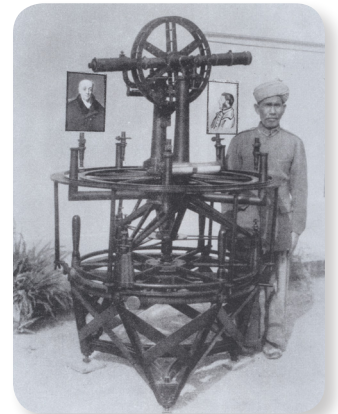
A surveyor can identify the location of an unknown point (such as the tip of a glacier) using two known locations (Location A and Location B) and the distance between them (5 kilometers). The surveyor goes to Location A, points the telescope of the theodolite to the tip of the glacier, and takes a reading. He then rotates it to known Location B, takes a reading, and records the angle of the difference (40°). Then the surveyor travels to Location B and repeats the process (50°). With the distance between the two known locations and the angle measurements, surveyors can use math processes called trigonometry to calculate the unknown distance to the tip of the glacier. They can then also determine the latitude and longitude at that third point.



In the early 1800s, the Andes Mountains of South America were thought to be the highest peaks in the world. As the India Survey extended their triangular measurements, it became clear that the distant peaks of Nepal were much higher than the peaks of the Andes. In 1848, James Nicolson of the India Survey team went to certain locations to take 36 theodolite readings of a summit known as peak b. He spent months traveling among six remote observation posts with the huge theodolite. James Nicolson contracted malaria and was transported home, but a team of surveyors led by Andrew

Waugh spent years using his data to calculate the elevation of the summit. In 1856, after years of work, Andrew Waugh wrote to his supervisor, "I am now in possession of the final values of the peak... it measures 29,002 feet."

The India surveyors used a very complex process of both vertical and horizontal readings to triangulate a distant elevation. To better understand triangulation we will try something simpler: measuring the height of a tree.



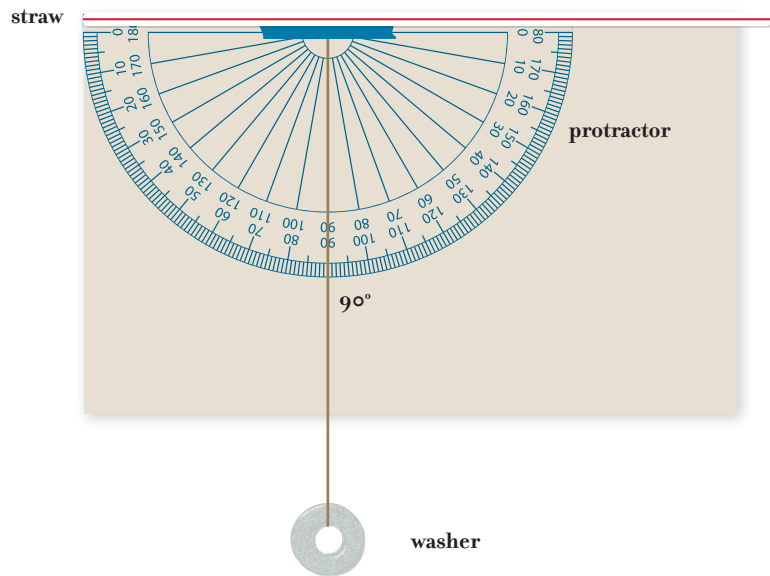
George Everest used this theodolite in the 1830s and 1840s during the Great Trigonometrical Survey of India. This instrument weighed approximately half a ton.

BUILD AN INCLINOMETER

Use the materials, procedure, and illustration below to build your own inclinometer.

Materials needed:

- piece of cardboard, 15 x 25 cm
- metal washer or paper clip
- protractor
- 30 cm string
- transparent tape
- drinking straw



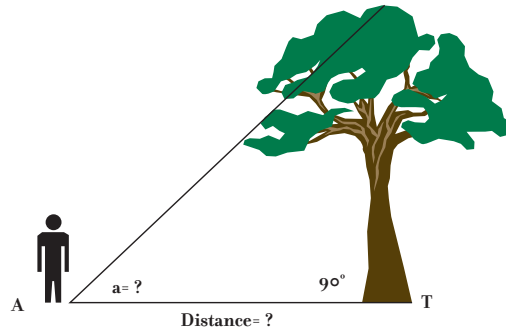
PROCEDURE

1. Tie string around the exact center of the straight edge of a protractor and tape it in place.
2. Tie a metal washer to the other end of the string.
3. Tape the protractor to the edge of the small cardboard. Line up the corner of the protractor with the corner of the cardboard as shown above.
4. Tape a straw along the edge of the cardboard and protractor, flush with the same corner.
5. Practice looking through the straw to site distant objects.

HOW TALL?

Materials needed:

- inclinometer
- clipboard
- 25-m tape measure
- calculator
- pencil



MEASURE:

1. Choose a clearly visible tree or other tall object. The base of the object is at Point T.
2. Walk 30 paces away from the tree and establish Point A. (see illustration)
3. Use a tape measure to measure Point A to Point T. Enter it in the chart below as Distance (D).
4. Stand at Point A and use the inclinometer to sight the top of the tree through the straw, as if you are looking through a telescope. Hold the inclinometer very still, so that the string with the washer is stationary.
6. Have a group member read the number where the string hangs next to the protractor.
6. Subtract that number from 90. Enter that number in the chart as angle (a).
7. You now have the three numbers you need: one line (D), angle (a), and a second angle at Point T, which is 90° (the right angle between ground and tree). Repeat steps 1-7 for two more objects.

Angle opposite the right angle	Tangent Ratio (T)
30°	.577
35°	.7
40°	.839
45°	1.0
50°	1.088
55°	1.176
60°	1.268
65°	1.364
70°	1.466

CALCULATE:

With any right triangle, the two sides that come together at the right angle have a ratio called a **tangent ratio**. Ratio simply means a comparison between two numbers. It can be written as a decimal. This is part of mathematics called **trigonometry**.

Use this formula to find the height of the objects, **Distance (D) x Tangent Ratio (T) = Height (H)**

HOW TALL? DATA CHART

	Object 1: _____	Object 2: _____	Object 3: _____
Distance (D) _____ m			
Angle opposite the right angle (at Point A) _____ °			
Tangent Ratio (T) (from chart)			
Calculation: D x T = H			
Height (H) _____ m			