Design a Clinometer

Overview:

In the 1920s, Carl Stromer from Norway used a mathematical formula called triangulation to determine the height of the aurora. Students build a simple measuring device with which they can determine the height of classroom objects.

Objectives:

The student will:

- build a working clinometer;
- use a clinometer to determine the height of an unknown object;
- use triangulation to determine the height of an object;
- measure in degrees, calculate averages, and interpret data; and
- determine that Carl Stromer used similar triangulation techniques to figure out the height of the aurora.

Materials:

- Protractors (the reproducible protractor can be cut out and glued to cardboard)
- Tape
- Drinking straws
- Metal washers
- String
- Hole punch (if using paper protractors)
- Calculators
- Scissors (if using paper protractors)
- Glue (if using paper protractors)
- Meter sticks or measuring tape
- Sight clinometer (such as those used by meteorologists to measure cloud height)
- VISUAL AID: “Measuring the Aurora”
- STUDENT INFORMATION SHEET: “Tangent Chart”
- STUDENT WORKSHEET: “Design a Clinometer”

Activity Preparation:

1. Measure the heights of two objects in or near the classroom and record information. Objects should be well above eye level such as a colored sticker near the ceiling, the top of a window or door, a light fixture, or the roof of the building. Label one object “Test” and the other object “Challenge.” Students need access to the “Test” object during the design activity. The “Challenge” object can be located outside the classroom.

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2. To accurately use their clinometers, students need to stand a known distance from the object they are measuring. For the "Test" object, this distance should be three meters. Measure three meters from the "Test" object and make a tape mark on the floor.
3. Students also need to determine the height of their "eye-level." On a wall, measure 1 meter up from the floor and tape a meter stick vertically to the wall with the "0" touching the 1 meter position. This will help students find their eye level. For more information, see STUDENT WORKSHEET: "Design a Clinometer" under Procedure, Step 1: a-d.

Activity Procedure:

1. Show the VISUAL AID: "Measuring the Aurora" and explain that scientist Carl Stromer, from Norway, used this method to measure the height of the aurora. (NOTE: If students participated in the "How High is the Aurora" activity located in this manual, they have already learned to use triangulation.) Show students the sight clinometer and explain that scientists use a clinometer to measure height via triangulation. The Height-O-Meter used in the previous activity is one type of clinometer.

2. Distribute the STUDENT WORKSHEET: "Design a Clinometer" and discuss the formulas located in the data tables on the worksheet. Ask students to identify the measurements needed to determine the height of an object using a clinometer (baseline distance and angle of elevation). Instruct students to design a clinometer. Because a clinometer must measure an object's angle of elevation, the angles marked on the protractor have an important role in a working clinometer.

3. Ask students to check off the hypothesis they think will be most accurate at the top of their worksheet.

4. Explain the importance of eye height when using a clinometer. Show the location of the meter stick you have taped to the wall and demonstrate how to determine eye height. Remind students that the meter stick is taped 100 centimeters from the ground and ask each student to find their eye height and record it in the data section of their worksheet.

5. Distribute the STUDENT INFORMATION SHEET: "Tangent Chart" and explain how to find the tangent of each angle they record in the data tables on the STUDENT WORKSHEET.

6. Distribute materials and ask students to design and build a clinometer.

7. Point out the "Test" object in the classroom and explain to students that in order to test the accuracy of their clinometer, they need to measure the height of the "Test" object. Ask students to stand on the tape line when measuring the Test object's angle of elevation so that the baseline distance (3 meters) written in the Test Object Data Table is accurate. After students measure the "Test" object's angle of elevation, ask them to perform the calculations necessary to complete the table. If a student's clinometer does not provide accurate measurements, give them some helpful hints for success. (See TEACHER INFORMATION SHEET: "Design a Clinometer.")

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8. After students have a consistently working clinometer, direct them to the "Challenge" object. Ask them to determine the height of that object. Students must measure and record the baseline distance (the distance from the student to the base of the object) to get an accurate measurement of the object's height.

Answers to Student Worksheet:

Data:

In-class "Test" object: *Answers will vary. However students should have correct calculations and should eventually get the correct answer.*

"Challenge" object: *Answers will depend upon the object chosen. Calculations should be correct.*

Analysis of Data:

1. *B. 3 meters*
2. *A. we measured from the base of the object to the feet of the person with the clinometer*
3. *Answer depends upon object chosen.*
4. *Answer depends upon object chosen.*

Conclusion: *A hand-made clinometer can be used to accurately measure height.*

Further Questions:

1. *B. height=angle tangent x baseline distance*
2. *triangulation*
3. *Answers will vary. Students should recognize that Stromer used triangulation.*

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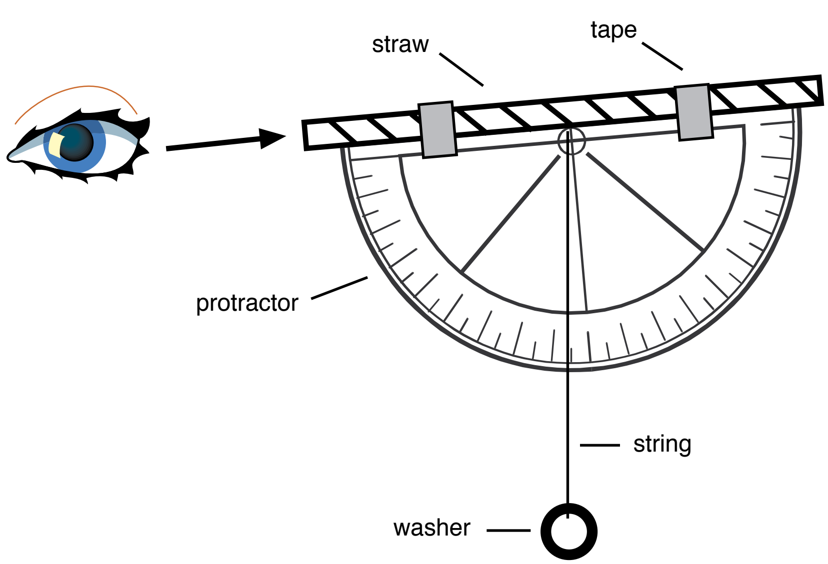
How to Build and use a Clinometer:

1. Tie a metal washer (or other small weight) to a piece of string, then tie the other end of the string through the hole on the ruler side of a protractor. (*NOTE: If you are using a paper protractor, cut it out and glue it to cardboard to make it stiff enough to use. Then punch a hole in the paper protractor at the point labeled "tack mark" through which to tie your string.)*
2. Tape the drinking straw along the ruler side of the protractor to create a "sight" through which to look.
3. To use the clinometer, hold it ruler side up at arm's length. The string with the washer on the bottom should hang along the side of the protractor, dangling over the degree marks.
4. Stand away from the object you are measuring and look through the straw "sight" at the top of the object.
5. Ask a partner to measure the distance from the base of the object being measured to your feet. Record this baseline distance. For the "Test" phase of this activity this distance should be 3 meters. For the "Challenge" object this distance will vary. The calculations will be simpler if you always use an even distance (3 meters, 4 meters, etc.).
6. After your partner has measured the baseline distance, ask them to observe the angle marked by the string on the protractor as you look through the "sight" on the clinometer at the top of the object. Record this information in the "Angle of Elevation" on the STUDENT WORKSHEET: "Design a Clinometer."
7. Perform the calculations shown on the worksheet to determine the height of the object.



Name:_______________________ **Student Worksheet (1 of 3)**

Design a Clinometer

Testable Question:

Can I accurately measure the height of objects in my classroom using a hand-made clinometer?

Background Information:

In the 1920s, Carl Stromer, from Norway, used a mathematical formula called triangulation to determine the height of the aurora. Triangulation is a very powerful mathematical tool used today to determine the location of earthquakes, for navigation using satellites, and for surveying land.

Hypothesis:

Use the background information provided by your teacher or on this worksheet to make a hypothesis (Check one):

______ A hand-made clinometer can be used to accurately measure height.

______ A hand-made clinometer cannot be used to accurately measure height.

Experiment:

Materials:

- Protractor
- Drinking straw
- Tape
- Metal washer
- String
- Meter stick
- Calculator
- STUDENT INFORMATION SHEET: "Tangent Chart"

Procedure:

1. Clinometers measure the height of an object from eye level rather than from the ground. Find your eye height using the following steps:
   a. Stand next to the meter stick taped to the wall and note the number closest to your eye.
   b. Add 100 centimeters to this number because the meter stick 100 centimeters above the floor.
   c. Convert the sum to meters, rounding to the nearest tenth. For example, if the number closest to your eye is 19 centimeters, your eye height is 119 centimeters, which converts to 1.2 meters.
   d. Record your eye height in the space provided at the beginning of the "Data" section.
2. Design your clinometer. A working clinometer needs a sight to look through, a protractor secureley attached to the sight, and a pointer to indicate the angle of elevation of the object being measured. The pointer <u>or</u> the protractor must pivot freely.
3. Test your clinometer by measuring the angle of elevation of a "Test" object. Stand 3 meters from the object (on the tape line) to take your measurement. The baseline distance is already recorded in the Test Object Data Table (Design #1). Record the angle of elevation in the column provided.
4. Complete the Tangent of Angle column using your tangent chart. Use a calculator to complete the height and total height columns, then average your results. Check your results with your teacher.
5. If your answer is incorrect, ask your teacher how to improve your design. Revise your clinometer and repeat steps 3-5. Record your data in the Test Object Data Table (Design #2).
6. If your answer is correct, congratulations! You are ready to measure the height of the "Challenge" object. Be sure to measure and record the baseline for this experiment.
7. Record the data you collect for the "Challenge" object in the Challenge Object Data Table.

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Data:

Eye height: ______________ (*Follow the instructions in Step 1 of the Procedure.*)

Test Object Data Table (Design #1)

	Baseline Distance	Angle of Elevation (using clinometer)	Tangent of Angle (from chart)	Height (tangent x baseline)	Total Height height + eye height)
Trial #1	3 meters				
Trial #2	3 meters				
Trial #3	3 meters				
		Average Height = (Total #1 + Total #2 + Total #3) ÷ 3			

Test Object Data Table (Design #2)

	Baseline Distance	Angle of Elevation (using clinometer)	Tangent of Angle (from chart)	Height (tangent x baseline)	Total Height height + eye height)
Trial #1	3 meters				
Trial #2	3 meters				
Trial #3	3 meters				
		Average Height = (Total #1 + Total #2 + Total #3) ÷ 3			

Challenge Object Data Table

	Baseline Distance	Angle of Elevation (using clinometer)	Tangent of Angle (from chart)	Height (tangent x baseline)	Total Height height + eye height)
Trial #1					
Trial #2					
Trial #3					
		Average Height = (Total #1 + Total #2 + Total #3) ÷ 3			

Name:____________________ **Student Worksheet (3 of 3)**

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Analysis of Data:

1. The baseline distance for the "Test" object measurements was:

   A. 6 meters B. 3 meters C. 3 feet D. 1 meter

2. When determining the baseline distance for the "Challenge" object:

   A. we measured from the base of the object to the feet of the person with the clinometer.

   B. we used the measurement given in the data table.

   C. we guessed.

3. The height of the "Test" object we measured in class was ______________________.

4. The height of the "Challenge" object was ______________________.

Conclusion:

______ A hand-made clinometer can be used to accurately measure height.

______ A hand-made clinometer cannot be used to accurately measure height.

Was your initial hypothesis proved or disproved? Use a complete sentence.

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Explain what evidence supports your conclusion. Use complete sentences

____

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Further Questions:

1. Using triangulation, what mathematical formula would you use to find the height of an object?

   A. height = pi2 + 2 C. height = mc2

   B. height = angle tangent x baseline distance D. height = perimeter x radius

2. Scientists use a method called ____________________ to measure the height of the aurora.

3. How might Carl Stromer have used a clinometer to measure the height of the aurora?

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