TEACHER'S GUIDE

# HEIGHT-O-METERS

Grades 6–10

**Skills**
Predicting, Estimating, Making and Calibrating Scientific Instruments,
Measuring in Degrees, Graphing, Calculating, Interpreting Data

**Concepts**
Angular and Linear Measurement,
Triangulation with Scale Drawings

**Themes**
Systems & Interactions,
Models & Simulations, Stability, Scale

**Nature of Science and Mathematics**
Scientific Community, Interdisciplinary,
Cooperative Efforts,
Theory-Based and Testable, Real-Life Applications,
Science and Technology

**Time**
Four 45- to 50-minute sessions
plus follow-up suggestions

**Cary I. Sneider**

LHS GEMS
**Great Explorations in Math and Science (GEMS)**
Lawrence Hall of Science
University of California at Berkeley

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Publication was made possible by grants from the A.W. Mellon Foundation and the Carnegie Corporation of New York. This support does not imply responsibility for statements or views expressed in publications of the GEMS program. GEMS also gratefully acknowledges the contribution of word processing equipment from Apple Computer, Inc. Under a grant from the National Science Foundation, GEMS Leader's Workshops have been held across the country. For further information on GEMS leadership opportunities, please contact GEMS at the address and phone number below.


Reprinted with revisions, 1991, 1996.

International Standard Book Number: 0-912511-22-2

**COMMENTS WELCOME**

Great Explorations in Math and Science (GEMS) is an ongoing curriculum development project. GEMS guides are revised periodically, to incorporate teacher comments and new approaches. We welcome your criticisms, suggestions, helpful hints, and any anecdotes about your experience presenting GEMS activities. Your suggestions will be reviewed each time a GEMS guide is revised. Please send your comments to: GEMS Revisions, c/o Lawrence Hall of Science, University of California Berkeley, CA 94720. The phone number is (510) 642-7771.

# Great Explorations in Math and Science (GEMS) Program

The Lawrence Hall of Science (LHS) is a public science center on the University of California at Berkeley campus. LHS offers a full program of activities for the public, including workshops and classes, exhibits, films, lectures, and special events. LHS is also a center for teacher education and curriculum research and development.

Over the years, LHS staff have developed a multitude of activities, assembly programs, classes, and interactive exhibits. These programs have proven to be successful at the Hall and should be useful to schools, other science centers, museums, and community groups. A number of these guided-discovery activities have been published under the Great Explorations in Math and Science (GEMS) title, after an extensive refinement process that includes classroom testing of trial versions, modifications to ensure the use of easy-to-obtain materials, and carefully written and edited step-by-step instructions and background information to allow presentation by teachers without special background in mathematics or science.

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# Contents

# *Acknowledgments*

These activities were adapted from a course for middle school students called "Learning to Experiment With Model Rockets," developed by Cary Sneider in the mid-1970s. Alan Gould developed the Height-O-Meter as a way to involve all the students in tracking rocket altitudes on launch day. The use of the Height-O-Meter to teach triangulation in classrooms was tested in the early 1980s with financial assistance from the National Science Foundation (grant #SED79-19011.)

# *Introduction*

A forest ranger in a lookout tower notices a plume of smoke in the distance, and calls a ranger in a second tower. During the next few minutes, spotters in the two towers use very accurate compasses to measure the angle between magnetic north and the plume of smoke. In a few seconds they pinpoint the location of the fire on a map to guide teams of firefighters.

Two groups of observers on a model rocketry range use instruments to measure the angle between the horizon and each rocket at maximum altitude. A few minutes after each flight, the altitude in meters is announced over the loudspeaker.

An astronomer measures the angle between two stars from a certain location in the earth's orbit, then measures that angle again six months later. The astronomer reports that the star Alpha Centauri is 24 trillion miles away.

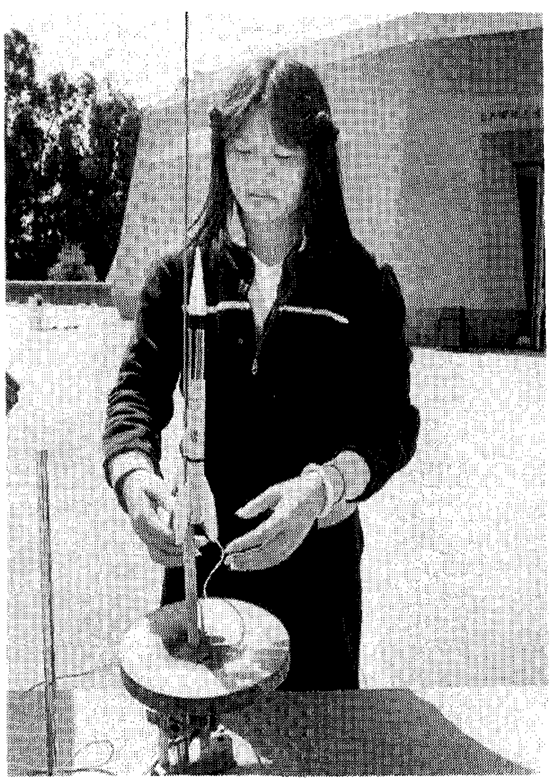
In each of these examples, people measure distances that are virtually impossible to measure directly. The principle is the same in each case: Measure angles between the object and some reference point from two different locations, a known distance apart. Next, make a scale drawing. The object and two locations form a triangle. By measuring the triangle on the scale drawing, you can measure the distance to the object. This method of indirect measurement is called ***triangulation***—a technique that has great practical value in many different fields.

Height-O-Meters make the principle of triangulation simple and fun to apply. These simple cardboard devices (technically called *clinometers*) can be used to measure the angular height of an object in degrees. Clinometers are commercially available for $5 to $10 each, and can also be made from plastic protractors and soda straws for under $1. The design in this guide costs only a few cents per student, and is easier to use than designs based on plastic protractors.

CONTINUED

In preliminary activities, your students construct and calibrate their Height-O-Meters so they read zero degrees when pointed horizontally. Next, they learn how to use their instruments to determine the height of the school flagpole. Finally, they perform an experiment to compare how high a styrofoam ball and a rubber ball can be thrown. The *Going Further* section suggests activities to clarify the relationship between angular and linear height, to illustrate how forest rangers use triangulation to spot fires, to introduce the tangent function, and explain how astronomers find the distances to stars.

While all of the basic Height-O-Meter activities are appropriate for sixth through tenth graders, older students will grasp the concepts at a deeper level than younger students. For example, all students will be able to learn how to measure angles and distances, using the metric system, and learn the fundamental concept of triangulation. Older students will appreciate how triangulation fits into the larger context of geometry and trigonometry.



After the unit, your students can bring their Height-O-Meters home to measure the heights of trees and houses in their neighborhoods. They can also use these devices to track the altitudes of model rockets as described in the GEMS Teacher's Guide, *Experimenting with Model Rockets.*

# Time Frame

**Session 1: Making Height-O-Meters**

| | |
|---|---|
| Teacher Preparation | 50–60 minutes |
| Constructing Height-O-Meters | 35–45 minutes |

**Session 2: Calibrating Height-O-Meters**

| | |
|---|---|
| Teacher Preparation | 15–20 minutes |
| Measuring Angles | 5–10 minutes |
| Calibrating | 20–30 minutes |
| Measuring Eye Level | 5–10 minutes |

**Session 3: How High Is the Flagpole?**

| | |
|---|---|
| Teacher Preparation | 30–40 minutes |
| Measuring the Flagpole | 15–20 minutes |
| Calculating the Height | 20–30 minutes |

**Session 4: Experimenting With Height-O-Meters**

| | |
|---|---|
| Teacher Preparation | 20–30 minutes |
| Performing the Experiment | 15–20 minutes |
| Analyzing the Results | 20–30 minutes |

# Session 1: Making Height-O-Meters

## Introduction

In the first session, each student constructs a Height-O-Meter by gluing a master onto cardboard, and cutting out two pieces: a handle piece with pointer, and a half-disk with a protractor scale. The students assemble these pieces to make Height-O-Meters, and test them to see if they work properly.

## What You Need

**For the class:**

- ☐ 1 roll of masking tape
- ☐ 2 copies of the "Height-O-Meter" sheet (master included, page 17.)

**For each group of four students:**

- ☐ 1 large glue stick or one jar of rubber cement
- ☐ 1 pair of scissors, sturdy enough to cut cardboard
- ☐ 1 ruler

**For each student:**

- ☐ 1 pencil
- ☐ 1 push pin
- ☐ 1 piece of wood (about 1/2" on each side, a piece of cork, or a pencil eraser cap
- ☐ 1 sheet of thin cardboard or posterboard ($8^1/_2$" × 11"), file folder stock, tagboard, or matte board
- ☐ 1 copy of the "Height-O-Meter" sheet (master included, page 17.)

*Gloria Hirata, a science and technology resource teacher from San Jose, California sent us an excellent alternative to the use of a push pin in the Height-O-Meter. She suggests obtaining a grommet gun from a sewing store, which is inexpensive and easy to use. A 3/16" hole is punched, then the small grommet (sewing eyelet) is fastened carefully to make sure the two parts swing freely. The sewing eyelet can be spread out or loosened slightly to allow for better swing. She also duplicated the template on to cardboard and laminated the holder of the Height-O-Meter.*

## Getting Ready

1. Cut the small pieces of wood or purchase pencil eraser caps. Each student will need a pencil eraser or small block of wood, about ½-inch on each side, to hold the point of the push pin. Pencil eraser caps (without pencils) can be purchased in quantity. If you choose to make small wood blocks, the exact dimensions are not critical. Soft pine is best because it can be cut easily by a hand or power saw and will hold the push pin firmly.

2. Make one copy of the "Height-O-Meter" sheet for each student (from the master on page 17), plus two additional copies.

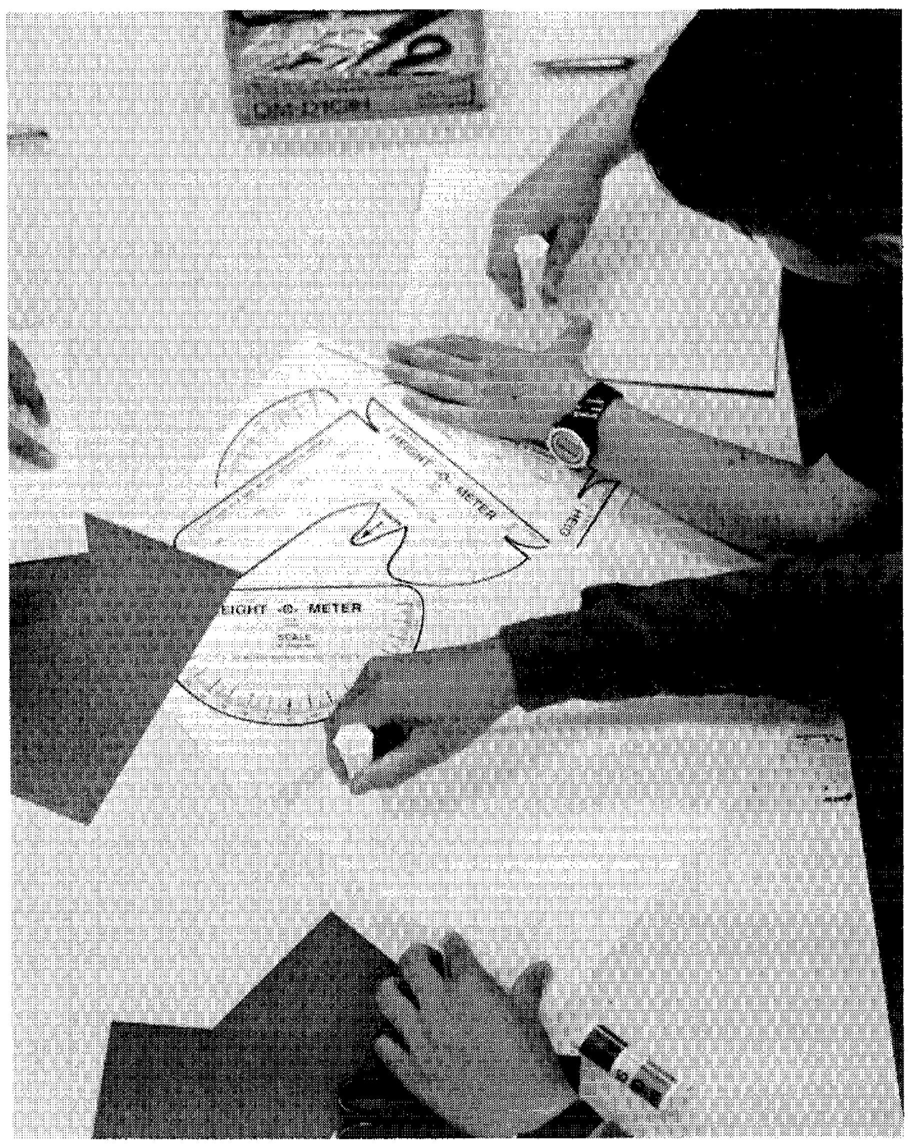
3. Collect all other materials:

- Scissors—The scissors must be able to cut thin cardboard. Ask your students to bring in a pair of scissors from home, or ask other teachers if you can borrow their scissors for the day.
- Cardboard — Purchase thin cardboard. Figure out how many large sheets you will need to provide one 8-½" × 11" sheet for each student in your class. Cut it into smaller sheets using a paper cutter or scissors.
- Push pins—Thumb tacks can be substituted, but push pins are easier for the students to use.
- Glue—Glue sticks are the least messy. One medium or large glue stick should be able to make four to six Height-O-Meters. Rubber cement is easy to spread smoothly, but the fumes are unhealthy. It can be used outdoors, or in the classroom if all windows can be opened. Other possibilities include using double-stick tape or having the Height-O-Meter master duplicated directly onto card stock.

*Manila folders can be used as the light cardboard to make Height-O-Meters, provided that glue sticks or rubber cement are used. Do NOT use white glue, as it will cause manila folders to warp.*

4. Try it yourself first. Make one Height-O-Meter and try out the activities in Sessions 1 and 2. That will enable you to explain the process of making and using a Height-O-Meter to your students, and help you anticipate problems they may encounter. A completed Height-O-Meter is needed to show the students what they will be constructing in Session 1.

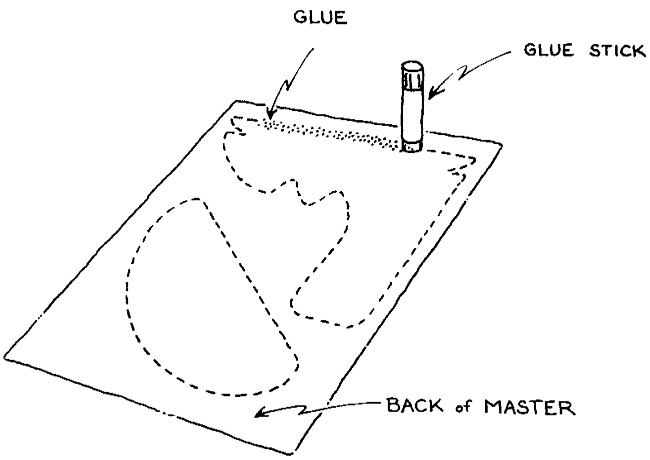
5. For this session only you will need to arrange the tables or desks so that students can work in groups of four to share materials. Place a wastebasket in a central area.



## Constructing Height-O-Meters

1. Introduce the activity by asking the students how they think scientists measure the distances to things that are very far away, such as a rocket, a space satellite, or a star.

2. Hold up the Height-O-Meter that you made before class and tell the students that they will make these instruments, called Height-O-Meters, which measure the heights of things that are very difficult to measure directly. You can add that scientists and engineers use similar instruments to measure how high rockets fly, and how far it is to the moon, or to a star.



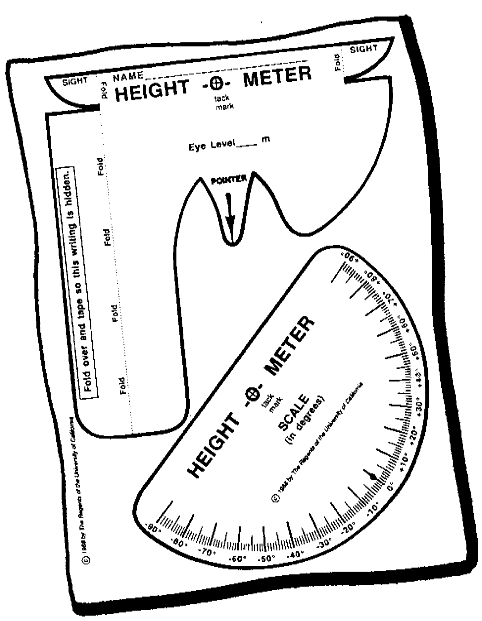

3. Demonstrate the first four steps in making Height-O-Meters:

   a. Hold up a glue stick, cardboard sheet, and Height-O-Meter master. Demonstrate how to place the master **face down** on a light-colored surface, such as a sheet of paper, so you can see the heavy lines through the back.

   b. Smear glue smoothly and evenly on the back of the master, covering the areas on and just inside the heavy lines that will later be cut out.

   c. Stick the Height-O-Meter master to the cardboard sheet, pressing and smoothing the master onto the glued backing sheet to eliminate wrinkles.

   d. Cut out the two parts of the Height-O-Meter, along the heavy solid lines.




4. Hand out glue sticks and scissors (at least one pair of scissors and one glue stick per group of four students). Have two students help you distribute one sheet of thin cardboard and a Height-O-Meter master to each student.

5. Help individuals as needed. Check to see if the two pieces cut out by each student will lie flat on the table. Too much glue, or cardboard that is too thin, will sometimes cause the pieces to warp. If that happens to some of your students' Height-O-Meter pieces, try bending them in the opposite direction. (*Note:* If that does not work, and the two pieces are still warped, have all of your students place them under a book overnight. In this case, stop the class at this point and continue the next day.)

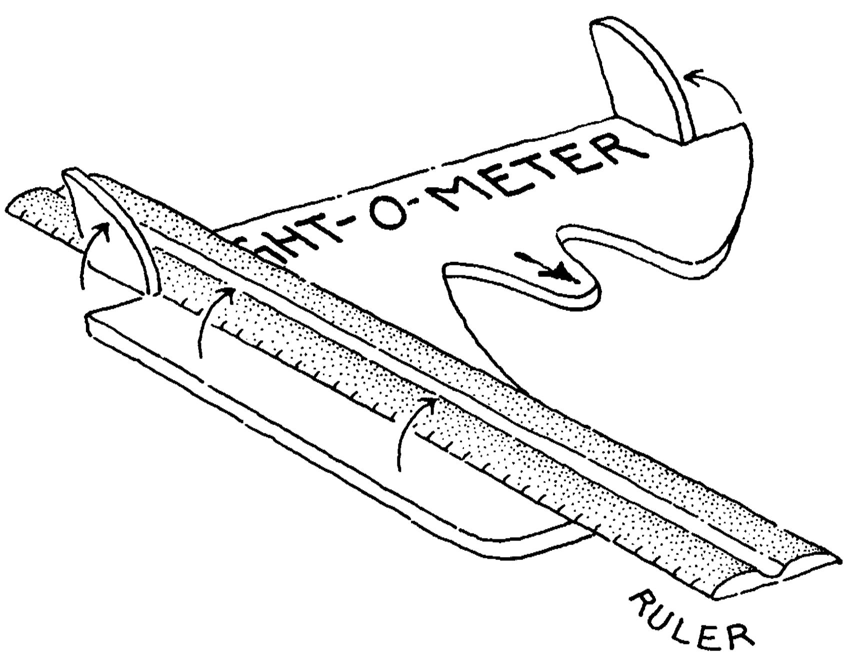
6. When most students have finished cutting out the two pieces, collect the glue sticks and scissors and demonstrate the next steps as follows:

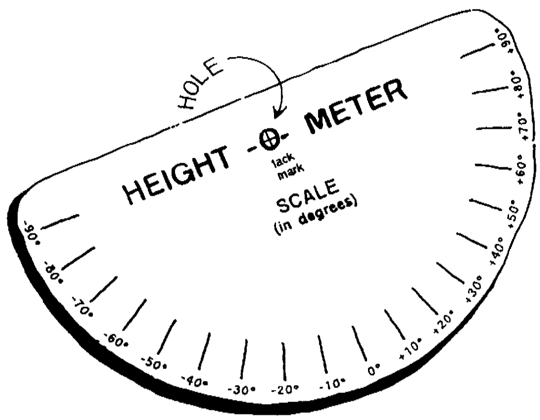
*If your students are good at following directions you may wish to demonstrate how to complete the Height-O-Meter (steps 6-9) all at once.*

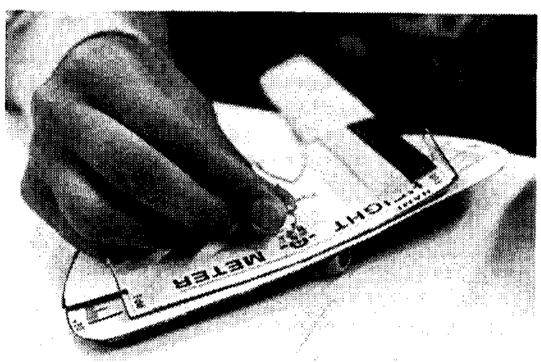
a. Toss all scraps into the wastebasket.

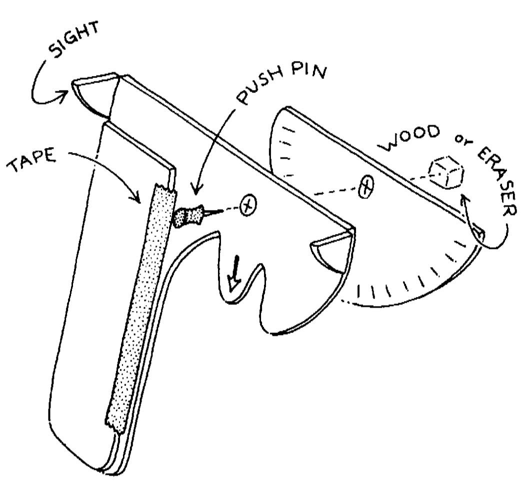
b. Lay the handle piece flat on a table with the printed side facing up. Lay a ruler along each "fold" line. Fold the two sights so they are pointing straight up. Fold the handle up and over, along the fold line. Tape the handle together lengthwise to strengthen it.

c. Write your name on the dashed line at the top of the handle piece.








7. As you check your students' work to be sure they cut and fold where they are supposed to, carry a roll of masking tape and a glue stick. Hand out a 4" piece of tape to students who are ready to tape their handles. Have students reglue any places where the master has separated from the cardboard.

8. When everyone has finished folding and taping the handle, hold up the half-disk with protractor scale and a push pin. Demonstrate how to place the half-disk face up on a notebook or desk, and push the pin through the half-disk. Then pick up the half-disk and work the push pin in a circle to enlarge the hole. Withdraw the push pin. **Caution the students not to stick themselves with the push pin.** Circulate among the students, helping as needed.

9. When all students have completed the above steps, show them how to assemble their Height-O-Meters as follows:

a. Place the handle piece face up on a notebook or desk. Push the pin through the tack mark on the handle.

b. Pick up the handle piece and insert the pin through the enlarged hole in the half-disk.

c. Place the piece of wood or eraser on the notebook or desk, and push the end of the pin into it. (Again, caution students to avoid sticking themselves by making sure they put the wood or eraser on the notebook or desk before inserting the push pin.)

d. Check to see if the pin is sticking out of the wood block or eraser. If it is, pull the pin back out a little way until the point does not stick out.

10. When your students finish assembling their Height-O-Meters, show them how to hold them vertically by the handle. They should hold the handle piece and sight along the tops of the two sights with one eye.

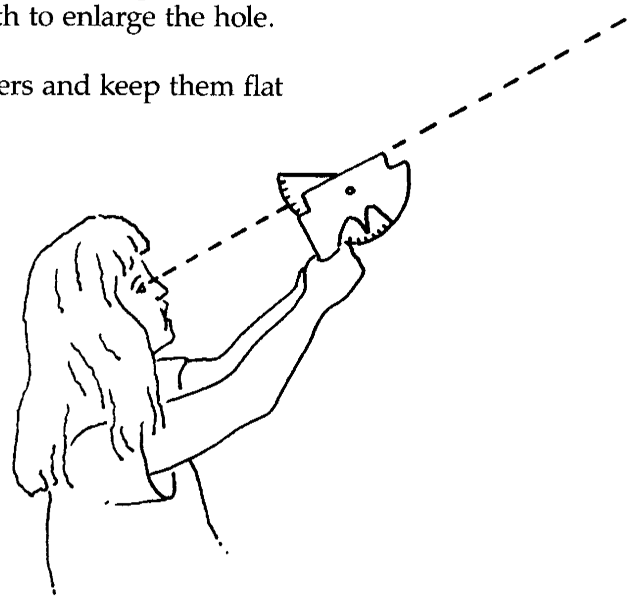
11. Demonstrate how the half-disk must swing freely when the Height-O-Meter is held vertically by its handle, and pointed up or down. Ask each student to show you how her Height-O-Meter works when pointed at some object near the ceiling. If the half-disk does *not* swing freely, here are some suggestions:

a. If the half-disk is warped, bend it back the other way.

b. If the push pin is in too tightly, pull it out a little.

c. If the half-disk hangs up on the pin, work the disk back and forth to enlarge the hole.

12. Collect the Height-O-Meters and keep them flat and dry until Session 2.



# Session 2: Calibrating Height-O-Meters

## Introduction

As with all scientific instruments, Height-O-Meters must be zero adjusted, or ***calibrated***. In this session, your students do this by placing a paper clip on the disk part of the instrument. The paper clip's position is adjusted until the Height-O-Meter reads zero degrees when aimed at eye level. Since Height-O-Meters measure *height above eye level*, your students must first measure their eye level above the ground, and record this on their Height-O-Meters.

*In a general sense, calibration means determining the accuracy of an instrument and adjusting it to be more accurate. Technically speaking, however, calibration derives from the word caliber, and relates to the graduated lines, divisions, or other units of measure that are on or are a part of an instrument. Calibration is usually done by measurement of an instrument's variation from a standard, to determine necessary corrective factors. Such calibration seeks to ensure that a scientific instrument, such as a thermometer, is as accurate as possible, not just at zero, but throughout its entire range, including the relation of readings to each other. Given this more technical definition, your students are **"zero adjusting"** their Height-O-Meters.*

## What You Need

**For the class:**
- ☐ 1 roll of masking tape
- ☐ 6 meter sticks or metric tape measures

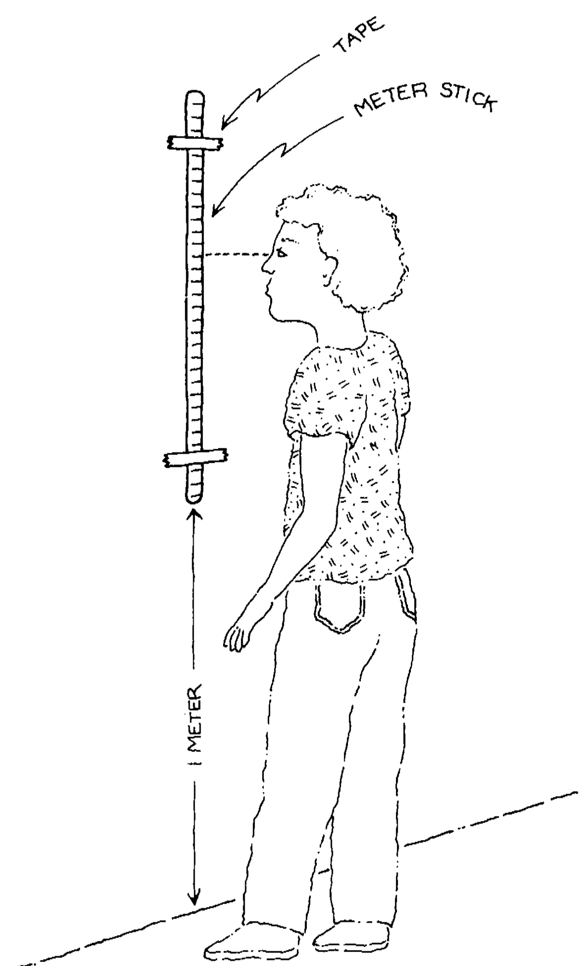
**For each student:**
- ☐ 1 pencil
- ☐ 1 paper clip
- ☐ 1 Height-O-Meter

## Getting Ready

1. Set up six stations in your classroom for your students to measure their eye level. At each station measure up one meter from the floor, and tape a meter stick or metric tape measure vertically on the wall, with "0" touching the one-meter position. (*Note:* if you have students whose eye level is less than one meter in height, you will need to tape a second meter stick from the ground to the one-meter mark at one of the stations.)

2. Tear off one short piece of masking tape (about 2" long) for each student, and stick one end to a desk or table so the student can pick it up during class.

3. Have Height-O-Meters and paper clips on hand.



## Measuring Angles

1. Hand out Height-O-Meters and demonstrate how to measure the angle of an object located high in the room:

   a. Holding the Height-O-Meter, sight along the top edges of the two sights so they both line up with the object. **Be sure that the half-disk swings freely as you point the instrument upwards.**

   b. When the tops of both sights are on a direct line with the object, use the thumb and forefinger of one hand to firmly press the half-disk against the handle piece.

   c. On the scale, read the number to which the arrow points. The unit of this scale is **degrees.**

2. Have your students practice reading the height of different objects in the room. Point out that one side of the scale is "+" and one side is "−". The plus (+) side of the scale indicates degrees above eye level. The minus (−) side of the scale indicates degrees below eye level. Invite the students to try sighting on objects above and below eye level.

## Calibrating

1. Ask, "What do you think the Height-O-Meter will read if you are looking exactly at eye level?" [Zero.] Tell the students that they will adjust their Height-O-Meters to read zero when pointed at eye level. This adjusting process is called ***calibration.*** Explain that just about all scientific instruments must be calibrated so they will measure accurately. (A common example of calibration is adjusting the bathroom scale so it reads "zero" before we weigh ourselves. This calibration process can also be called "zeroing.")

2. Demonstrate how to calibrate the Height-O-Meter as follows:

   a. Place a piece of masking tape on the wall or chalkboard at your eye level.

   b. Write your name on the tape with a pen or pencil.

   c. Step back to the middle of the room, sight on the center of the tape, and read the angle.

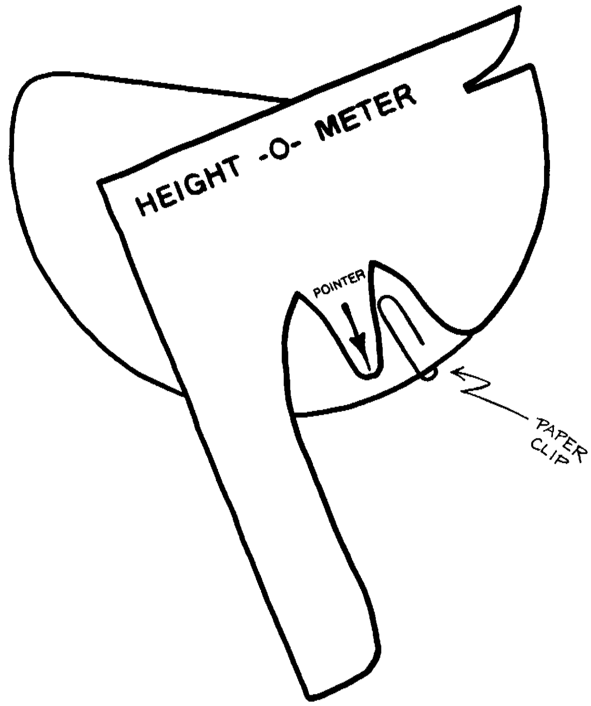
   d. Take three sightings on the tape and see if the Height-O- Meter reads close to zero.

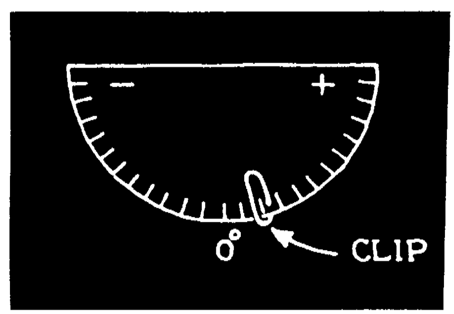
   e. Clip a paper clip near the zero mark of the scale on the half-disk.

3. Draw a diagram on the chalkboard, showing how to place the paper clip. Ask your students: If the Height-O-Meter reads a few degrees on the plus side of zero, where should I place the paper clip? [On the minus side.] If it reads a few degrees minus, where should I place the clip? [On the plus side.] What should I do if the paper clip changes it too much? [Move it closer to zero.] Tell the students to continue adjusting the position of the clip until the Height-O-Meter reads within one degree of zero when pointed at eye level.

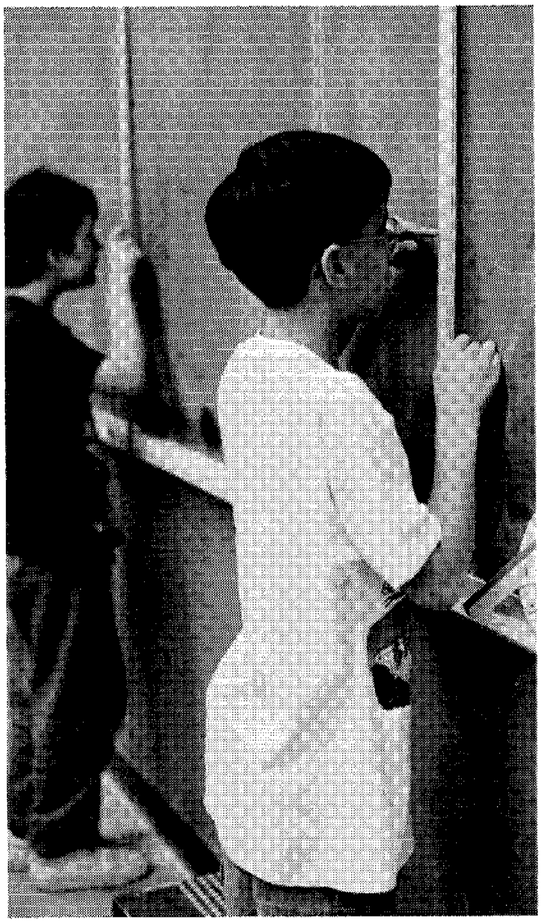
4. When the clip is adjusted, tape it in place on the unprinted side of the half-disk with a bit of masking tape. Make sure it does not block the scale.

5. Allow time for your students to carry out these steps, helping individuals as needed.




*After calibration, slip the clip off, place it on the back of the half-disk in exactly the same calibrated position, and then tape it.*



## Measuring Eye Level

1. When the students have finished calibrating their Height-O-Meters, call the attention of the class to the stations where the meter sticks or tape measures are taped to the wall. Explain that the Height-O-Meters actually measure the height of objects from their eye level, rather than from the ground. So in order to find the real height of something, they also need to know the height of their eye level.

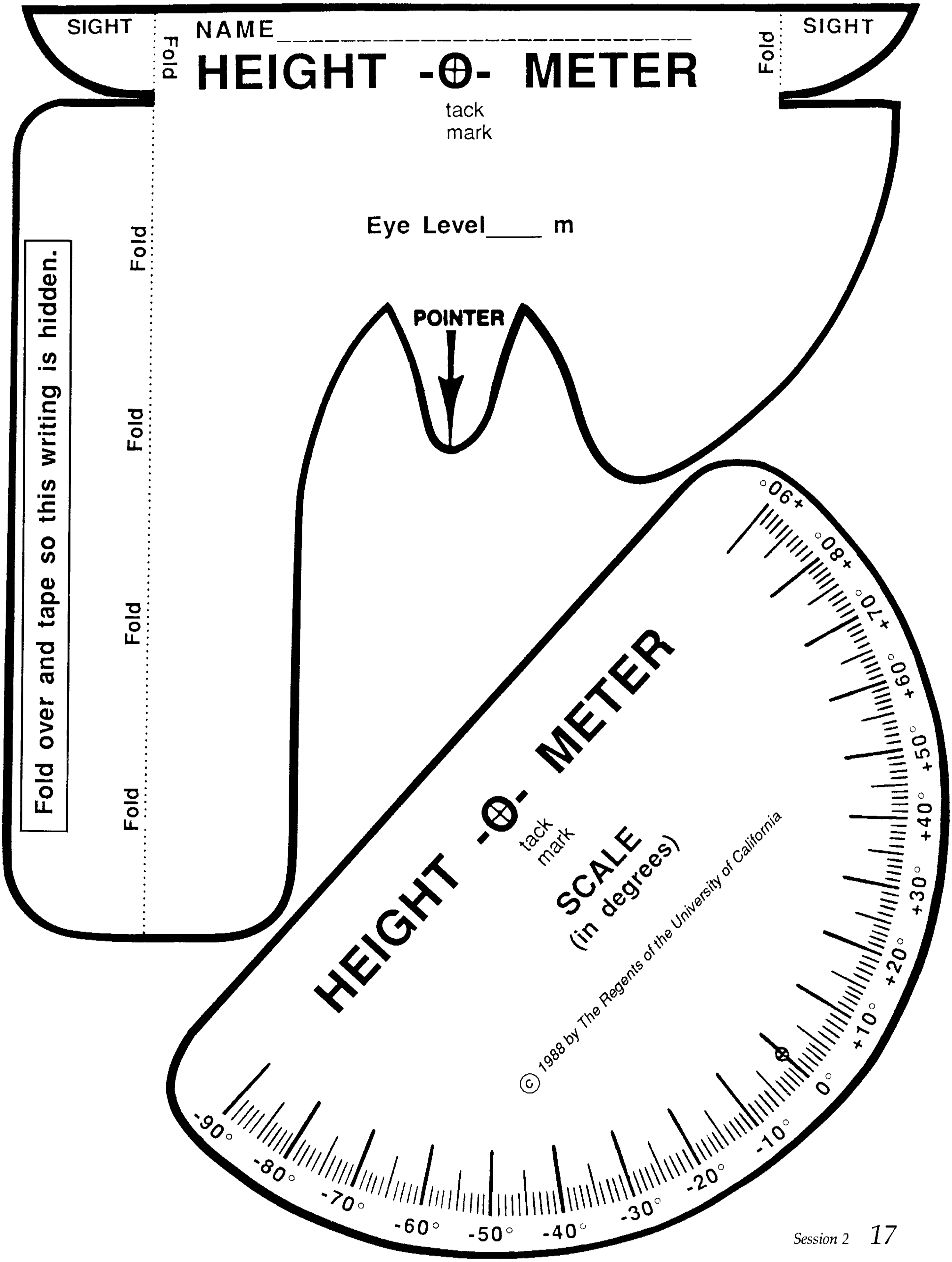
2. Tell the students that 1 meter is equal to 100 centimeters. If you have a meter stick taped to the wall, explain that it starts one meter, or 100 centimeters, above the ground. Demonstrate how to stand next to the measuring stick and notice the number closest to your eye level. (If you have a metric tape measure starting at the floor, the students do not need to add 100 cm.)

3. Tell the students to work together in pairs to help each other read the height of their eye level accurately and to write this number down on scratch paper.

4. When the students have finished measuring their eye levels, demonstrate on the chalkboard how to add 100 cm to that number, convert to meters, and round off to the nearest tenth of a meter. Explain that, for example, if you read the number "53" at your eye level, your eye level height is 153 cm, or about 1.5 meters. Help individuals as needed. Tell the students to write their eye levels on their Height-O-Meters.

5. As students finish, ask each one to show you that the completed Height-O-Meter works by having each student sight on the eye level tape and press the disks together. Look at the pointer. If it points within a degree or two of zero, it is calibrated. Check to make sure that the eye level height is recorded on each student's Height-O-Meter, to the nearest tenth of a meter, and that the number seems reasonable.

6. Collect the Height-O-Meters, and put them aside for use in Session 3.


SIGHT
Fold
NAME
HEIGHT -Θ- METER
Fold
SIGHT
tack
mark
Eye Level____ m
POINTER
Fold over and tape so this writing is hidden.
Fold
Fold
Fold
Fold
HEIGHT -Θ- METER
tack
mark
SCALE
(in degrees)
© 1988 by The Regents of the University of California
+90°
+80°
+70°
+60°
+50°
+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
-50°
-60°
-70°
-80°
-90°

# Session 3: How High Is the Flagpole?

## Introduction

In this session, your students learn how to use their Height-O-Meters to measure the linear height of an object above the ground. They also gain confidence in the accuracy of their Height-O-Meters by measuring the height of the school flagpole, and comparing their results with a direct measurement made by the teacher before class.

## What You Need

**For the class:**

- ☐ 1 50-foot roll of white string
- ☐ 1 meter stick or metric tape measure
- ☐ 1 roll of masking tape
- ☐ 4 pieces of chalk that are different colors

*A fiberglass tape for measuring distances is often used in sports. You may be able to borrow one from the athletic department or order one from a supplier, such as Springco Athletics in Torrance, California, which sells a 165-foot (50 meter) measuring tape.*

**For each student:**

- ☐ 1 pencil
- ☐ 1 ruler
- ☐ 1 Height-O-Meter
- ☐ 1 copy of the "Height Finder Chart" data sheet (master included, page 27.)

## Getting Ready

1. Duplicate data sheets. Make one copy of the "Height Finder Chart" for each student from the master on page 27.

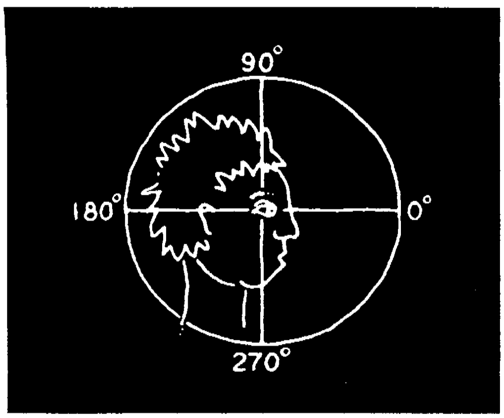
2. Collect all other materials. Place colored chalk near the chalkboard. Have the class set of Height-O-Meters, string, and tape on hand.

3. Decide on a tall object to measure. If your school has a tall flagpole that the students can stand near, on level ground, measure its height as described below. If not, choose some other vertical distance that can be measured directly, such as the height of a second story window.

4. Measure the height of the object. To measure the flagpole, lower the flag and tie a piece of string to the top clip. Raise the flag, pulling the string up with it. When the flag is all the way up, tie a knot at ground level to mark the string. Lower the flag again to remove the string. Measure the string up to the knot to the nearest tenth of a meter. Write that distance on a piece of paper. Make sure the number is large enough to be seen easily by all your students when you hold it up later. Place the paper in an envelope and seal it. Put the envelope where you can quickly retrieve it at the end of class. (*Note:* To measure the height of a window ledge, tie a weight to a string and lower it to the ground from the window. Mark the window level on the string. Pull it up and measure the string.)

5. Draw a semi-circle around the flagpole with chalk, 8 meters from its base. To do this, tie a string to the base of the flagpole. Stretch the string out, and measure 8 meters from the flagpole base. Hold a piece of white or yellow chalk at the 8 meter mark, and use the string and chalk as a compass to draw a semi-circle with an 8 meter radius. Your class will stand with their toes on this line when they measure the height of the flagpole, so make sure to draw the semi-circle large enough for the entire class. Save the string for Session 4. (*Note:* If the flagpole is on a hill, and the students' feet are lower than the base, they will actually be measuring the pole's height above "foot level." Point this out to the students later, when they calculate the height of the flagpole in meters.)

6. Draw a circle on the chalkboard as shown on this page. Divide the circle into quarters, and label the right side "0°" the top "90°" the left side "180°" and the bottom "270°" Draw the circle near the middle of the chalkboard, so there is room to extend the diagram as illustrated later in this lesson. You may wish to sketch the profile of a face on the circle, with the person's eye at the center.



## Measuring the Flagpole

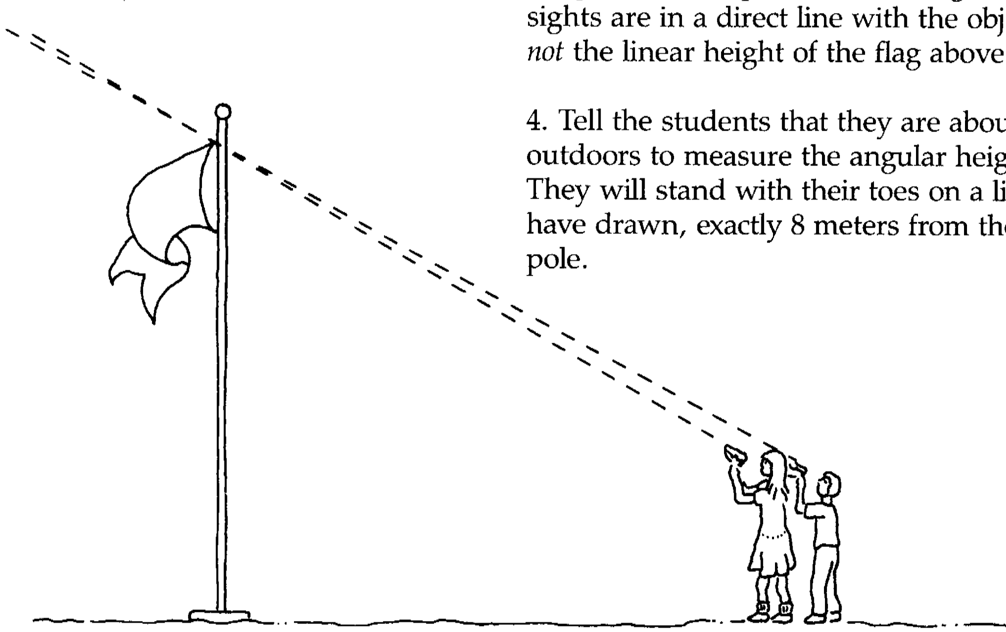
1. Tell your students that today they will test their Height-O-Meters by measuring the height of the school's flagpole. Mention that you have already measured this height directly by tying a string to the top of the flag, running it up the pole, and then lowering it and measuring the string. You have written this direct measurement on a sheet of paper and sealed it in an envelope. At the end of this activity they can compare this number with their Height-O-Meter measurements.

2. Explain that Height-O-Meters measure a part of a circle, called an ***angle.*** Point to the diagram on the board, and explain that a circle is divided into 360 ***degrees*** (°). Each quarter of a circle has 90° in it. The students should imagine that their eye is at the very center of the circle. Ask: How many degrees will you read if you are looking straight up? [90°]. How many degrees will you read if you are looking at eye level? [0°]. Explain that they will measure angles that fall between eye level and directly overhead, so they will be concerned with only the quarter of the circle between 0° and 90°. Erase the other three quarters of the circle.

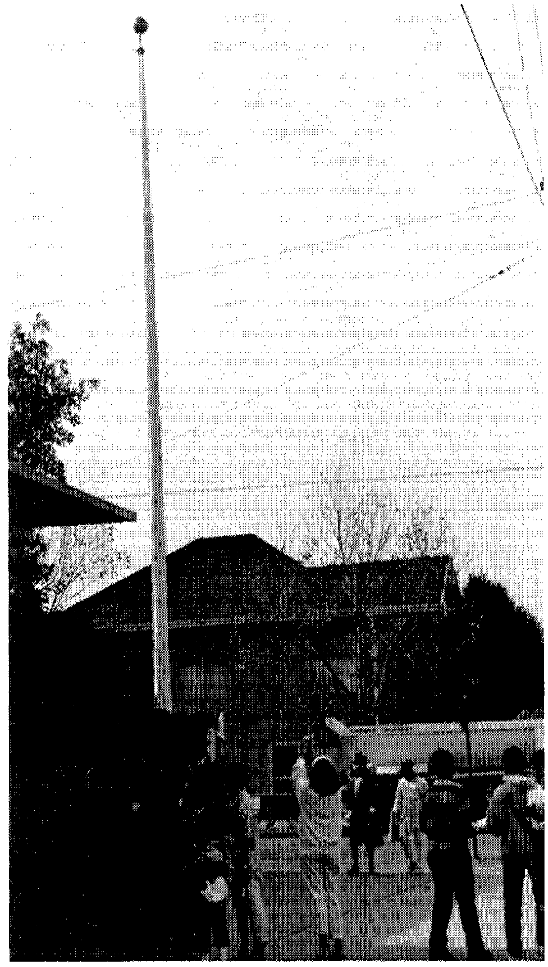
*The phrase "elevation angle" means the same thing as "angular height." The word "altitude" can refer to an object's angular height measured by a ground-based observer, as in the "altitude" of the sun at noon. However, "altitude" can also refer to an object's linear height, as in the altitude of an airplane.*

3. Define the ***angular height*** of an object as the angle between a horizontal line at eye level and the direction they must look to see the object. The Height-O-Meter points to this angle when the two sights are in a direct line with the object. (This is *not* the linear height of the flag above the ground.)

4. Tell the students that they are about to go outdoors to measure the angular height of the flag. They will stand with their toes on a line that you have drawn, exactly 8 meters from the base of the pole.



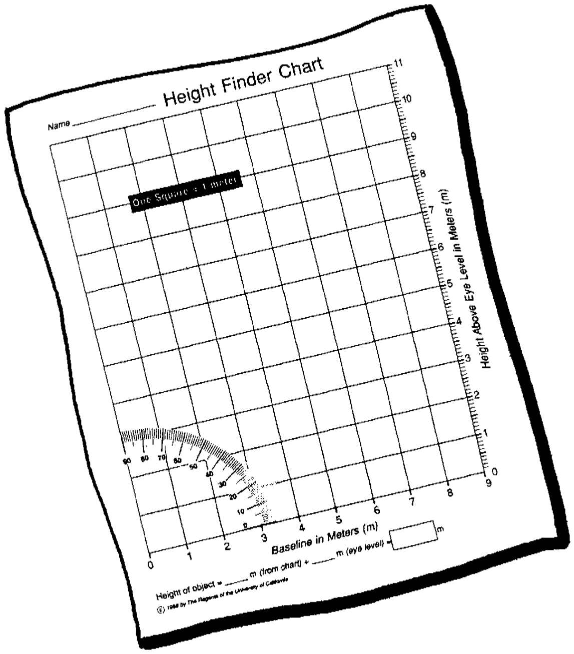
5. Explain that they should measure **the top corner of the flag** three or four times, and then estimate the correct angular height. As an example, write these readings on the chalkboard: 40°, 42°, 10°, and 41°. Ask the students to imagine that one person made these readings. What might cause one of the readings (10°) to be so different from the others, and what should be done about it? [Leave it out, as it was probably a mistake in reading the scale, or because the half-disk got stuck.] What is the best estimate of the angular height? [the average of the other three, or 41°].



6. Ask two or three students to help you hand out Height-O-Meters.

7. Tell your students to take their Height-O-Meters as you lead them outdoors to the flagpole. When you get there, direct them to stand with their toes along the semi-circle and to measure the angular height of the top of the flag. (Make sure the flag is raised all the way.) Caution the students to **measure only to the top of the flag, and not the very tip of the flagpole** (to be consistent with your earlier measurement with string).

8. Tell your students to measure the angular height to the top of the flag three or four times and to estimate the average. They should memorize this number. Before leaving the flagpole, quickly poll the class for their results. They should say "degrees" after their answers. Help individuals whose answers differ from the others by 10° or more. Bring the students back inside.



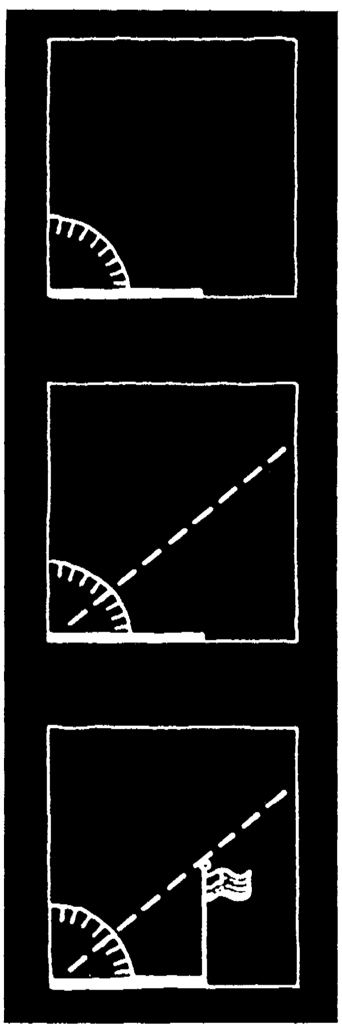

## Calculating the Height

1. Explain that in order to find out how high the object is, it is necessary to measure two things: (1) the ***angle*** between eye level and the object; and (2) the distance between where the observer is standing and the place on the ground directly under the object. This latter distance is called the ***baseline.*** Tell the students that before class you measured the baseline and it is 8 meters long. Write "8 meters" on the board. This is the distance between their toes and the bottom of the flagpole.

2. Hand out one data sheet entitled "Height Finder Chart" to each student. Ask them to look at the quarter of a circle at the lower left of the paper, and to notice the degree scale, like the quarter of a circle on the chalkboard. Add to the diagram on the chalkboard by drawing a large rectangle to represent the rest of the data sheet, with its lower left corner at the center of the degree scale.

3. Explain that this is a ***scale drawing,*** on which one square equals one meter in the real world.

4. Tell the students that their first task is to draw the baseline along the bottom of their paper. They must use a ruler to draw a dark line from the lower left point to the 8 meter mark. Illustrate this step with colored chalk. Tell them to label this line as the ***baseline.*** Hand out rulers so the students can draw their baselines.



5. Next, tell your students to find the ***angle*** they measured on the circle at the lower left. They should use their rulers to draw a dotted line from the center of the circle (lower left corner of the grid) through the correct angle, and extend that line to the side of the paper. Illustrate this step with a ruler and chalk of a different color.

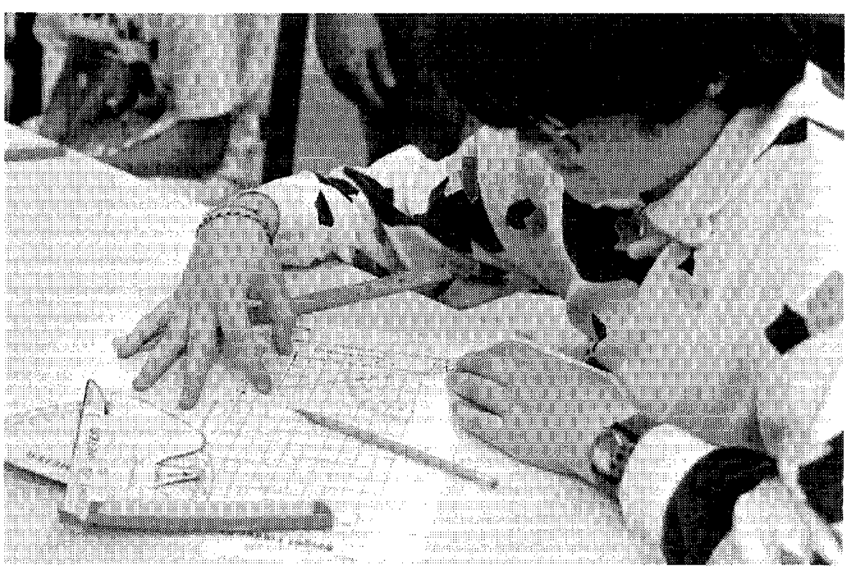
6. Explain that the dotted line represents the direction they were looking when sighting on the top of the flag, and that the baseline is the distance between their toes and the bottom of the flagpole. Ask, "Can anyone guess where we should draw the flagpole?" [From the **end of the baseline,** vertically upward until it touches the dotted line.] Illustrate this step with a third color, using a ruler to be sure the line is vertical.

7. Ask your students how they might find out how high the flagpole is in meters. [Look at the right hand side of the chart. That shows height in meters, with one square per meter.] Tell your students to use a ruler to draw a line from the top of the flagpole to the right hand margin to find out how tall it is. Illustrate this step with a fourth color.

8. Ask students to draw on their data sheets to find the height of the top of the flag, using the angle that they measured outdoors. Help individuals as needed.

9. When everyone has finished, point out that the answer the students found represents the height of the top of the flag **above eye level.** Ask your students how they should correct for this. [Add the heights of their eye levels, as written on their Height-O-Meters.] Tell your students to do this by filling in the blanks at the bottom of the page.

10. When your students have finished, poll them for their answers. Write these numbers on the chalkboard. Finally, hold up the envelope containing your own measurement. Remind the students that you measured the distance to the top of the flag before class by tying a string to the top of the flag and running it up the pole, then you lowered the string and measured it. Open the envelope and reveal the results. Compare it with the numbers on the chalkboard. If a student's results are more than four meters off, check his procedure.



11. Ask the students why people may have had different measurements. [Disk may have gotten stuck, mistakes in drawing the lines on the data sheet, inaccuracy of the Height-O-Meter, etc. If most of the measurements are below the distance you measured, or most are above the amount you measured, there could also be a mistake in the length of the baseline, or in your direct measurement of the flagpole.]

12. Ask the students to look at the list of numbers and estimate the average measurement of the class. How close is this number to your direct measurement? What is the advantage of averaging a large number of measurements, instead of asking just one person to measure a given height? [Errors made by individuals tend to cancel out. The group average is probably closer to the actual height than any single individual's measurement.]

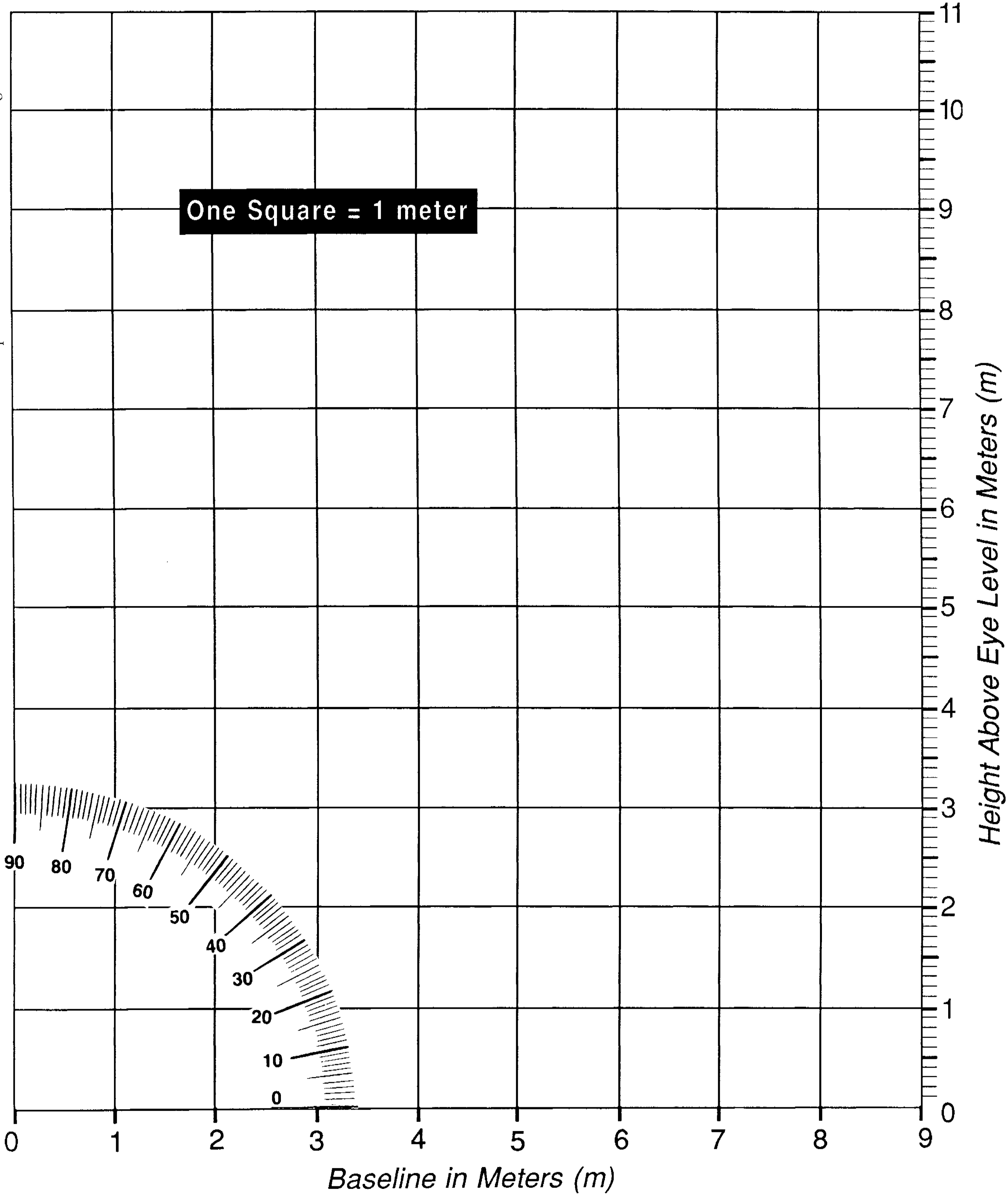
13. Summarize the lesson by saying that the Height-O-Meters only measure the ***angular height*** of something. Angular height is measured in ***degrees.*** However, if they also measure the ***baseline,*** they can figure out the ***linear height*** above the ground in meters. Averaging many results gives a more accurate estimate of height than any single measurement is likely to give.

14. Point out the colored ***triangle*** in the diagram. Remind the students that the Height Finder Chart is really a scale drawing, on which one square equals one meter. So the triangle on the chart is a scaled-down version of the real triangle, made by the flagpole, the baseline, and the sightline between your eye and the top of the flag. This method of height-finding is called ***triangulation.***

15. Conclude by explaining that measuring the height of the flagpole was intended to give them practice and confidence in using their Height-O-Meters. In the next session they will measure the height of something that is impossible to measure directly—how high a ball is thrown. Collect the Height-O-Meters for use during the next session.

Name ____________________

# Height Finder Chart






Height of object = ______ m *(from chart)* + ______ m *(eye level)* = [          ] m

# Session 4: Experimenting with Height-O-Meters

## Introduction

If thrown with the same force, which would go higher, a rubber ball or a styrofoam ball? Your students make predictions about this question, then use their Height-O-Meters to find out if they are right. This experiment allows students to apply what they learned in previous sessions, and to develop their skills in performing controlled experiments and interpreting results.

*This session is written so that each student measures the angular height of both balls. Another way to organize the activity is to have students work in teams of two. Each pair of students has one person on Team A and one on Team B. Using this approach, there is no need to average the students' eye levels. Each pair graphs a height for each ball. The class averages are done on charts like the one on page 34 of this guide, but the vertical axis would be in meters rather than degrees.*

## What You Need

**For the class:**

- ☐ 1 50-foot roll of white string (from previous session)
- ☐ 5 pieces of chalk that are different colors
- ☐ 1 rubber ball
- ☐ 1 styrofoam ball

**For each student:**

- ☐ 1 sheet of scratch paper
- ☐ 1 pencil
- ☐ 1 ruler
- ☐ 1 Height-O-Meter from Session 1
- ☐ 1 copy of "Height Finder Chart—Two Observers" data sheet (master included, page 39)
- ☐ 1 calculator (optional)

## Getting Ready

1. Duplicate the data sheet from the master on page 39. Make one copy of the "Height Finder Chart—Two Observers" for each student.

2. Collect all other materials. Place the two balls and the colored chalk near the chalkboard. Have the class set of Height-O-Meters on hand.

3. Decide in advance if you will toss the balls into the air, or if you want a student to do that. The balls will be tossed underhand, straight upward.

4. Draw a circle on the playground with an 8 meter radius. Measure an 8 meter length of string. Have a student hold one end of the string in a single spot (or tie it to a stake) while you hold a piece of chalk (or a stick to draw in dirt or snow) at the other end. Use the string as a compass to draw a circle with an 8 meter radius (16 meter diameter).

5. Decide if you want your students to calculate exact averages, or make estimates. Calculating averages can be difficult, since it is easy to make mistakes. Therefore, even if exact calculation is chosen, it is always best to have your students estimate first so that they will know if they are "in the right ballpark" when calculating averages precisely. If you do want your students to practice calculating averages, plan on an additional class period to analyze the experiment, and allow your students to use calculators.

6. Prepare a chart for summarizing the data on the chalkboard as shown:

| | Team A Rubber | Team B Rubber | Team A Styrofoam | Team B Styrofoam |
|---|---|---|---|---|
| 60°-64° | | | | |
| 55°-59° | | | | |
| 50°-54° | | | | |
| 45°-49° | | | | |
| 40°-44° | | | | |
| 35°-39° | | | | |
| 30°-34° | | | | |
| 25°-29° | | | | |
| 20°-24° | | | | |
| 15°-19° | | | | |
| 10°-14° | | | | |
| 5°-9° | | | | |
| 0°-4° | | | | |

7. Prepare a chart to summarize data on the students' eye levels:

| | Eye Level In Meters |
|---|---|
| 1.9 | |
| 1.8 | |
| 1.7 | |
| 1.6 | |
| 1.5 | |
| 1.4 | |
| 1.3 | |
| 1.2 | |
| 1.1 | |
| 1.0 | |

## Performing the Experiment

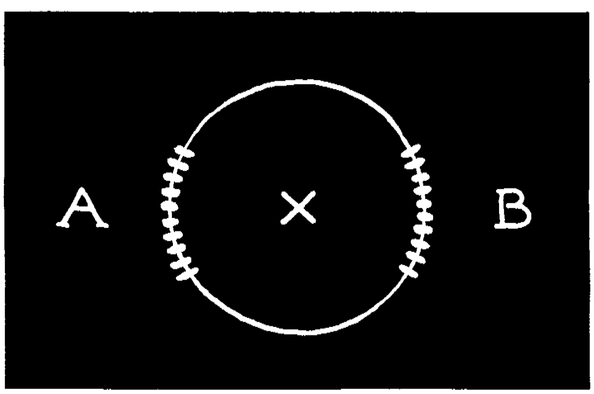
1. Hold up a styrofoam ball and a rubber ball. Ask your students to vote on which can be thrown higher. (Nearly all students will probably expect that the rubber ball can be thrown higher.) Then, ask your students, "Do you think the styrofoam ball will go 25% as high as the rubber ball? 50% as high? 75% as high? or almost 100% as high? Count their votes and make a graph on the chalkboard showing their predictions.

2. Tell your students that they will go outdoors and measure the angular height of each ball as you (or your helper) toss it up in the air. Later they will use the angles to find out how high each ball went.

3. Draw a diagram on the chalkboard to illustrate that Team A stands on one side of the circle, and Team B on the other side. You stand in the middle. Explain that you (or your helper) will try to throw both balls underhand **as fast as you can, straight up.**

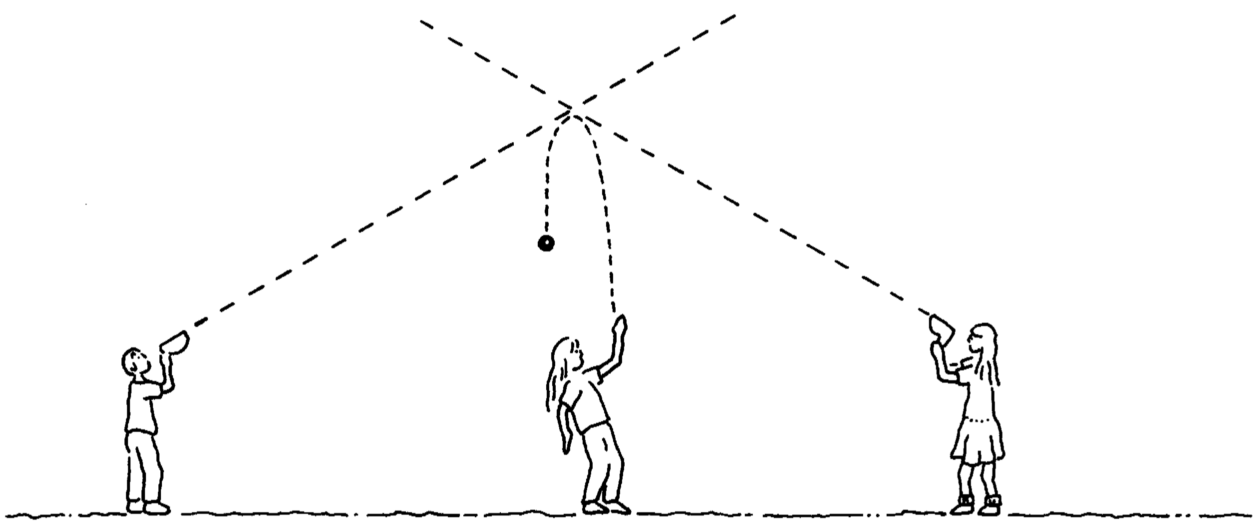
4. Hand out the Height-O-Meters. Tell your students to bring a pencil and sheet of scratch paper to record their measurements. Take the two balls with you.

5. Lead your class outside to the circle drawn on the playground. Have students from Team A stand on one side of the circle with toes on the line. Team B should stand on the opposite side of the circle.



6. Stand in the middle of the circle. After two or three practice tosses with the rubber ball, announce that the real experiment will begin. It is easier to toss the ball straight up if you throw underhand, rather than overhand.

7. Throw the rubber ball up first. Allow a minute or two for your students to write down their measurements. Do the same with the styrofoam ball, again tossing it underhand as fast as you can, straight up. Allow your students time to write down the measured angles, then take them back inside.



## Analyzing the Results

1. Ask your students for their two measurements, and list these as "x's" on the chart under the appropriate column headings. Following are some typical results from a class of 32 students:

| | Team A Rubber | Team B Rubber | Team A Styrofoam | Team B Styrofoam |
|---|---|---|---|---|
| 60°-64° | xx | | | |
| 55°-59° | xxxx | x | | |
| 50°-54° | xxxxx | xxxxxx | | |
| 45°-49° | xxxx | xxxxx | | |
| 40°-44° | | xxx | | |
| 35°-39° | | | | |
| 30°-34° | | | x | xxx |
| 25°-29° | | | xxxxxxxxx | xxxxxxxxxx |
| 20°-24° | | | xxx | xxx |
| 15°-19° | | | xx | |
| 10°-14° | x | | | |
| 5°-9° | | | x | |
| 0°-4° | | | | |
| Est. Average | 53° | 50° | 25° | 27° |

2. Explain that the most accurate way to determine how high the two balls went is to average the teams' results. Remind the students that an average of everyone's eye level is also needed. Have your students estimate averages as follows:

a. Ask if there are any measurements that are obviously mistakes that should be ignored. [Probably the 10° measurement in column 1 of the sample data.] Erase marks that are obvious mistakes. If students disagree, vote on whether or not to erase an x.

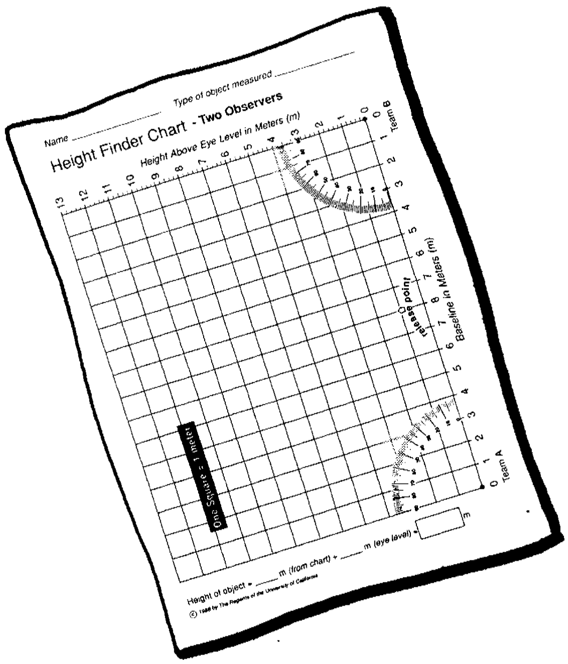
b. Ask for student volunteers to estimate the average of each column. Allow for two or three answers, and write down the answer that you feel is the most accurate estimate. One class' estimates are shown at the bottom of the columns above. (*Note:* If you choose to have your students calculate exact averages, you will need to list exact measurements in columns. Tell the students to add all numbers not erased and divide by the number of measurements.)

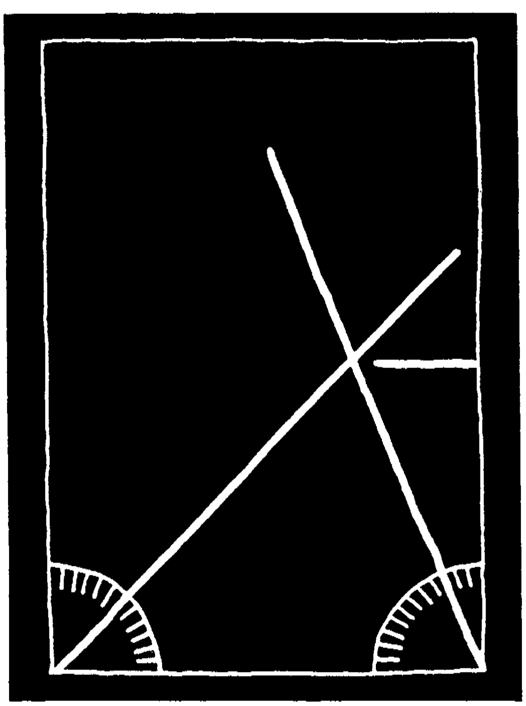
3. Use a similar method to find the average eye level of the class, asking students to read their eye levels from their Height-O-Meters as you place x's on the chart. Following is an example from the same class of 32 students.

| | Eye Level In Meters |
|---|---|
| 1.9 | |
| 1.8 | |
| 1.7 | xx |
| 1.6 | xx |
| 1.5 | xxx |
| 1.4 | xxxxxxxxx |
| 1.3 | xxxxxxxxxx |
| 1.2 | xxxx |
| 1.1 | xx |
| 1.0 | |

Est. Average 1.4 meters

*Your students may ask where the baseline is, since there are now two observers. One way of looking at it is to imagine two baselines, one for each observer. To find the baselines, draw a vertical line from the place where the two sightlines cross. This line divides the distance between the two observers into two baselines. Another way to look at it is that the entire 8-meter distance is the baseline for one large triangle.*



4. Ask a couple of students to hand out the new data sheet as you sketch it on the board, "Height Finder Chart—Two Observers." Ask the students how this data sheet is different from the last one they used. [It has two quarter circles rather than one.]

5. Explain that only one observer was needed before because the flagpole was straight up—that is, at a 90° angle to the ground. We could assume a line drawn straight up would intersect with the sight line, thus pinpointing the object. However, the ball does not necessarily go straight up, so it is necessary to observe it from two positions. In this way, the sight lines will cross, pinpointing the position of the ball. (See diagram).

6. On the chalkboard show how to figure out how high the rubber ball went. Use a different color chalk for each step:

a. Draw a line from the center of one circle (the corner of the grid) through the number of degrees measured by Team A. Extend the line to the edge of the page.

b. Draw a line from the center of the other circle, through the number of degrees measured by Team B. Extend the line so it crosses the previous line.

c. Find the height of the ball by drawing a horizontal line from the top of the triangle across to the side of the page.

d. Add the average eye level at the bottom of the page.

7. Ask half of your students to calculate the height of the styrofoam ball, and the other half of the class to find the height of the rubber ball. As you assign students, ask them to write the type of ball at the top of their sheet, and point to the estimated averages they should use in making their calculations. (Older students can calculate the height of both balls on the same sheet, using a solid line for one set of calculations and a dotted line for the other.)

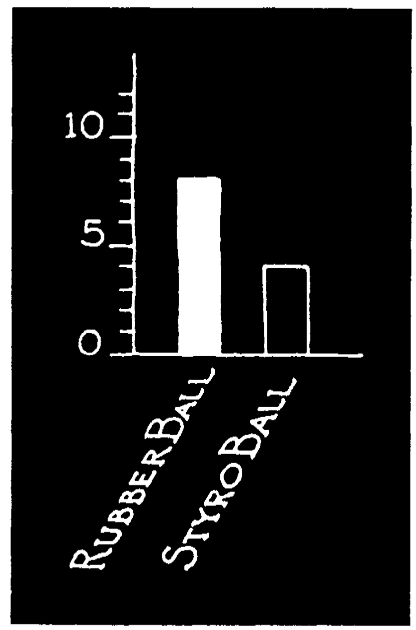
8. Circulate around the room, helping groups as needed. Each student should plot the results on her own data sheet. Encourage the students to check each other's work to see if they agree, and decide whose calculation is most accurate.

9. When the students have finished, and seem to agree on the results, draw a bar graph on the chalkboard. The vertical axis should have tick marks at every meter, up to 10 or 12 meters. The two bars will represent the two balls.

10. Ask the students who calculated the height of the styrofoam ball to report their results in meters. Color in one bar to represent that height. Ask the students who calculated the height of the rubber ball to tell you their results. Color in a second bar to represent that height.

11. Ask the students what conclusions they can draw from the graph. They should be able to state which ball went higher, and by how much. Compare the results with the predictions.

12. The objectives of this lesson are for your students to practice measuring angles, calculating heights, and drawing conclusions, not to speculate about *why* a rubber ball can be thrown higher than a styrofoam ball. Nonetheless, most students are interested in why the experiment comes out the way it does. Encourage them to discuss their opinions.



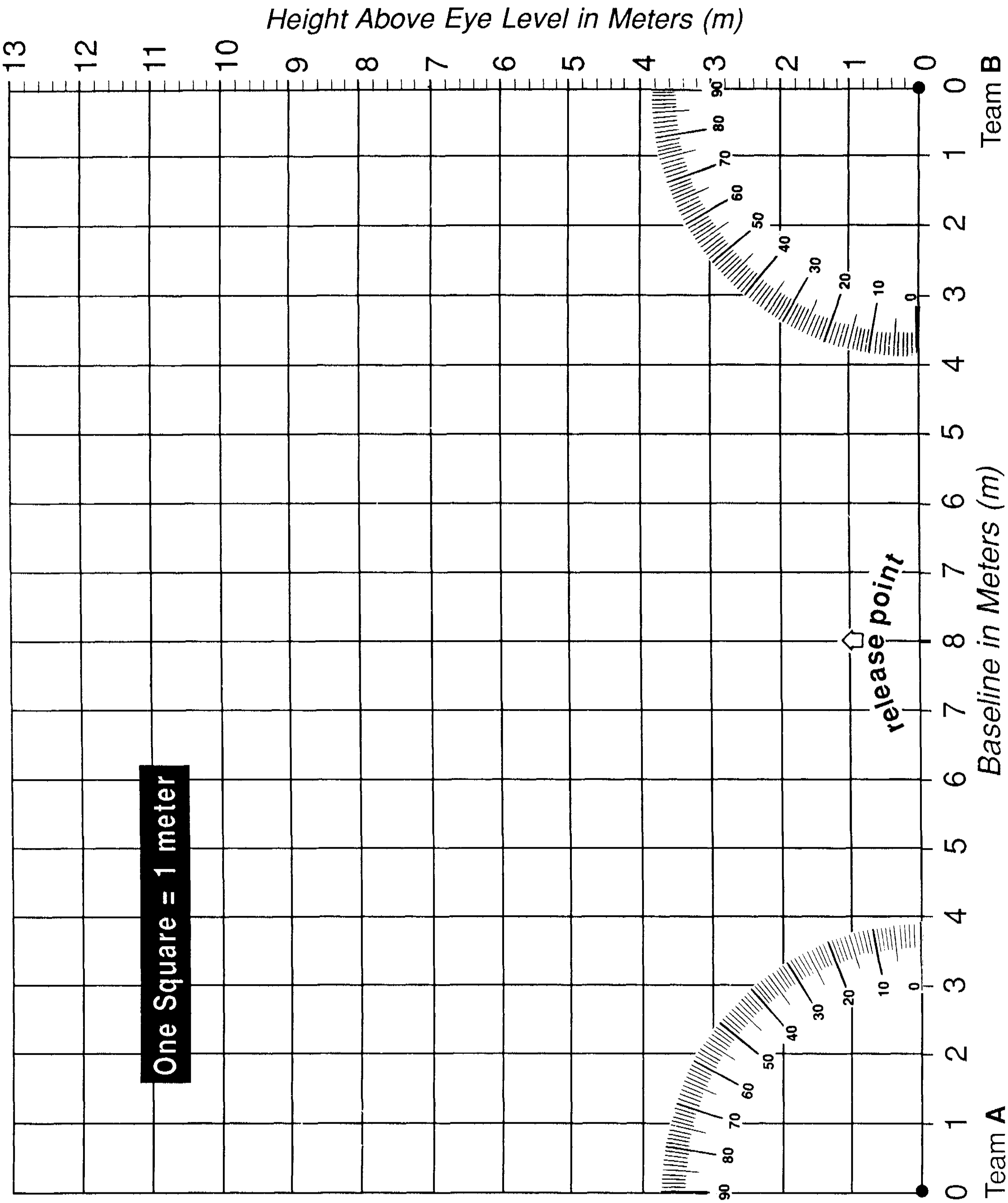

*For your information, here is a brief explanation for why the rubber ball can be thrown higher: When both balls leave your hand they are going at the same speed. If they are the same size, the force of air resistance on each ball is also the same. However, because the rubber ball weighs more, it has more momentum, so the air resistance has a smaller effect on its motion. In the same way, a ten-ton truck has more momentum than a bicycle. Should both vehicles hit the same kind of street sign, the bicycle would be slowed down much more than the truck.*

13. Explain that the method your students used to measure the height of a ball, called ***triangulation,*** is used by space scientists whenever they launch rockets. To track a rocket, however, the baseline must be many, many miles long. Telescopes are sometimes attached to the tracking instruments to see the rockets at great distances. Sometimes radio signals are used for triangulation, rather than telescopes.

14. Ask the students for their ideas on what other things might be measured with the method of triangulation. [The height of kites, birds, airplanes, clouds, UFOs, space satellites, mountains, etc.]

Name ____________________ *Type of object measured* __________________

# Height Finder Chart - **Two Observers**




Height of object = _____ m *(from chart)* + _____ m *(eye level)* = [ ] m

# *Going Further*

Some students have difficulty understanding why the angle that they measure is not the height of the object in meters. Others want to know if there is a "simple" relationship between the number of degrees and the number of meters. The first activity, "Angles and Meters," will help your students answer these questions for themselves. The second activity, "Where's The Fire?" illustrates how forest rangers use triangulation in their work. "Introducing the Tangent Function," and "Finding the Distance to a Star" are most appropriate for high school students.

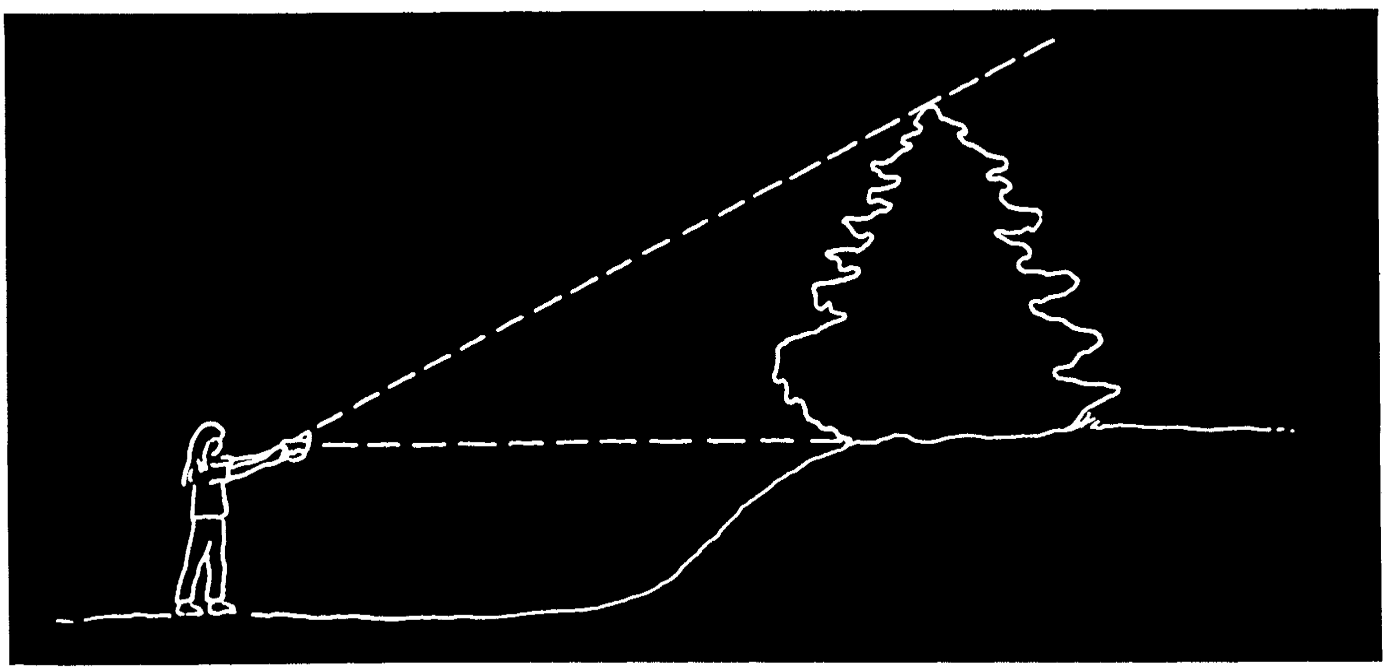
## Angles and Meters

Make one copy of the data sheet from Session 3, "Height Finder Chart" for each of your students. Tell your students that they are going to imagine they are measuring the height of a fast-growing tree every month. To make things simple, they should imagine that they are standing 6 meters from the base of the tree, and the tree is on a hill that is about eye level (so they do not have to add their eye level to each measurement).

Hand out data sheets and rulers. Tell your students that the height of the tree the first month is 10°. How high is that in meters? As the students figure out the answer, tell them to write the answer on a sheet of paper, opposite month #1. Tell the students that in the second month, the angular height of the tree is 20°. Use the same sheet of paper to find that altitude in meters, and write that answer down opposite month #2. The height in month #3 is 30°, and so on until it reaches 60° in month #6. By now, the students will have created the following table showing how angles relate to heights in meters:

| Month | Angular Height | Linear Height |
|---|---|---|
| 1 | 10° | 1.1 meters |
| 2 | 20° | 2.2 meters |
| 3 | 30° | 3.5 meters |
| 4 | 40° | 5.1 meters |
| 5 | 50° | 7.3 meters |
| 6 | 60° | 10.5 meters |

Ask if the increase from 10° to 20° represents the same increase in tree height as from 50° to 60°? [No! An increase in angular height from 10° to 20° represents an increase in linear height of 1.1 meter, but an increase in angle from 50° to 60° represents an increase in height of 3.2 meters.] Which measurements are most accurate, low or high angular heights? [Low angular heights. A mistake in one degree will mean a difference of many more meters at high angular heights.]



## Where's The Fire?

Forest rangers use triangulation to find the distance to fires. You can demonstrate how this is done by drawing a simple diagram on the chalkboard.

Ask the students to imagine that the board represents a map of a forest. Show two observation towers where rangers are searching for forest fires. Mark the location of a plume of smoke that indicates a fire.

Explain that the forest rangers in each of the towers have compasses that allow them to determine the direction to any plume of smoke. Draw a little compass around each observation tower, with N, S, E, and W symbols around each compass. Draw a plume of smoke on the map.

Ask the students, "What direction does each forest ranger look to see the fire?" Tell the students that by measuring these directions very accurately in degrees the rangers are able to draw a triangle on their map that pinpoints the fire. The base of the triangle is the line between the two towers. The other two sides of the triangle are the sightlines from each tower to the fire. The map coordinates (latitude and longitude) provide directions to firefighters.

You can make this demonstration into a paper and pencil activity by creating a data sheet for your students. The data sheet should look like a map with a latitude and longitude grid. Draw the positions of two towers with compass rosettes, marked in degrees, around each. Make up directions that rangers in each of the towers must look to see the plume of smoke. Ask the students to use pencils and rulers to figure out the coordinates of the fire's location, so they can direct the firefighters.

A further extension of this activity is to have the students measure the angles to the "fire," rather than simply making them up. To do this you will need two "ranger stations." To make a ranger station:

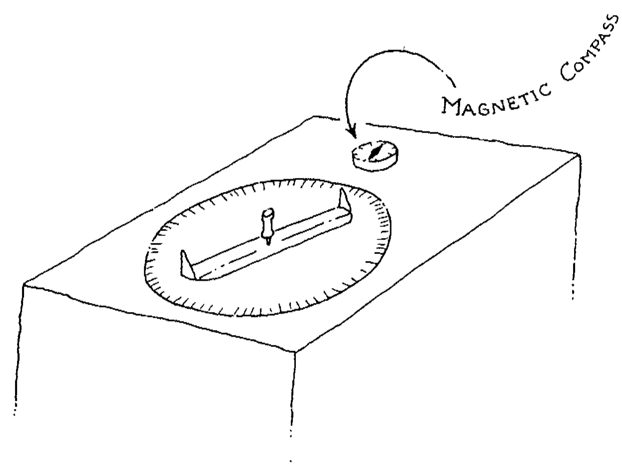
1. Duplicate page 44.

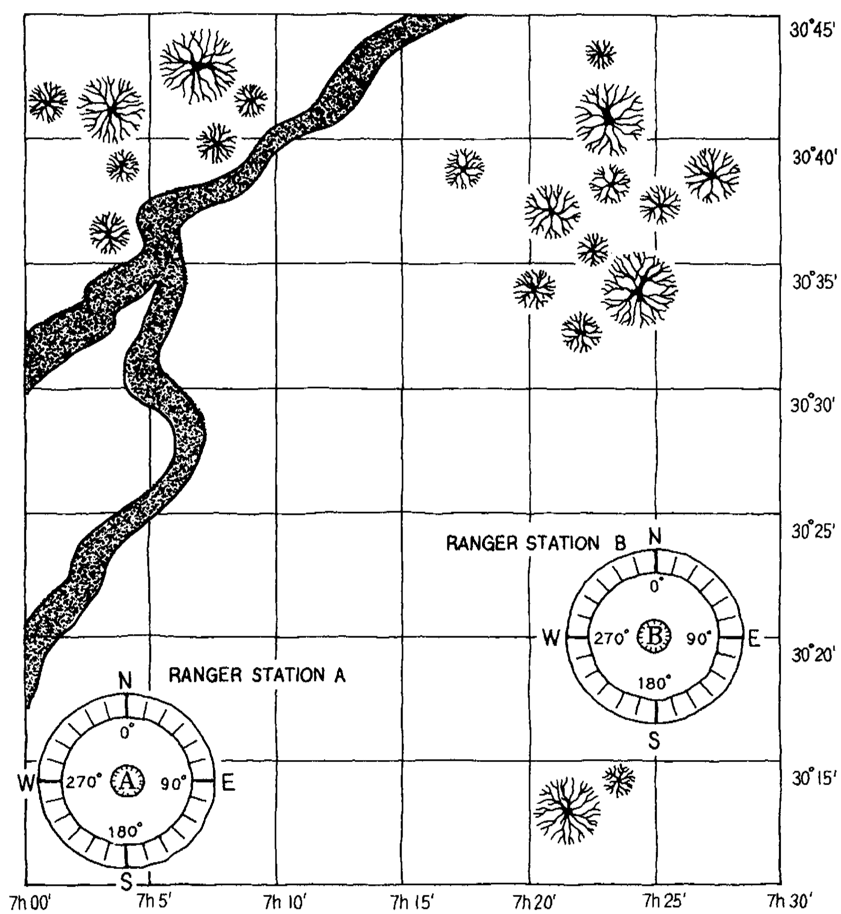
2. Cut out the sighter/pointer and fold the ends up along the dotted lines.

3. Cut out and tape the 360° scale to a large box with clear tape.

4. Put a tack through the center mark of the pointer, then into the center mark of the 360° scale.

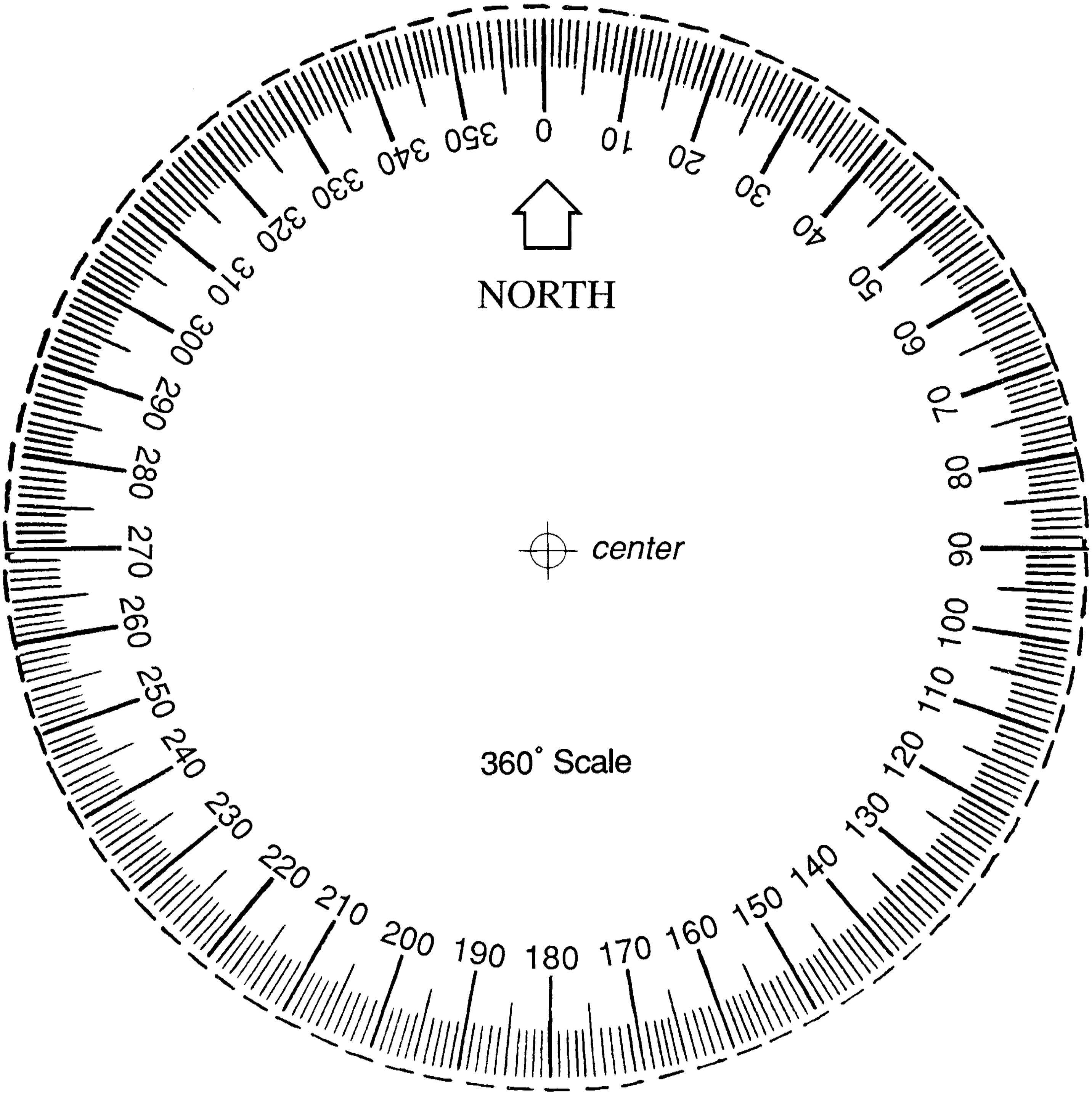
Make the second station in the same way. Set up the two ranger stations at the ends of a measured baseline. Use a magnetic compass placed near the "0" mark of the scale to align each station so that each sighter/pointer points north when it reads "0" degrees (see illustration). A stick, flag, or other object some distance away can represent the "fire." The students can measure the angle between magnetic north and the fire. Using the data sheet described in the paper and pencil activity above, they can then plot the location of the fire.




WHERE'S THE FIRE?

A plume of smoke was spotted:
22° from station A
310° from station B
Where's the fire?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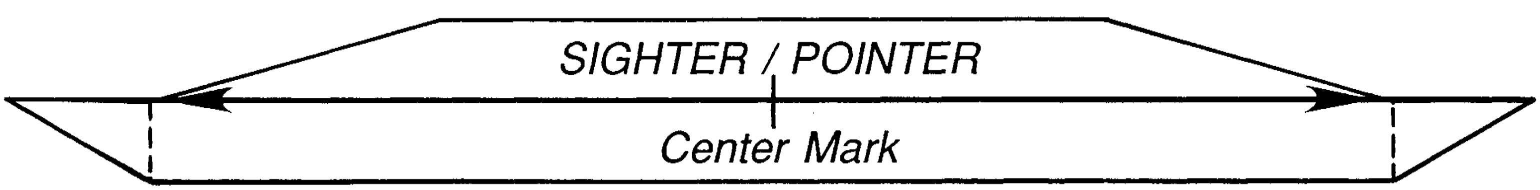
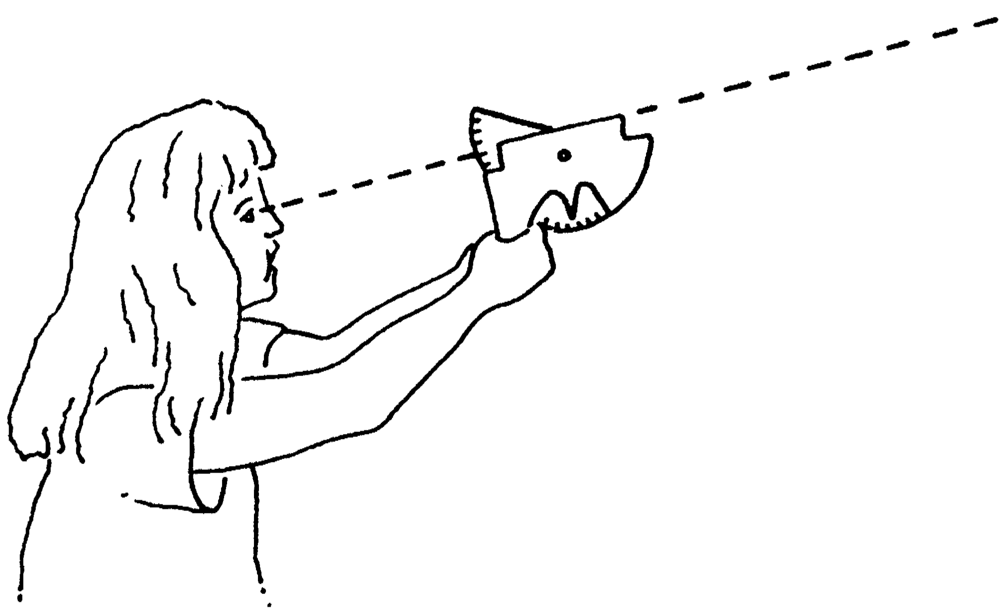
360° Scale


SIGHTER / POINTER
Center Mark

## Tracking Helium Balloons

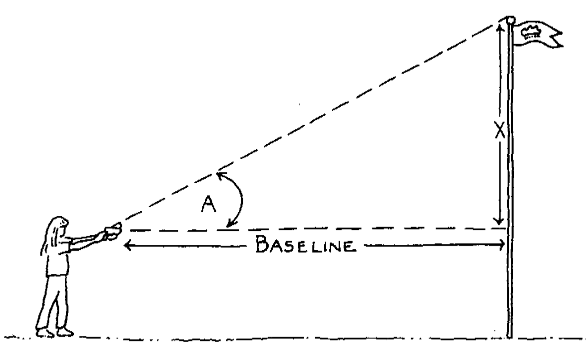
An exciting additional experiment is to release a helium balloon. You will need two teams of students, one team upwind and one team downwind, with Height-O-Meters. The balloon is released somewhere between the two teams and a timer with each team calls off intervals of 20 seconds at which to measure the angular height of the balloon. Back in the classroom these results can be graphed to reveal wind patterns.



## Introducing the Tangent Function

Trigonometric functions are powerful mathematical concepts with a wide range of applications in science and engineering. The graphic method of triangulation presented in this guide can provide a concrete framework for introducing one of these functions—the tangent—to high school geometry students. A good time to do this is just after Session 3, when the students have determined the height of a flagpole by use of a scale drawing. The tangent can then be introduced as a way to perform the calculation of linear height more quickly and accurately than making a scale drawing.

The tangent function can be used only when there is a right angle involved. If the flagpole is straight up and down, it forms a 90° angle with the ground. This right angle is one corner of a triangle formed by the flagpole, the baseline (which extends from the base of the flagpole to the observer) and the sightline (from the observer to the top of the flagpole). In the diagram, Angle A is the angle measured by the observer.




The ***tangent of angle A*** is defined as the ratio of the opposite side of the triangle (the height of the flagpole, which we will call X) to the adjacent side (the baseline). That is:

$$\text{Tangent A} = \frac{X}{\text{Baseline}}$$

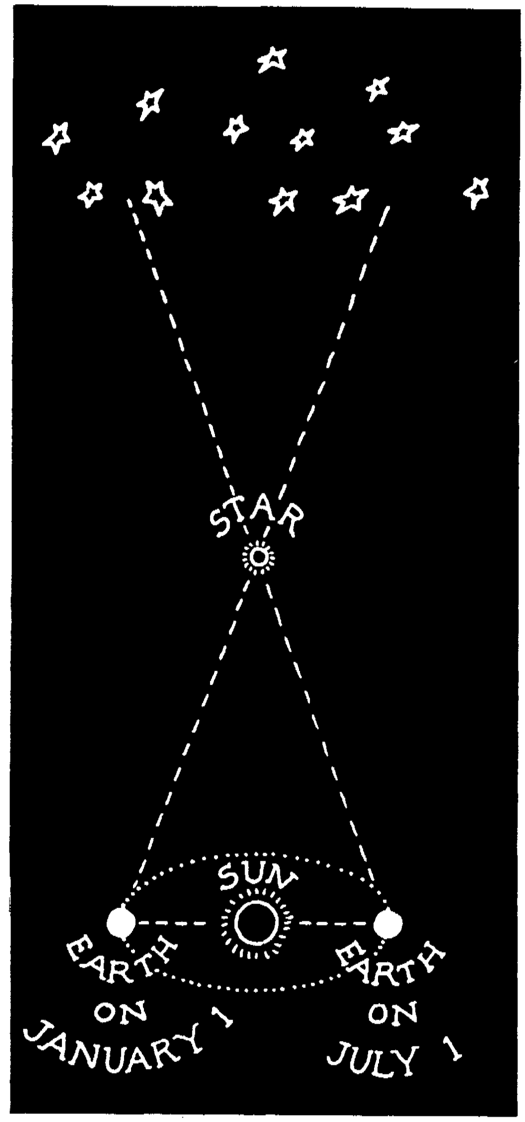
$$X = (\text{Baseline})\ (\text{Tangent A})$$

We can find the tangent of any angle from a table of tangents or from a calculator with trigonometric functions. Let's suppose angle A is 45° and the baseline is 12 meters. A table of tangents shows that the tangent of 45° is 1. So, the height of the flagpole is:

$$X = 12 \text{ meters} \times 1 = 12 \text{ meters}$$

## Finding the Distance to a Star

Astronomers use triangulation to determine the distances to stars. The angles involved in such measurements are so small that drawing scale models is virtually impossible. To illustrate the method used by astronomers, ask your students to hold one finger about a foot in front of their eyes. Tell them to blink first one eye then the other, and notice how the finger seems to jump back and forth. Ask them to explain why it seems to do that. [One eye sees the finger against some background objects. The other eye sees the same finger from a different angle, so it appears to be against different background objects. Thus it appears to jump back and forth when we look at it from different angles.]




On the chalkboard, draw a diagram showing the earth, sun, a nearby star, and some very distant background stars. Suppose we photograph the nearby star against the distant background stars. Then we photograph the same stars again, six months later, when the earth has moved to the other side of the sun. The nearby star will seem to have "jumped," because we see it from two different positions. By knowing the diameter of the earth's orbit and measuring how far the nearby star seemed to "jump," we can find out how far away the star is.

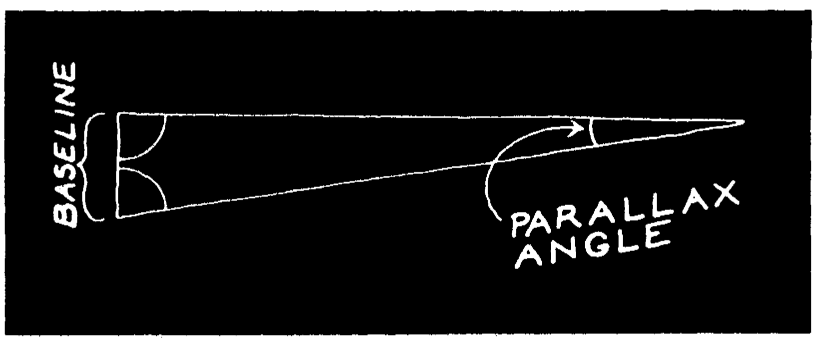
To use triangulation in this method, astronomers define a star's ***parallax*** angle as one half of the "jump" angle that is measured on a photographic plate when a star is observed from two points of the earth's orbit, six months apart. Suppose the parallax angle is 1° and a line from the sun to the star forms a right triangle with the earth. In this case, angle A is the angle between the star and the sun. Because the angles of a triangle always add up to 180°, angle A = 90° minus the parallax, or 89°. We also know that the distance from the earth to the sun is 92,900,000 miles, or 149,598,000 km. We can then find the distance X from the sun to the star using trigonometry, as shown on page 48.

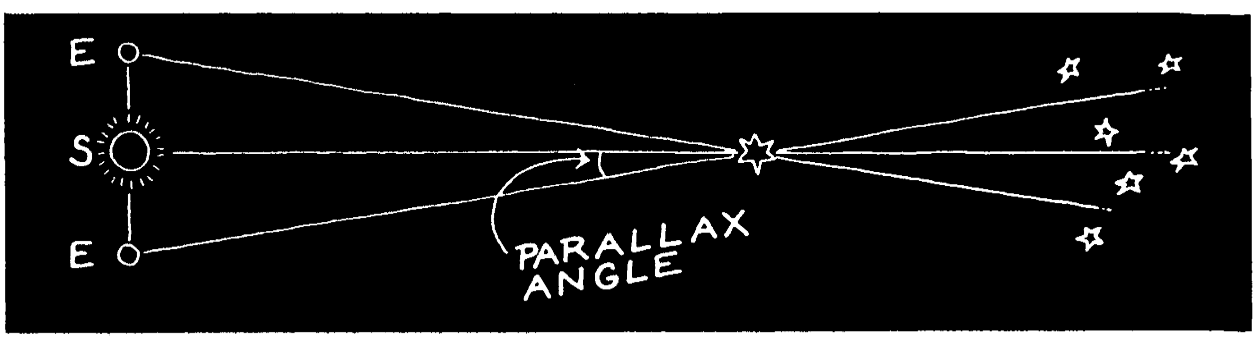
$$\text{The tangent of } 89° = \frac{X}{149{,}598{,}000 \text{ km}}$$

A calculator shows that the tangent of 89° = 57.29. So,

$$X = (149{,}598{,}000 \text{ kilometers})\ (57.29) = 8{,}570{,}469{,}000 \text{ km.}$$

As far as we know, there are no stars that are this close to earth. One of the nearest stars is Alpha Centauri, about 40,700,000,000,000 km away, with a parallax angle of only 0.0002106°. That angle is so close to 0° it is extremely difficult to measure—and that is one of the closest stars to earth!



# *Assessment Suggestions*

## Selected Student Outcomes

1. Students apply geometry skills to build and "zero" an instrument that measures degrees of altitude.

2. Students articulate the difference between angular and linear distance.

3. Students use a graphical method to triangulate the height of an object.

4. Students use words and/or diagrams to articulate why measuring the base line and angle are sufficient to determine the height of an object.

## Built-In Assessment Activities

**Building Height-O-Meters:** During Sessions 1 and 2, students construct and "zero" the scale of Height-O-Meters (clinometers) and learn how to use them to measure angular heights. At the end of the activity, they test their instruments to measure the altitude of some point in the classroom. The teacher can ask each student for their measurement and immediately determine which students may have incorrectly constructed or adjusted their instrument. With this information, the teacher can provide extra assistance as needed. (Outcome 1)

**Measuring the Height of a Flagpole:** In Session 3, students use their Height-O-Meters to measure the angular height of the flagpole or some other tall object in or near their school. The teacher has previously measured the object and placed the results in an envelope. After the students calculate the height of the flagpole with the base line and the angles they measured, the teacher graphs the results of the class and opens the envelope. At this point, teachers and students can evaluate how accurately they have determined the height of the flagpole. (Outcomes 2, 3)

**Applying the Concept of Triangulation:** In Session 4, students apply the technique of triangulation to complete an experiment and determine how high different kinds of balls can be thrown. The teacher can look at each team's results, and pose questions during the activity to determine the degree to which students are able to describe the technique and explain why it works. (Outcomes 2, 3, 4)

## Additional Assessment Idea

**Where's the Fire?** In a Going Further activity, students assume the role of forest rangers who use triangulation to find the distance to a forest fire. Provide the equipment the students will need, have them proceed on their own, and observe whether or not they are able to meet the challenge (the triangle in the model is horizontal rather than vertical). Note the problems they encounter, and provide assistance when necessary. After the activity, ask students why our measurements did not determine the distance to the fire without additional information. (Students must also know the distance between the two ranger stations). In addition, ask students to describe in their own words how the triangulation method works. (Outcomes 2, 3, 4)

# *Literature Connections*

We welcome your suggestions for other literature connections to this GEMS guide. At this point, we've found the excellent book below, which connects to the flagpole from a flag-sitter's perspective. Books about forest rangers, astronomers, or others who use triangulation would make more central connections. For many excellent books that relate to major science themes, mathematics strands, and other GEMS guides, please consult the GEMS children's literature handbook, *Once Upon A GEMS Guide: Connecting Young People's Literature to Great Explorations in Math and Science.*

**M.C. Higgins, The Great**
by Virginia Hamilton
Macmillan, New York. 1974
*Grades: 7–12*
This strange and moving slice-of-life tale features teen-aged Mayo Cornelius Higgins who sits on a 40-foot pole and surveys the denizens of Sarah's Mountain. M.C.'s life is changed forever when a wandering young woman spends time in the area, and a man from the city comes to record his mother's folk singing. The early chapters, particularly the end of Chapter 1 and all of Chapter 2, are concerned with the view and perspective from the pole's height, and so connect most directly with the flagpole measurement activity. Eventually the pole becomes a symbol, a marker of the family's multi-generational connection to their home. There is also information on the way that strip mining has ravaged the land, is threatening their house, and affecting the lives of their unusual neighbors and the local animals. The real "measurement" in this award-winning novel is of maturity, responsibility, and a growing appreciation of family and an understanding of self.

## Send us your suggestions!

# *Summary Outlines*

### Session 1: Making Height-O-Meters

1. Ask how scientists measure distances to faraway things.
2. Hold up Height-O-Meter you made; students will be making these.
3. Demonstrate first four steps, as described on page 8.
4. Hand out materials and have students begin. Help as needed.
5. Collect glue sticks and scissors and demonstrate next steps (page 9).
6. Demonstrate push pin and assembly of Height-O-Meters (page 10).
7. Demonstrate how half-disk must swing freely and suggest adjustments.
8. Collect Height-O-Meters and keep clean and dry for next session.

### Session 2: Calibrating Height-O-Meters

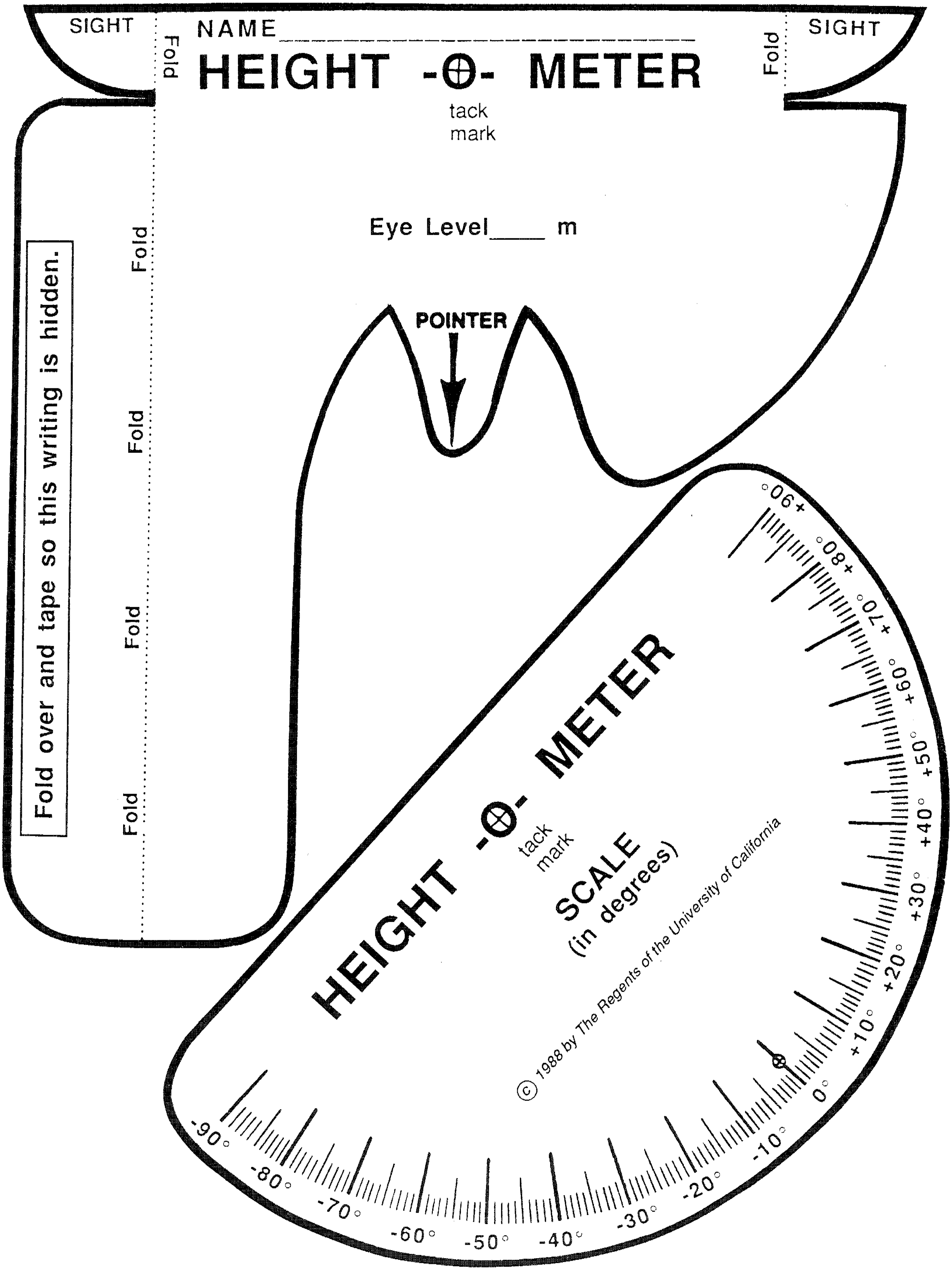
1. Hand out Height-O-Meters. Show how to measure angle of a high object.
2. Have students practice.
3. Have students adjust for zero and tape paper clip in place.
4. Have students measure eye level and write it on Height-O-Meters.
5. Check "zeroing." All sight on eye level tape and press disks together.

### Session 3: How High Is the Flagpole?

1. Students will test Height-O-Meters by measuring flagpole. You have the actual measurement in a sealed envelope.
2. Explain angles and degrees and define angular height.
3. Explain that all students should stand exactly 8 meters from base of pole, measure top corner of flag three or four times, then estimate angular height.
4. Go outside and conduct activity; poll class quickly for results.
5. Inside, explain that the angle between eye level and object and the baseline are both needed to determine the height.
6. Hand out "Height Finder Chart." Explain that it is a scale drawing.
7. Have students draw baseline, find angle, and use ruler to draw line from top of flagpole to right hand margin.
8. Have students correct for eye level.
9. Poll for answers then reveal the results and discuss.
10. Ask students to estimate the class average.
11. Summarize methods used. Point out colored triangle in diagram, and explain that this method of height-finding is called triangulation.
12. In next session they will measure something that can't be measured directly—how high a ball is thrown.

### Session 4: Experimenting with Height-O-Meters

1. Hold up a styrofoam and a rubber ball.
2. Students will go outside and measure the angular heights. Draw a diagram showing where Team A and Team B stand (page 32).
3. Outside, after some practice tosses, throw the rubber ball first.
4. Inside, record results. Determine class average (average eye level also needed). Take several student estimates for both.
5. Use the "Height Finder Chart—Two Observers" data sheet. Show on chalkboard how to figure out how high the balls went (page 36).
6. Have half of class calculate styrofoam, half the rubber ball.
7. Express results in a bar graph.
8. Ask students what conclusions they can draw from the graph.
9. Explain that this method is also triangulation.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© 1988 by The Regents of the University of California
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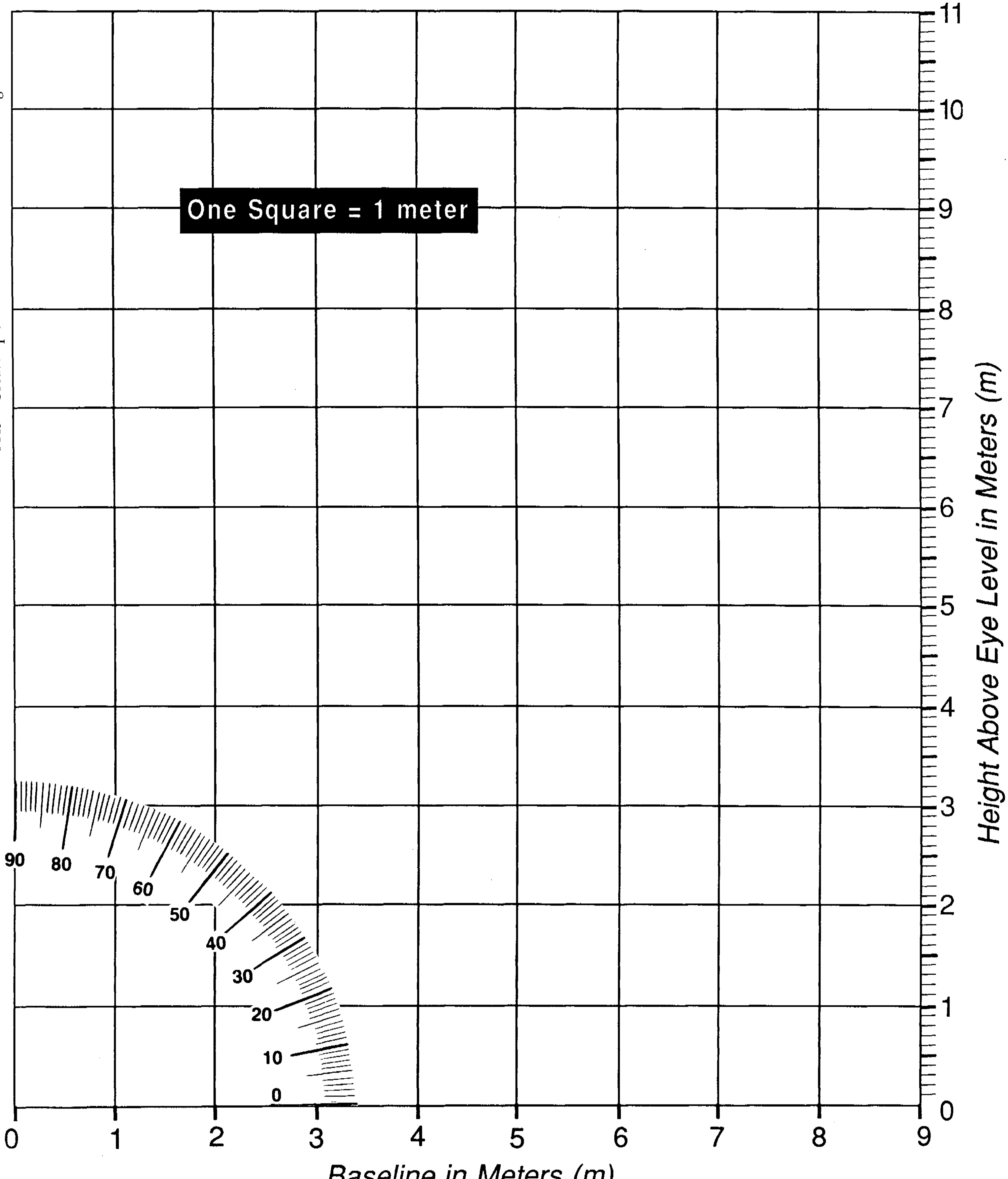
-80°
-90°

Name ____________________

# Height Finder Chart

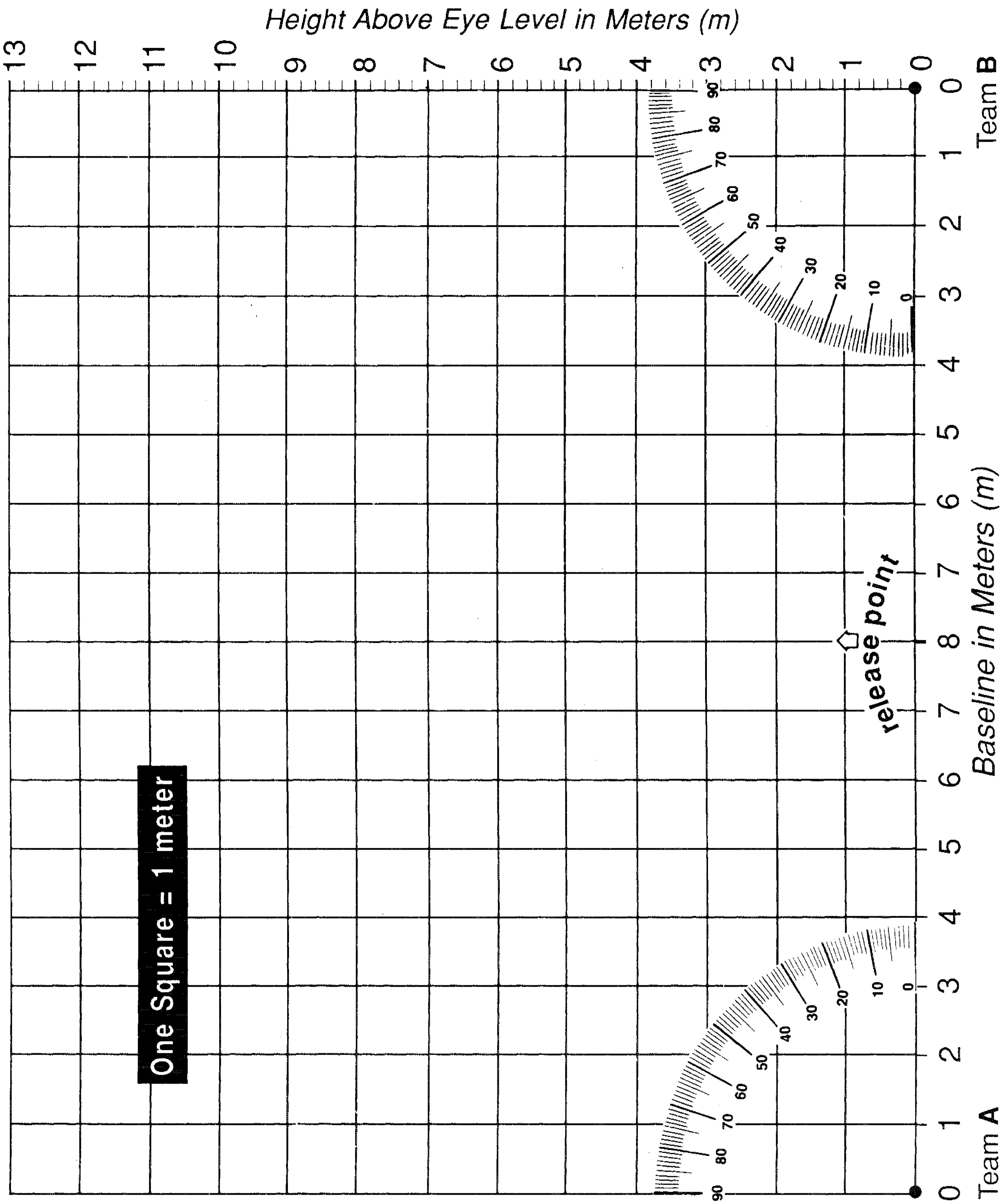





Height of object = ______ m *(from chart)* + ______ m *(eye level)* = [      ] m

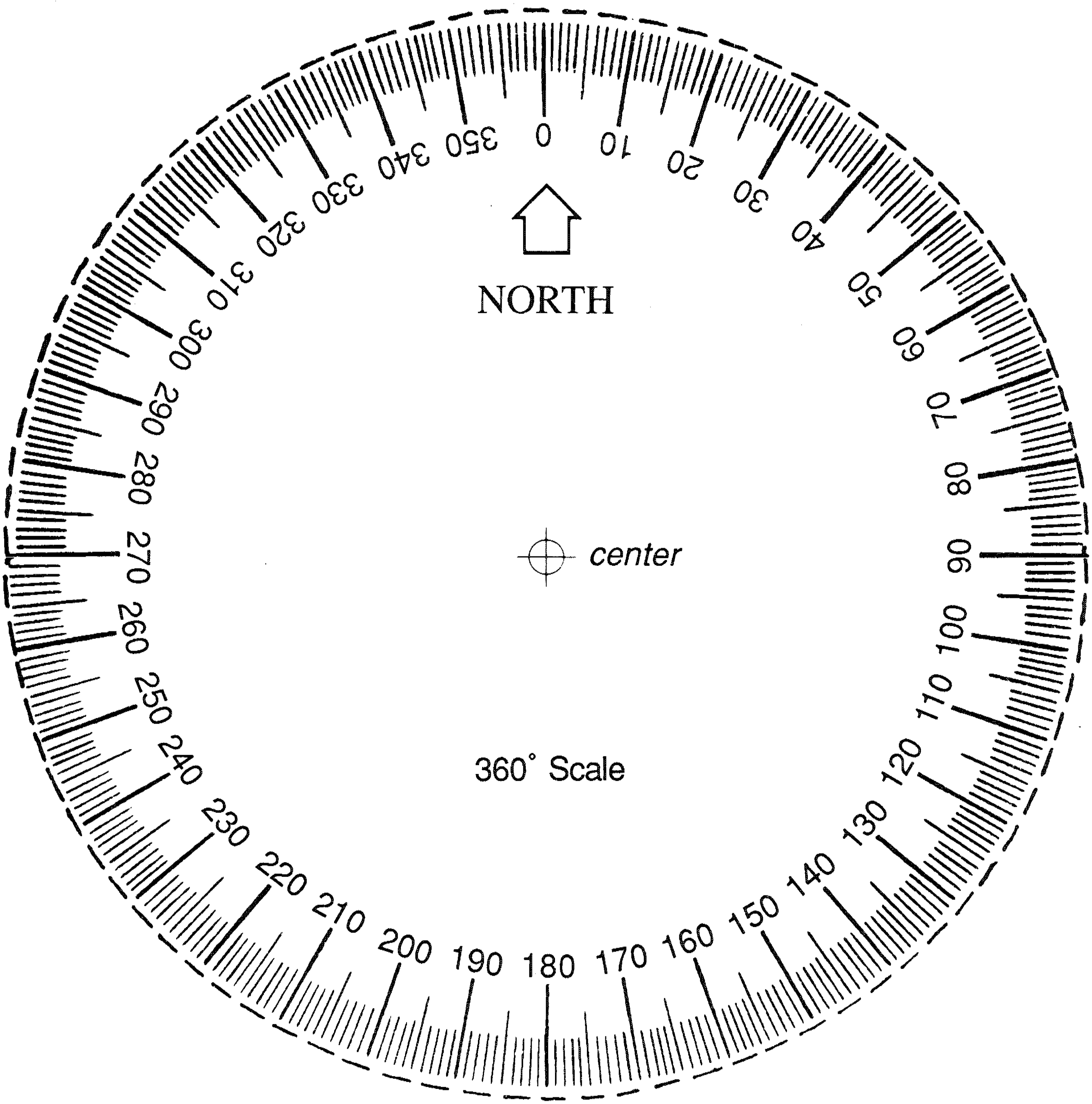
Name ____________________ Type of object measured ____________________

# Height Finder Chart - Two Observers






Height of object = ______ m *(from chart)* + ______ m *(eye level)* = [ ] m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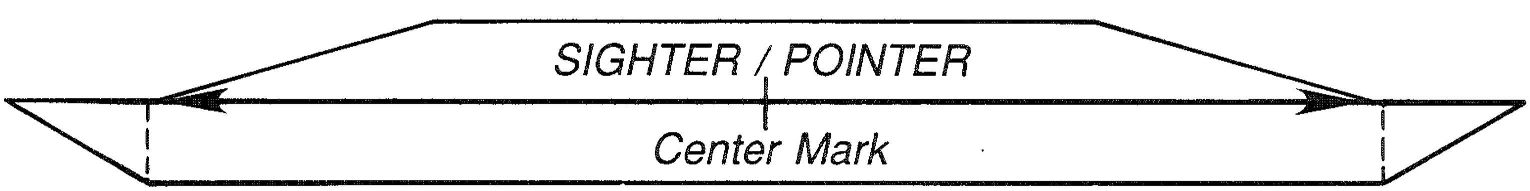
center
360° Scale


SIGHTER / POINTER
Center Mark