topic III

What Is Our Model of the Earth?

Time Emphasis: 10 days

	INVESTIGATION		A-1a	A-2a	A-2b	A-3a	B-1a	B-2a	B-2b	B-2c	FE -#1
	Estimated Time (Periods)		1	2½	1½	1½	2	2½	1½	1	
TOPIC OUTLINE	A. Earth dimensions										
	A-1 Shape		*How Can the Earth's Shape Be Determined?*								
	A-1.1 Evidence	A-1.11	■								
		A-1.12									
	A-2 Size		*How Can the Earth's Size Be Determined?*								
	A-2.1 Measurement techniques	A-2.11									
		A-2.12		■							
		A-2.13		■							
	A-2.2 Measurement determinations	A-2.21			■						
		A-2.22			■						
	A-3 Extent of the atmosphere, hydrosphere, and lithosphere		*What is the Extent of the Atmosphere, Hydrosphere, and Lithosphere?*								
	A-3.1 Atmosphere	A-3.11									
		A-3.12									
	A-3.2 Hydrosphere	A-3.21				■					
	A-3.3 Lithosphere	A-3.31									
	B. Positions on the earth										
	B-1 Position determination		*How Can a Position On the Earth's Surface Be Determined?*								
	B-1.1 Coordinate systems	B-1.11					■				
		B-1.12					■				
	B-2 Position description		*How Can the Characteristics of a Position Be Measured and Described?*								
	B-2.1 Vector-scalar properties	B-2.11									
	B-2.2 Fields	B-2.21						■	■	■	■
		B-2.22						■	■		■
		B-2.23						■	■		■
		B-2.24						■	■		
		B-2.25						■	■		■
PROCESS OF INQUIRY OBJECTIVES	Mathematical Skill	PIO-1	■	■	■						■
	Measurement Skill	PIO-2	■	■	■			■	■	■	■
	Creating Models	PIO-3	■		■	■	■	■	■	■	■
	Analysis of Error	PIO-4	■	■	■			■	■		
	Data Analysis	PIO-5	■	■	■	■		■	■		
TITLES	Multimedia: Check Multimedia Section of Supplement for reference to this topic.		Earth Shape	Earth's Circumference	Roundness and Smoothness	Ocean Bottom Profile	Locating Positions	Temperature Field	Contour Mapping	Earth's Magnetic Field	School Building and Grounds

Easy (1)

III-A-1a: EARTH'S SHAPE

QUESTION:

How can the earth's shape be determined?

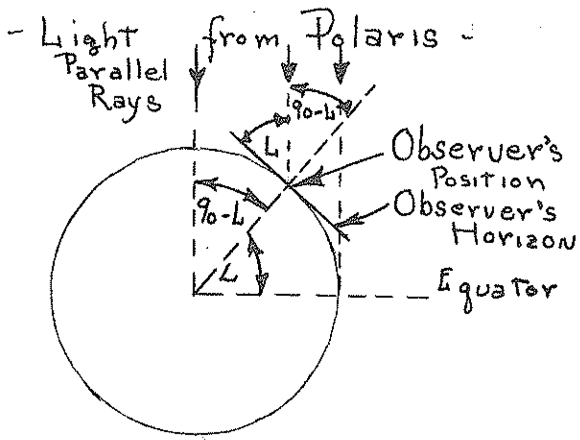
MATERIALS:

Astrolabe.

SUGGESTED APPROACH:

1. Have students make a sighting of Polaris' altitude at home, using either an astrolabe or the handspan method.

2. Using a globe, develop the understanding that the altitude of Polaris is equal to the latitude of the position from which Polaris was sighted. (See diagram.) Ask what the local latitude must be.



Given the distance in kilometers from the equator to the north pole, have students calculate the distance that would be covered for every 10° of latitude traveled, assuming that the earth is a perfect sphere. Have students compare their calculated values with the actual measured values.

Km./10° change of latitude

0-10° - 1105.7	40-50° - 1108.7
10-20° - 1106.0	50-60° - 1110.2
20-30° - 1106.6	60-70° - 1112.0
30-40° - 1107.5	70-80° - 1114.1
	80-90° - 1116.5

MODIFICATIONS:

1. If work has previously been done on pendulum measurements of gravity, have students compare the results of this exercise with the data in the following table:

Length of a Pendulum Which Swings
Once per Second

Latitude (°)	Pendulum Length (inches)
0	39.01
10	39.02
20	39.04
30	39.07
40	39.10
50	39.14
60	39.17
70	39.20
80	39.21
90	39.22

REFERENCES:

Investigating the Earth, pp. 70-73, Teacher's Guide, pp. 106-108, 117
Exploring Earth Science, pp. 156-157
Focus on Earth Science, pp. 24-28

III-A-1a: EARTH'S SHAPE - POLARIS DETERMINATION

QUESTION:

How can the earth's shape be determined?

INTRODUCTION:

Sketch what you think is an accurate representation of the earth's shape. What shape is it? Keep your sketch and compare it with the model which will be developed during this investigation. How could you obtain data that could be used to make an accurate scale model of the shape of the earth?

OBJECTIVES:

When you finish this investigation you should be able to:

1. state the latitude of a position, given the altitude of Polaris at that position.
2. explain why the observed altitude of Polaris is numerically equivalent to the latitude of the observer.
3. choose from among several given models the one that best represents the true shape of the earth, and defend your choice.

METHOD:

1. Using an astrolabe or the hand span method, make a sighting of the altitude of Polaris. The altitude of Polaris is always equal to the latitude of the observer. Make a diagram that will show why this is true.
2. Assume that you could travel from the equator to the pole and that as you traveled you took sightings of Polaris to determine your latitude. If the distance from the equator to the pole is 10,000 kilometers, and assuming that the earth is a perfect sphere, calculate how many kilometers would be covered for every 10° of latitude you traveled.
3. Compare the distance obtained above with the actual measured distances provided by your teacher.
4. Develop a model of the earth's shape that would take into account the data from #3. How close to a perfect sphere is the earth?

QUESTIONS:

(A-1.11) 1. What is the relationship between the altitude of Polaris and an observer's latitude? Explain by means of a diagram.

(A-2.21) 2. How would the earth's circumference measured along the equator compare its circumference measured through the poles?

(A-1.11) 3. What is the earth's shape? List evidence to support your answer.

(A-2.22) 4. If you had an exact scale model of the earth the size of a basketball, how near a perfect sphere would the model be?

Challenging (2.5)

III-A-2a: EARTH'S CIRCUMFERENCE

QUESTION:

How can the earth's size be determined?

MATERIALS:

Globe or sphere, clay, two toothpicks, protractor, flexible centimeter ruler, string and weight, ring stand.

SUGGESTED APPROACH:

1. Have the students fasten toothpicks about 5 cm. apart, on a line of longitude, as in the diagram on the student's sheet; measure distance "S" and the shadow angle "L". Repeat the procedure at least twice using different areas on the globe.

2. Use the chalkboard or overhead projector to develop the equation; $\frac{S}{C} = \frac{L}{360°}$, where S = measured distance; C = unknown circumference; L = measured angle. After the students understand the equation, have them calculate the circumference, using the average of the data obtained.

3. The students should measure the circumference of the model. They should compare the calculated and measured results, and calculate the percent error.

4. Have the students calculate the diameter and the volume, using their experimental data.

5. Discuss with the students what additional data they would need to calculate the earth's circumference when given their shadow angle "L". If the students can use the analemma, they can easily find at what latitude the sun will be at the zenith on this date. The distance can be calculated by assuming 1° of latitude = 70 miles.

6. When the sun is at its highest altitude, have the students measure the angle the sun makes with the vertical. With this angle and the information given on the supplementary sheet have them compute the earth's circumference.

PRECAUTIONS:

1. Percent error should not be greater than 10% (20% indoors with bulb).

2. Be sure the students understand why the formula used is valid. To do this, they must realize that the sun's rays are parallel and that alternate interior angles are always equal.

3. The students will need some help in using the protractor properly to measure the shadow angle.

4. Sticks mounted on the globe must be perpendicular to the surface of the globe at that point.

5. If at all possible, do this investigation outside. An artificial light source, such as a light bulb results in a loss of accuracy due to diverging light rays.

MODIFICATIONS:

Obtain shadow angle data from a school directly north or south of you; use a map to determine the distance between the schools and use this data to calculate the earth's circumference.

REFERENCES:

Investigating the Earth, pp. 68-70, Teacher's Guide, pp. 102-106

III-A-2a: EARTH'S CIRCUMFERENCE

QUESTION:

How can the earth's size be determined?

INTRODUCTION:

Very often we want to know the size of objects that are either too large or too small to measure directly. In these cases we must use an indirect technique that usually involves a ratio between the size of something we can measure and the size of the object we are trying to find. In this investigation you will devise a method that could be used to find the size of the earth.

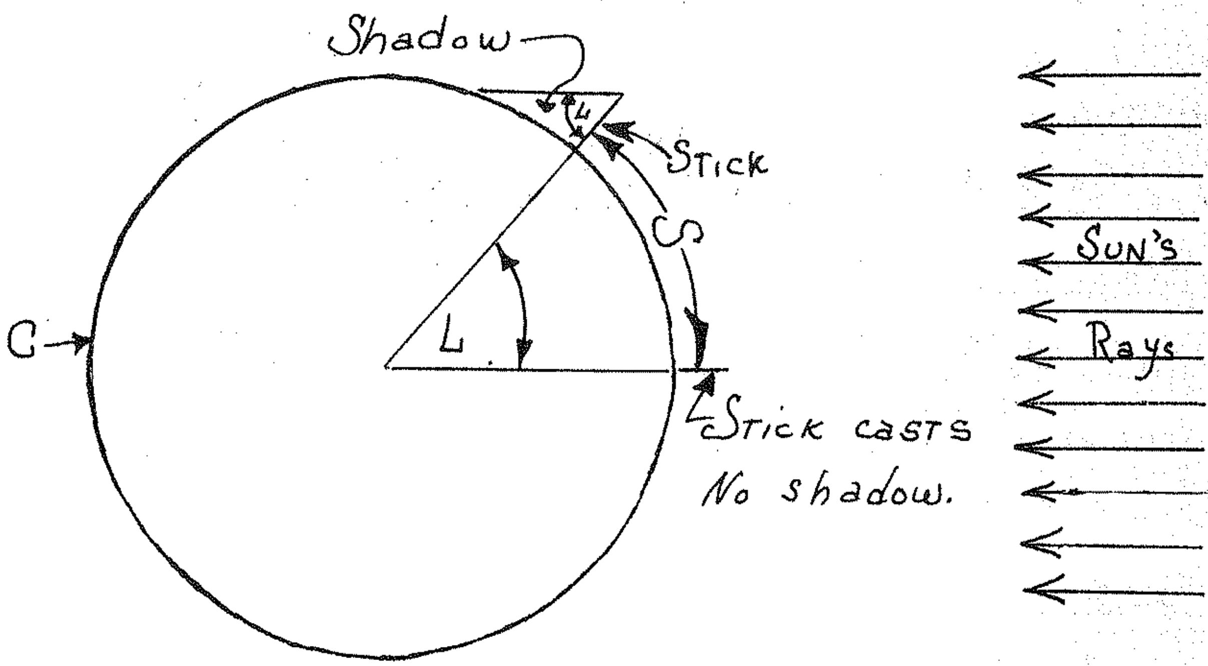
OBJECTIVES:

When you finish this investigation you should be able to:

1. measure distances on the globe to an accuracy of ± 0.2 cm.
2. observe and measure shadow angles to an accuracy of ± 5 degrees.
3. compute the globe's circumference using your data and the formula: $\frac{S}{C} = \frac{L}{360°}$
4. given the circumference of a globe, calculate its diameter, volume, and surface area.
5. determine the percentage error using a calculated value and a standard value.
6. describe how the basic technique, used to determine the circumference of the model, could be used to determine the circumference of the earth.

METHOD:

1. Set up a globe (as in the diagram below) so that you can determine a shadow angle of a toothpick, which is supported by clay and points toward the center of the globe. This toothpick should be positioned at a measured distance from another similarly supported toothpick which casts no shadow.



2. Measure and record the shadow angle and distance between the two toothpicks . Repeat this for at least three separate positions of the toothpicks.

3. Use the equation: $\frac{S}{C} = \frac{L}{360°}$ to determine the circumference of the globe. (Where S = the distance measured between sticks, C = the unknown circumference of the globe, and L = the measured angle.) Repeat the calculations for each of the three sets of data and determine the average.

4. Measure the circumference of your globe directly.

5. Determine your percent of error.

6. Calculate the diameter of the globe using your experimental data.

7. Calculate the volume using your experimental data.

8. When the sun is highest in the sky (solar noon), measure the angle of a shadow from a vertical stick and record the angle. This procedure should be done with good sunlight conditions (i.e., sharp shadows).

9. Using your measured angle and the information given on the supplementary sheet, determine the earth's circumference.

QUESTIONS:

(A-2.12) 1. What is the basis for the technique you used to determine the circumference of the earth?

2. Could this technique be used to find the size of a flat earth? Explain.

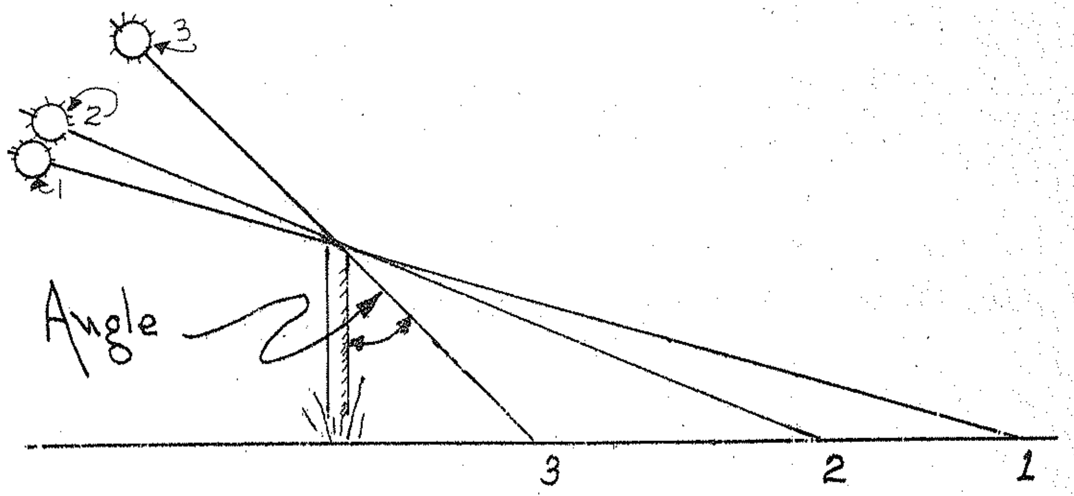
3. What are some possible sources of error that could have influenced your determination of the earth's circumference?

4. What other methods of determining the size of the earth might be used today?

(A-2.13) 5. Given the accepted polar circumference of 40,008 km., what is the diameter, volume, and surface area of the earth?

6. What is the percent of error in your computation of the earth's circumference from step 9? Use the circumference given in question 5.

SUPPLEMENTARY SHEET
EARTH'S CIRCUMFERENCE



1. Measure the angle of the sun at solar noon as illustrated in the diagram.

2. Use the measured angle and the information below to calculate the circumference of the earth.

Angle	*Distance(km.)	Angle	*Distance(km.)	Angle	*Distance(km.)
10	1110	26	2890	42	4670
11	1220	27	3000	43	4780
12	1330	28	3110	44	4890
13	1440	29	3220	45	5000
14	1560	30	3330	46	5110
15	1670	31	3450	47	5220
16	1780	32	3560	48	5330
17	1890	33	3670	49	5450
18	2000	34	3780	50	5560
19	2110	35	3890	51	5670
20	2220	36	4000	52	5780
21	2330	37	4110	53	5890
22	2440	38	4220	54	6000
23	2560	39	4330	55	6110
24	2670	40	4450	56	6220
25	2780	41	4560	57	6330
				58	6450
				59	6560

*Distance given represents the distance between location where your angular measurement was made and the location where there would be no shadow (sun at zenith)

III-A-2b: ROUNDNESS AND SMOOTHNESS

QUESTION:

How can the earth's shape be determined?

MATERIALS:

Globe (or some equivalent spherical object), ruler, caliper (for diameter) or flexible ruler (for circumference). Note: a strip of paper may be substituted for a flexible ruler.

SUGGESTED APPROACH:

1. Ask the students which they think is rounder and smoother, the earth or a globe. Have the students suggest ways to find out the answer to this question.

2. Have the students carry out their own procedures to determine the answer. The following is a description of one method:

   a. Roundness: Have the students determine the polar and equatorial diameter of the globe. Have the students find the decimal ratio of the two values. A perfect sphere would have a ratio of one, therefore, the closer to one, the more nearly spherical the object. Have the students determine a polar:equatorial diameter ratio for the earth and compare it to the ratio for the globe.

   b. Smoothness: Have the students measure (estimate if the actual value is less than 1 mm.) the height of any protrusion above the surface of the globe. Set up a ratio between this value and the average or approximate diameter of the globe. Develop the concept that the smaller the numerical result, the smoother the object. Have the students select the height of a mountain or depth of a valley on the earth and set up a ratio with the approximate diameter of the earth. Compare the values for the two ratios.

3. Review the question of roundness and smoothness (step #1). Briefly discuss the results with students, as well as any problems that developed.

PRECAUTIONS:

1. Students must be able to transfer between a mathematical and physical model. This is difficult for many students, but it is an important objective of the course. Individual assistance will be needed by many students.

2. Accuracy is extremely important if you really want to prove that the earth is rounder and smoother than a globe; an experimental error of 3-4 mm. will yield misleading results based upon experimental error rather than on actual differences. The measuring instruments must be capable of measuring to the nearest mm. Be careful of most types of string since they usually stretch several mm. when pulled tight.

TYPICAL RESULTS:

	ROUNDNESS	SMOOTHNESS
GLOBE	$\frac{\text{Polar diam.}}{\text{Equat. diam.}} = \frac{20.2\text{cm.}}{20.4\text{cm.}} = .990$	$\frac{\text{Relief height}}{\text{Approx. diam.}} = \frac{0.5\text{mm.}}{202\text{mm.}} = .0025$
EARTH	$\frac{\text{Polar diam.}}{\text{Equat. diam.}} = \frac{12714\text{km.}}{12756\text{km.}} = .997$	$\frac{\text{Height of Everest}}{\text{Approx. Equat. diam.}} = \frac{8.8\text{km.}}{12{,}800\text{km.}} = .0007$

REFERENCES:

Investigating the Earth, pp. 70-73, Teacher's Guide, pp. 106-108. 117
Exploring Earth Science, pp. 156-157
Focus on Earth Science, pp. 24-28

III-A-2b: ROUNDNESS AND SMOOTHNESS

QUESTION:

How can the earth's shape be determined?

INTRODUCTION:

The earth, whose shape is usually referred to as round, is in fact not perfectly round as the following data indicates:

EARTH DATA

Polar diameter (accepted)	12,714 km.
Polar diameter (approximate)	12,700 km.
Equatorial diameter (accepted)	12,756 km.
Equatorial diameter (approx.)	12,800 km.
(Height of Mt. Everest	8.8 km.)

If the earth is not round, how much out of round is it? For example, which do you think is rounder, the earth or a globe? Which is smoother? In this investigation you are to devise a method for answering these questions.

OBJECTIVES:

When you finish this investigation you should be able to:

1. when given the polar and equatorial diameters of the earth and similar data for a model, determine which is roundest and defend your choice.

2. determine how high a relief feature of the earth would be on a model if constructed to scale given the following: the height of the feature on the earth, the diameter of the earth, and any necessary measurements on the model.

3. Choose from among several given models the one that best represents the true shape of the earth and defend your choice.

METHOD:

1. Determine a procedure by which you can measure and compare the roundness and smoothness of the earth with that of a globe.

2. Check with your teacher and, with approval, carry out your procedure. Be sure your measurements and calculations are accurate or your results will lead you to incorrect conclusions.

QUESTIONS:

(A-2.21) 1. How does the earth's circumference measured through the poles compare to its circumference measured along the equator?

(A-2.22) 2. Which is more nearly round, the earth or a globe? How do you know? (Support your answer with numerical data.)

3. Which is smoother, the earth of a globe? How do you know? (Support your answer with numerical data.)

4. How high would Mt. Everest (Elevation 8.8 km.) appear on your globe if constructed to true scale?

III-A-3a: OCEAN BOTTOM PROFILE

QUESTION:

What is the extent of the earth's atmosphere, hydrosphere, and lithosphere?

MATERIALS:

Graph paper, hand-out sheet with data tables.

SUGGESTED APPROACH:

1. Briefly discuss with the students the extent of the hydrosphere by asking them to study a globe and estimate the proportion of the earth's surface that is covered with water. Ask them how deep the oceans are compared to the diameter of the earth? Compared to the thickness of the atmosphere?

2. Discuss briefly determination of water depth by sonar. Sound travels at a rate of 4800 feet per second in water, so by timing how long it takes a sound to go from a ship to the bottom and back, it is possible to determine the depth of the water.

$$\text{depth in feet} = \frac{\text{time in seconds}}{2} \times 4800 \text{ ft./sec.}$$

3. Have the students make and label a profile of the ocean bottom by plotting depths against distance. Have them use true scale (i.e., no vertical exaggeration). In order to have any observable depth have them work in large groups and make the graph about 5-10 sheets long.

4. Lead the students in a discussion of the shape of the profile and the problems that developed in making it. Emphasize the thinness of the hydrosphere relative to its surface area. The students could also calculate the actual gradients of the continental shelf and slope and the average depth of the oceans in the area of the profile.

5. Using the measurement-of-squares technique, have the students estimate the percentage of the earth's surface covered by oceans.

PRECAUTIONS:

1. This exercise must be done to true scale or the value of it is lost. The students should realize that the ocean represents a relatively thin layer of water compared to its surface area.

REFERENCES:

Investigating the Earth, pp. 320-321
Our Planet in Space, pp. 488-496
Focus on Earth Science, pp. 210-215

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III-A-3a: OCEAN BOTTOM PROFILE

QUESTION:

What is the extent of the earth's atmosphere, hydrosphere, and lithosphere?

INTRODUCTION:

How much of the earth's surface is covered with water? How deep is the water? What is the shape of the ocean bottom? In this investigation, you will make a profile of the ocean bottom which will help answer these questions and others.

OBJECTIVES:

When you finish this investigation you should be able to:

1. given distance and depth data, draw a profile of the ocean floor that illustrates the relief in true scale.

2. choose from among several given models the one that best represents the true shape of the ocean floor and defend your choice.

METHOD:

1. Using data given below, construct a profile of the ocean bottom. Connect sheets of graph paper end to end, plot distance on the horizontal axis and depth on the vertical axis. Be certain that you use the same scale on both axes since you want a true scale diagram.

2. By estimating the number of square centimeters of ocean compared to land on a globe, determine the approximate percentage of the earth's surface covered by water.

DISTANCE (Miles)	DEPTH (Miles)	LOCATION LANDMARK
0	0	Cape May
100	0.1	
125	1.0	
325	2.0	
475	2.5	
650	3.0	
900	2.8	
1125	2.9	
1300	3.1	
1425	2.9	
1475	2.0	
1600	1.6	
1900	2.5	
2000	2.1	
2150	1.8	
2200	1.2	
2225	0.8	North Atlantic Ridge
2325	0.7	" " "
2450	0.6	" " "
2475	0.0	Graciosa Island, Azores
2525	1.0	
2700	2.0	
2800	2.8	
3150	2.7	
3300	2.3	
3400	1.0	
3425	0.5	
3475	0.1	
3500	0	Cape Roca

Data are a series of depth soundings taken along the 39°N parallel from Cape May, New Jersey to Cape Roca, Portugal

QUESTIONS:

(A-3.21) 1. How deep are the oceans relative to the size of the earth?

(B-3.31) 2. What is the approximate percentage of the surface covered by water?

(B-3.31) 3. What was the maximum depth in cm. of the Atlantic Ocean drawn to the scale you used in this exercise?

Challenging (2)

III-B-1a: LOCATING POSITIONS

QUESTION:

How can a position on the earth's surface be determined?

MATERIALS:

Unmarked spheres (e.g. basketballs, volley balls, globes, plastic hemispheres).

SUGGESTED APPROACH:

1. Place a dot on one of the unmarked spheres and ask students to put a dot on their sphere at exactly the same location.

2. Briefly discuss with students the apparent problems resulting from step 1. Ask what else is needed to allow them to locate the point accurately.

3. Challenge the students to develop, on their spheres, a coordinate system that will allow them to locate positions. If most of them seem to feel constrained to use a latitude-longitude type grid, ask them if latitude-longitude is real or imaginary and therefore whether it's the only possible system; encourage them to use their imaginations.

4. Lead the students in a discussion of the systems they have devised. Develop from the discussion the basic requirements for a workable system.

5. Ask students to imagine that they have to set up their system on the real earth or moon; remind them that they obviously cannot hold these in their hands like the sphere and that this may result in some additional problems. Develop from this step the idea that to set up a coordinate system it is necessary to use observations of objects external to the earth, i.e. celestial objects as reference points.

6. Discuss the advantages and disadvantages of the latitude and longitude system with the students.

MODIFICATIONS:

1. Extend the idea of locating a position to the concept of time measurement by introducing the fact that the earth is a rotating sphere. Ask what system of time measurement might have developed if man used one of the student-developed systems of location. Would it be different?

2. Develop the idea that terms like top, bottom, up, down, east, west, are only relative.

3. Check student systems by having one student locate positions on a sphere using a system as directed by the student who designed the system.

4. Extend the concepts developed in the investigation to ideas about how man can locate positions in space. This is more difficult since a three dimensional system is required.

REFERENCES:

Investigation the Earth, pp. 63-66, Teacher's Guide pp. 96-100, 117-119.
Focus on Earth Science, p. 29.
Our Planet in Space, pp. 134-138.

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III-B-1a: LOCATING POSITIONS

QUESTION:

How can a position on the earth's surface be determined?

INTRODUCTION:

We are continually using systems to describe positions of objects. The radio announcer uses a one-dimensional system to describe the position of the football on the field. The ship captain uses a two-dimensional system to describe his position at sea. The astronaut uses a three-dimensional system to describe his position. Each of these systems have some things in common, each is different in some respects. What general problems are involved in devising these systems? In this investigation you will be faced with some of these problems as you devise a system for locating positions.

OBJECTIVES:

When you have finished this investigation you should be able to:

1. develop a coordinate system to locate positions on a blank sphere.
2. given a sphere or a map with any coordinate system marked on it and a denoted position, determine the coordinates of the position.
3. explain the basis of the latitude-longitude system.

METHOD:

1. Locate on your sphere the position marked on your instructor's sphere.
2. Develop a coordinate system that will allow you to locate positions on a sphere more accurately.
3. Discuss your system with other students. Make a list of the basic requirements of any workable position-locating system. As a result of this list, make any changes in your system that you now feel are necessary.
4. Imagine now that you have to set up your system on the real earth. Determine the reference points you will use to establish your system. Keep in mind the list of basic requirements.
5. Compare your system with the latitude-longitude system used on the earth.

QUESTIONS:

1. What is the position-locating system that you have devised?

2. Using your system, what is the minimum information necessary to exactly locate a position on a sphere?

(B-1.11) 3. What are the basic characteristics of the latitude-longitude system?

(B-1.12) 4. What is the basis for the latitude-longitude system?

5. Explain how your system would have to be changed if the model were larger or smaller?

6. How would the latitude-longitude system have to be changed if the earth were larger or smaller?

Challenging (2.5)

III-B-2a: TEMPERATURE FIELD

QUESTION:

How can the characteristics of a position be measured and described?

MATERIALS:

Thermometers (at least 25), room plan maps (3 per student), fence diagram kit (optional).

SUGGESTED APPROACH:

1. Briefly discuss with students the nature of a field, have them give examples of fields, and then try to define fields based on these examples.

2. Have students distribute themselves around the room so that students are at each of the stations located on the blank maps. Each should have a thermometer.

3. After measuring the temperature at the floor, desk top level, and 1 meter above the desk top, the students should be prepared to report their data.

4. At least one student should be free to record data as it is called out by students around the room.

5. Each student should have the temperature data to be plotted for all the stations at three levels, i.e., he should have three maps. Have the students draw the isotherms according to their interpretations.

6. If you wish, have some of the students transfer their maps to a fence diagram; be sure they estimate the appearance of the isolines on the crosspieces.

7. Discuss with students the significance of the field and any problems they had in measuring and mapping the field. Have them locate on their maps the room's heat sources and sinks; have them predict what would happen if, for example, a window was opened (or closed); have them suggest some other fields that might exist in the room.

PRECAUTIONS:

1. Using a water bath, check the thermometers to see that they all record the same temperature. Those that do not should be labeled with a correction factor.

2. Check the room temperature at different levels in different parts of the room. You should detect at least a 2°C. range. If you do not, open a window, direct a heat lamp against one corner of the room, or adjust the heating system in some manner that will produce some variation.

3. To prevent thermometers from rolling, attach a spring-type clothespin to each.

4. If possible, have students read the temperature to the nearest 0.5°C.

5. Check students when they are constructing their maps to be sure they are drawing isotherms and not simply connecting all points that have the same value. Frequent errors include: allowing lines to cross, and omitting an interpolated value.

6. Because of the problems of drawing the isolines, be sure students use pencil.

TYPICAL RESULTS:

Results will vary depending on local climatic conditions and on the heating system of the room. A typical map will show a 2°-4°C. temperature variation at any one level. Students will have difficulty in correctly drawing the isotherms, they will need help and constant reminding of the properties of an isoline.

MODIFICATIONS:

1. Measure the temperature field outside the classroom. Use the natural variation that exists due to shade or the presence of water. This would be a useful prelude to the study of weather and climate.

2. Use the school district for temperature analysis; allow the students to take thermometers home.

3. Since the purpose of this investigation is to allow students to become aware of the characteristics of a field, any kind of field can be used. For example, if light meters are available, a light intensity field can be measured. Another possibility is to have students bring in their pocket transistor radios and detect the field that surrounds power lines by means of the intensity of the static.

REFERENCES:

Investigating the Earth, pp. 106-107, Teacher's Guide pp. 149-152

III-B-2a: TEMPERATURE FIELD

QUESTION:

How can the characteristics of a position be measured and described?

INTRODUCTION:

What does the word "field" mean to you as it is used in the question? What are some examples of fields? What characteristics do all of these fields have in common? In this investigation you will measure and map the characteristics of a field.

OBJECTIVES:

When you finish this investigation you should be able to:

1. measure the temperature to the nearest half division at several locations within a temperature field.

2. plot field values on a map and draw isotherms.

3. prepare a three-dimensional model of the temperature field.

4. identify the isosurfaces within the field

5. locate heat sources and sinks within the field.

6. given a temperature field map, estimate the temperature at any given point.

7. given a temperature field map, indicate the areas of highest and lowest temperature, and the areas of maximum and minimum gradient.

METHOD:

1. At each station measure and record the temperature at the following elevations: floor level, desk-top level, and 1 meter above the desk.

2. Plot the measurements of temperature at each of the stations at floor level on a blank map of the room. Draw in the isotherms that must exist in the room at that level; remember that isotherms cannot cross and do not omit an isoline that must exist between two isolines even though no measurements were taken at those points.

3. Repeat step 2 for each of the other levels.

4. Transfer your three maps to the plastic sheets of the fence diagram kit. Sketch in the probable appearance of your map on the outside vertical cross pieces. Color the spaces between isotherms so that areas of the same temperature range are all the same color.

5. Compare your results with those of other students.

QUESTIONS:

(B-2.21) 1. How would you define a field?

(B-2.22) 2. Explain how field characteristics can be shown in two dimensions.

(B-2.23) 3. Explain how field characteristics can be shown in three dimensions.

(B-2.24) 4. Would the field you measured and mapped have the same appearance tomorrow? next week? next month? Explain.

(B-2.24) 5. How can the degree of change in field characteristics (gradient) be observed on a two-dimensional model?

6. What other fields do you think might exist in the room? How could you find out?

7. What factors do you think caused the variations in the room? How could you test to find out if you are correct?

8. Look at a U.S. weather bureau map. What characteristics does it have that indicate it is a map of a field? How many fields are mapped on a weather map?

Easy (1.5,

III-B-2b: CONTOUR MAPPING

QUESTION:

How can the characteristics of a position be measured and described?

MATERIALS:

Plastic shoebox, landform model to fit inside shoebox, clear plastic sheet, marking pen, water.

SUGGESTED APPROACH:

1. Have the students make a contour map of the landform model by placing it in the shoebox, marking off equal divisions of depth on the side of the box, and then filling the box to the first line with water. The interface between land form and the water can then be traced. This should be repeated until the land form is completely covered with water. At this point the water can be poured out, and a plastic sheet placed on top of the shoebox top. Have the students look directly down at the model and trace the lines on the model on to the plastic sheet. The plastic sheet is now a contour map of the landform model.

2. Lead the students in a discussion of their contour maps. Emphasize that; contour lines are isolines; that altitude is a scalar field quantity; how areas of maximum and minimum elevation are shown; how areas of maximum and minimum gradient are shown; what contour interval means.

3. Have the students complete the exercise on the supplementary sheet for further map reading practice.

PRECAUTIONS:

1. The plastic landform models in the commercial contour model kits will float and may need to be fastened down with masking tape.

2. Use nonwater soluble pens when marking on the landform model; grease pens work well. However, water soluble marking pens are excellent for the plastic sheet.

MODIFICATIONS:

1. Add food coloring to the water and have the students draw the contour map on the plastic sheet directly without first marking on the landform model.

2. Have the students actually make a contour map of a small nearby hill. Simple surveying instruments can be easily constructed, especially if your school has a cooperative shop teacher.

3. If possible, use local maps and photographs of areas that will be used later in the course as field trip sites.

REFERENCES:

Investigating the Earth, pp. 76-79, Teacher's Guide, pp. 109-112, 117-119
Our Planet in Space, p. 441
Exploring Earth Science, pp. 400-421
Geology and Earth Sciences Sourcebook, pp. 365-376

Do not Print

III-B-2b: CONTOUR MAPPING

QUESTION:

How can the characteristics of a position be measured and described?

INTRODUCTION:

Maps are models. The kind of maps most often used by earth scientists are called contour or topographic maps. In this investigation, you will work with and make contour maps to determine how they portray the physical environment and to learn some of their advantages and disadvantages.

OBJECTIVES:

When you finish this investigation you should be able to:

1. match actual landforms and photographs of landforms with their map projections.

2. describe the properties of contour lines, and given some field data, determine whether it is scalar or vector.

3. given a topographic map, estimate the elevation at any given point.

4. given a topographic map, indicate the areas of highest and lowest elevation, and the areas of maximum and minimum gradient.

METHOD:

1. Place the landform model in the plastic shoebox. Mark the side of the box with equal divisions (1 centimeter is an appropriate division). Pour water into the box until the water level is at the first division mark. With the grease pencil, trace the interface between the water and the model. Repeat this until the water level is above the top of the model.

2. Pour out the water and put the top on the shoebox. Place a plastic sheet over the cover and trace onto the sheet the lines you just drew on the landform model. These lines on the sheet are called contour lines, the completed sheet is a contour map of the landform model.

3. Complete the topographic map exercise on the supplementary sheet.

QUESTIONS:

(B-2.21) 1. What is a field?

2. What field quantity does a contour map represent?

(B-2.22) 3. Explain how field characteristics can be shown in two dimensions.

(B-2.23) 4. Explain how field characteristics can be shown in three dimensions.

(B-2.24) 5. Would a field represented by contour lines be likely to undergo change with the passage of time?

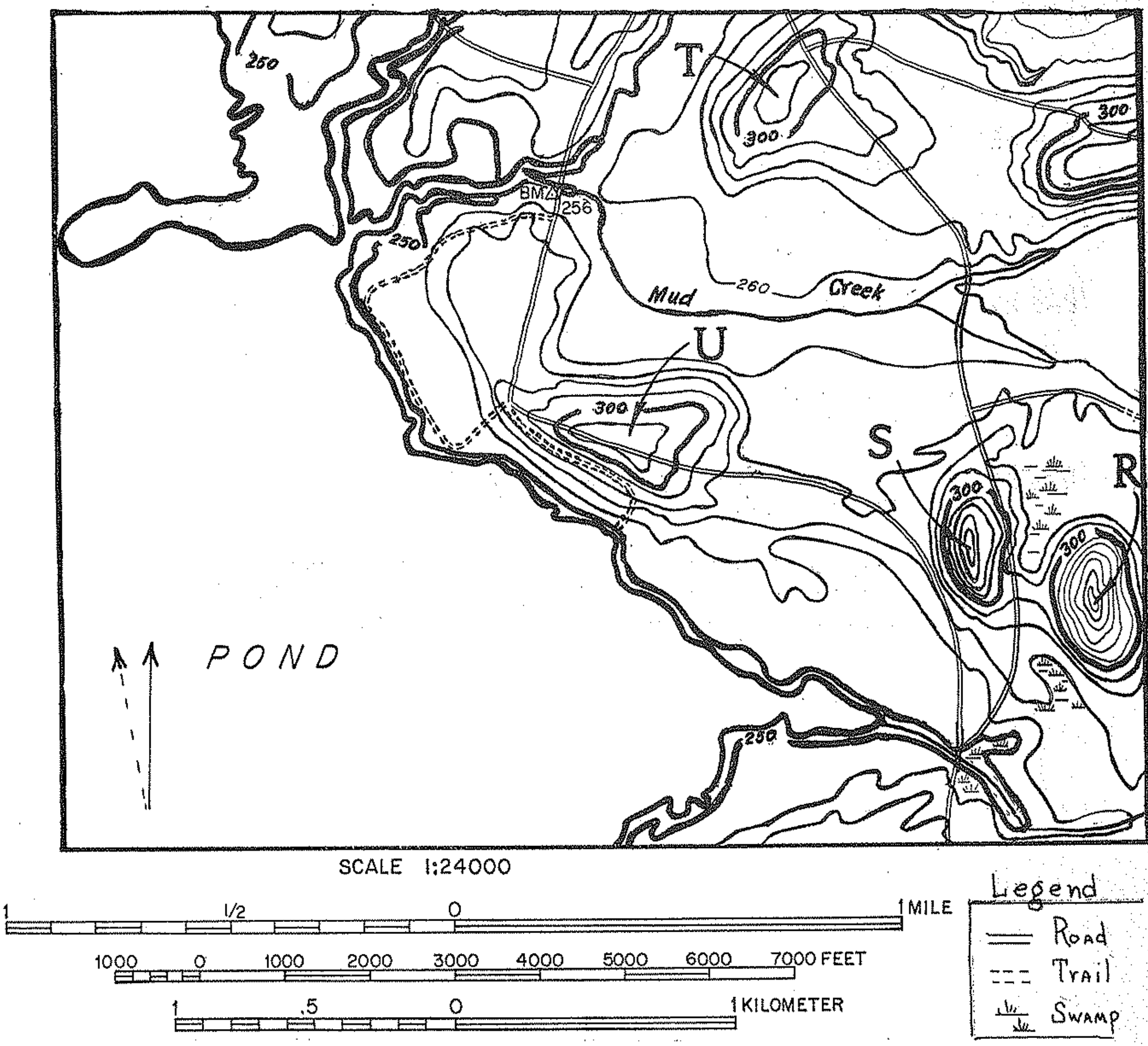
6. What information is necessary to make an accurate contour map?

(B-2.25) 7. How does a contour map show areas of steep gradient? low gradient?

8. What characteristic shape does a valley have on a contour map? Explain how you could determine the direction of stream flow from a contour map.

SUPPLEMENTARY SHEET

CONTOUR MAP EXERCISE



1. How far would you have to walk, in miles, if you followed the trail from where it leaves the highway, just below the BM 256 marker, to the point where it again joins the highway?

2. Which of the lettered hills has the highest elevation? What is it?

3. In what general direction does Mud Creek flow?

4. Which side of hill "T" has the least gradient?

5. What is the approximate elevation of the water in North Pond?

Easy (1)

III-B-2c: EARTH'S MAGNETIC FIELD

QUESTION:

How can field quantities of the earth be measured and described?

MATERIALS:

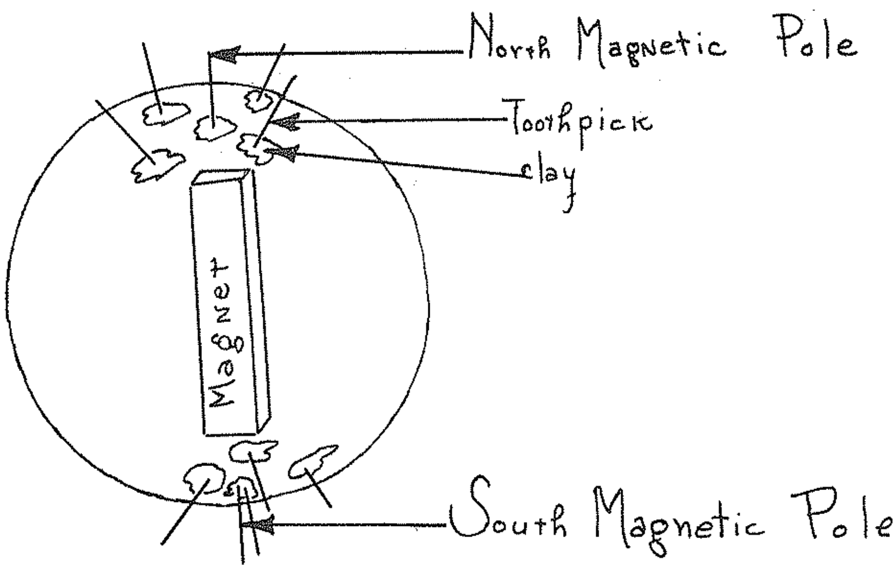
Compass, small magnet, globe (which can be taken apart), toothpicks, clay, topographic maps of several widely separated areas.

SUGGESTED APPROACH:

1. Tape a bar magnet to a disc which can then be taped into position within the globe. The position should not be divulged to the students. The orientation of the magnet need not represent the present position of the earth's magnetic poles.

2. Have the students locate the poles by rotating the sphere while holding a compass next to it. Be sure the compass is held horizontally so that the needle swings freely.

3. Have the students attach toothpicks to the sphere with clay in such a way that the orientation of the long axes of the toothpicks represent the shape of the magnetic lines of force at the surface of the sphere. See figure below for diagram of this step.



4. Lead the students in a discussion of the properties of the earth's magnetic field. Remind the students that, although only direction was measured, the magnetic field is vector in nature. Relate the field map to magnetic declination figures found on topographic maps. Compare the location and meaning of geographic and magnetic north poles.

PRECAUTIONS:

1. If compasses are placed on desks to keep them horizontal, be sure that there are no metal parts of the desk that will interfere with the magnet's field.

2. Be sure that the magnet has definite north and south poles.

MODIFICATIONS:

1. If the magnet is strong enough or the sphere small enough, the poles can be detected by having students lightly cover the bottom of a petri dish with iron filings and moving the sphere under the dish. The filings will react to the magnetic field by lining up in the direction of the field.

2. If clarification of the effect of a magnet on a compass is necessary, suspend a magnet and bring a horizontally-held compass near it from several different directions.

3. To illustrate a three-dimensional magnetic field, fill a large round-bottomed or Florence flask with glycerin or some other clear, viscous, nonreactive liquid. Add iron filings and shake. Set the flask on a strong horseshoe magnet. The filings will line up along the lines of force. This demonstration may be kept from year to year if the flask is kept stoppered.

4. To demonstrate magnetic declination, have students determine the direction of a high noon shadow and compare it to the compass direction at that point.

REFERENCES:

The Earth Sciences, Chp. 9, "The Earth as a Magnet"
Investigating the Earth, pp. 120-125, Teacher's Guide pp. 160-164, 169
Our Planet in Space, pp. 156-167
Exploring Earth Science, pp. 162-163

III-B-2c: EARTH'S MAGNETIC FIELD

QUESTION:

How can field quantities of the earth be measured and described?

INTRODUCTION:

Most of the fields you have studied have been ones that you can detect through your senses. However, there are some that you cannot detect directly because you have no specific sense for them. One of these field quantities is magnetism. In this investigation, you will measure and map a model of the earth's magnetic field.

OBJECTIVES:

When you finish this investigation you should be able to:

1. use a compass to describe the direction of the earth's magnetic field at any location.
2. describe the characteristics of the magnetic field model as they compare to the earth's magnetic field.
3. given the declination, use a compass to find the direction of of magnetic and true north.

METHOD:

1. Locate the magnetic poles on the earth model by holding a compass horizontally and rotating the sphere next to the compass.
2. Attach toothpicks to the sphere with clay in such a way that the long axes of the toothpicks represent the magnetic lines of force at the sphere's surface.
3. Discuss the characteristics of your model compared to the earth's magnetic field.
4. Look at the magnetic declination indicators on several topographic maps. Plot the declination direction on a blank U.S. map.

QUESTIONS:

(B-2.21) 1. What is a field?

2. What evidence indicates that magnetism is a field quantity?

3. Why can a compass be used to locate the poles?

4. Are magnetic lines of force a type of isoline? Why?

5. What is the relationship between the magnetic and the geographic north poles of the earth? Which one does a compass indicate?

6. Why do different locations have different magnetic declinations?