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This guide is designed to assist teachers of the intermediate level grades in the preparation of students to visit the Strasenburgh Planetarium. This initial preparation and follow-up are essential because the programs are given to groups of 240 students and consequently there is little opportunity for individual discussion with the planetarium instructor. The materials are coordinated with the five 1968-69 planetarium school programs: (1) Earth, Sun and Moon; (2) All About Planets; (3) Exploring the Universe; (4) Sky-Scanning; and (5) Man in Space. The materials for each program provide statements of student behavioral outcomes, activities for the attainment of these outcomes, selected references, and suggestions for evaluation. Also provided are a description of the planetarium, the services it renders, and the arrangements to be made prior to a visitation. Appended are (1) a bibliography, (2) an extensive list of appropriate audiovisual materials and their sources, (3) a glossary, and (4) an equipment list. This work was prepared under ESEA Title III contract. (RS)

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TEACHER'S GUIDE

to the

STRASENBURGH PLANETARIUM

Prepared by the

Earth-Space Science Education Center

Fairport Central School

a Title III ESEA Project

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CONTENTS

PREFACE

The primary purpose of the material in this notebook is to prepare students for trips to the Strasenburgh Planetarium. Such preparation is helpful, if not essential, if your students are to maximize the benefits of planetarium visitations.

The planetarium programs will be given to groups of 240 students at one time and, as a result, there will be little opportunity for students to ask questions of the planetarium instructor. Because of this, students should have some familiarity with the concepts, astronomical events, and vocabulary that will comprise the programs. Such familiarity can be obtained by using the materials in this notebook prior to your planetarium visit.

These materials are written and organized for the five 1968-69 planetarium school programs:

Earth, Sun, and Moon
All About Planets
Exploring the Universe
Sky-Scanning
Man in Space

The materials for each program have been printed on different colored pages for added convenience. As additional programs are developed in the future, you will receive copies of the related materials to add to your notebook.

These materials are only in a test phase and will be revised as needed. We ask that you participate in this revision process by providing the planetarium staff with your written reactions, evaluations, and suggested changes of the activities and their usefullness as preparatory instruments. All such comments will be welcomed and used. Only your assistance can result in increasingly effective, coordinated programs and activities.

WHY GO TO THE STRASENBURGH PLANETARIUM

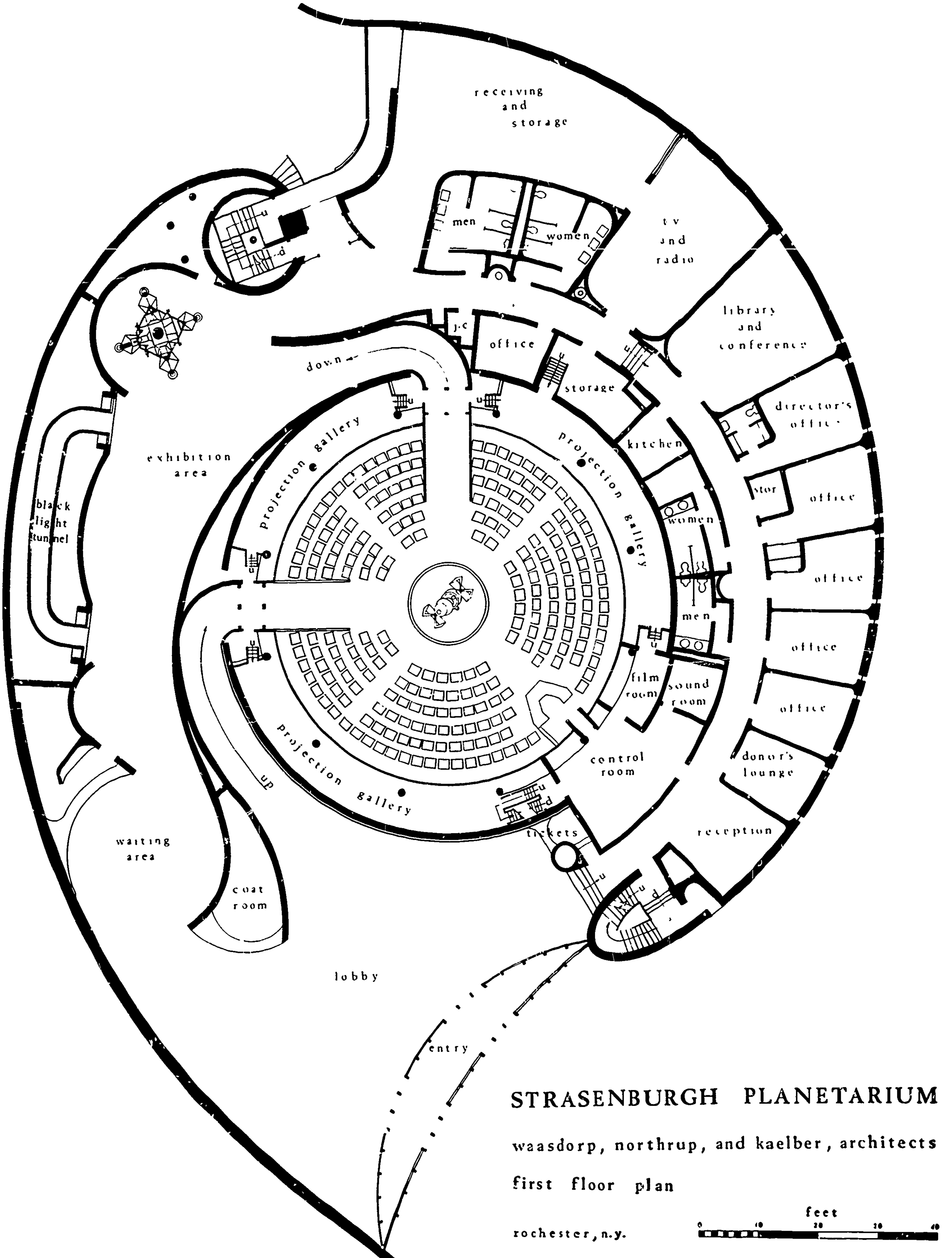
by Donald S. Hall, Education Director of the Strasenburgh Planetarium

Active planning for the Strasenburgh Planetarium began in 1964. This foundation of advanced thought has allowed the project to include many innovations in the field of planetarium education. In designing the planetarium, it has been considered a communications medium, not merely a teaching device whose function it is to create astronomical environments. School presentations in the Star Theatre will not be lectures, but will be dialogues between the Planetarium Instructor and the students.

Not only is the Strasenburgh Planetarium innovative in its educational philosophy, but also in its physical design and equipment. The Zeiss planetarium projector is the first of a revolutionary new series. With the aid of hundreds of auxiliary projectors, all under the control of a digital computer, the planetarium will be able to visualize a wide variety of astronomical topics ranging from our own backyard sky to the creation of the universe. The Strasenburgh Planetarium visitor will be comfortably seated in a high back reclining lounge chair which will swivel to ensure a view of the entire sky. Two speakers built into the headrest of each of these chairs will carry the Instructor's voice and are but a part of the audience enveloping stereophonic sound system for music, sound effects and narration.

Outside the Star Theatre, building visitors will enjoy the exhibit area. The attractions in this area include the ASTRO-SCREEN where multi-projector shows will be staged on a screen whose dimensions are 12 by 48 feet. In addition, the visitor may stroll through the SPACE TUNNEL where he will be led from the sun past the most distant objects in the universe. After his walk through this exhibit, the observer may view the TONIGHT SCREEN which will keep him posted on current events in the sky.

It is the aim of the Strasenburgh Planetarium staff to make a visit to the planetarium an educational experience not to be forgotten for a lifetime. With an innovating education philosophy and a unique physical plant, this goal should be attained.



STRASENBURGH PLANETARIUM

waasdorp, northrup, and kaelber, architects

first floor plan

rochester, n.y.

feet

0 10 20 30 40

HOW TO MAKE RESERVATIONS

School programs last 50 minutes and are presented on Tuesdays, Wednesdays and Thursdays. The programs "Earth, Sun and Moon," "All About Planets" and "Exploring the Universe" may be seen at 10:00 a.m., 1:00 p.m. and 2:00 p.m. The "Sky Scanning" and "Man in Space" programs are offered at 11 a.m. It is necessary that you call or write the Planetarium to obtain the exact schedule of performances. The address is:

The Strasenburgh Planetarium
663 East Avenue
Rochester, New York 14607
Telephone (716)244-6060

Other times and days are available by special arrangement.

In making the actual reservation to bring your class to the planetarium you will be asked:

1. your name, address and school system
2. approximate number (total) in your group
3. the time, date and title of the program you wish to see.

ALL GROUPS MUST HAVE RESERVATIONS IN ORDER TO ATTEND PLANETARIUM SCHOOL PROGRAMS.

Students who live inside Monroe County have had their admissions to school programs paid in the County and City budgets. Those outside of Monroe County will have to pay their own admissions. Please collect the money BEFORE arriving at the planetarium and be prepared to pay for the tickets by check (first choice) or with cash.

ADMISSION RATES (for those outside Monroe County only)

Children	$ .50
Students (grade 7 through college)	$ .75
Adults	$ 1.25

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HOW TO USE THE TEACHER'S GUIDE

> "Once an instructor decides he will teach his students something, several kinds of activities are necessary on his part if he is to succeed. He must first decide upon the goals he intends to reach at the end of his course or program. He must then select procedures, content, and methods that are relevant to the objectives; cause the student to interact with appropriate subject matter in accordance with principles of learning; and finally measure or evaluate the students performance according to the objectives or goals originally selected." [1]

With the above statement in mind this teacher's guide was prepared for use in conjunction with the Strasenburgh Planetarium School Programs. For each program there is a list of behavioral objectives, a student activity and an evaluation that measures the students' performance according to the behavioral objective. Complete instructions for the teacher are included with each activity.

First, from the description of the five planetarium school programs, the teacher chooses the program that is most appropriate to his students. Next the teacher reads the section in this guide about that program including behavioral objectives, information to the teachers, activities and their evaluations. The teacher should collect all the materials that will be necessary for the activity. The teacher then teaches the activity modifying it as needed for his own classroom situation. These activities should then be followed by the actual visit to the Strasenburgh Planetarium. Finally the student's performance is evaluated in terms of the previously stated behavioral objectives.

Since the material in this guide will be continually evaluated and, hopefully, improved, it would be helpful if you would write comments, suggestions, and criticisms as you teach the material to the students. A form for this purpose will be given to you when you visit the Planetarium. You may also, find some of the activities useful as follow-up to the planetarium visit.

[1] Mager, Robert F., Preparing Instructional Objectives, 1962: Fearon Publishers, Palo Alto, California.

ACTION VERBS USED

Construct	—	make or build.
Demonstrate	—	show by doing.
Describe	—	represent either in writing, verbally or by diagrams.
Distinguish	—	tell the difference between 2 or more things.
Graph	—	make a 2 or 3 dimensional representation of information.
Identify	—	indicate by pointing, selecting, touching.
Index	—	place objects or information in groups based on common characteristics or sequences.
Infer	—	state assumptions (plausible conclusions) based on observations or the results of investigations.
Inquire	—	ask a question; to seek information.
Investigate	—	seek answers to an inquiry through an activity or experiment.
Measure	—	determine dimensions, rate, capacity, amount, or direction either through estimating or using a given device or scale.
Name	—	designate a label.
Observe	—	examine by using one or more of the senses.
Predict	—	make an educated guess based on investigation or known data.
State	—	set forth a concise description.

PROGRAM CONSULTANTS

The outlines for the planetarium programs were prepared with the aid of the following consultants.

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EARTH, SUN AND MOON

a program for beginning science students

The presentation starts at Cape Kennedy as we watch a dramatic recreation of the blast off of a Saturn V rocket carrying the Apollo astronauts to the moon. The moon grows larger in the sky vanishing from sight just short of having filled the entire planetarium dome. We are then on the lunar surface watching the astronauts land their Lunar Module. Around us is the moon's surface and the base of a fantastically dark and star filled sky. In that sky, we see the planet we left behind rotating lazily as time passes. We leave the moon to watch both it and the earth in motion and to compare their relative sizes on our return to earth. Back on earth we look at the moon again, this time from the more familiar view from our back-yards. We review the rising and setting points of the sun and moon and investigate the two week long period of the moon's waning phases. At sunrise, we leave earth once again to move to an imaginary landing on our star's surface. After looking at the surface of the sun and its features from close at hand, we spot the earth - moon system almost 100,000,000 miles away as it slowly moves against a starry background.

BEHAVIORAL OBJECTIVES: EARTH, SUN AND MOON

The student should be able to:

1. index pictures and terms relating to the sun, moon and earth.

2. a. observe on a scale model the relative distances between the earth and the sun and the earth and moon and describe his observations.
   b. observe and describe the size differences of the sun, moon and earth both through direct observations and observation of a scale model.

3. a. observe that some objects give off light and others reflect light.
   b. identify the sun as a source of light and the moon as a reflector of light.

4. a. name the causes of day and night.
   b. demonstrate the change of day and night on a globe.

5. a. identify east and west when using a magnetic compass.
   b. identify and name the direction in which the sun rises and sets.

6. a. observe the apparent changes in the shape of the moon and construct a series of pictures to describe his observations.
   b. identify and name the apparent shapes of the moon.
   c. demonstrate the cause of the moon's phases.

OBJECTIVE 1. The student should be able to index pictures and terms relating to the sun, moon and earth.

ACTIVITY

Materials: individual pictures and terms on cards showing scenes or descriptive terms related to the sun, moon and earth

examples for sun: pictures of sun, sunspots, sunset, and descriptive terms such as star, solar, hot, light, round

examples for moon: pictures of moon, moon craters, moon phases, and terms such as lunar, craters, round

examples for earth: pictures of earth, people, animals, plants, water, and terms such as land, planet, air, round

Place the headings SUN; MOON; EARTH, on a chalkboard, bulletin board or experience chart. Have the children discuss each term or picture as they determine which heading to place it under. In cases where the term or picture may apply to more than one heading, include the item under all appropriate heading.

EVALUATION: Given sets of pictures and terms, the student should index them under the headings of sun, moon and earth using characteristic features as his criteria.

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OBJECTIVE 2: The student should be able to:
- a. observe on a scale model, the relative distances between the earth and sun and the earth and moon and decsribe his observations.
- b. observe and describe the size differences of the sun, moon and earth both through direct observations and observations of scale models.

ACTIVITY 1

Materials: posterboard or tagboard, common pin, tape measure or yard stick

Have the students draw a circle 12" in diameter on a piece of tagboard and cut it out. Place the circle on a wall in the hall or outdoors on the side of the building. Label it: SUN. Another circle 1/8" in diameter should be cut out to represent the earth. It should be placed 110 ' from the sun. The head of a common pin can be used to represent the moon and should be placed 3 3/4" from the earth. A discussion of why these sizes and distances were used should take place throughout the activity.

ACTIVITY 2

Materials:colored construction paper, strips of white paper or adding machine tape, yard stick

Have the students prepare a bulletin board showing a scale model of the earth and moon. Using the scale, one inch = 1000 miles. determine the diameter necessary to represent the earth (diameter about 8000 mi.) as being 8". Draw an 8" circle on a piece of paper, cut it out and label it EARTH. Using the same scale, determine the representative diameter for the moon as being 2" (diameter is about 2,000 miles) and cut outand label it MOON. Connect the two with a narrow strip of paper cut to the same scale using 240,000 miles as the distance to the moon. Label the scale used on the bulletin board. Discuss the use of scale models to represent large objects and distances.

ACTIVITY 3 (Optional)

Materials; basketball, marble, beebe or piece of KIX cereal, yardstick

Place a basket ball in the hall or playground to represent the sun. Place a marble 110 feet away from the "sun" to represent the earth. Finally, place a beebe or piece of KIX cereal about 3" from the "earth" to represent the moon. Discuss the relative distances and sizes of the earth, moon and sun.

EVALUATION: Given a representation of another planet and told that it was made using the same scale as was used in activity 1, the student should state whether the planet would be larger or smaller than the earth, moon and sun.
Given two objects of different size, the student should demonstrate how they may be made to appear to be the same size.

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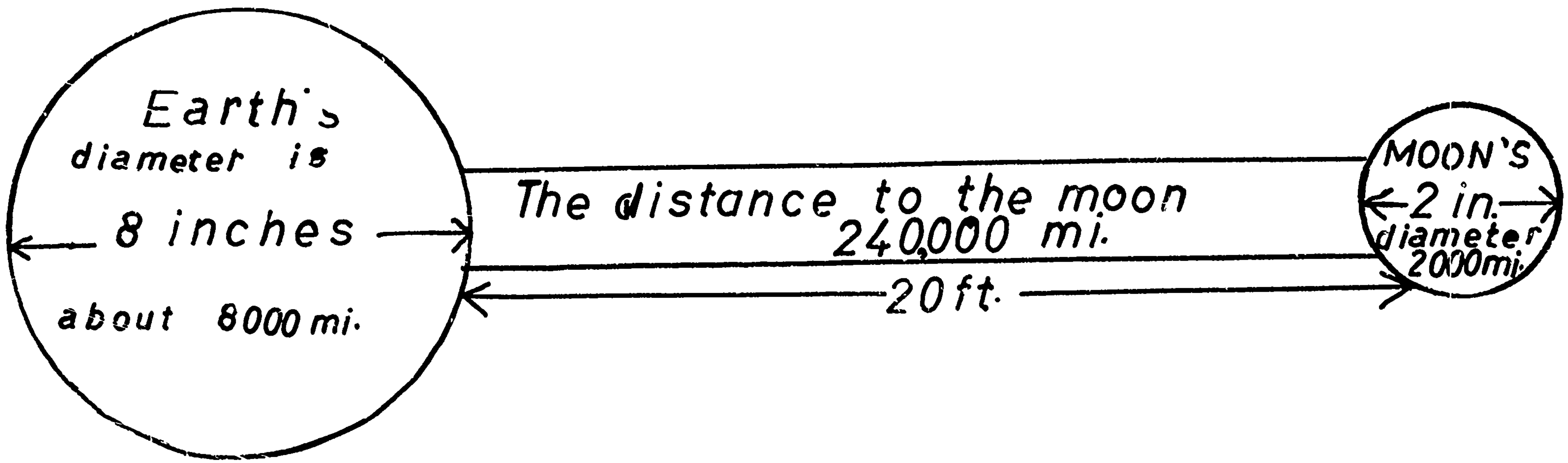
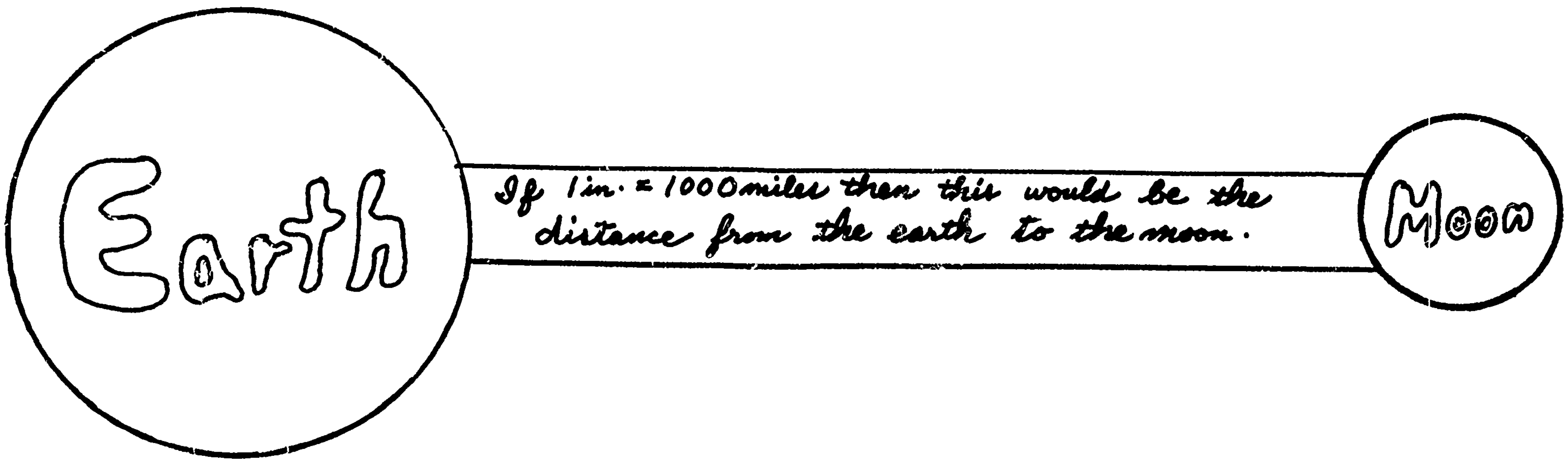

Earth's
diameter is
8 inches
about 8000 mi.
The distance to the moon
240,000 mi.
20 ft.
MOON'S
2 in.
diameter
2000 mi.


Earth
If 1 in. = 1000 miles then this would be the
distance from the earth to the moon.
Moon

OBJECTIVE 3: The student should be able to:

a. observe that some objects give off light and others reflect light.

b. identify the sun as the source of light and the moon as a reflector of light.

ACTIVITY

Materials: light source (filmstrip projector or flashlight), reflector (sheet of smooth light-colored paper or metal, mirror), cardboard box.

Enclose a light source in a cardboard box which has a 3" opening on one side. Face the opening away from the students and place the reflector inside the box near the opening. Darken the room and turn on the light source. The students should indicate that light is coming from the reflecting surface. Once the reflector is established as the origin, turn off the light source. Have the students indicate why the reflected light is gone. Turn the light source back on to show that the reflector is dependent on the light source for its light and does not actually give off its own light.

Remove the cardboard box to show the light source. Discuss the sun, moon and earth and establish in this discussion that the sun is like the light source and that the moon and earth are like the reflector.

EVALUATION: Given an object which gives off light and an object which reflects light, identify and name the source and the reflector and relate these terms to the earth, sun and moon.

OBJECTIVE 4: The student should be able to :
a. name the causes of day and night
b. demonstrate the change of day and night on a globe.

ACTIVITY

Materials: large (about 16 to 24 inches) rotating globe, a stationary light source (overhead projector, opaque projector, or filmstrip projector), tape, paper.

From a piece of paper cut a figure about three-quarters of an inch high to represent a man. Tape the figure so that it stands perpendicular to the globe on your state. Darken the room and place the globe five to seven feet from the light source (sun). Point out that half the globe (earth) is lighted and the other half is dark. Have the children name these areas in terms of night and day. Turn the globe so that the figure is entirely in the dark side by rotating the globe slowly in a counter-clockwise (west to east) direction. Have the students discuss when the figure is in the night and in the day and the relationship of a round earth to day and night.

EVALUATION: Given the materials used in the activity, the student should demonstrate the changing from daylight to darkness for a given location on the globe.

OBJECTIVE 5. The student should be able to:

a. identify east and west when using a magnetic compass.

b. identify and name the direction in which the sun rises and sets.

ACTIVITY 1

Materials: yellow construction paper, 3" circles for tracing, yellow crepe paper.

Have each student cut out a 3" circle from yellow construction paper to represent the sun and write his name in the center of his "sun". Each morning for three sunny mornings, have the student place his "sun" on the wall that is on the same side of the room as the sun is. (East wall - the student should look outdoors and see which wall this is). At the end of the school day for three days, the student should move his "sun" to the wall where the sun is (West wall). It may help to string a strip of yellow crepe paper in an arc across the room from east to west to represent the daily path of their "suns".

ACTIVITY 2

Materials: 8½ x 11" white paper, magnetic compass (1 per student)

Working as individuals or in pairs, have the students fasten a piece of paper to the floor and place a compass near the center of the paper. (Avoid metal objects.) The students should turn their compasses slowly until the north mark on the needle is pointing to the N on the dial of the compass. They then mark N on the paper next to the N on the dial and without moving the compass, mark E, S, and W on the paper. Ask the students what N,E,S, and W represent and have them complete writing each of the words on their paper. Have the students point to where the sun rises, identify the direction as east and label their paper. Repeat with where the sun sets.

EVALUATION: Given a compass, the student can identify the east side of the playground and state that the sun rises in that direction.

OBJECTIVE 6. The student should be able to:

a. observe the apparent changes in the shape of the moon and construct a series of pictures to describe his observations.

b. identify and name the apparent shapes of the moon.

c. demonstrate the cause of the moon's phases.

ACTIVITY 1

Materials: chalk or crayons, paper (you may want to use white paper for pictures drawn during the day and dark blue or black for those drawn after dark)

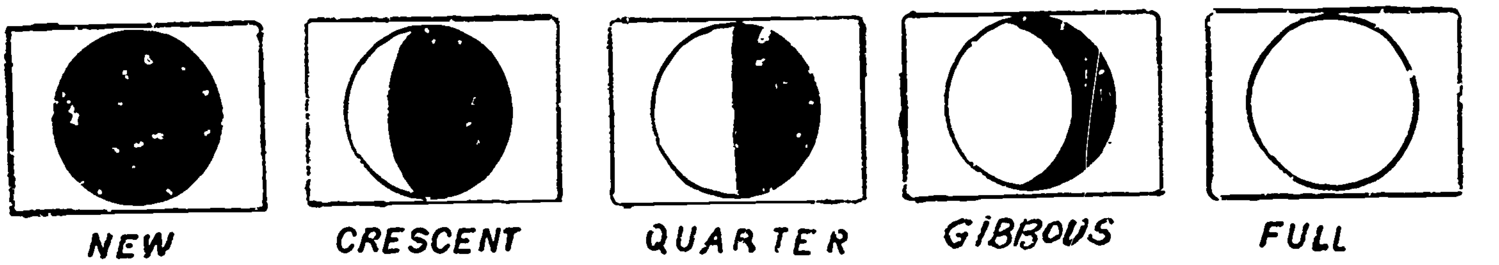
Tell the class that each student is going to make a picture of what the moon looks like each day it is visible for a period of several days. These pictures are going to be saved in a folder as a record of their observations and each picture must contain three things: a. a picture of the moon as it looks to you; b. a landmark against which it was seen; and c. the date and time the observation was made. Remind the pupils of their assignment each clear day. (Note: The moon is visible during the day time for nearly two weeks each month. You may wish to begin this activity three or four days after a new moon phase so that the first few drawings can be made during class time.) Compare the pictures daily. Use some of these questions for the class discussion:

a. What can you tell the class about your picture?
b. Is this picture the same as the others you have drawn? How is it different?
c. Has the position of the moon changed? How?
d. Has the shape of the moon changed? How?
e. Look at the time on your drawing. Did anyone see the moon earlier than this time?
f. Point to the landmark under the moon and ask, "Where do you think the moon will be tomorrow night?"

ACTIVITY 2

Materials: five tagboard cards, 6" x 6", five tagboard cards, 2" x 6", marking pen

Draw a circle five inches in diameter on each 6" x 6" square to represent the moon. Shade each circle as shown.



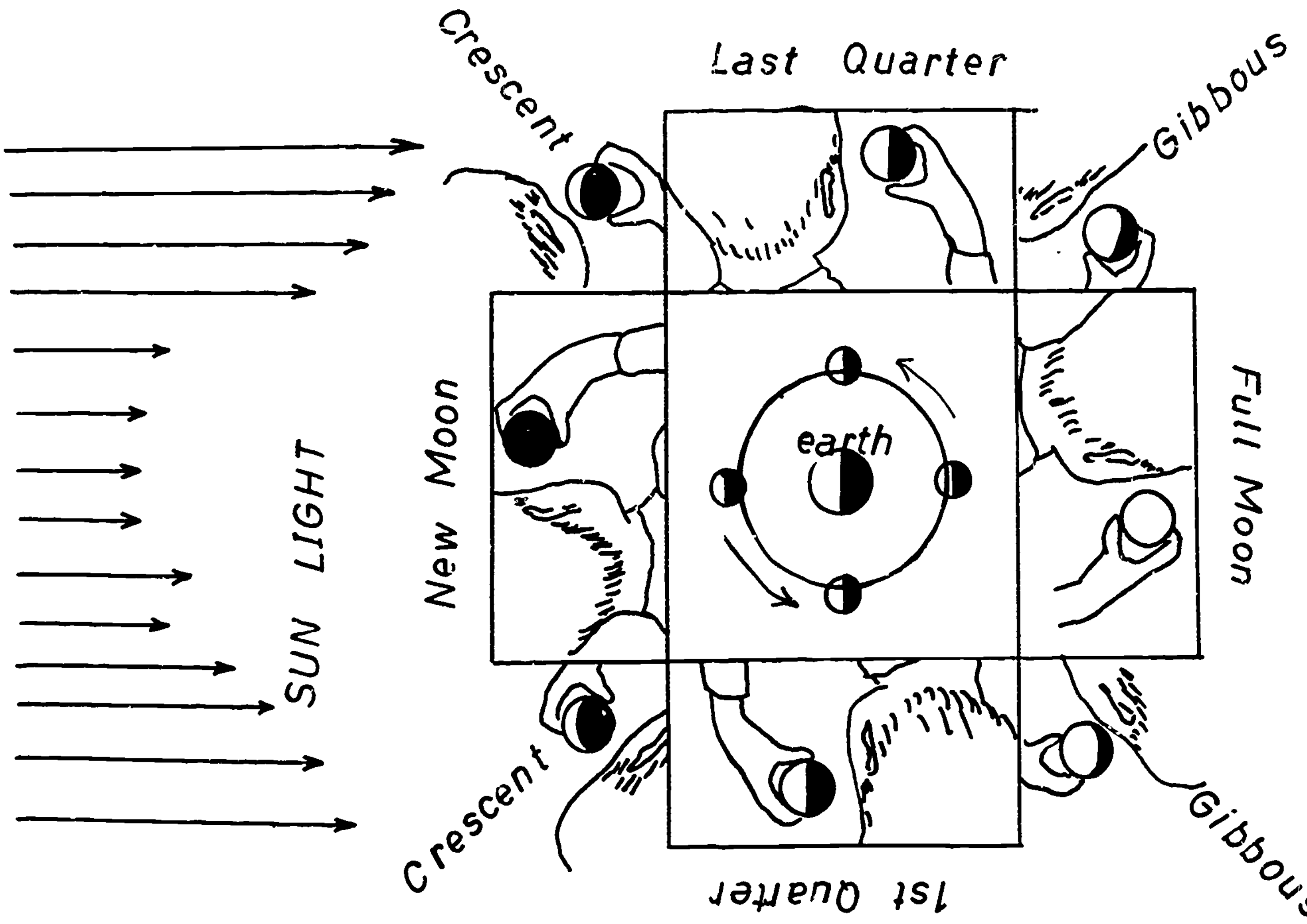
On the 2" x 6" pieces of tagboard, write the names: new, crescent, quarter, gibbous and full. Using the cards as flash cards, introduce the names of the moon phases and match them with the right drawing.

After practicing with the flash cards for several minutes, set the name cards, face down on a desk in the middle of the classroom. Set the cards with the moon shapes along a chalk tray, about two feet apart. Form two teams from the class. Upon a signal the first person on each team rushes to the middle desk and takes a card, reads it and quickly stands in front of the card on the chalk tray with the correct shape. He then must face the class and show the name on the card to his team members. The team responds with a, "yes" if the member is in front of the correct shape or a "no" if the member is not correct. In the latter case the pupil must move to another spot in front of a moon shape and again show his name card. He continues changing spots until his team members respond with a "yes". When the team says "yes" then the member returns the card to the central desk and moves to the end of his team line. The next person in line then takes his turn. The team whose members complete their turns first is the winner of the game.

ACTIVITY 3

Materials: ball, slide or overhead projector

In a darkened room, have a pupil stand 10 to 15 feet from the projector in the center of the light beam. Have a pupil hold a ball at arms length in from of him and turn around in one spot so that the light from the projector is always on the ball. Have him describe how the lighted part of the ball appears to change shape.



ACTIVITY 4

Materials: black and yellow crayons, copies of pupil diagram (p. 18)

Give each student a copy of the pupil diagram. Have the students discuss how much of the moon is lighted by the sun and how much of the moon is in a shadow. On the diagram, color the lettered circles to show the light part and the shadowed part. In each case, the half towards the sun should be colored yellow and the opposite half black. (see Teacher's Diagram) In the numbered circles, the pupils should draw and color the shape the moon would appear to have when in that position in the sky. Do one shape at a time with the class. Now have the students label their diagram as follows: 1. New Moon 2. Crescent 3. Quarter 4. Gibbous 5 Full Moon 6. Gibbous 7. Quarter 8. Crescent.

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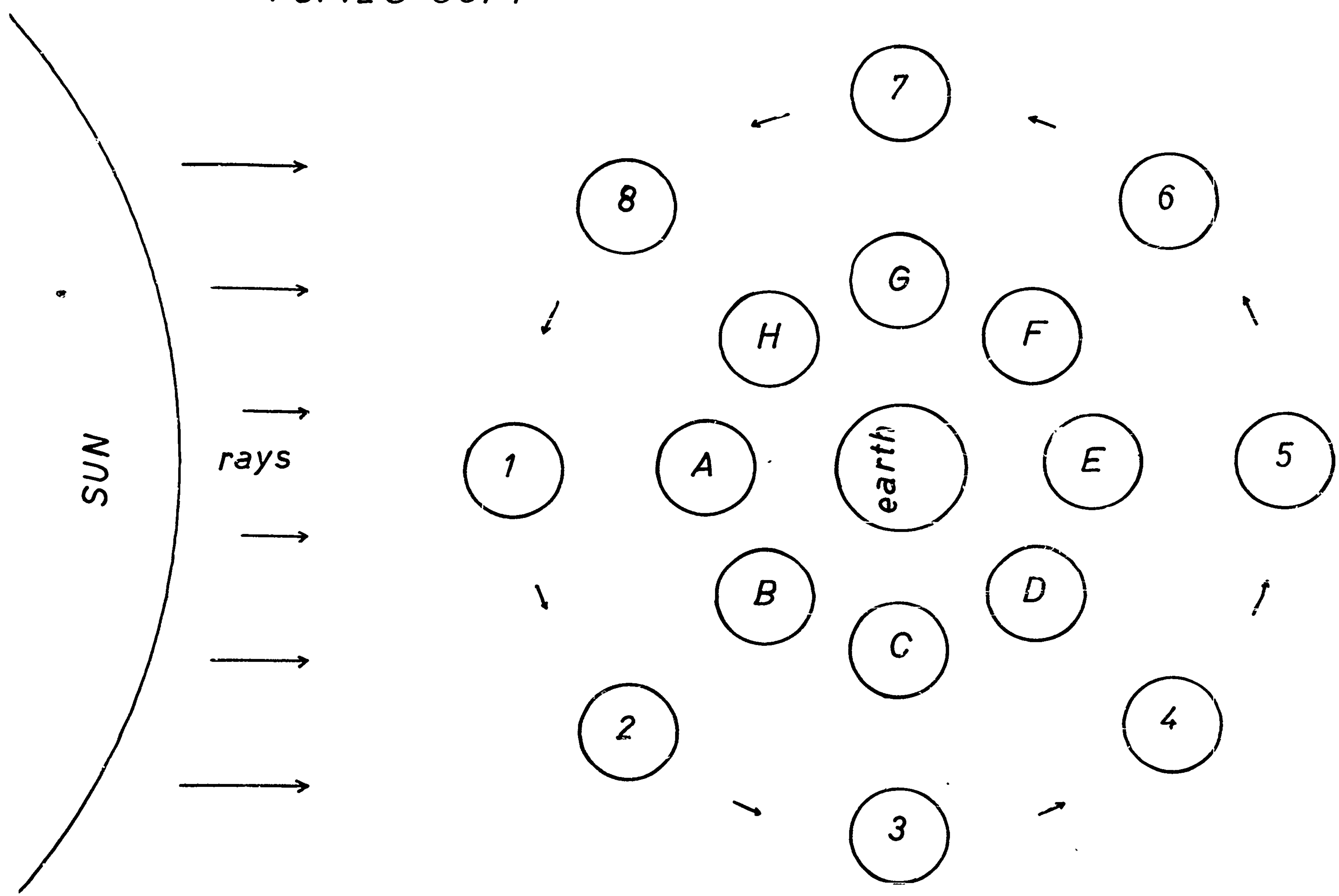
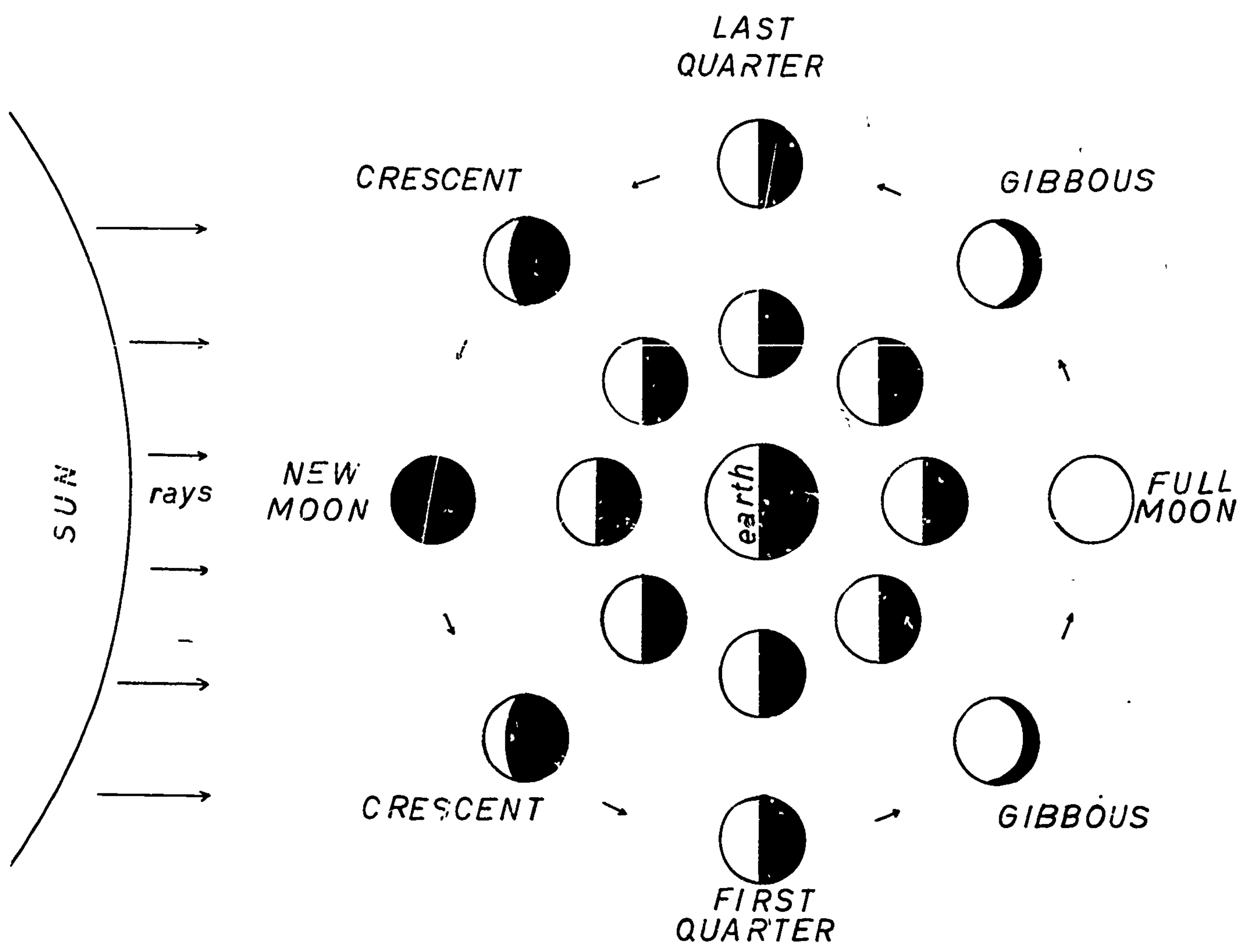




Teacher's Diagram

ACTIVITY 5

Materials: construction paper (1 sheet, 3' x 4', white or buff; 1 strip, 6" x 4', white or buff; 1 circle, 2' diameter, green; 1 circle, 6" diameter, white or yellow), paper fastener

To construct a bulletin board to show the moon's phases, draw a line across the middle of the 3' x 4' piece of paper the long way of the paper. Draw a line perpendicular to your first line, 1½' from one end. (diagram a) Place a paper fastener through the center of the 2' diameter circle and through one end of the 6" x 4' strip. Then attach the circle and strip to the 3' x 4' paper where the two lines intersect. Fasten the 1" circle at the other end of the strip (diagram b) and place an arrow next to it on the strip pointing in a counter-clockwise direction. The large circle represents the earth, the small one the moon and the strip the "visible" gravity force between the two.

The size (100 x's that of the earth) and distance (400 x's that to the moon) of the sun, its existence can be indicated by arrows representing its rays. To draw and label the moon as it appears when it revolves around the earth, place the moon directly between the earth and sun. In this position, the dark side of the moon faces the earth during the new moon phase. A dotted circle can be drawn to indicate that the moon is not visible after the moon has been moved counter-clockwise to its next phase. For about two weeks after new moon, the moon appears to be getting larger (waxing) until it becomes full after which it appears to be getting smaller (waning). Mark the chart as shown in diagram c.

EVALUATION: Given diagrams of eight phases of the moon, index and label the diagrams and describe the location of the sun.

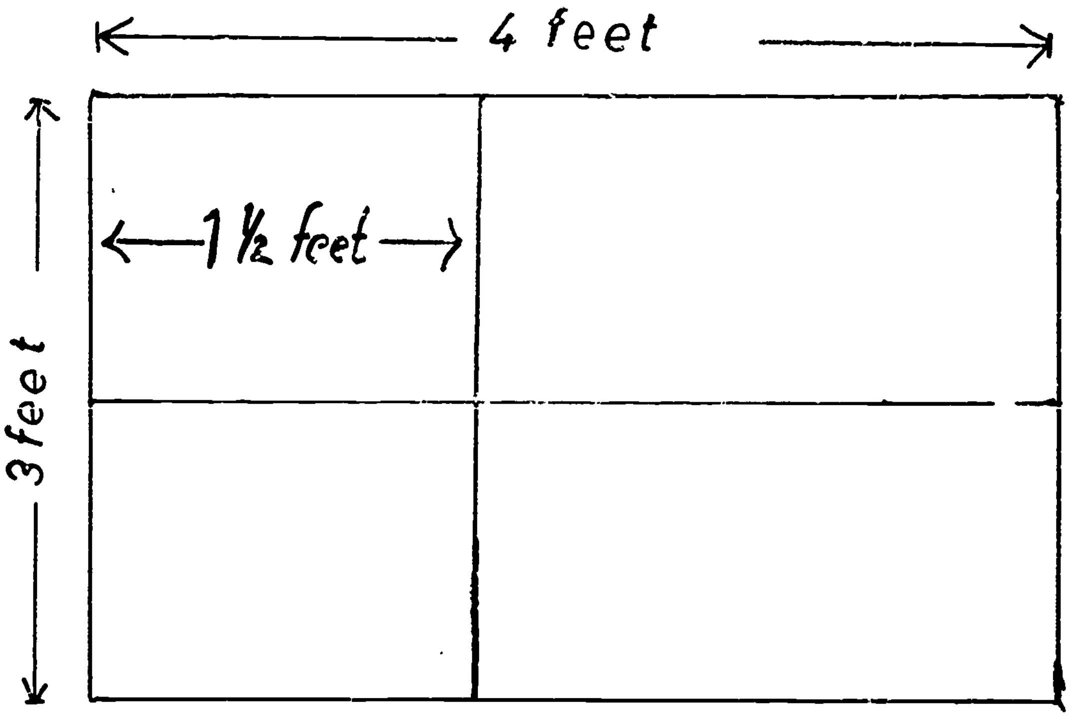


Diagram a.

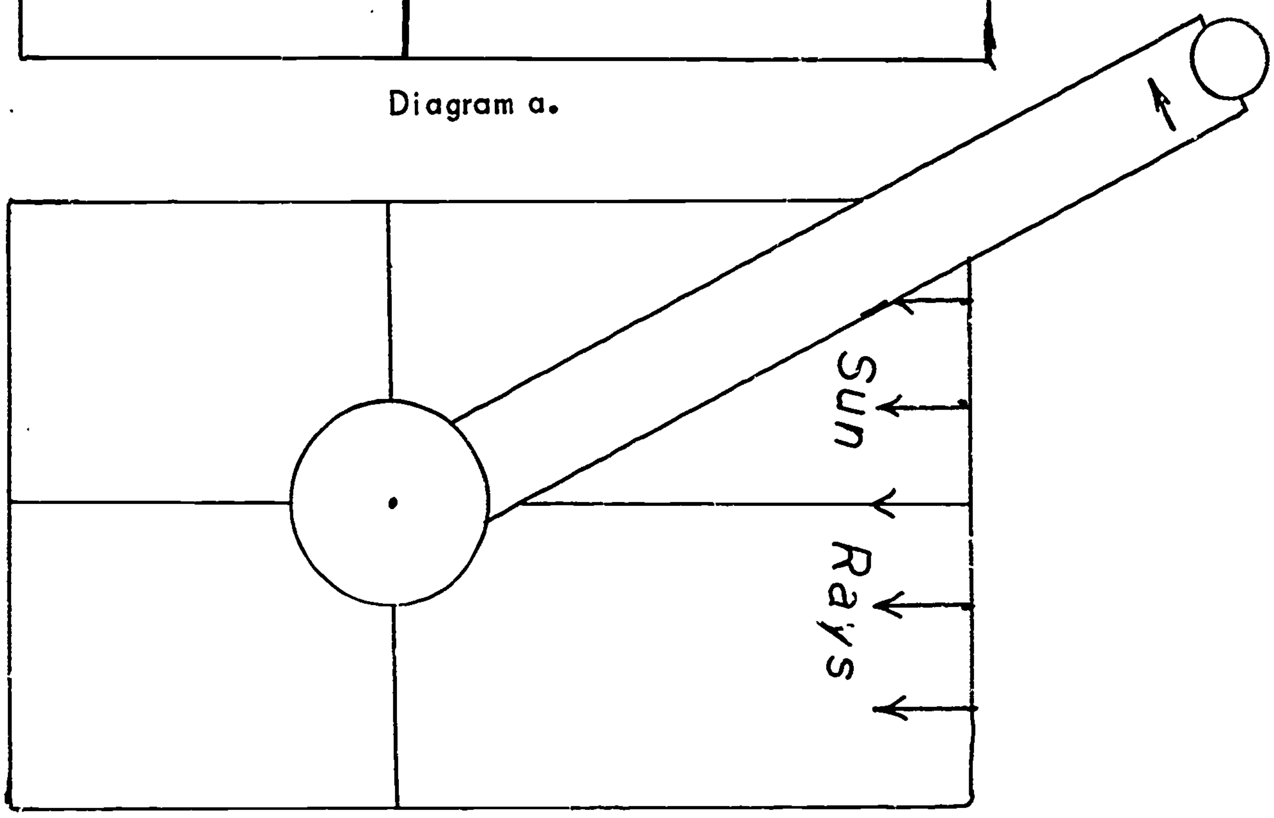


Diagram b.

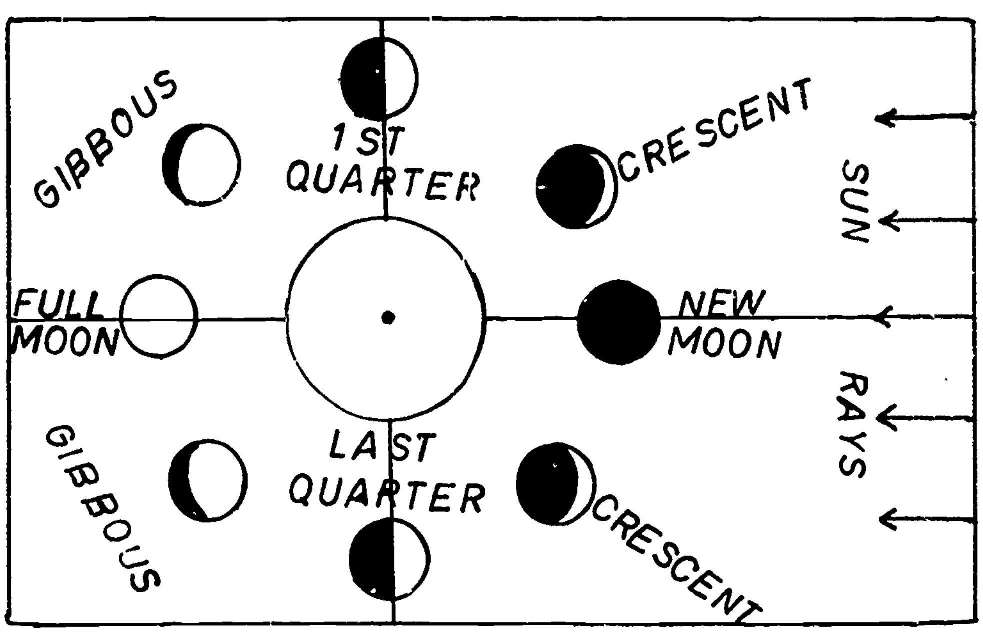


Diagram c.

ALL ABOUT PLANETS

a program for intermediate science students

As the sun sets and the sky fills with stars, Mars rises in the east. We discuss why objects seem to rise and set, then when Mars is high overhead (on the meridian) the earth stops its rotation and we watch about five months of time pass, indicated by Mar's going through retrograde looping motion. This peculiar movement leads to a discussion of theories of the construction of the solar system and the motions of the planets. The two theories discussed and visualized are the geocentric and heliocentric theories. Some of the observations of Galileo are brought into play to support the heliocentric theory as the true one. We are then led to an individual investigation of each planet, with emphasis on new discoveries about them.

In our imagination we visit Mercury, look at its sunburned surface, and note that its rotation period is 59 days so it will not always keep this side of Mercury toward the sun. We look at Venus from outer space and watch a spaceprobe fly-by. From under the dense atmosphere of our sister planet, we experience the "greenhouse effect" and note how it influences this planet's surface temperature. Earth is seen as few have seen it--from outer space--with the passage of a day portrayed in just moments. The Planetarium dome is next filled with projections pertaining to Mars, such as, Schaperilli's maps, H.G. Well's ideas of what Martians look like and Mariner IV's photos. After zooming through the planetoid belt we watch Jupiter grow in size until it nearly fills the sky. Saturn is represented in 12 positions around the base of the planetarium horizon. These positions show the varying views we have of this beautiful planet's rings as we both circle the sun. On our way to visit Pluto we move through the space where Uranus and Neptune swing around our star. Before we arrive at the Planet of Darkness, time is spent reviewing what we have learned about the planets so far leading to the conclusion that planets are of two types, like earth (Terrestrial) or like Jupiter (Jovian). On Pluto at last, we watch the eastern horizon as an intensely bright nighttime star rises, our own familiar sun, as seen from a distance of nearly 4 billion miles. Speculations of other planets circling other suns end this program with a question.

ERIC

OBJECTIVES: ALL ABOUT PLANETS

The student should be able to:

1. index the planets according to their distance from the sun.

2. inquire about the theories of planetary motion through using reference materials.

3. construct a data table in which he states the physical characteristics of each planet.

4. a. index the planets using given physical characteristics as their criteria.

   b. name and describe the two most common groups used for indexing the planets.

5. infer from data provided that the earth revolves around the sun.

6. name and describe the two forces which when balanced keep an object in orbit.

7. a. identify the differences between an ellipse and a circle.

   b. identify and name the shape which best described the earth's orbit.

8. describe the relationship between the planets' orbits.

9. describe at least two instruments used to obtain information about the planets.

ERIC

OBJECTIVE 1 The student should be able to index the planets according to their distance from the sun.

ACTIVITY

Materials: alphbetical list of the planets with their relative distance from the sun, paper, pencil, tagboard cards each with the name of a planet and its distance from the sun on it (optional)

Give each student an alphabetized list of the planets and their relative distance from the sun. Have them make their own list which arranges the planets in order from closest to farthest from the sun. The students may work individually and check their list with one they put on the board.

Using the tagboard cards, distribute them to students and have them arrange themselves in correct order from the spot designated as the sun based on the information in their card. It may be advantageous to have several sets of cards and to divide the class into teams using the activity as a relay race. (optional)

The list to be distributed should show the following information.

Planet	Distance from sun (in millions of miles)	Distance from sun (in Astronomical Units)
Earth	93	1
Jupiter	485	5.20
Mars	142	1.52
Mercury	36	.39
Neptune	2,810	30.17
Pluto	3,670	39.46
Saturn	890	9.58
Uranus	1,780	19.19
Venus	67	.72

Answer Key: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto

EVALUATION: Given a random list of five planets and their distance from the sun, the student should index them from closest to farthest from the sun.

OBJECTIVE 2. The student should be able to inquire about the theories of planetary motion through using reference materials.

ACTIVITY

Materials: reference books (see bibliography), construction paper

Direct the students to inquire into the theories of planetary motion as presented by Copernicus and Ptolemy. They should record the information they find interesting and represent the two theories in diagrams.

You may find the following resume helpful.

As man observed the heavenly bodies and their motion he concluded that the earth was motionless and all heavenly bodies moved around the earth.

In the third century B.C. a Greek astromomer, Aristarchus of Samos, stated that the sun, because of its great size, did not travel around the earth, but the earth traveled around the sun. If this were true then the stars should shift as the earth moves around the sun in one year. Aristarchus correctly stated that because the stars were so far away the instruments of his day could not measure the star shift. Aristarchus was 2,000 years ahead of his time and, because of the authority of Aristotle, Aristarchus' ideas were disregarded.

In the second century A.D., the Alexandrian astronomer, Ptolemy, set forth arguments that seemed to prove that the earth could not move in space. These arguments enabled man to ridicule and resist any other theories for over a thousand years.

In the sixteenth century Nicholas Copernicus, a Polish monk, resurrected the ideas of Aristarchus and furnished reasons why the sun was the center of the planetary system. Many scientists began to look favorably upon a sun-centered system and finally in 1838 scientists were able to measure the apparent annual shift of a star, thus proving that the earth revolved around the sun.

EVALUATION: Given the name of one of the theories of planetary motion, the student should describe the theory.

OBJECTIVE 3. The student should be able to construct a data table in which he states the physical characteristics of each planet.

ACTIVITY 1

Ask the class which characteristics of the planets they think would be either helpful or interesting to know. List all of these on the chalk board.

Students will undoubedly suggest some characteristics, such as color, which will not be particularly helpful in doing the next objective (four) or which will be difficult to find out about. These suggestions should not be discouraged at this time as carrying out the activity for objective four will indicate which characteristics are useful and information that is difficult to find will rapidly become apparent. In addition, they may be able to describe but not name some characteristics. If this happens, tell them the name.

Be sure that at least the following characteristics have been included in the list: mass, volume, diameter. Accelerated or upper grade level students should have density listed. These characteristics are most useful in classifying the planets into two main groups, the outcome of behavioral objective four. Do not, however, limit your list to these characteristics as many others will be useful for other parts of this program, e.g. distance from the sun, period of revolution, escape velocitv, temperature, surface gravity.

ACTIVITY 2

Materials: most of the books on the bibliography listed below or adequate substitutes for them, blank paper, ruler, pencil.

Alter, D., Cleminshaw, C.H., Phillips, J.G. Pictorial Astronomy, 2nd ed. New York: Thomas Y. Crowell, 1963.

Chamberlain, J.M., Nicholson, T.D. Planets, Stars and Space, Mankato, Minnesota: Creative Educational Society, 1962.

Gallant, R.A. Exploring the Planets, Garden City: Doubleday, 1967.

Gamow, G. Matter, Earth and Sky, Englewood Cliffs, N.J.: Prentice-Hall, 1958.

Hesse, W.H. Astronomy: A Brief Introduction, Reading, Mass.: Addison-Wesley, 1967.

Huffer, C.M., Trinklein, F.E., Bunge, M. An Introduction to Astronomy, New York; Holt, Rinehart, and Winston, 1967.

Moore, P. The Picture History of Astronomy, 3rd ed., New York: Grosset and Dunlap, 1967.

Streuve, O., Lunds, B., Pillans, H. Elementary Astonomy, New York: Oxford University, 1959.

Tricker, R.A.R. The Paths of the Planets, New York: American Elsevier, 1967.

Wolfe, W.C., Battan, L.J. Fleming, R.H., Hawkins, G.S., Skornik, H. Earth and Space Science, Boston: D.C. Heath, 1966.

Zim, H.S., Baker, R.H. Stars, New York: Golden Press, 1964.

Provide the students with some or all of the books on the bibliography list. Additional books should be used if their copyright dates indicate recent data.

Before students actually begin looking up information, guide them in developing a table on which to record the data. As soon as this is done, invite them to use the books and complete their tables.

When the tables are completed, they should be compared and any major differences reconciled. Allow students to argue for their version of the data; usually data from a book with the most recent copyright date is the most accurate. A table, labeled "Characteristics of the Solar System," is included for your reference; it is based largely on 1968 data. Do not expect your students to develop this complete a listing.

At this point, you may have students make a large class chart for the bulletin board.

This would be helpful for later class discussions.

If your students have not had experience with some of the characteristics on their data tables; e.g. mass, volume, diameter, it will be essential to have them measure such characteristics. Use familiar classroom objects that have a symmetrical shape and then relate these measurements to those of the planets.

Variations. It is not necessary that every student look up each characteristic for all nine planets. There are many possible methods of grouping students for this activity: teams can be based on the planets (each team member obtains all the characteristics for one planet), on the characteristics (each team member finds data for one characteristic for all nine planets), or on some combination of these two basic methods.

Precautions: Different references will often give different values for the same characteristic of a particular planet. This is usually due to different original measurements and to improved accuracy with time due to improved instruments. Choose the most recent data.

ACTIVITY 3

(optional)

Some classes may wish to make scale models and/or graphs of the solar system. Such models, if done carefully, are useful aids to discussion. This can be done with one or more of the characteristics on the table.

Any scale can be used but some are certainly more convenient than others; check convenience by initially calculating the sizes of the smallest and largest parts of the model. An example of model dimensions for diameter and distance using a scale of the sun's diameter = 1.0 feet is given below; this clearly illustrates the idea of convenience and inconvenience.

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Distance (feet)	51	93	130	196	672	1,270	2,480	3,890	5,120
Diameter (inches)	1/16	1/8	1/8	1/16	1-1/4	1-1/8	1/2	1/2	1/8?

EVALUATION: 1. Given a set of objects and characteristics of these objects, contruct a convenient data table on which to record the information.

2. Given previously used reference books, look up and record at least two out of three characteristics for at least two planets.

CHARACTERISTICS OF THE SOLAR SYSTEM

	SUN	PLUTO	NEPTUNE	URANUS	SATURN	JUPITER	MARS	MOON	EARTH	VENUS	MERCURY
DISTANCE FROM SUN IN ASTRONOMICAL UNITS	---	39.46	30.17	19.19	9.58	5.20	1.52		1.00	.72	.39
DISTANCE FROM SUN IN MILLIONS OF MILES	---	3670	2793	1782	886	483	142		93	67	36
VOLUME IN EARTH VOLUMES	1,300,000	?	44	60	729	1260	.15	.022	1.0	.88	.065
MASS IN TONS	1.97×10^{29}	?			5.57×10^{23}	1.85×10^{24}	6.3×10^{20}	7.2×10^{19}	5.85×10^{21}	4.8×10^{21}	3.2×10^{20}
MASS IN EARTH MASSES	338,000	.09?	17.2	14.5	95.2	317	.108	.0123	1.0	.82	.056
DENSITY IN gm/cm^3	1.4	?	2.2	1.7	.68	1.33	4.0	3.5	5.52	5.1	5.2
TEMPERATURE °F	10,400	UNKNOWN	-330	-300	-243	-216	-50 to 50	-240 to 214	50	800	-400 to 700
PERIOD OF REVOLUTION		248.4 years	164.8 years	84.0 years	29.5 years	11.9 years	689 days	27-1/3 days	365-1/4 days	225 days	88 days
PERIOD OF ROTATION	24.65 days	6.5 days	12 hr. 48 min.	10 hr. 45 min.	10 hr. 14 min.	9 hr. 50 min.	24 hr. 37 min.	27-1/3 days	24 hrs.	UNKNOWN	59 ± 3 days
EQUATORIAL DIAMETER IN MILES	864,000	3600	27,700	29,300	75,100	88,600	4210	2160	7927	7570	3100
EQUATORIAL DIAMETER IN EARTH DIAMETERS	109				9.36	11.1	.530	.28	1.002	.960	.403
ATMOSPHERE		UNKNOWN	PROBABLY EXTENSIVE	PRO-BABLY EXTENSIVE	EXTEN-SIVE	EXTEN-SIVE	THIN	NONE	EXTENSIVE	EXTENSIVE	NONE
NATURAL SATELLITES		UNKNOWN	2	5	10	12	2	-	1	0	0
GRAVITATIONAL ACCELERATION AT SURFACE IN CM/SEC^2	27,900	UNKNOWN			1120	2590	373	163	981	824	345
EQUATORIAL SURFACE GRAVITY EARTH GRAVITY = 1		UNKNOWN	1.38	1.08	1.06	2.54	.39	.1653	1.00	.89	.36
ESCAPE VELOCITY (MI/SEC)		UNKNOWN	15.4	13.9	22.3	37.1	3.2	.212	7.0	6.5	2.6
ECCENTRICITY OF ORBIT	---	.249	.009	.047	.056	.048	.093		.017	.007	.206
MAGNITUDE WHEN BRIGHTEST		+14.5	+7.6	+5.7	-0.4	-2.5	-2.8	-12.6	--	-4.3	-1.2

OBJECTIVE 4. The student should be able to:

a. index the planets using given physical characteristics as their criteria.

b. name and describe the two most common groups used for indexing the planets.

ACTIVITY 1

Materials: "Characteristics of the Solar System" chart prepared by students in Objective 3.

For this activity the students may be grouped in teams ranging in size from two to four. Small teams are preferable to the whole class as it is more likely to assure that all students are participating in the group decisions.

Select one characteristic from the chart and have each group look at it. Tell them to look carefully at the data in the column, divide it into groups that are similar, and record their arrangements. Students should not be forced into dividing the planets into two groups at this time. If some think they see only one or three or four groups, allow them to group them that way. They will have to justify their reasoning during class discussion and will find this difficult to do relative to the far better arguments for the two groups

Repeat the above procedure for at least two other characteristics.

During the post-activity discussion, have examples of the possible grouping for each characteristic written on the chalk board. Be sure that the student authors of these groupings justify their reasoning, that all class arguments are solved, and that necessary changes are are made before you agree that the groupings are correct.

As soon as the groupings for each of the characteristics used are justified and correct, ask the students to look for similarities in the groupings. They should see that for each of th the characteristics used, Mercury, Venus, Earth, and Mars compose one group, Jupiter, Saturn, Uranus, and Neptune a second and that there is insufficient information about Pluto to place it in either group.

Precautions: Terrestrial and Jovian planets are also sometimes referred to as minor and major, inner and outer, smaller and larger, rocky cored and gas giants. Inferior and superior, however, are not synonomous terms since inferior means the planets between the earth and the sun while superior means the planets beyond earth.

ACTIVITY 2

If your students are capable of graphing data, the simplest way of dividing the planets into two groups is with a bar graph. Such graphs can be constructed for each characteristic used.

Even if your students cannot graph, you might find it advantageous to do the graphing for them. Such graphs could be posted on the bulletin board if large or transferred on to ditto and distributed.

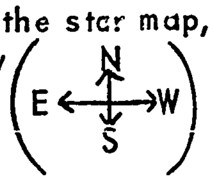
EVALUATION:

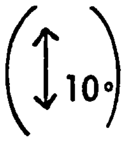
1. Given the class developed chart, the student should place the planets in two groups and justify the grouping with at least one correct reason.
2. Given a list of the planets, the student should index them into two groups, Terrestrial and Jovian.

OBJECTIVE 5. The student should be able to infer from the data provided that the earth revolves around the sun.

ACTIVITY 1

Materials: continuous star map of the zodiac constellations (reproduce accompanying pages and assemble by taping a to b , etc.), colored pencils, tape

Precaution: Before students can plot the data on the star map, they must be able to determine the cardinal points given the direction arrow 

and to measure distance in degrees using the degree arrow 

as the scale in the same manner you would use the miles scale on a road map. (The distance from one point on the arrow to the opposite point represents 10°.) It would be helpful if you plotted at least the first positions with them; with some groups, you may wish to do all or almost all of the plotting with them. Finally, if students are not familiar with constellations and star maps, it will be necessary to discuss these with them before beginning the activity.

Both the sun and moon data are to be plotted on the same map. To avoid confusion, have students use different colors for the sun and moon lines.

Activity: Ask the students to predict what they would see if they observed the moon at the same time every day for several weeks. List their ideas on the chalkboard. If they suggest only phase changes, guide them, by questioning, into a discussion of position changes (this is something they may never have noticed). Ask them how they might check their predictions and suggest that some of them might collect observational data for the entire class (see additional activities for greater detail).

At this point, present them with the data table below and their star maps. Ask them to plot the data for one month on the map and demonstrate how it is done by first taking the data provided for Jan. 18, locating Pleiades on the star chart and placing a dot 6° (a little over half of the 10° arrow) southeast of the star group Pleiades. The dot will represent the moon. Locate Pollax and place a dot 4° south east of it to represent the moon, and so on down through the moon table.

The data shows the position of the moon at the same hour on a number of different evenings. When they have completed plotting, direct them to join the points with a line.

Moon Data Table

January 18	moon 6° southeast of the Pleiades
January 22	moon 4° southeast of Pollux
January 24	moon 3° northwest of the star in Leo directly north of Regulus
January 29	moon 8° east of Spica
February 1	moon 3° north of Antares
February 3	moon 1° south of top of teapot of Sagittarius
February 4-8	moon too close to sun in sky to plot
February 9	moon 12° south of center of circlet in western Pisces
February 12	moon 13° south of easternmost star of Aries
February 14	moon 5° south of the Pleiades
February 16	moon 5° southeast of star that joins Taurus with Auriga
February 18	moon 3° south of Pollux

Repeat the above procedure for the sun. (Remember that the sun can be plotted against the stars but the stars cannot be seen, except during an eclipse, because of the sun's brightness.)

Sun Data Table

October 12, 1892	sun 3° north of Spica
October 22, 1892	sun 7° east of Spica
December 3, 1892	sun 5° north of Antares
December 31, 1892	sun 3° north of top of teapot of Sagittarius
March 10, 1893	sun 8° south of center of circlet in western Pisces
April 23, 1893	sun 10° south of center of Aries
May 21, 1893	sun 4° south of the Pleiades
June 13, 1893	sun on line connecting Capella and Betelgeuse, six tenths of the way from Capella to Betelgeuse
July 14, 1893	sun three tenths of the way from Pollux to Procyon
August 22, 1893	sun just about in front of Regulus
October 12, 1893	sun 3° north of Spica
December 3, 1893	sun 5° north of Antares
April 23, 1894	sun 10° south of center of Aries
October 12, 1951	sun 3° north of Spica

Students should now have moon and sun paths that pass through the twelve zodiac constellations: 1.Aries, 2. Taurus, 3. Gemini, 4. Cancer, 5. Leo, 6. Virgo, 7. Libra, 8. Scorpius, 9. Sagittarius, 10. Capricornus, 11. Aquarius, 12. Pisces. Have them tape their star maps into a cylinder with the constellations on the inside; the paths will now be continous.

Ask the students where an earth observer must be relative to the constellations on the star map (answer: at a point in the center of the cylinder). Ask what causes the sun's and moon's path to appear as plotted (several answers are possible: either the sun and moon are going around the earth or the earth is going around them or some combination of these answers). It may be necessary here to use a commercially available celestial sphere to illustrate the paper model more clearly. List the answers on the chalkboard and discuss which ones are most likely to be true; you will find that with only the evidence given, any of the answers can be true.

The discussion can be ended here and the more enthusiastic students can be encouraged to find other evidence on which to base their decision. If students are not sophisticated or eager enough for this approach, complete the discussion by sending them to reference books to find the best answer.

ACTIVITY 2
(optional)

Additional Activity. The moon data above can be obtained by students in the following manner, provided that your students are able to recognize the major zodiac constellations in the sky and on a star map. It is best to begin the observations three or four days following new moon. Instruct students to observe the moon at the same time each night and to plot its position as carefully as they can on their star maps. The data and time should also be recorded. If this is done for about two weeks and again after the next new moon, students will see for themselves the pattern of the moon's motion.

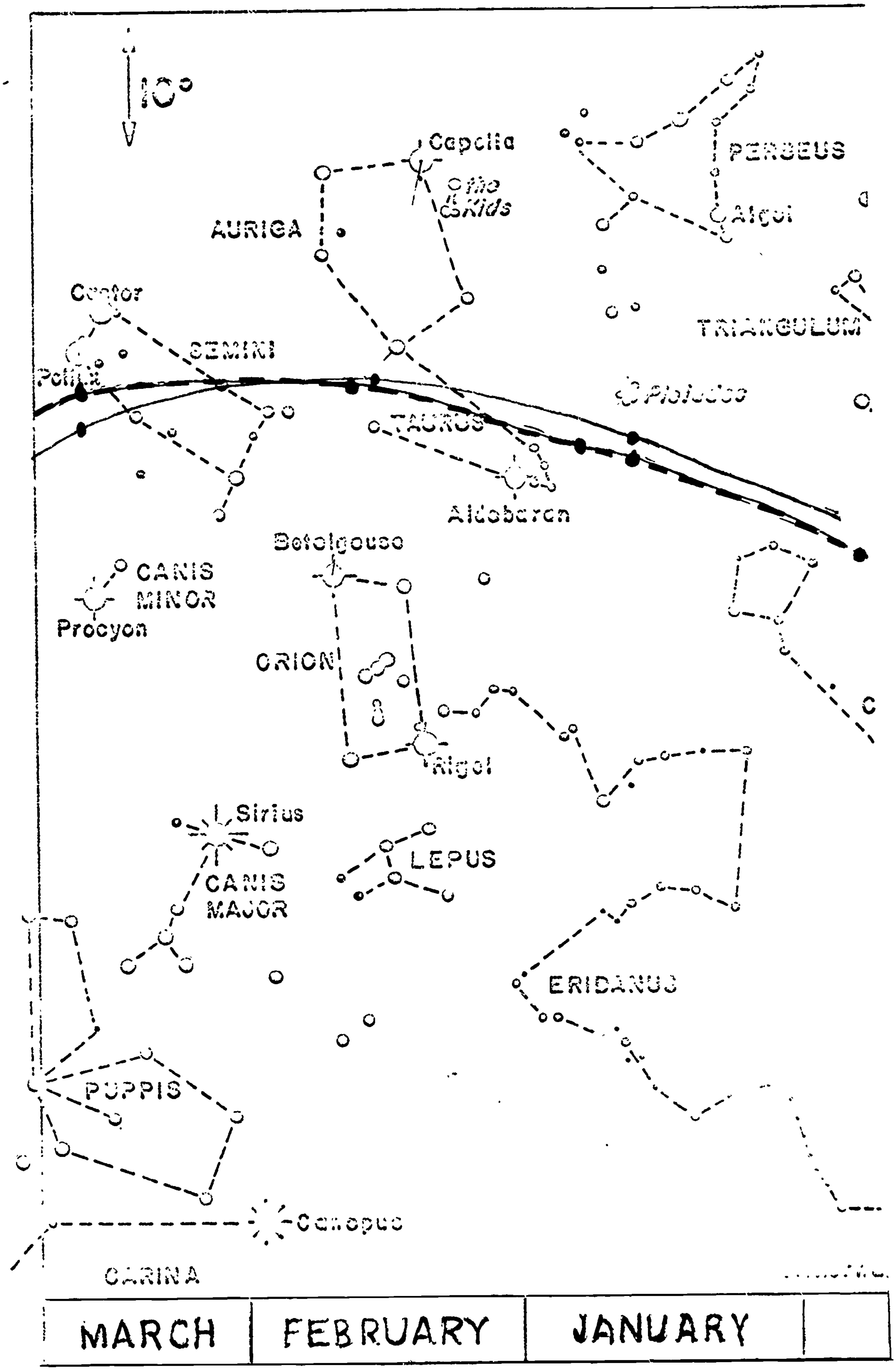
Actual plotting of the sun's motion against the stars is difficult since when the sun is up, the stars cannot be seen and when the stars are visible, the sun is hidden below the horizon. The job can be done crudely by noticing what stars and constellations are in the west after sunset and in the east before sunrise; the actual position of the sun is between these two positions.

EVALUATION: Given his star map with the sun and moon data plotted on it, the student should describe one evidence which suggests that the earth revolves around the sun or one evidence which suggests that the moon revolves around the earth.

A.

WINTER

Teacher's copy



B.

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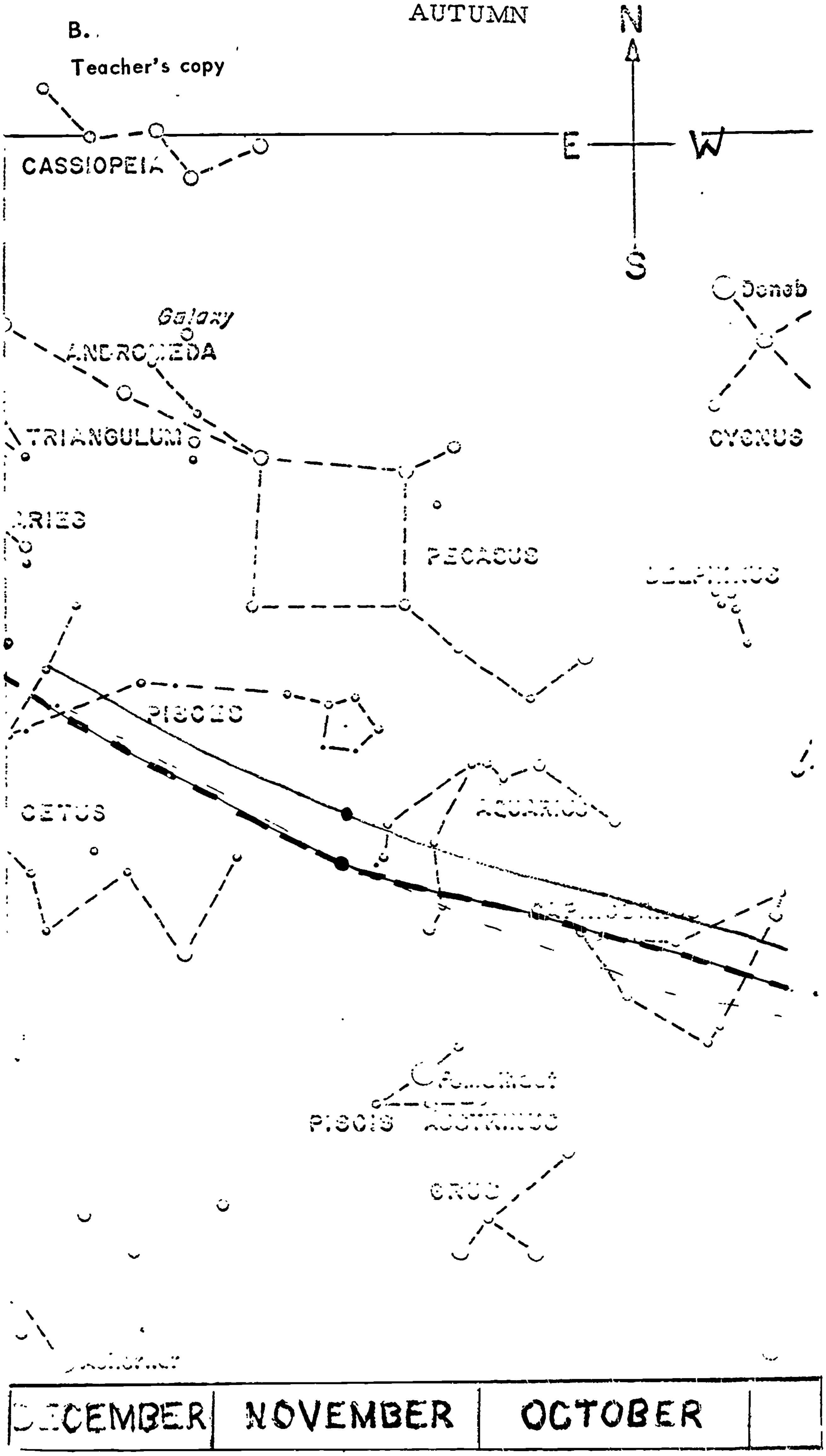
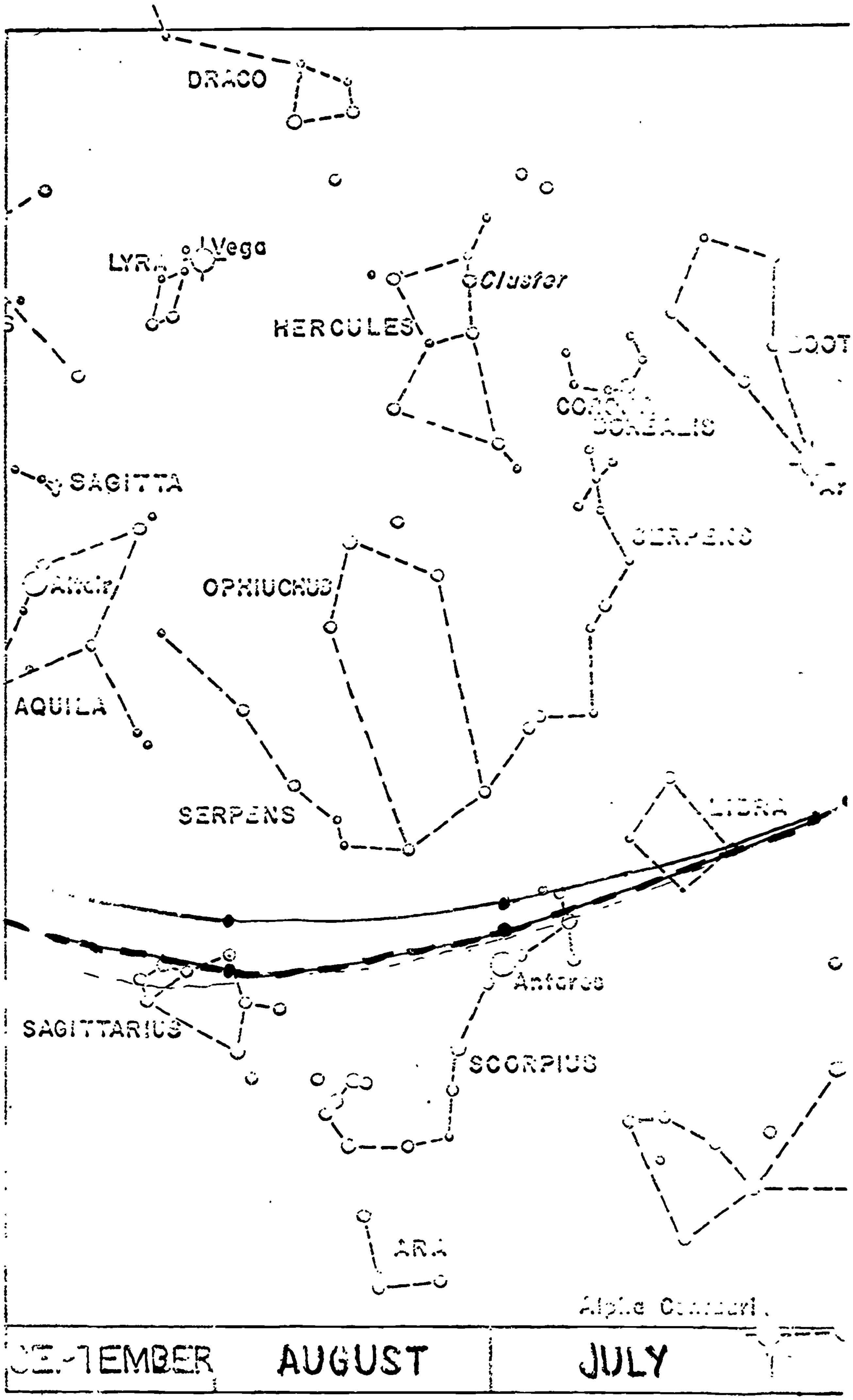
AUTUMN



C. SUMMER

Teacher's copy



D.

SPRING

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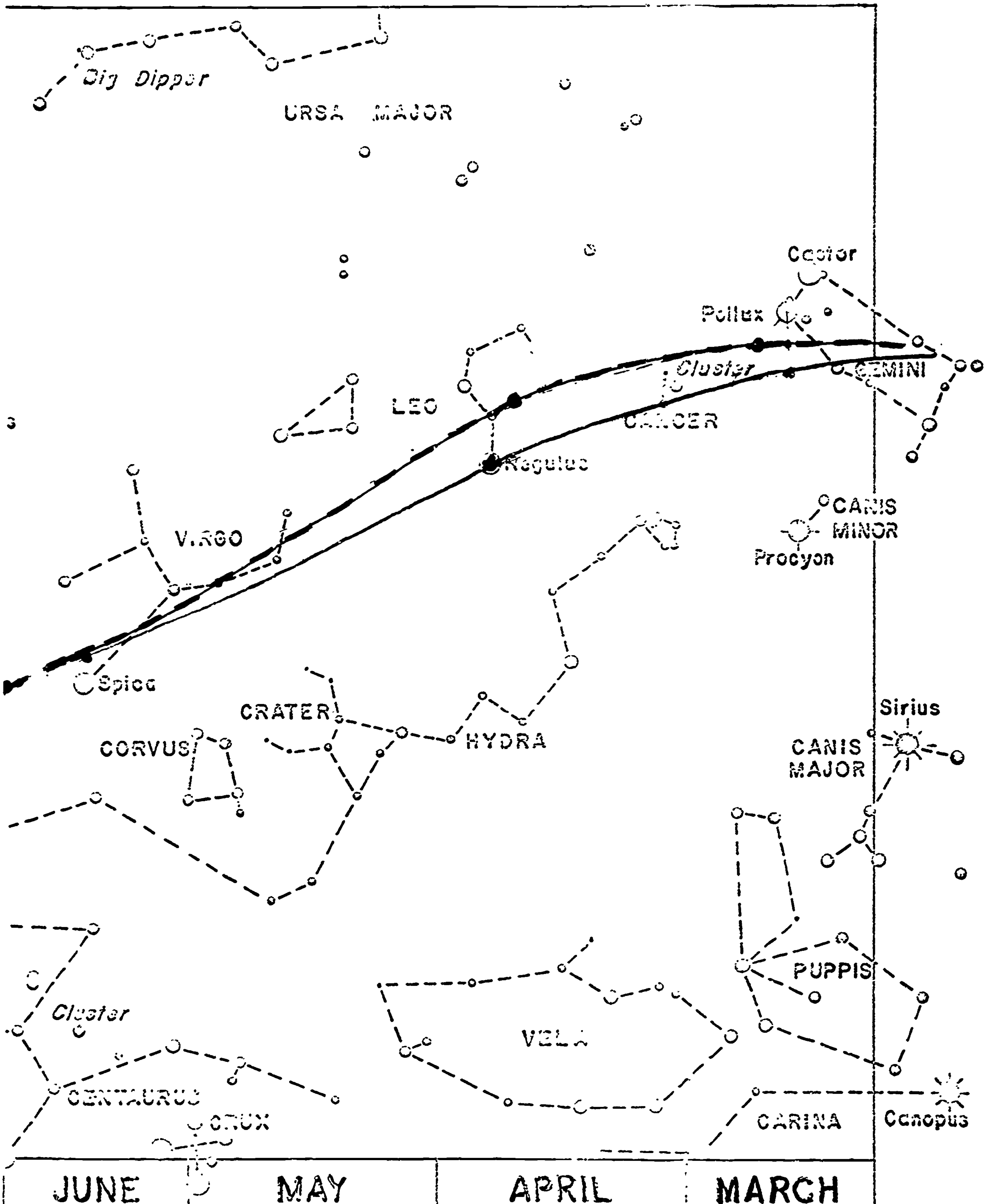
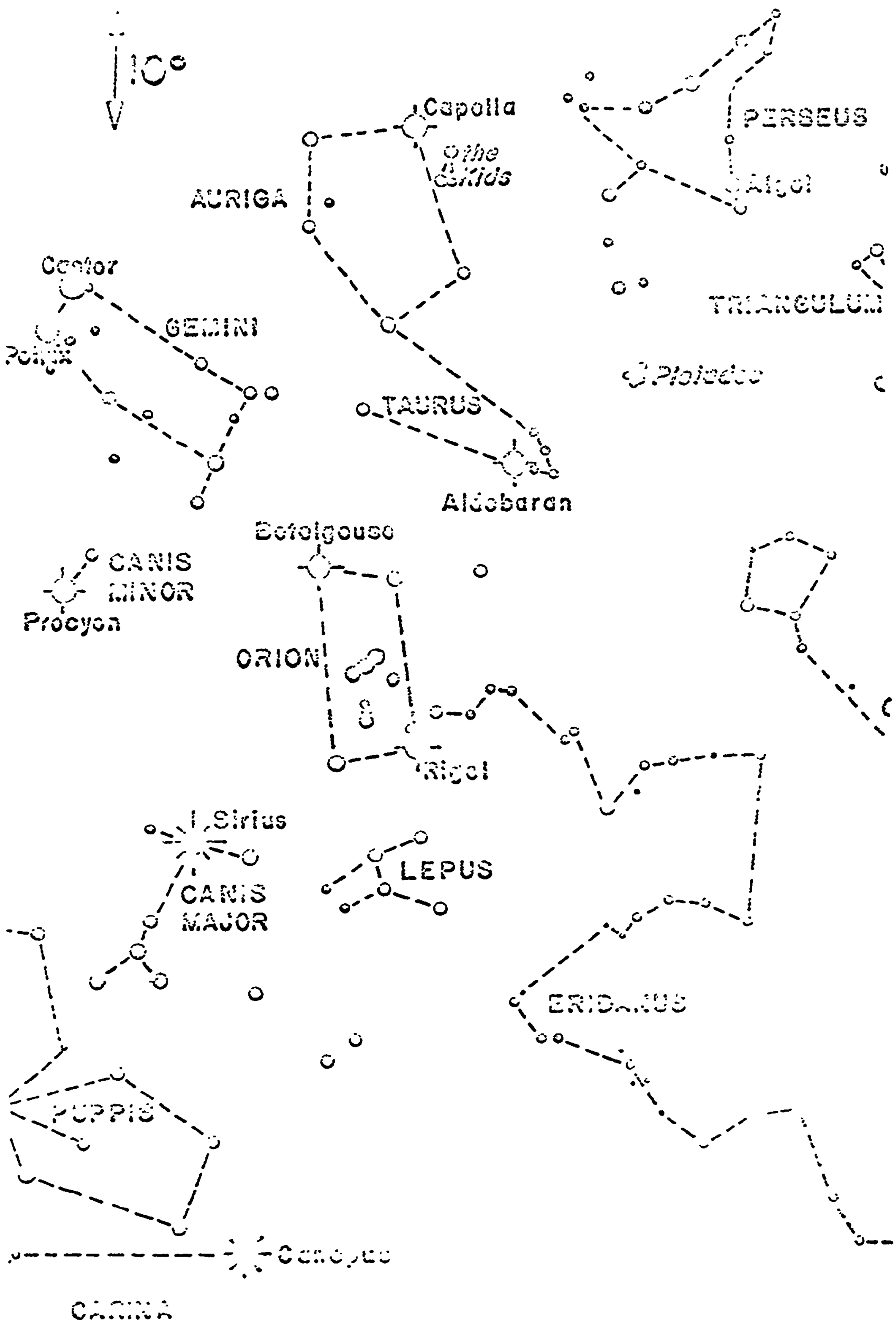


WINTER

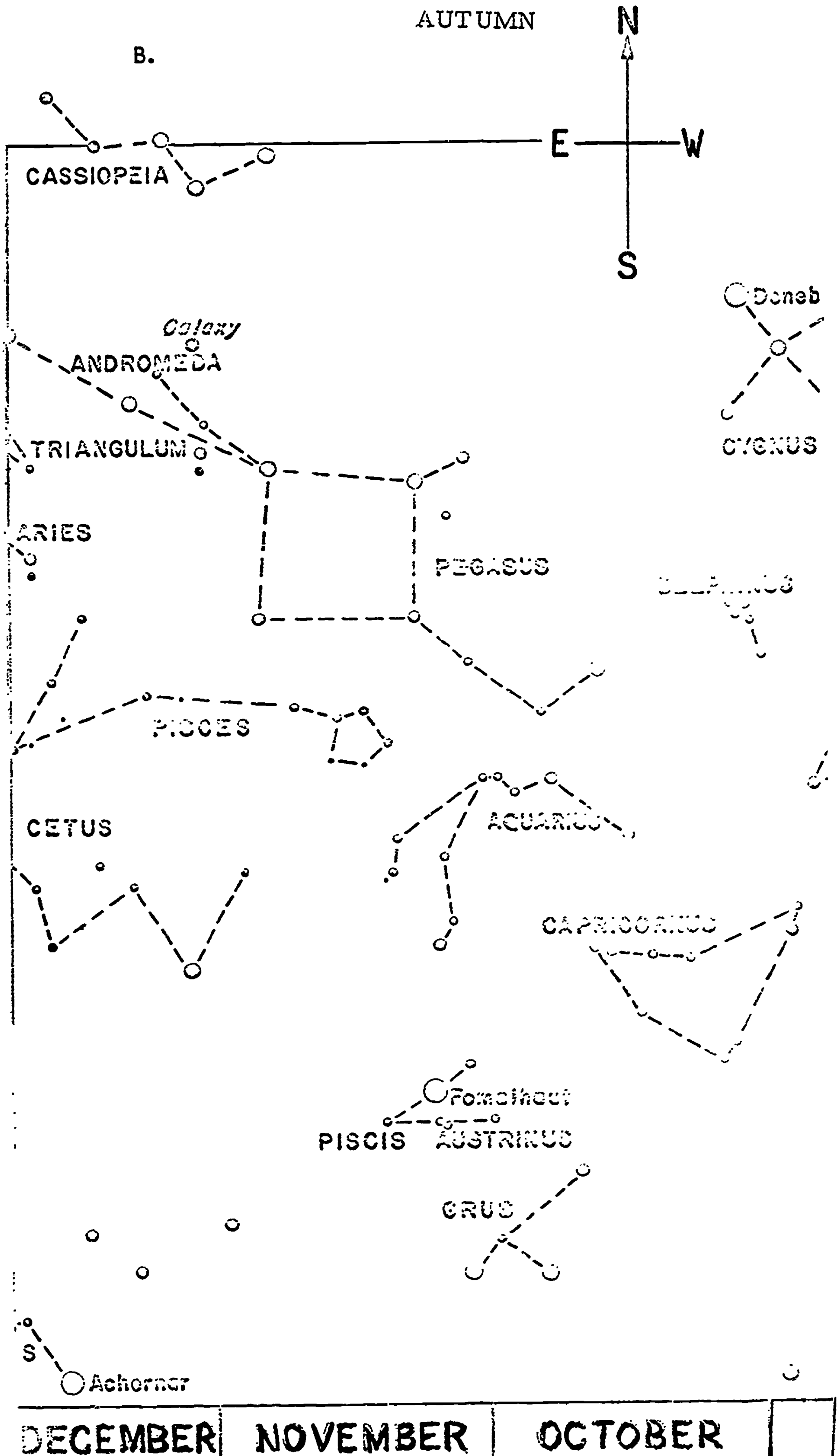
A.



MARCH	FEBRUARY	JANUARY	

B.

AUTUMN


N
E
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TRIANGULUM
ARIES
PEGASUS
Deneb
CYGNUS
PISCES
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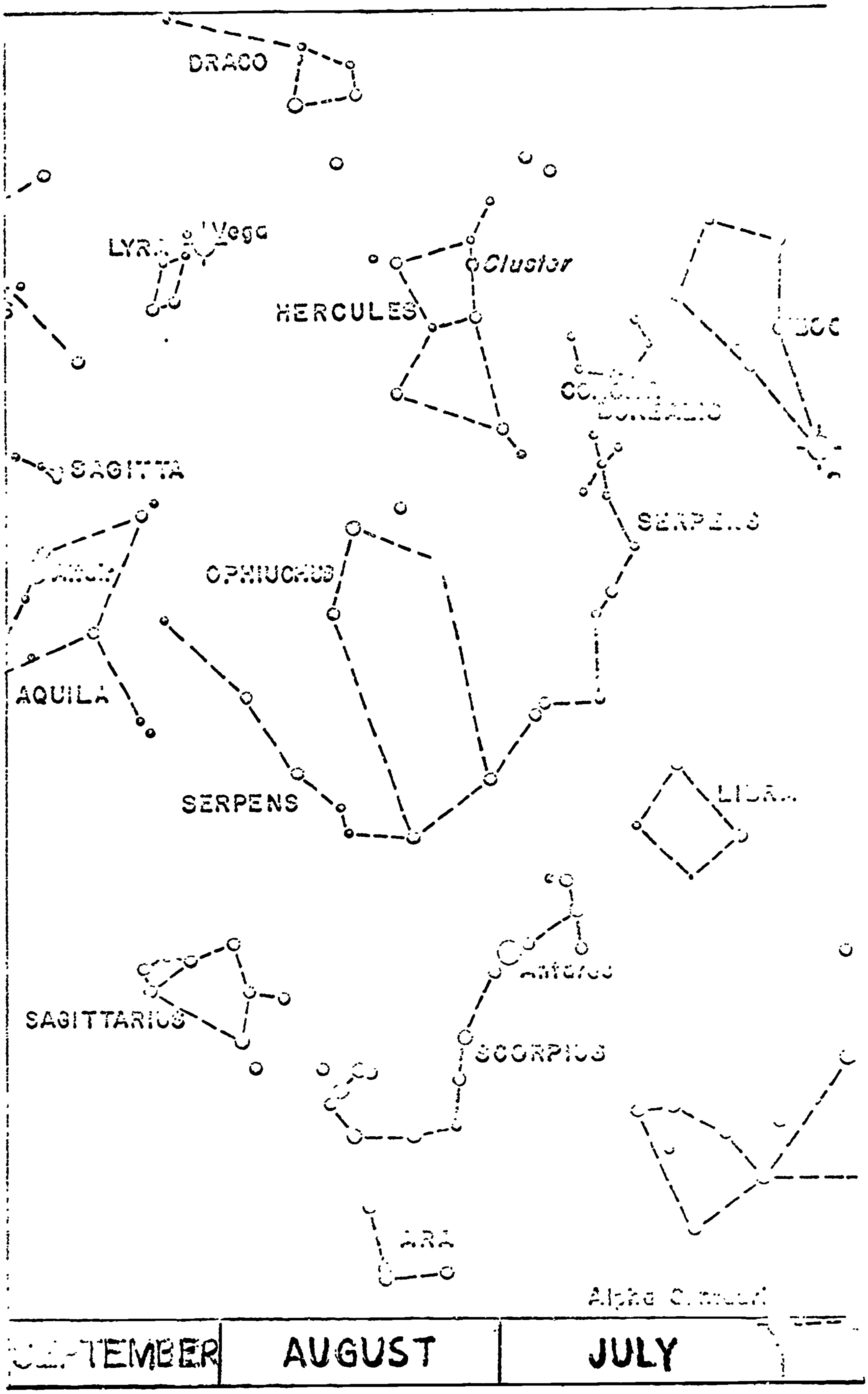
CAPRICORNUS
Fomalhaut
PISCIS AUSTRINUS
GRUS
Achernar
DECEMBER
NOVEMBER
OCTOBER

SUMMER

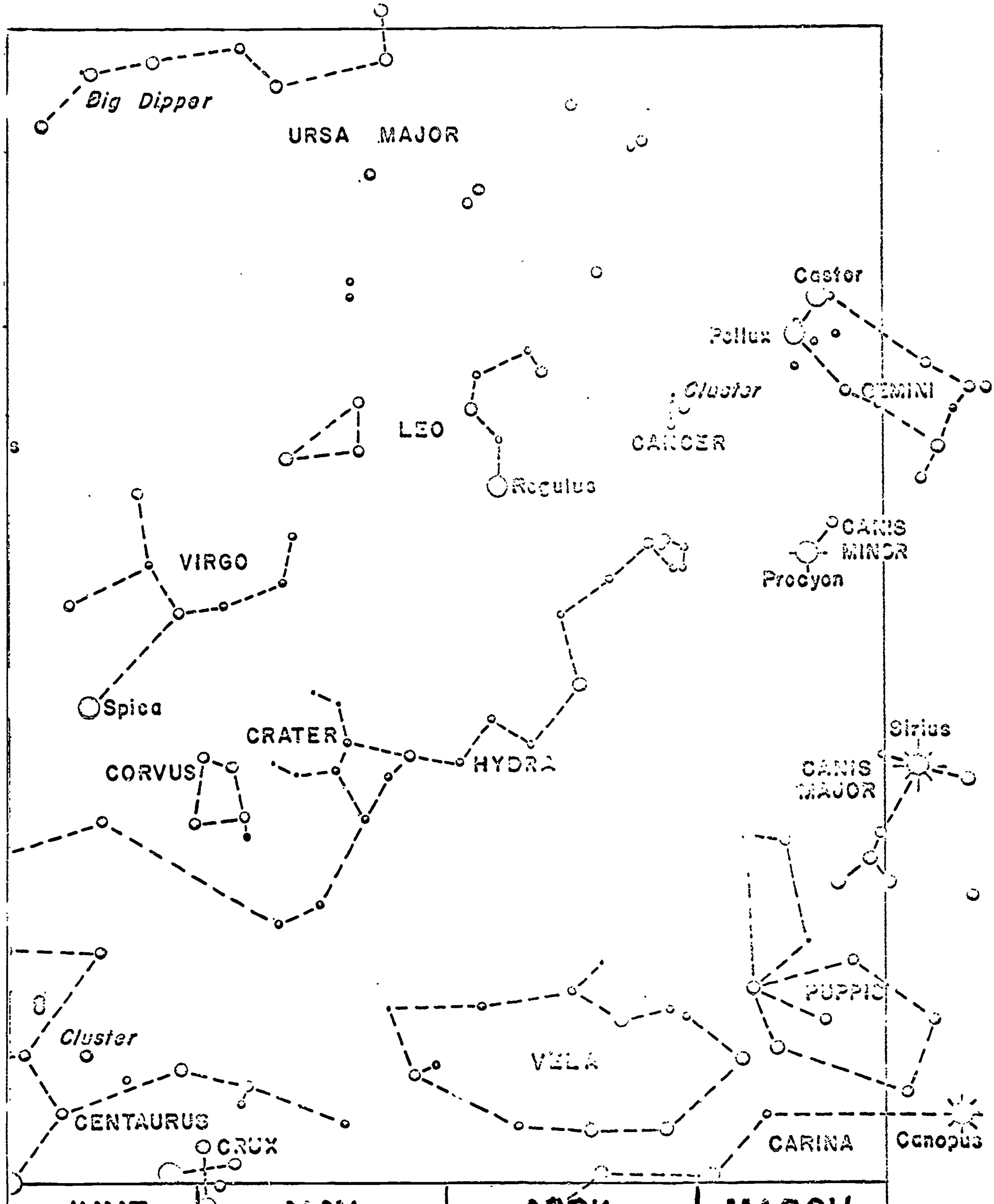
C.



DRACO
Vega
Cluster
HERCULES
SAGITTA
OPHIUCHUS
AQUILA
SERPENS
SAGITTARIUS
SCORPIUS
ARA
AUGUST
JULY

SPRING

D.



Big Dipper
URSA MAJOR
Castor
Pollux
GEMINI
Cluster
CANCER
LEO
Regulus
CANIS MINOR
Procyon
VIRGO
Spica
CRATER
CORVUS
HYDRA
Sirius
CANIS MAJOR
PUPPIS
Cluster
VELA
CENTAURUS
CRUX
CARINA
Canopus
JUNE
MAY
APRIL
MARCH

OBJECTIVE 6. The student should be able to name and describe the two forces, which, when balanced, keep an object in orbit.

ACTIVITY 1

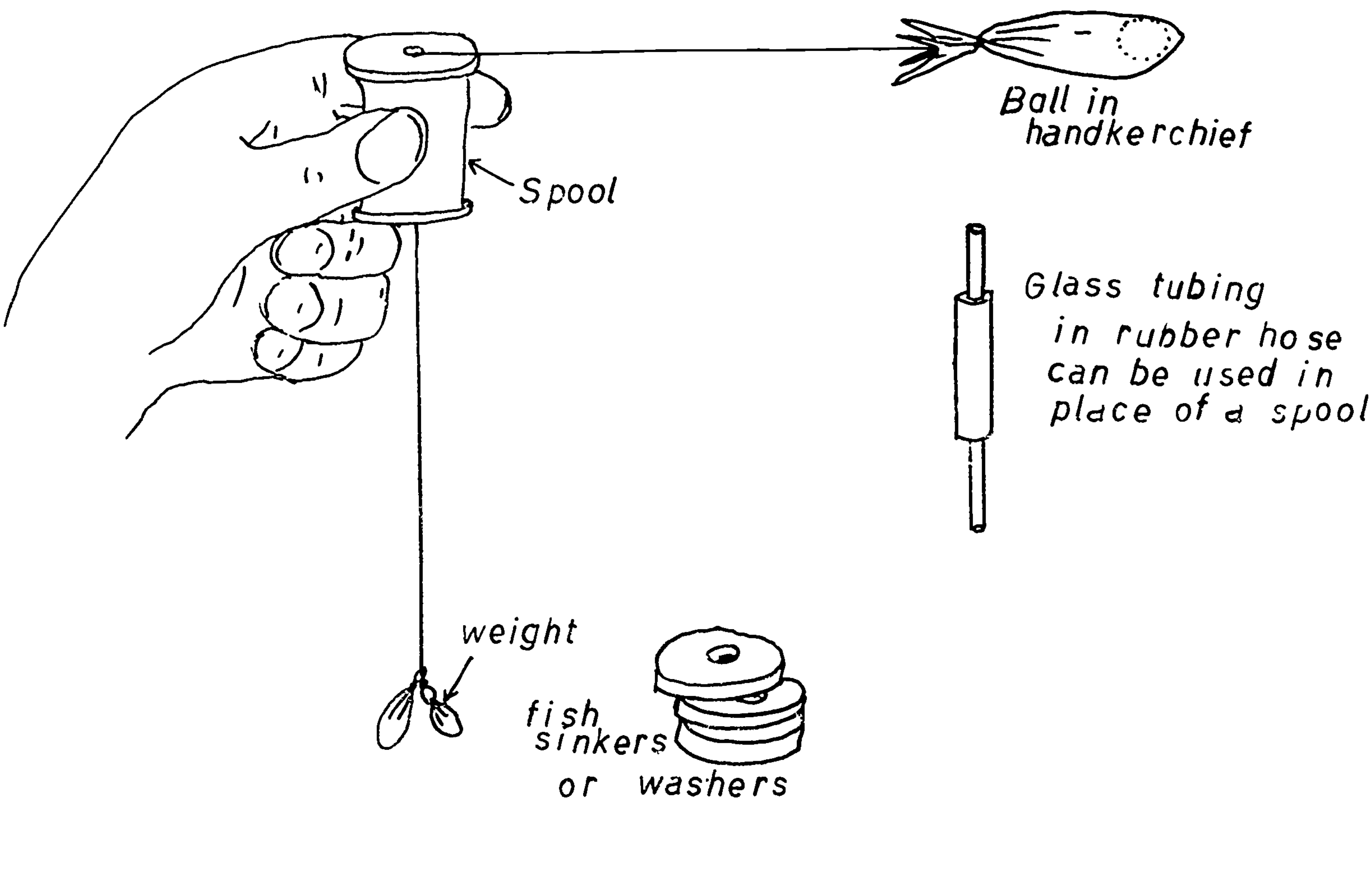
Materials: ball, string (10-15 feet), an empty thread spool, weight, scissors, (the ball must be attached to a string, therefore a whiffle ball or a ball tied in a handkerchief may be used.)

Thread the string through the spool and tie a ball to one end of the string and a weight such as a washer to the other end. Hold the spool with the ball above it and spin the ball around your head. Change the speed of the ball and have the students observe the effect on the weight. Have the students predict what would happen to the ball if the string were to break while the ball was spinning. Cut the string above the weight. Which prediction was right? (The ball would fly off in a straight line.) Repeat and have the students associate the model with the sun, moon and earth. The spool represents the sun; the ball the earth; the string the gravitational attraction between the earth and sun, and, the motion of the ball the inertia or forward momentum of the earth.

Repeat the activity but vary the length of the string by pulling down on the string below the spool. Observe what happens. (The ball spins faster as the string is shortened.) Relate this to the speeds and distances of the planets.

EVALUATION: Given a diagram of the activity, the student should:

1. name the force which the earth exerts on the moon and indicate the direction of the force.
2. name the force which prevents the moon from hitting the earth, and,
3. tell what would happen if one of these forces should increase.



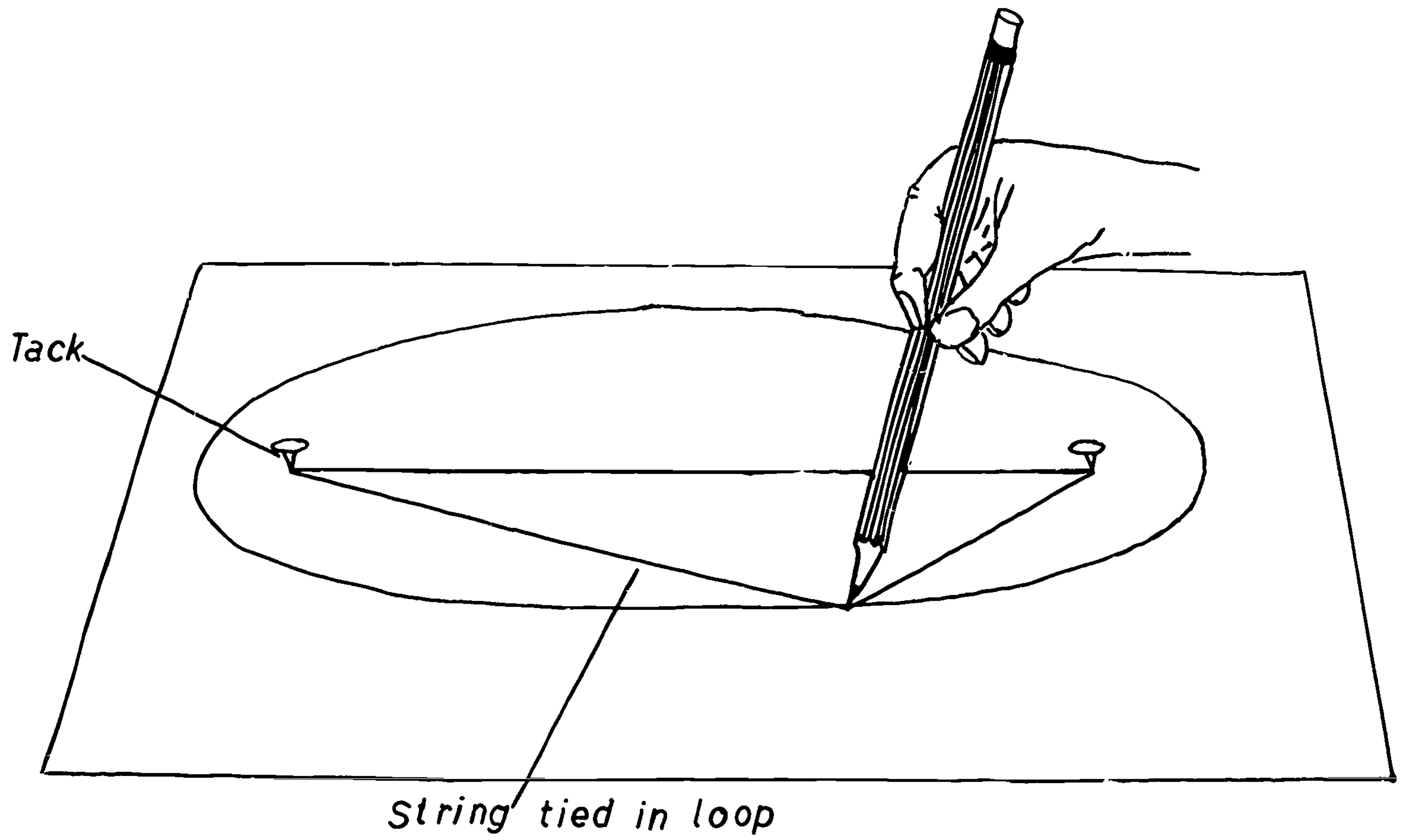
OBJECTIVE 7: The student should be able to:

a. identify the difference between an ellipse and a circle.
b. identify and name the shape which best describes the earth's orbit.

ACTIVITY 1

Materials: two thumbtacks, string, pencil, paper, corrugated cardboard (12" x 12"), compass, ruler (enough sets for every two students).

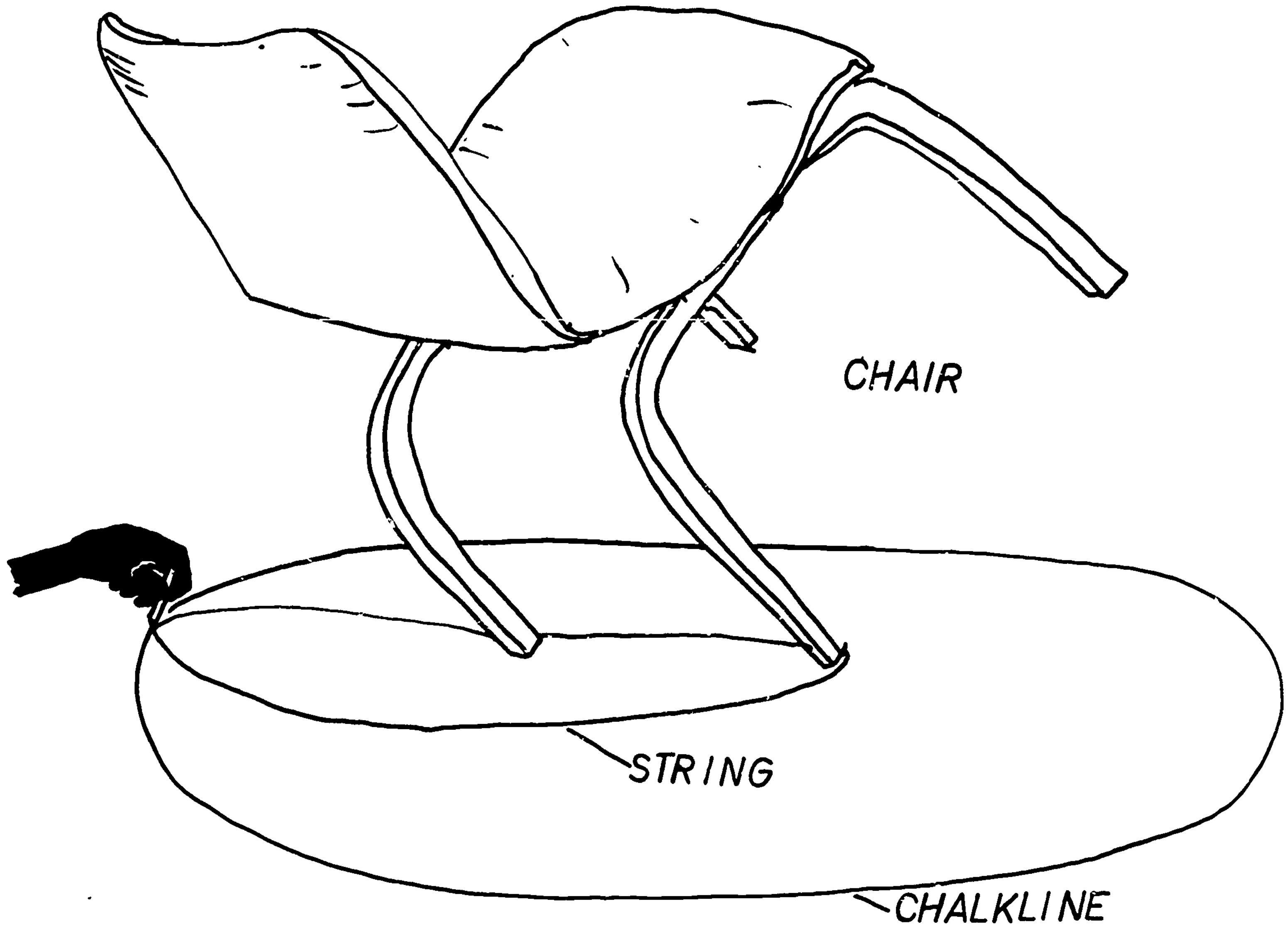
Give each group of students a piece of cardboard (12" x 12"), two thumbtacks, a piece of string (9" long), a ruler and a compass. Have each group place the point of a compass near the middle of the cardboard and draw a circle three inches in radius. They should then draw a diameter for the circle and fasten a thumbtack to each of these new points. Tie the ends of a 9" string together so as to form a loop and place it on the cardboard with the two thumbtacks within the loop. Now put the point of a pencil against the inside of the loop of string and, keeping the string taut, draw a line using the string as a guide. Compare the drawings of the circle and the ellipse. (Observe a circle has one focus (center) and the ellipse has two foci.) If time permits, make several more ellipses. For each new ellipse move the tacks closer together. Observe what happens to the ellipse. (As the foci come closer, the ellipse will look more and more like a circle.)



ACTIVITY 2
(Optional)

Materials: chair, string (6-10 feet long), chalk, light source, globe.

Working in large groups, tip a chair on two legs, and tie the string in a circle. Loop the string aroung the legs the chair is balanced on.



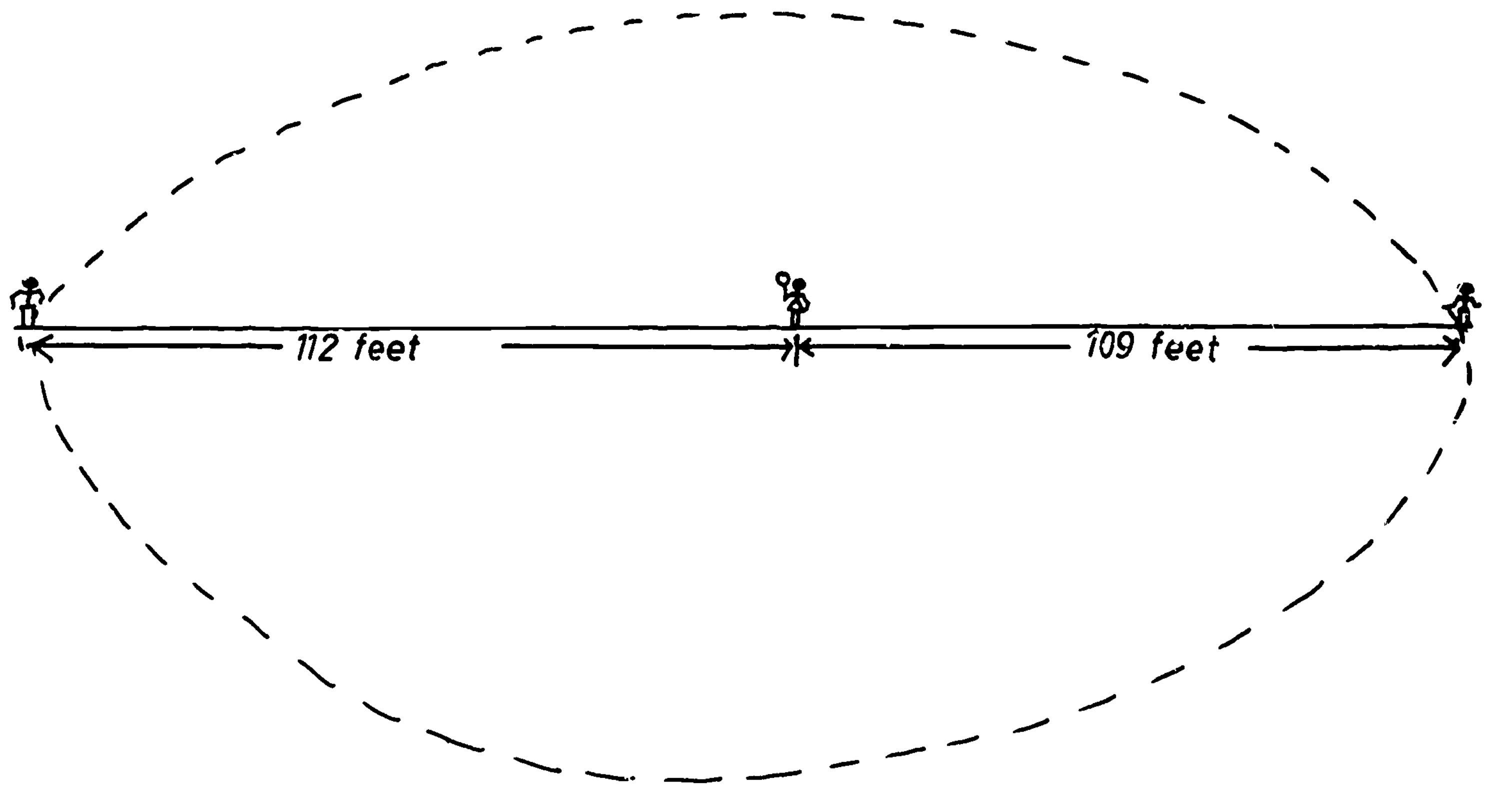
Tilt the chair and the legs act as the foci of the ellipse. Mark where the two legs are on the floor. Draw an ellipse by placing a piece of chalk against the loop of string and, keeping the string taut, draw a line on the floor using the string as a guide. Remove the chair and place a light source at one of the foci to represent the sun. Place the globe at the curve of the loop closest to the light source, so its axis is tipped away from the center of the ellipse. Keeping the axis at the same angle (same spot in the ceiling), move the globe around the ellipse using this as a model of the earth's orbit around the sun. You may wish to identify the closest point of the ellipse to the light source as the perihelion and the farthest as the aphelion.

ACTIVITY 3

Materials: 100 ft. tape measure, playground

To make a scale model of the earth's orbit using a scale of 1'' = 70,000 miles. A ball about 12'' in diameter can represent the sun and a 1/8'' circle the earth. In January the earth is about 91,500,000 miles from the sun (109') and in July it's about 94,500,000 miles from the Sun (112').

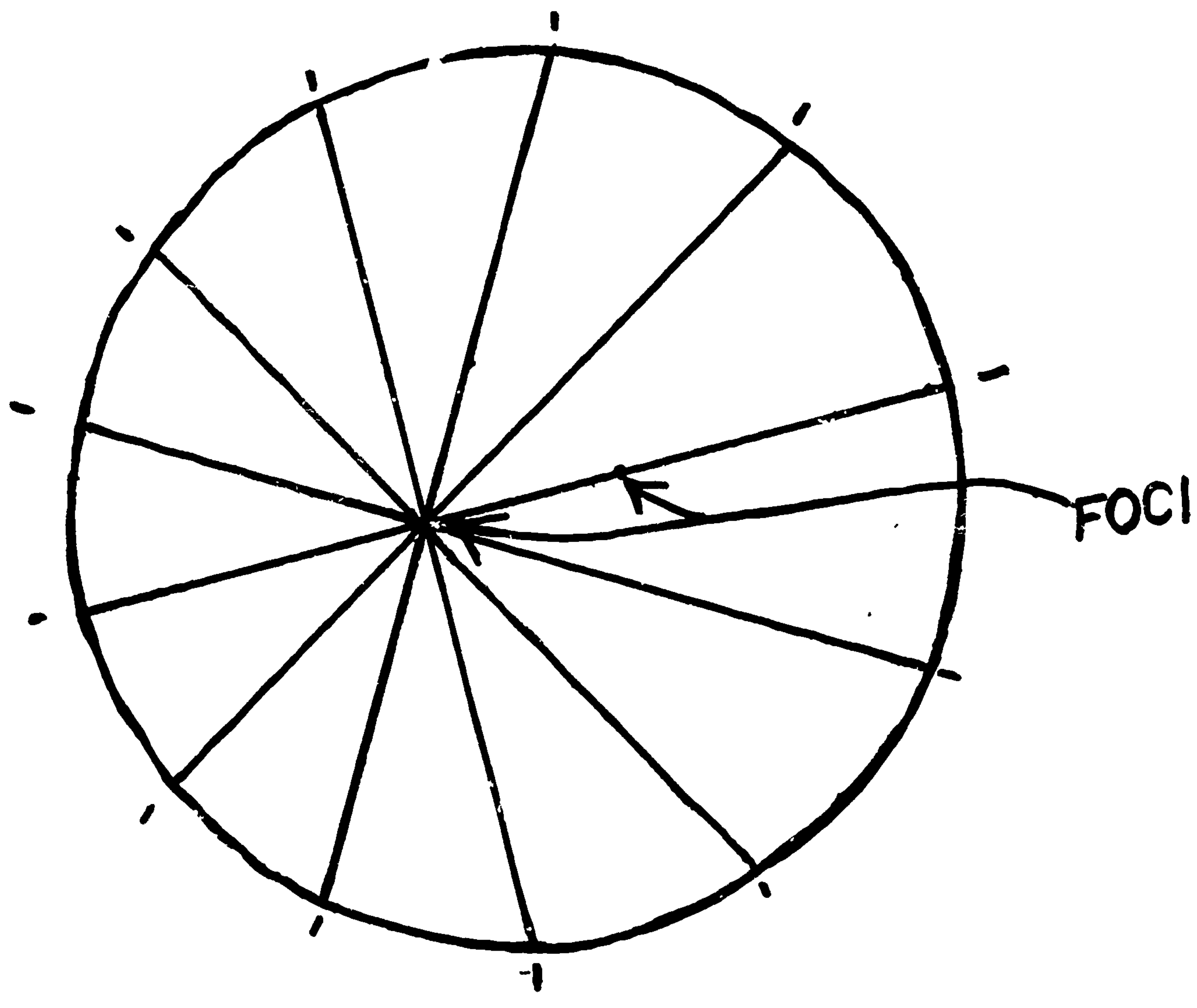
On the playground, have one student hold the 12 inch "sun" while others position the earth in January (109 feet in one direction), and in July (112' in the opposite direction). Take the rest of the class for a circle walk of the model earth's orbit comparing the sizes of the earth and sun and the ellipse of the earth's orbit with a circular orbit. Have them estimate what the average distance of the earth to the sun would be. Discuss artists representations of the earth's orbit by using a disc and viewing it from the edge rather than the top. Most diagrams show the earth's orbit from a side view.



ACTIVITY 4
(Optional)

Materials: protractor, ruler, pencil, paper

Using a seven inch string tied in a loop around two thumbtacks that are one inch apart, draw an ellipse. Place the protractor on the ellipse so that the center of the protractor is at one of the foci. Measure from that point every 30° and mark your paper. Rotate the protractor and continue marking your paper every 30° until you have gone around the focus point.



Count the sections (12) and tell the class that each section could be compared to the distance the earth travels in one month with twelve months equaling one year or one trip of the earth around the sun. Observe whether each section is equal (No). Have the students discuss what the speed of the earth must be at various parts of the ellipse. (Where the arc is longer, the speed must be greater. Refer to Objective VI).

EVALUATION: Given diagrams of a circle, square, rectangle, ellipse and triangle the student should be able to identify and name the circle as the shape which most resembles the earth's orbit.

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OBJECTIVE 8. The student should be able to describe the relationship between the planets' orbits.

Materials: two coat hangers, string, tagboard, 1" diameter styrofoam ball, tape, compass

Have the students construct a model of the solar system by fastening two wire coat hangers together (diagram a.). On a piece of tagboard draw a circle with a 15" diameter and cut it out. Starting at the edge of the round paper, measure in ¾" and draw a circle. Repeat this until you have a series of 8 concentric circles to represent the orbits of the 9 planets with the outside edge serving as Pluto's orbit. Repeat this so the orbits are shown on both sides of the paper. Remove the 3" circle from the center of the tagboard and cut four 1" slits, equidistant from each other, on the edge of the paper (diagram b.). Tie four equal lengths of string to the outer corners of the coat hangers. Slip the strings through the slits and tie a knot in the end of the strings to hold the model level. Suspend a 1" diameter styrofoam ball from a string attached to the intersection of the coat hangers so that half of it appears below the edge of the cardboard and half appears above the cardboard. The planets may be drawn on the appropriate orbits.

Have the students observe the model of the orbits of the solar system which has been constructed. Have them list the common characteristics of the orbits such as, the sun is at the center of each orbit and all orbits are on the same plane or level. Have the students observe the rotating model from an edge-on-view and from different vantage points against the background of the model of the sun's path (on the star maps from Objective 5).

Point out that since the planets are on the same plane as the sun then to view the planets in the sky they should be found where the sun is, has been or will be.

EVALUATION: Asked to describe the orbits of the planets, the student should describe them as concentric circles on the same plane.

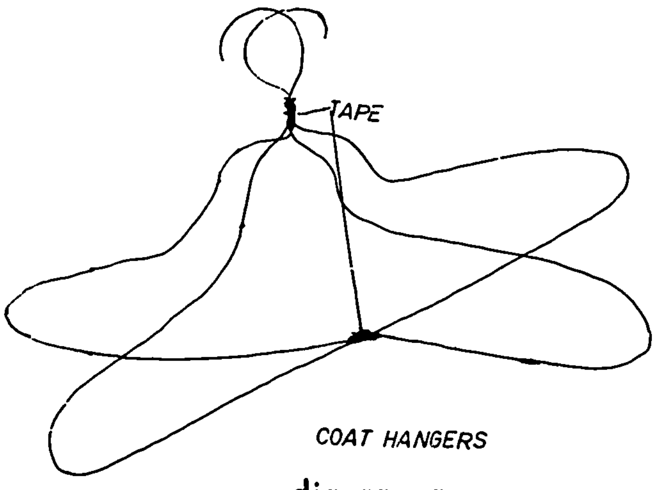


diagram a.

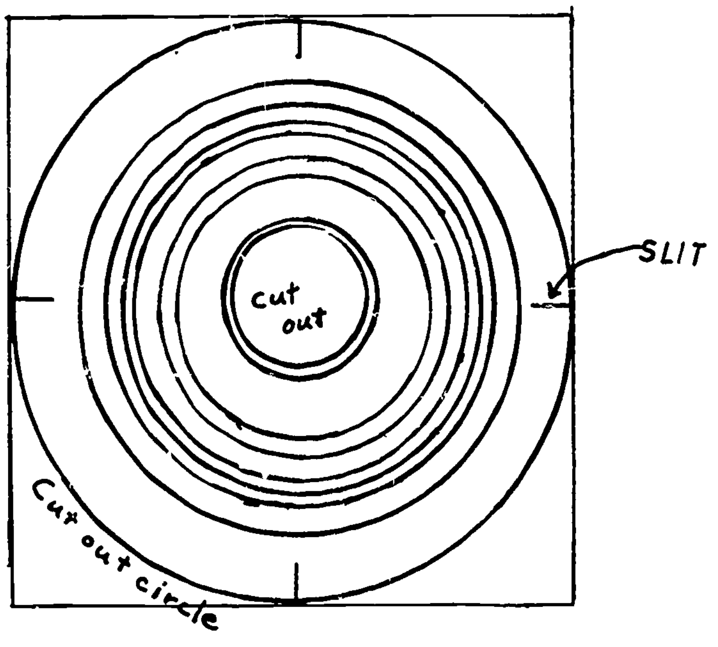


diagram b.

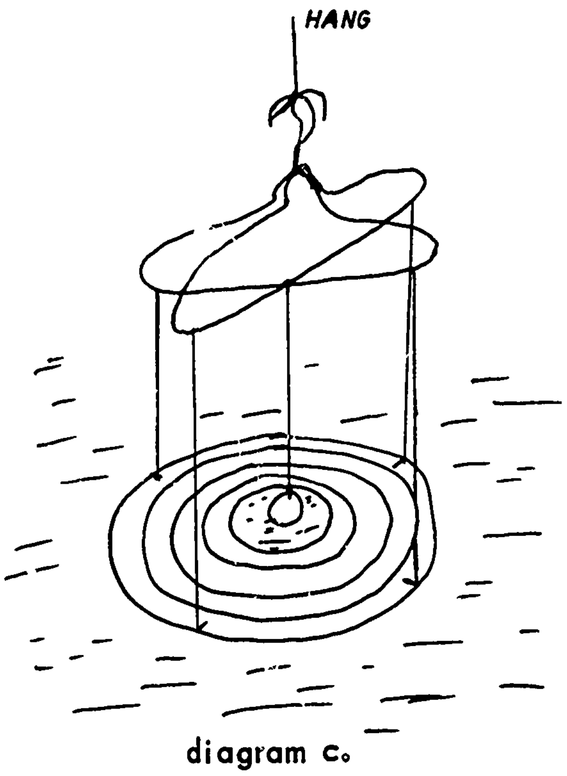


diagram c.

OBJECTIVE 9: The student should be able to describe at least two instruments used to obtain information about the planets.

ACTIVITY

Materials: Most of the books on the bibliography listed below or adequate substitutes.

Bergamini, David, Life Nature Library: The Universe, New York: Time Incorporated, 1966.

Branley, Franklyn M., Experiments in Sky Watching, New York: Thomas Y. Crowell Co., 1959.

Branley, Franklyn M., Mars Planet Number Four, New York: Thomas Y. Crowell Co., 1966.

Branley, Franklyn, The Nine Planets, New York: Thomas Y. Crowell Co., 1958.

Freeman, Mae, and Freeman, Ira, Fun with Astronomy, Easu Claire, Wisconsin: E. M. Hale and Co., 1953.

Moore, Patrick, Telescopes and Observatories, New York: The John Day Co., 1962.

Halacy, D.S., Fabulous Fireball, New York: The Mac Millan Co., 1957.

Donan, Colin A., The Stars, New York: McGraw-Hill Book Co., 1966.

Sagan, Carl and Leonard, Jonathan Norton, Life Science Library: Planets, New York: Time Incorporated, 1966.

Simon, Tony, The Search for Planet X, New York: Basic Books, Inc., 1962.

Sutton, Felix, The How and Why Wonder Book of The Moon, New York: Grosset & Dunlap, 1963.

Wyler, Rose and Ames, Gerald, The New Golden Book of Astronomy, New York: Golden Press, 1965.

Zim, Herbert S., The Universe, New York: William Morrow and Co., 1961.

Zim, Herbert S., and Baker, Robert H., Stars, New York: Golden Press, 1964.

Ask the class what tools astronomers use in their study of the sky and list their ideas on the chalkboard. A description of these instruments follows but the students may have additional suggestions. Sources of information for some of the tools may be difficult to find but the bibliography should be helpful. The students may work individually or in small groups to research the instrument of their choice. They may report orally to the class on their findings. A bulletin board with pictures and written summaries may be helpful.

THE MOST COMMON TOOLS USED BY ASTRONOMERS ARE:

TELESCOPES.....There are two kinds of telescopes, optical and radio. Optical telescopes gather light and fall into two categories: reflecting telescopes which use a concave mirror to catch and focus light; and, refracting telescopes which use a lens to catch and focus light.

Radio telescopes gather types of radiation other than light and have been used to map the radio "appearance" of the entire sky. So far astronomers have discovered hundreds of "bright spots", where radio waves are intense.

SPECTROSCOPE.....This is an instrument that analyzes light. Each color has a different wavelength. When the light from a star is studied, a dark line spectrum can be obtained from the spectroscope. The dark lines indicate that some light was absorbed as it passed through the cooler gases above the star's surface. The arrangement of the dark lines (called Fraunhofer Lines) in the spectrum tells the scientist what kinds of elements are in that star.

CAMERA.....Our eyes can only see the light which comes to us each moment. A camera has the ability to record light and add (accumulate) light on a film. This additive power gives us brighter, more detailed records of the sky. Cameras may be used separately for observations or in conjunction with telescopes, spectroscopes and other instruments.

RADAR.....Radar sets are complex electronic instruments, but the principle of operation is fairly simple. A short burst of very short-wave length radio waves is transmitted at the speed of light from an antenna which focuses the outgoing radio energy into a narrow beam. When the outgoing pulse strikes a target, some of the energy is reflected towards the antenna (like an invisible ball bouncing back from an object). The time between the transmission of the pulse and the reception of the reflected pulse can be measured automatically even though it is very short. It is like listening for an echo. Since the speed of light is known, this method can be used to measure distances in our solar system by measuring the time between transmission and the echo.

SATELLITES.....A satellite is defined as a small body that revolves around a larger one. The earth's natural satellite is our moon. The term, man-made satellite, means a package of instruments that is in orbit around the Earth. On October 4, 1957 the Russians launched the first successful man-made earth satellite, Sputnik I. Its weight of 184 pounds was composed of a radio transmitter and devices for measuring temperature and pressures inside the satellite. Sputnik II was placed in orbit on November 3, 1957. This weighed over half a ton and carried instruments for measuring cosmic rays, ultra-violet and X-ray radiation and contained a small passenger compartment in which a dog, Laika, remained alive for about a week. The first American satellite, Explorer I, was launched on January 31, 1958. It was packed with many miniature instruments for measuring radiation and temperature and weighed 18 pounds. Today there are many satellites orbiting the earth.

SPACE PROBE.....These are research packages that are similar to satellites except they are not in orbit around the earth. They are sent deep into space to record and send back information about their environments. These space probes may even land on a planet or natural satellite to perform experiments by remote control.

EVALUATION: The student should upon request name and describe two tools used in studying the planets.

EXPLORING THE UNIVERSE

a program for advanced science--junior high
and earth science--students)

After everyone is seated in the Star Theatre, the lights grow dimme and dimmer, until the audience is sitting in total darkness. Coordinated with dramatic music, a stylized representation of the Big Bang theory of the origin of the universe is presented suddenly filling the space overhead with quasars, peculiar galaxies and then the four main types of galaxies: irregular, elliptical, barred spiral and spiral. As one spiral galaxy draws near, we examine the globular clusters in the galatic halo and the two populations of stars: the old, near the center, and the young ones, in the arms of the galaxy. Once inside this galaxy we discover it is our own Milky Way. Our attention is drawn to a gas cloud (the Great Nebula in Orion) as millions of years of time are condensed and we watch the birth, development and death of a star. At last we move within our galaxy to observe our own sun from a point near the star system Alpha Centauri. Since the planets surrounding the sun cannot be seen even from this close distance (4.3 light years) we move still closer to see these tiny bodies circling the star which is their sun. On earth we look back out into deep space to view the quasars, galaxies, nebulae, clusters and stars as seen from our own backyard. The gentle light of dawn brings us back to reality.

OBJECTIVES: EXPLORING THE UNIVERSE

The student should be able to:

1. describe the major objects found in the universe.
2. state the types of bodies which appear in the various zones of the universe.
3. describe the origin of stars and predict the evolution of stars.
4. identify a change in frequency of light being received from a star as an indication of a change in position of the star.

OBJECTIVE 1. The student should be able to describe the major objects found in the universe.

ACTIVITY 1

Materials: Most of the bibliography listed below or adequate substitutes, 3" x 5" file cards

Alter, D., Cleminshaw, C.H., Phillips, J.G., Pictorial Astronomy, 2nd ed., Thomas Y. Crowell: New York, 1963.

Astronomy Highlights (series), American Museum-Hayden Planetarium, Natural History Press: New York, 1964.

Bondi, Hermann, The Universe at Large, Doubleday and Co., Inc.: New York, 1960.

Chamberlain, J. M., Nicholson, T. E., Planets, Stars and Space, Creative Educ nal Society: Mankato, Minnesota, 1962.

Dodson, R.S. Jr., Dr. Clyde Fisher's Exploring the Heavens, Thomas Y. Crowell Company: New York, 1964.

Fanning, Commander A. E., Planets, Stars and Galaxies, Revised by Donald H. Menzel, Dover Publications, Inc.: New York 1966.

Fea, Kenneth Hugh, Astronomy and Beginning Astrophysics. D. Van Nostrand Co., Inc.: New York, 1963.

Flammarion, Camille, The Flammarion Book of Astronomy, Simon and Schuster: New York, 1964.

Freedman, Russell, 2000 Years of Space Travel, Holiday House: New York, 1963.

Hoyle, Fred, Frontiers of Astronomy, Harper and Row, Publishers: New York, 1955.

Hoyle, Fred, The Nature of the Universe, Harper and Row, Publishers: New York, 1960.

Huffer, Charles M., Trinklein, Frederick E. and Bunge, Mark, An Introduction to Astronomy, Holt, Reinhart and Winston, Inc.: New York, 1967.

King, Henry C., Pictorial Guide to the Stars, Thomas Y. Crowell Co.: New York, 1967.

Moore, P., The Picture History of Astronomy, 3rd Ed., Grossett and Dunlap: New York, 1967.

ed. Motz, Lloyd, Astronomy A to Z, Grosset and Dunlap, Inc.: New York, 1964.

Olcott, William T., Field Book of the Skies, 4th ed., G. P. Putnam's Sons: New York, 1954.

Ovenden, Michael W., Life in the Universe, Doubleday & Co., Inc.: New York, 1962.

Page, Lou Williams, A Dipper Full of Stars, Follett Publishing Co.: Chicago, 1964.

Shapley, Harlow, Galaxies, Harvard University Press: Cambridge, 1961.

Streuve, O., Lynds, B., Pillans, H., Elementary Astronomy, New York, Oxford University: New York, 1959.

Zim, Herbert S. and Baker, Robert H., Stars, Golden Press: New York, 1964.

Write each of the following terms on a separate 3" x 5" file card: star, quasar, galaxy, nebula, planet, globular star cluster, galactic star cluster, multiple star, local group. Place the cards in a container and have each pupil select two cards, write down the words which appear on the cards and return the cards to the container. Using the reference materials, the pupil is to write a paragraph explaining the terms he drew (several students may be looking up the same information). Have different students read their paragraphs to the class discussing each one and finally writing a composite definition of the term on the chalk board which is acceptable to the students and teacher.

ACTIVITY 2

Have a student select an example of one of the terms in the previous activity or one of the terms itself and write it on a piece of paper which he then places face down on a desk. (This will be used later to check his answer.) This student then calls on another student who proceeds to ask a question which provides a clue to the term and which can be answered "yes" or "no". This continues until either the term is identified or the tenth person has asked a question at which time, if none of the students called on can identify the term, the term is identified and the ten students must write the definition of the term. Another person is identified to write another term and the game continues.

EVALUATION: Given the names of three different objects in the universe, the student can describe two of them. (Objects to use as choices: star, galaxy, nebula, planet, globular star cluster, galactic star cluster, quasar, multiple star, local group.)

ERIC

OBJECTIVE 2. The student should be able to state the types of bodies which appear in the various zones of the universe.

ACTIVITY

Materials: logarithmic graph paper (full log 2 x 2), white poster paper, felt pen, chart below (1 per student)

BODIES	DISTANCE (in light years)
Sun	0
Alpha Centauri	4.3
Betelgeuse	520
Deneb	1,600
Hyades	129.6
Pleiades	405
Great Orion Nebula	1,800
North American Nebula	3,000
Crab Nebula	4,100
Ring Nebula	5,400
M-13	20,400
Large Magellanic Cloud	160,000
Small Magellanic Cloud	190,000
Andromeda Galaxy	2,100,000
3C273	1,500,000,000
3C295	4,500,000,000

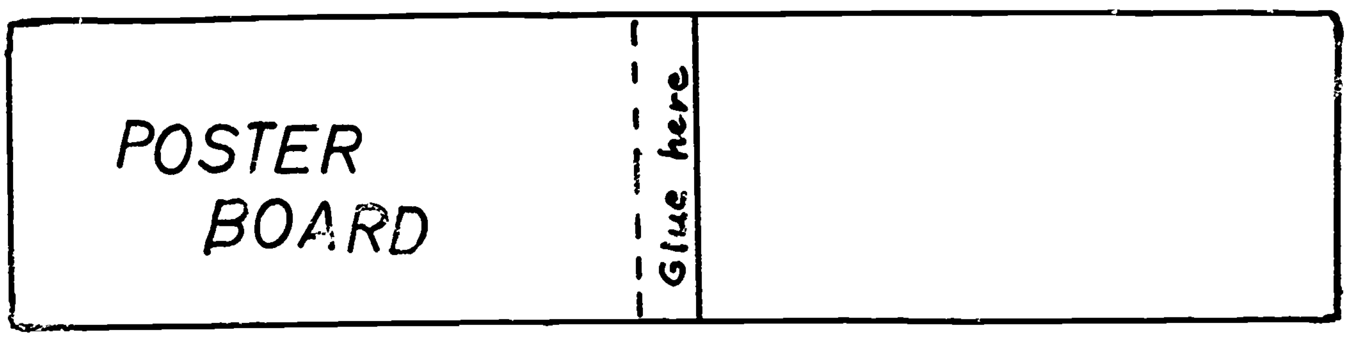
Have the students place two sheets of 18" x 24" poster paper end to end so there is an overlap of 3". Glue the overlapping section. Have other students trim the top border from one sheet of logarithmic graph paper and both the top and bottom border from five sheets. Glue the sheets together end to end horizontally across the poster paper so the untrimmed border is on one edge of the strip (see diagram on next page).

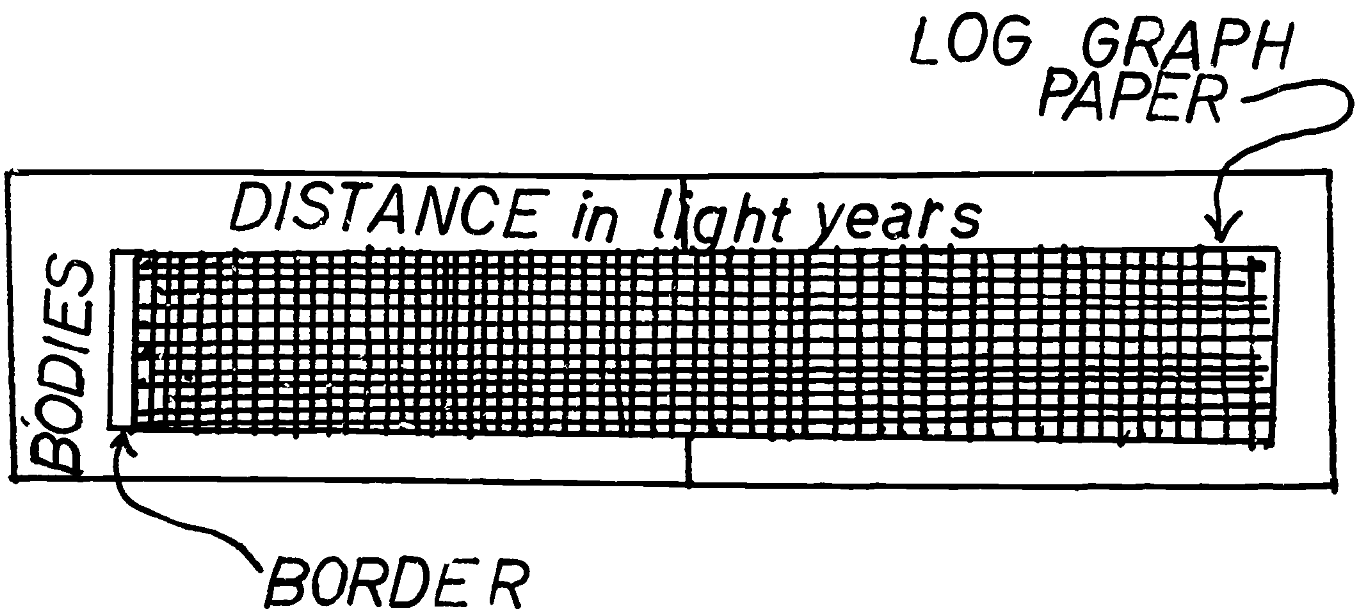
Using the information from the chart provided, plot the data on the graph paper by plotting the name on the horizontal scale and distance on the long vertical scale. From the horizontal bar graph, have the students observe any similarities or differences in these distances. Identify the bodies represented as stars, (sun, Alpha Centauri, Betelgeuse, Deneb, Hyades, Pleiades), nebula (Great Orion Nebula, North American Nebula, Crab Nebula, Ring Nebula), globular star cluster (M-13), galaxies (Large Magellanic Cloud, Small Magellanic Cloud, Andromeda), or quasars (3C273, 3C295), list them by groups on the chalkboard, and compare the distances within each group and between the groups. Identify the areas in which these bodies occur as Zones and describe the limits of each zone.

You may want to have the students calculate the number of sheets of regular centimeter graph paper it would require to plot the above information using the scale of one light year to a centimeter (the greatest distance would require about 18 million sheets).

EVALUATION: Given the accompanying chart without the answers the student should place at least 4 of the terms, stars, nebula, globular star clusters, galaxies and quasars in the appropriate columns.

ZONE "A" 0 - 6000 light Y.	ZONE "B" 6000 - 30,000 l.y.	ZONE "C" 30,000-3,000,000 l.y.	ZONE "D" 3,000,000-4,500,000,000 l.y.
STARS **NEBULA**	**GLOBULAR** **STAR CLUSTER**	**GALAXY**	**QUASAR**


POSTER
BOARD
Glue here


LOG GRAPH
PAPER
DISTANCE in light years
BODIES
BORDER

OBJECTIVE 3. The student should be able to describe the origin of stars and predict the evolution of stars.

ACTIVITY 1

The activities below are sequential and must be done in the order given. Because some of them require graphing, interpreting and mathematical skills that may be beyond the capabilities of your students, you may wish to do some or all of these steps with them by using an overhead projector.

By means of a short discussion, review the basic composition of stars. Then ask the students to list the materials that would be necessary before a star could be made (a large, source of hydrogen gas and dust). Next ask where in space these materials could be found (either in interstellar space or in nebulae). To decide which source is more likely, give the students the following problems.

a. Assuming that there is one hydrogen atom per cubic centimeter of interstellar space, how many hydrogen atoms are there in a cubic light year (a light year is about 10^{18} cm long)?

Ans. $10^{18} \times 10^{18} \times 10^{18} = 10^{54}$ cm.3

$10^{54} \times 1 = 10^{54}$ atoms

b. If 10^{24} hydrogen atoms weigh about one gram, how many grams of hydrogen are there in a cubic light year?

Ans. $10^{54} \div 10^{24} = 10^{30}$ gm

c. How many grams would 8000 cubic light years of interstellar space weigh?

Ans. $10^{30} \times 8000 = 8 \times 10^{33}$ gm

d. The Orion Nebula is about 20 light years across and each cubic centimeter of the nebula contains about 1000 hydrogen atoms. If you assume the nebula is cubic in shape, what is the volume of the Orion Nebula? How many hydrogen atoms does it contain? How many grams does the nebula weigh?

Ans. $(20 \times 10^{18}) \times (20 \times 10^{18}) \times (20 \times 10^{18}) = 8000 \times 10^{54} =$
8×10^{57} cm.3

$(8 \times 10^{57}) \times 1000 = 8000 \times 10^{57} = 8 \times 10^{60}$ atoms

$(8 \times 10^{60}) \div 10^{24} = 8 \times 10^{36}$ gm

e. The mass of the sun is 2×10^{33} grams. If all the matter in the final answer to (c) were made into stars like the sun, how many stars could be formed?

Ans. $8 \times 10^{33} \div 2 \times 10^{33} = 4$ stars

f. If all the matter in the Orion Nebula were made into stars like the sun, how many stars could be formed?

Ans. $8 \times 10^{36} \div 2 \times 10^{33} = 4 \times 10^{3}$ or 4000 stars

With the answers to problems (e) and (f), students should now be able to hypothesize that stars develop from nebulae. You may wish to mention two other evidences for this: 1) nebulae are the only places where extremely young, luminous, blue stars are found and 2) small, rounding, dark (and therefore denser than surrounding areas) spots several astronomical units in diameter have been observed in some nebulae.

As an enrichment activity, some students may wish to find out where the material in nebulae and interstellar space comes from. Library research should indicate four possible sources: supernovae, novae, solar winds, and remains of the origin of the universe.

The question of how a nebula becomes a star must be answered before the graph in the next activity is done and can be handled either through discussion or library research. The former is preferable as it is less time consuming and because the answer will come directly from the students.

Begin the discussion by reminding students that they have concluded that nebulae are the birth places of stars and also that nebulae are much less dense than the stars that form from them. Now ask what would cause the atoms and dust particles of a nebula to contract to t form a star (gravity). Then ask what would happen as a result of these atoms and particles coming closer together (star would become more dense, friction would result in increased temperature which in turn would eventually result in luminosity and nuclear reactions; at this point, the mass of gases can be called a star).

ACTIVITY 2

Materials: luminosity - temperature data table and graph (included on next 2 pages)

Introduce main sequence stars, dwarfs, and giants by having the class make and discuss a list of the distinguishing characteristics of stars, including brightness, temperature, color, distance, composition, size. The students should realize that temperature and color are related; if they do not, demonstrate the relationship by holding a paper clip in a burner flame until it glows red. Differences in brightness as they view the stars are apparent since distance is a factor; at this point, luminosity, the birghtness of a star if all stars were placed at the same distance from the viewer, should be introduced. Composition can be discarded as a differentiating factor since most stars are essentially composed of hydrogen and helium gas.

As a result of the above discussion, luminosity, temperature, and size should remain as the major distinguishing characteristics of stars. To see if these characteristics have any relationship and thus might be used to indicate something about stellar evolution, have the students plot a graph showing the temperature-luminosity data for twenty-eight representative stars. Size is left out at present since some predictions about size can be made from the T-L graph. It should also be noted that the graph's axes have logarithmic scales; if students have not used this type of scale before, it would be worthwhile to plot the first several positions with them. To make discussion easier, it would be well to have students number each position with the appropriate star number from the list.

When the T-L graphs are completed, ask the following questions to guide student interpretation of them:

Where are the cool stars? (lower right)
Where are the hot stars? (upper left)
Where are the most luminous stars? (upper left)
Where are the least luminous stars? (lower right)
Where are most stars found? Shade in this area. (along a line from upper left to lower right; this area is called the main sequence)
Where else are stars found? Circle these. (upper right and center bottom)
How can two stars, for example Deneb and Sirius A, have nearly the same temperature but different luminosities? (since temperature is the same, the difference must be surface area, i.e. Deneb is much larger than Sirius A: this means that the upper right stars are giants or super giants when compared to those on the main sequence)
How can two stars, for example Sirius B and Lalande 21185, have nearly the same luminosity but different temperatures? (since luminosity is the same, the difference must be surface area, i.e. Sirius B must be much smaller than Lalande 21185; this means these center bottom stars are dwarfs when compared to those on the main sequence)
Predict what the T-L graph would look like if the billions of stars in our galaxy were plotted on it. (same pattern but many more points)

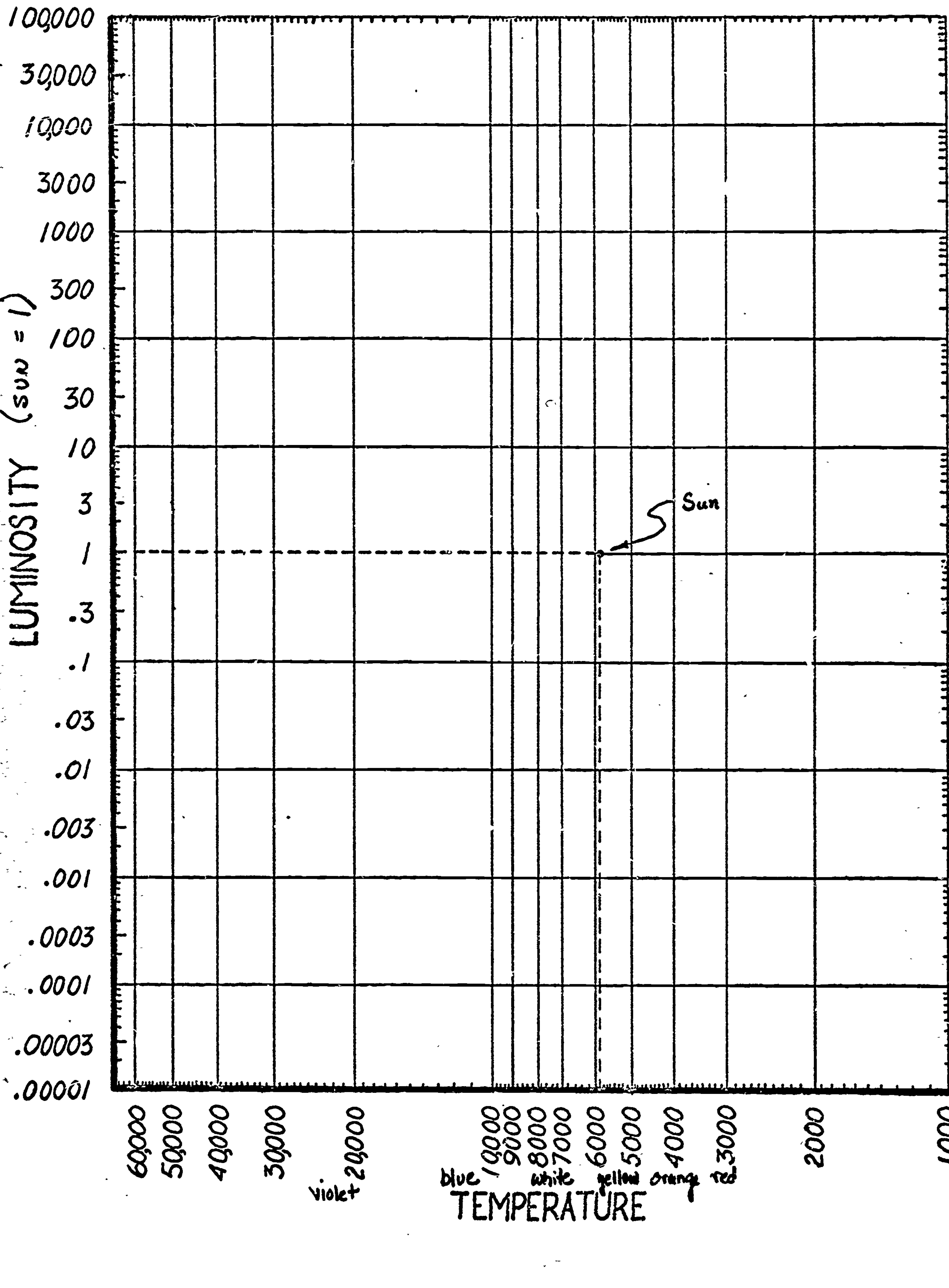
As an enrichment activity, students may want to locate the twenty-eight stars on a star map (see All About Planets, Objective five), while others could use reference materials to find out more about dwarf, giant, and supergiant stars and about Ejnar Hertzspring and Henry Norris Russell, the astronomers who first made T-L graphs.

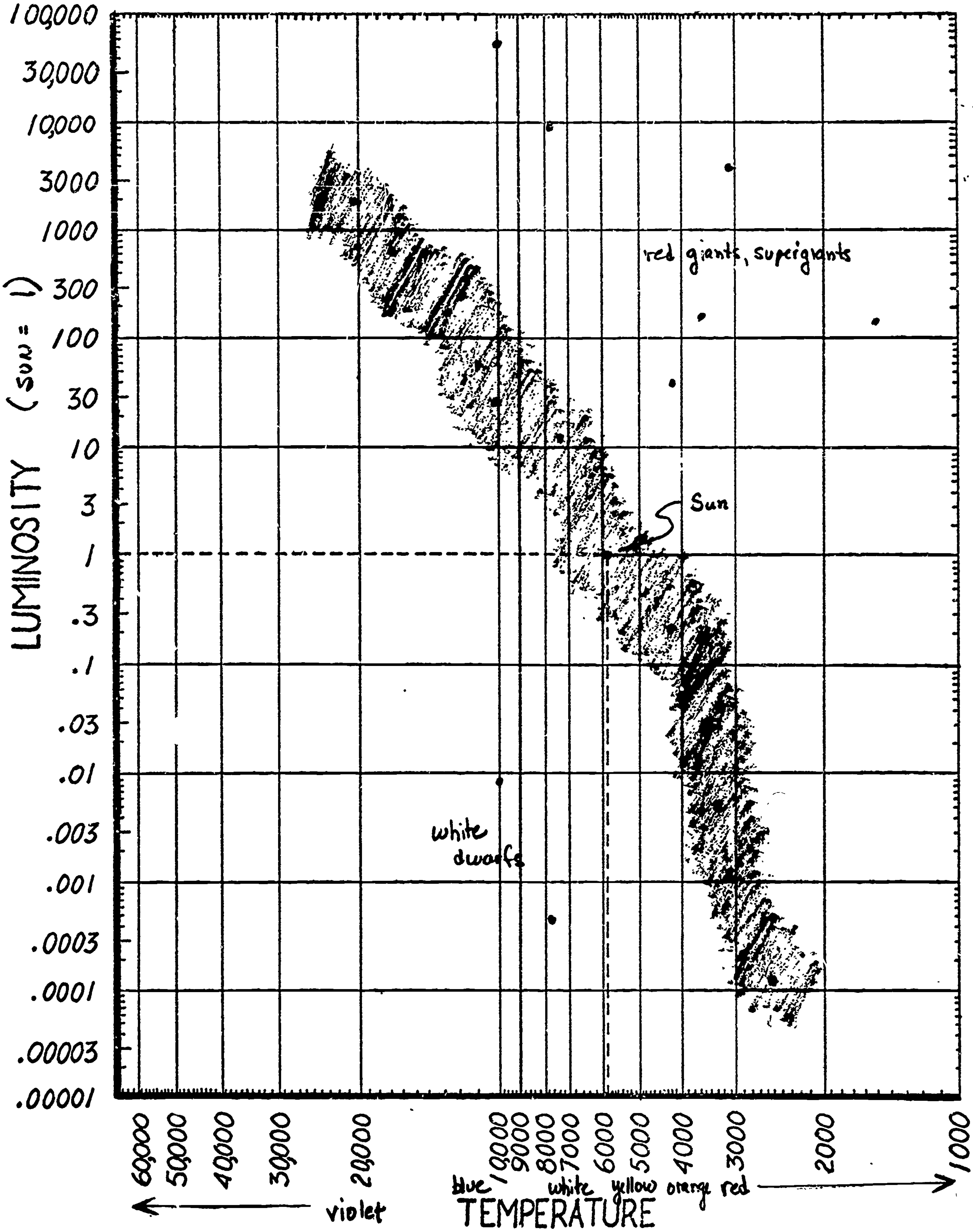
ERIC

TWENTY-EIGHT REPRESENTATIVE STARS

Number	Name	Luminosity (Sun = 1)	Temperature
1	Deneb	58,000	9,800
2	Rigel	36,000	12,000
3	Canopus	9,100	7,400
4	Betelgeuse	4,000	2,900
5	Antares	3,600	3,000
6	Spica	1,900	20,000
7	Zeta Canis Majoris	780	17,000
8	Beta Canis Minoris	240	12,500
9	Aldebaran	160	3,600
10	Capella	140	1,500
11	Arcturus	76	3,900
12	Vega	52	11,000
13	Pollux	36	4,000
14	Sirius A	23	10,000
15	Altair	8.3	8,100
16	Procyon A	5.8	6,500
17	Sun	1.0	6,000
18	70 Ophiuchi A	.4	4,800
19	Alpha Centauri B	.28	4,200
20	61 Cygni A	.052	4,200
21	Lacaille 8760	.028	3,500
22	Sirius B	.008	10,000
23	Lalande 21185	.0048	3,300
24	BD + 5° 1668	.001	3,000
25	Procyon B	.00044	8,000
26	Barnard's Star	.0004	2,800
27	Ross 248	.0001	2,600
28	Wolf 359	.00002	2,600

STUDENT COPY





main sequence

ACTIVITY 3

Materials: temperature-luminosity graphs for 4 galactic star clusters (included)

To determine what happens to a star after the main sequence, it is necessary to tell students that when a star is formed, it can be placed somewhere on the main sequence. Its exact location depends on its original mass, since it has been found that luminosity increases with mass as can be seen on a mass-luminosity graph.

With this in mind, ask the students to hypothesize what might happen to a star after it is in the main sequence. Remind them that every star is luminous because it is consuming its hydrogen supply by nuclear fusion. Direct their discussion to the conclusion that the more luminous stars must be using up their hydrogen supplies faster since they produce more light; of course they also have a larger initial supply of hydrogen.

If the life span of the sun (about 10 billion years) is known, the mass and luminosity of other stars can be used to estimate their life spans. For example, Betelgeuse is 4,000 times as luminous as the sun and about 14 times as massive. Therefore, it is using up hydrogen 4000 times as fast but has initially 14 times more hydrogen upon which to draw. Thus the life span of Betelgeuse is about

$$10^{10} \text{ years} \times \frac{1}{4000} \times 14 = 5.6 \times 10^{8} \text{ or 560 million years.}$$

Another example, Sirius B, is 0.008 times as luminous and 0.17 times as massive as the sun. Thus its life span is about

$$10^{10} \text{ years} \times \frac{1}{.008} \times .17 = 2.1 \times 10^{11} \text{ or } 10 \text{ billion years.}$$

Using the M-L graph and the data table of the twenty-eight representative stars, many more life spans can be estimated. It can thus easily be seen that the star in the upper left portion of the main sequence are relatively short-lived while those at the lower right are long-lived.

But what happens to a star when its hydrogen supply is consumed? Give your students copies of the included T-L graph for the four galactic star clusters. These clusters are composed of stars which are all about the same age and thus any differences can only be due to differences in temperature and luminosity.

Direct the students to cut out the four graphs and study them carefully. Ask questions like the following:

> Which graph most nearly looks like your T-L graph? (Pleiades)
> Which graph looks the least like your graph? (M67)
> Arrange the two other graphs in apparent sequence with Pleiades and M67. (Pleiades, Perseus, Hyades(M67)
> Which stars turn off the main sequence first? (most luminous ones)
> From the life span problems, what could this "turning-off" be caused by? (consumption of the hydrogen fuel supply)
> What happens to the stars that turn-off the main sequence? (become cooler)
> Looking at your T-L graph, what might be the origin of the red giant and super-giant stars? (stars that have used up much of their hydrogen supply and "turned-off" the main sequence)

Students can now hypothesize about the life sequence of a star from its original formation from a nebula to its arrival on the main sequence and its eventual turning off from this sequence to become a red giant. The students have now examined three of the five stages of stellar evolution. The only unanswered question is the "death" of a star and the origin of the white dwarfs: these two factors are probably related.

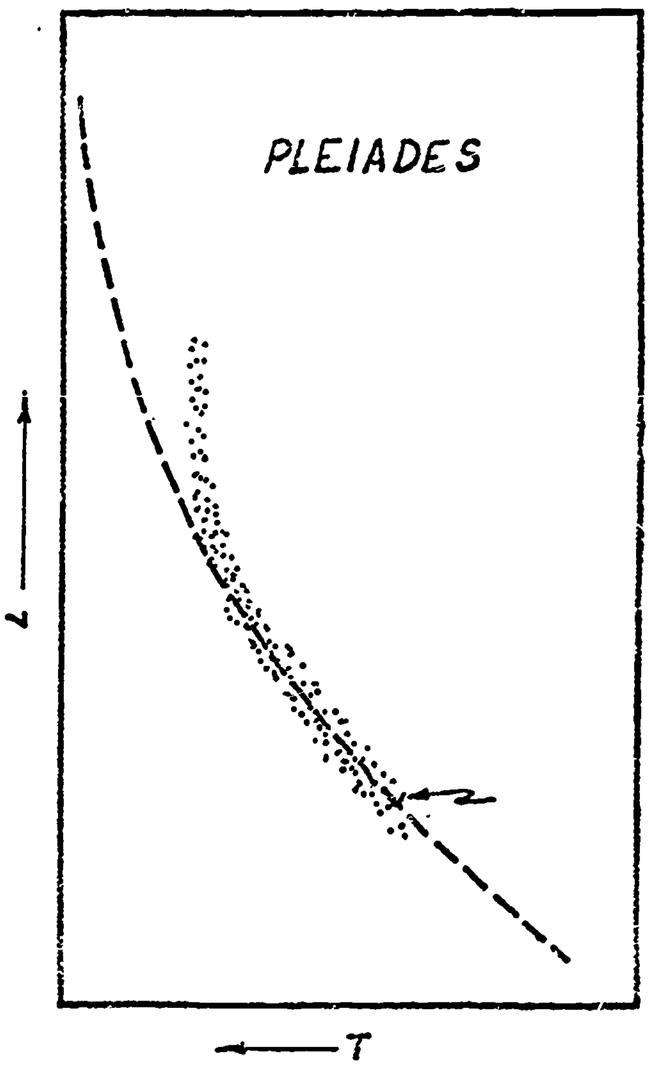
As an enrichment activity, students could use reference materials to find out more about the life sequence of stars, especially about the final phases and such things as supernovae, novae, gravitational contraction and collapse, nuclear fusion. Others may want to locate the galactic star clusters on their star maps.

EVALUATION: 1. Given the terms nebula, main sequence, giant, dwarf, the student should index them using sequence of stellar evolution as his criteria.

ERIC

2. Given temperature and luminosity data for five stars the student should locate these stars on a T-L graph and indicate whether each star is on the main sequence, or turned off the sequence becoming either a giant or dwarf star.

3. Given a star's position on a T-L graph, the student should predict the future evolution of a star at that position.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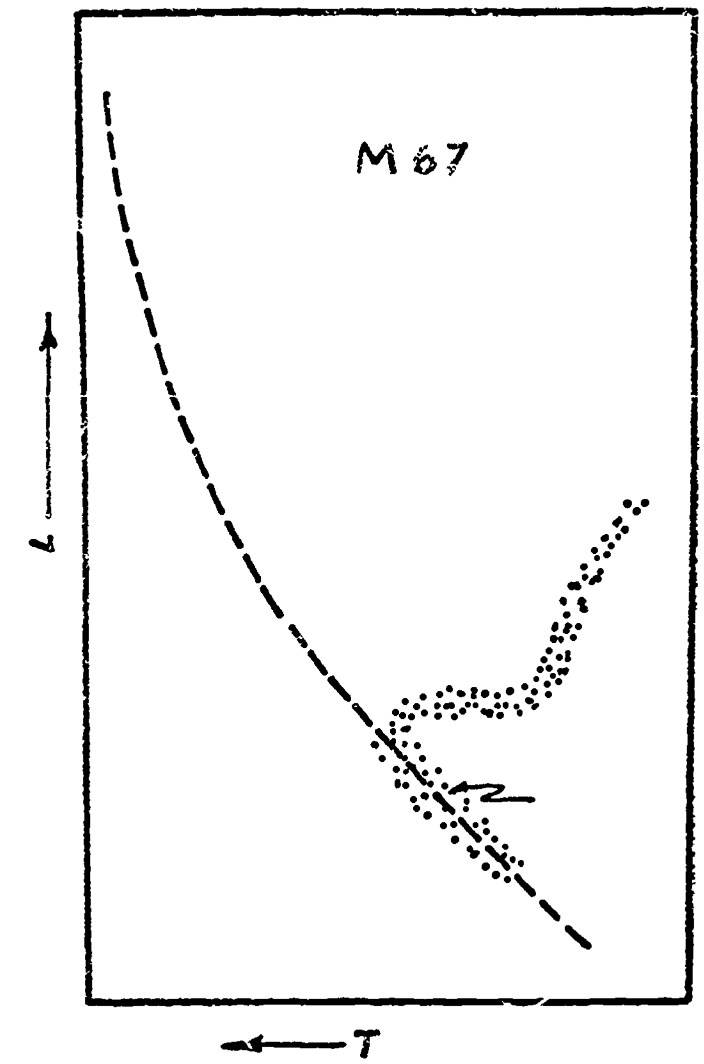
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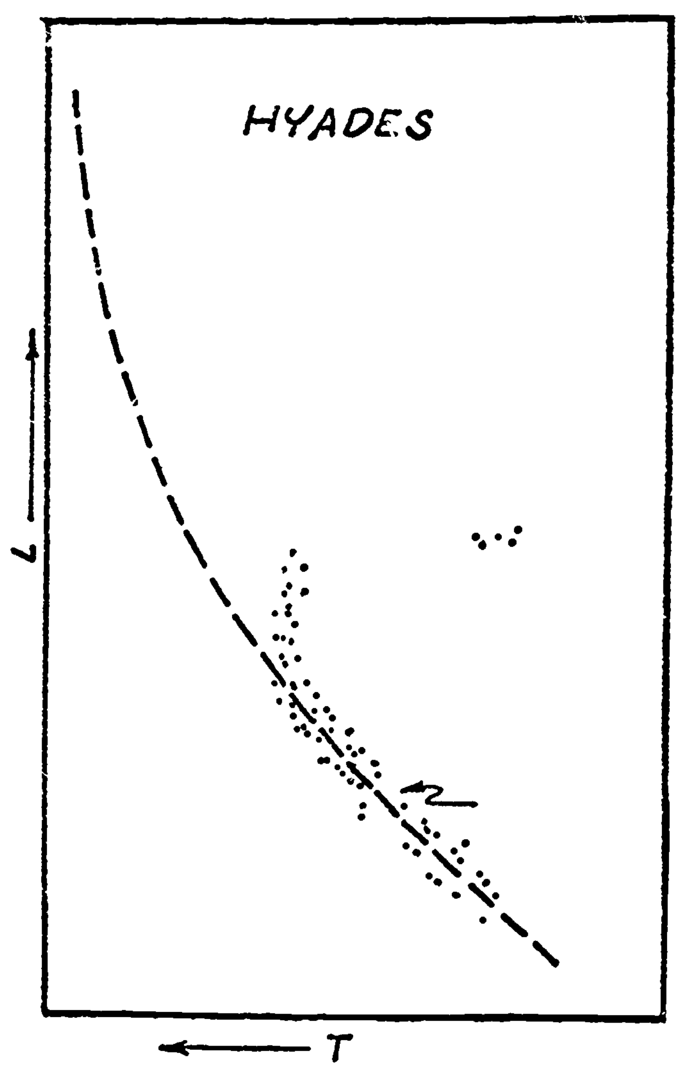
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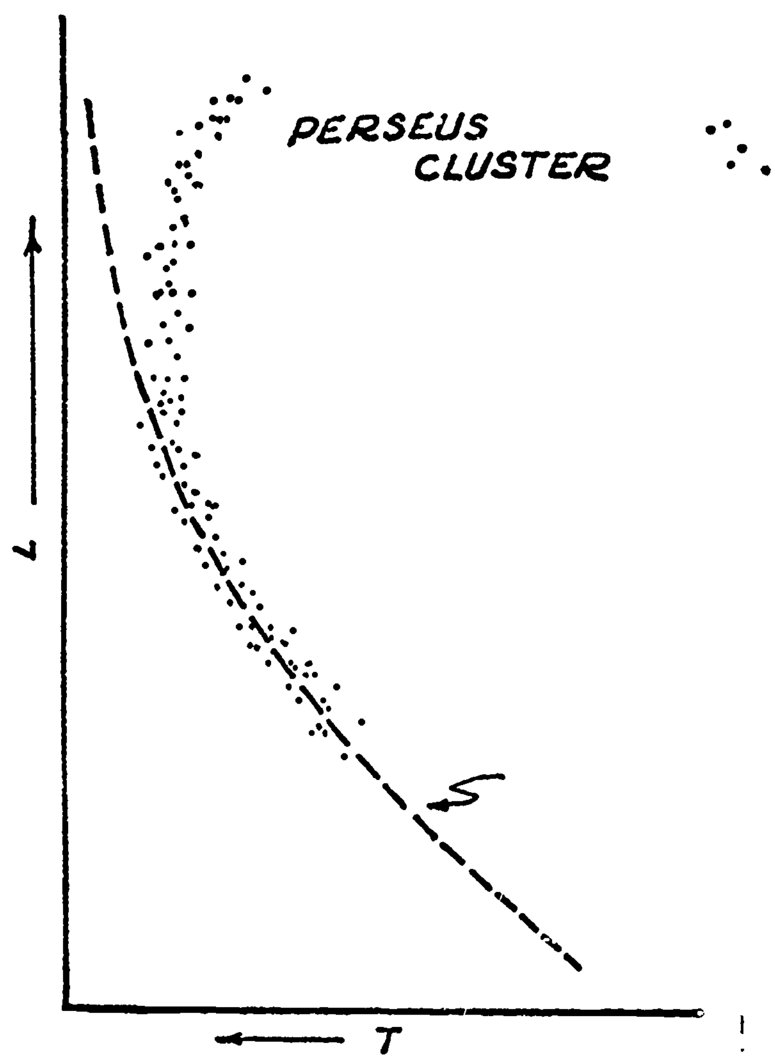
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OBJECTIVE 4. The student should be able to identify a change in frequency of light being received from a star as an indication of a change in position of the star.

ACTIVITY 1

Materials: buzzer, 12' bell wire, 1.5 v. dry cell

In 1842 Christian Doppler, an Austrian physicist, showed that when the source of sound is moving toward an observer, more sound waves will reach him per second than if the source were stationary. This has the effect of raising the frequency of the sound. Likewise the frequency will be lowered for a source moving away from the observer.

Attach the buzzer to the dry cell with two 6' lengths of wire. Have the students take turns swinging the buzzing buzzer around their head by turning their body with the buzzer. Have them observe any change in the sound of the buzzer (none). Then have them swing the buzzer around their head while their body remains stationary. Again ask for observations about the sound (changes pitch). Discuss these observations, ask a music student to suggest ways pitch may be changed. Through a series of diagrams show the difference in frequency between high and low pitched sounds. Then ask:

What would happen to the sound waves as the buzzer moves away from the observer? (they move farther apart)
Would this effect the frequency? (yes) How? (lower it)
Would this effect the pitch? (yes) How? (lower it)
What would happen to the sound waves as the buzzer moved towards the observer? (they would squeeze together)
What would this do to the frequency? (raise it)
How would this effect the pitch? (raise it)

Identify this as the Doppler effect and encourage the students to do additional research on this topic.

ACTIVITY 2

Materials: overhead projector, prism, 3 x 5 cards, colored pencils

Turn on an overhead projector and place a prism in front of the light source very close to the lens. Rotate the prism until a spectrum shows on the ceiling. (It is easier to show the spectrum on the ceiling than on a screen.)

On 3 x 5 cards the students make a labeled colored drawing of the light spectrum. Ask the students what colors are visible and then list the colors on the chalkboard in sequence (red, orange, yellow, green, blue, indigo, violet). Explain that the wave lengths are shorter at the violet end of a spectrum and get longer towards the red end. They should then indicate this change on their diagram.

ROYGBIV
long ← → short

As in activity 1, draw diagrams of different wavelengths of light and discuss the frequency as related to colors in the spectrum. Discuss what would happen to the color of the light if the source were moving away from the observer (wavelengths get longer, frequency lowers, color changes towards red) and if the source were moving towards the observer (wavelength shortens, frenquency increases, color shifts towards violet)

ACTIVITY 3

Materials: several spectroscopes, library

Using the spectroscopes, have the students observe several light sources (fluorescent, neon, sodium vapor lamps, sun and/or the flame produced by several different chemicals as they are individually placed into a flame [hold a dime in forceps, dip it in water and the into the chemical]). Discuss differences in the spectra observed.

Have the students use reference materials to find the following information:

1. What are two types of spectra produced by stars and galaxies? (dark line and absorption)
2. What does the red shift indicate about a star? (receding)
3. What is Hubbles constant? (farther a body is from an observer the faster it appears to recede)
4. What does the general motion of the stars and galaxies suggest? (expanding universe)
5. What relationship is there between the Doppler effect and the Big Bang and Steady State theories of the origin of the universe?

Discuss the information found.

EVALUATION: Given 2 spectra produced by a star showing a shift to violet, the student should identify the motion of the star as being towards the earth.

SKY SCANNING

a program for all science students

After the sun has set, we look toward the sky to watch the evening stars being uncovered by the darkness. We note that the magnitude of the stars governs which stars we see first and which come out of hiding only under the darkest conditions. Even though we are tempted, like early man, to call everything in the sky a star, there are a variety of objects overhead. We zoom in on Jupiter or Saturn and discover that what looked like a bright star was indeed a planet. We then zoom in on a true star, only to discover that we see no more of it except an increase in brightness. A shooting star (meteor) lights the sky for a moment serving as another reminder that the heavens are filled with a variety of objects. Through a special animated projection we review why the sky looks different at each season of the year, then see an impossible sight--the sun moving eastward in a starry sky due to the earth's revolution. After looking at the true composition and structure of our galaxy, the Milky Way, the remainder of the program is spent in learning to recognize about 5 to 7 constellations that can be seen overhead in the current night sky. After reviewing the constellations' names and positions, the earth is set rotating and we watch the changes that this produces in the sky, the rising and setting of objects and the circumpolarity of stars near Polaris. At last the earth's rotation brings the light of dawn to the sky.

OBJECTIVES: SKY SCANNING

The student should be able to:

1. observe that the stars differ in brightness (magnitude).

2. name and describe the types of natural objects in the sky.

3. describe why the night sky differs from season to season.

4. infer from a model that the sun appears to move against a background of stars as seen from the earth during the course of a year.

5. name a constellation, describe its mythological background and identify the bright stars found in it.

6. identify Polaris as the pole star.

ERIC

OBJECTIVE 1. The student should be able to observe that the stars differ in brightness (magnitude).

ACTIVITY

On a day when the weather report indicates a high pressure system in your area (hopefully resulting in a clear sky), give the students the assignment to view the night sky and observe differences among the stars. Discuss their observation as they relate to brightness and color and any other differences they may have noticed. In the lower grades, you may want the students to draw a picture of their observations. (Some stars should be bigger or brighter than others. Dots rather than pointed diagrams are more accurate representations of the true shape of stars.)

A discussion for reasons for the differences in brightness should bring forth such ideas as differences in temperature, distances and size. Identify the term first magnitude.

EVALUATION: Ask the student to observe the sky on a clear night, one-half hour after sunset and count the brightest stars that are visible.

(If they are counting first magnitude stars only, their answers should be near what appears on the chart.)

Season		Number of bright stars (1st magnitude)
Fall	September	3 to 5
Winter	December	6 to 9
Spring	March	7 to 10
Summer	June	5 to 7

OBJECTIVE 2. The students should be able to name and describe the types of natural objects in the sky.

ACTIVITY

Materials: list of natural objects (moon, stars, planets, comets, meteors, galactic star clusters, a galaxy, a nebula)

Using the overhead projector or the chlkabocrd, develop a class list of all the natural bodies that could be seen in a clear night sky. Have the students construct a bulletin board display with the name of the object and a corresponding picture or other representation. In the upper grades, a report may be desirable on each type of object. Since only one galaxy (M31 in Andromeda) and one nebula (Great Orion Nebula) can be seen with the unaided eye, it would be best to point this fact out and name the two bodies.

It is recom. ended that the students actually attempt to identify some of the objects either through individual observations or a class sky watch directed either by the teacher, high school earth science teacher or area astronomy enthusiast.

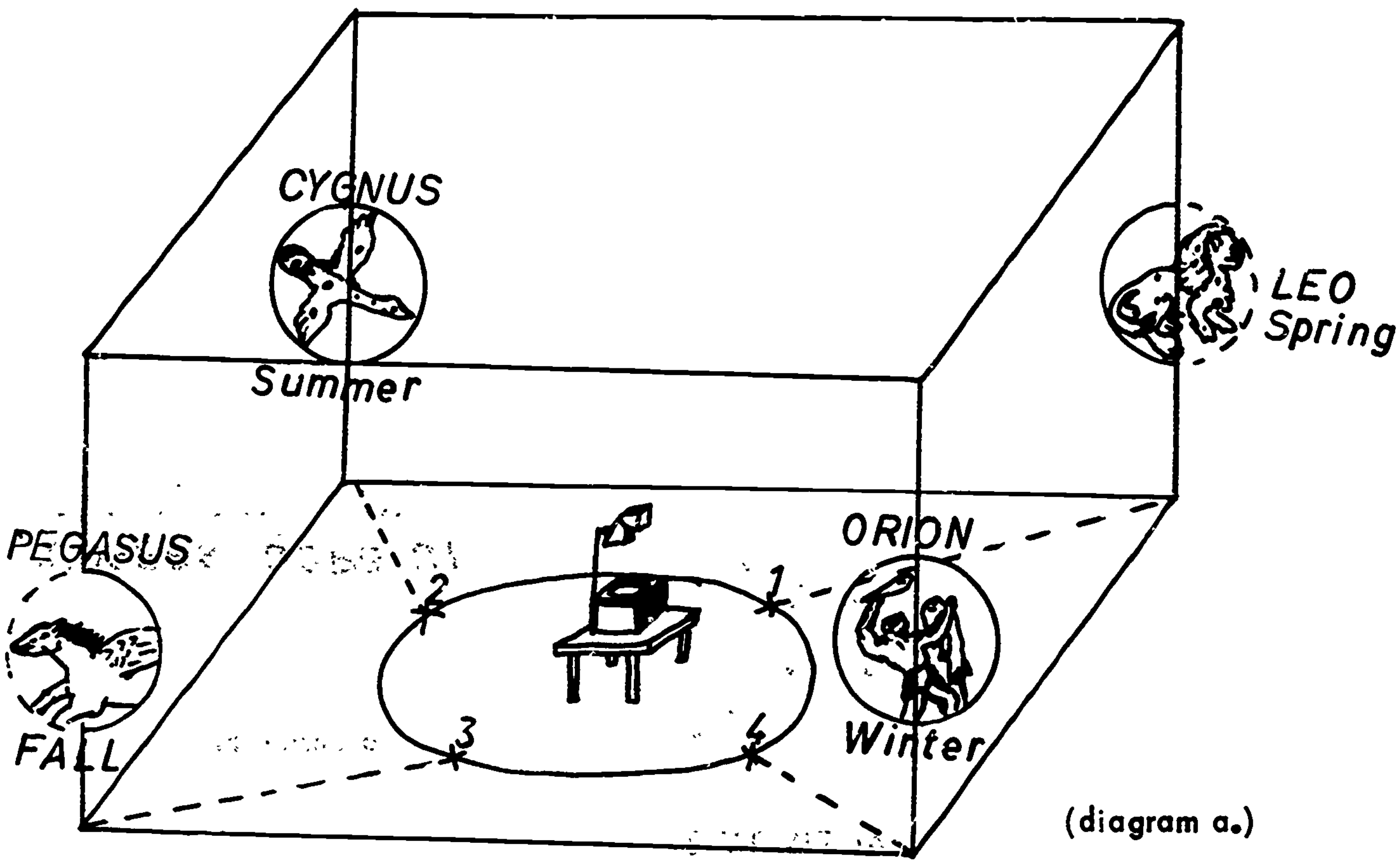
EVALUATION: Given a list of descriptions of 8 objects visible in the night sky, the student should name 6 of these.

OBJECTIVE 3: The student should be able to describe why the night sky differs from season to season.

ACTIVITY 1

Materials: overhead projector, constellation pictures (Leo, Cygnus, Pegasus, Orion), chalk, 3'' x 5'' cards

Place an overhead projector in the center of the room to represent the sun. Going counter-clockwise around the room, hang a constellation picture in each corner starting with Leo (spring night sky), then, Cygnus (summer night sky), Pegasus (fall night sky) and Orion (winter night sky). Draw a large circle on the floor around the projector with a piece of chalk. On the part of the circle closest to Leo, mark station one. Repeat this for each constellation until four stations are designated (see diagram a).

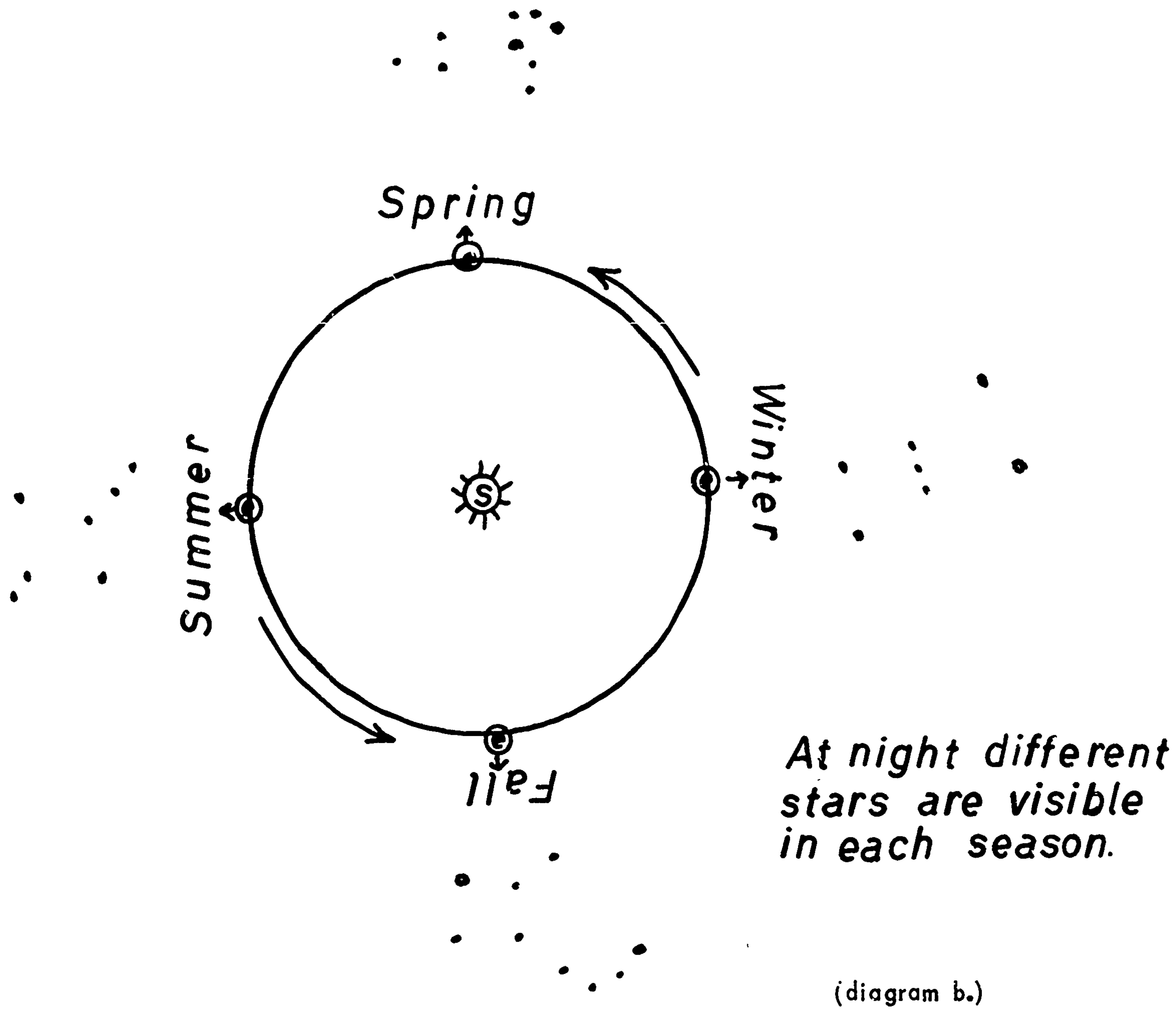


(diagram a.)

Give a student two 3'' x 5'' cards to hold beside his head acting as blinders cutting off peripheral vision and have him stand at station one. Have the student face the "sun" (projector) and ask if it would be night or day (day). Have the student turn and face Leo and ask if it would be day or night (night). Tell the student that when he is at station one it should be spring. Have him turn slowly in a counter-clockwise direction and name the constellations he can see (Orion and then Leo). When he is facing Leo, have him stop and tell if it is day or night, the constellation visible, and the season it would be (night, Leo, spring). Next, have the student move to station 2 (turn the projector so it shines on the student) and repeat the procedure and questions from station one. (He should see Leo and Cygnus at night in the summer.) The student then moves to station 3 (seeing Cygnus and Pegasus at night in the fall) and station 4 (seeing Pegasus and Orion at night in the winter). Have each student go through this precedure pointing out that as they turn very slowly they will see the previous season's constellation just at "sunset" followed by the present season's constellation and then the next season's constellation just before dawn.

After each student has completed the activity, discuss the changes that were observed in the night sky and why the night sky actually changes. If they question that the sky is changing every night, you can agree with them since the earth's revolution around the sun at the rate of about one degree , makes it difficult to notice any change over a few days if the hour of observation remains the same.

The students may make a diagram to represent their observations (see diagram b).



(diagram b.)

ACTIVITY 2

Have the students complete the following paragraph and discuss their answers.

In one day the earth takes____hours to rotate. During this time _____of the earth is in sunlight and half of the earth is in_________ . If you are on the half of the earth that is facing away from the sun it is_______time and if it is a cloudless night, you will see thousands of_______ . Some of these stars may appear to form figures called_________ . When you face the sun it will be______time and you will not see any________ except the sun.

As the earth rotates, it revolves around the sun once in about______days. Once around the sun by the earth is called a___________ and this is divided into four_______ . The half of the earth facing away from the sun will be having ______time and you will see different constellations during each season because the earth is ________around the sun and during each season we look out at night towards another part of space.

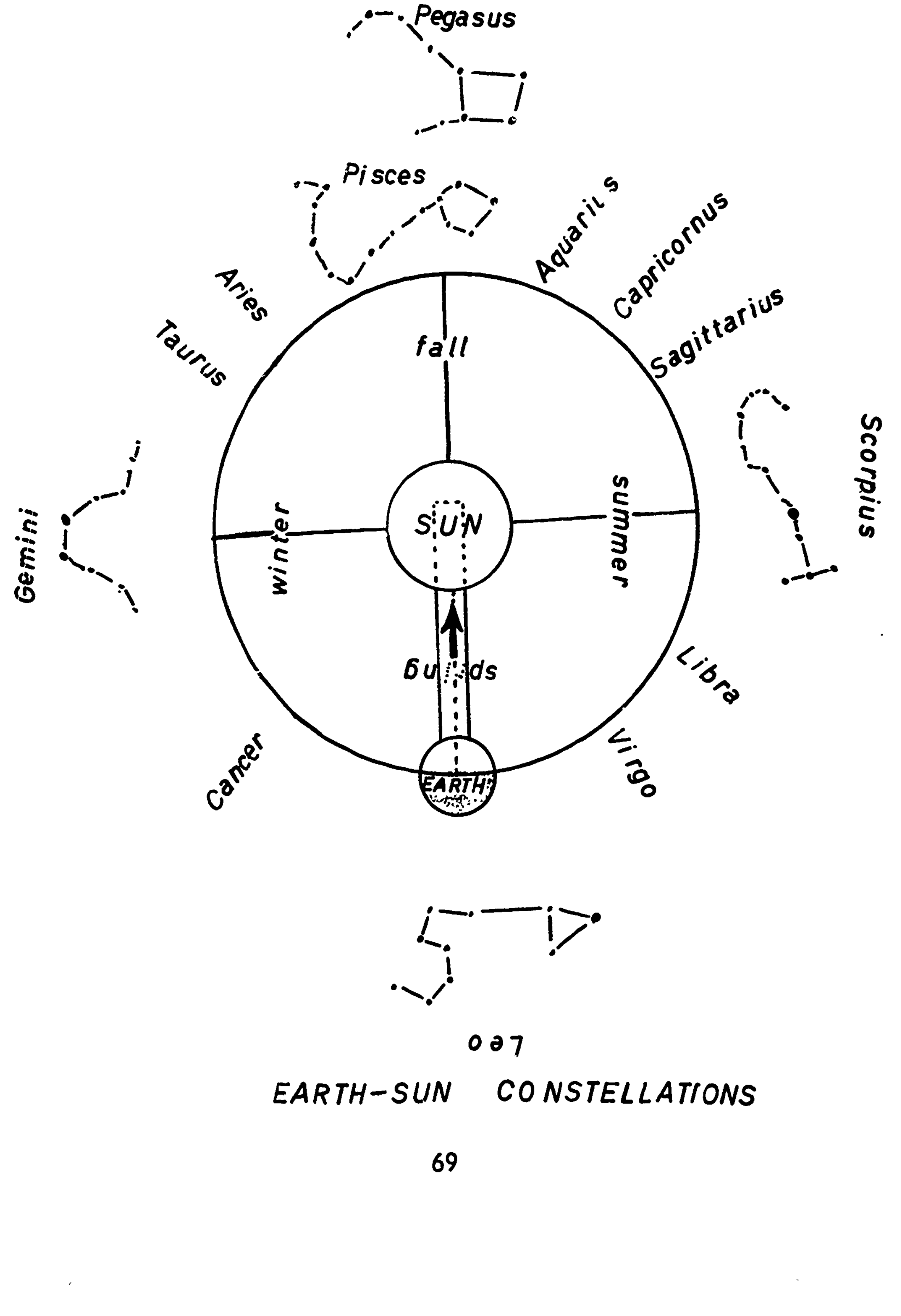
EVALUATION: Asked to describe the cause of changes in the night sky throughout the course of a year, the student should base his description on the changing position of the earth in relationship to the sun and stars.

OBJECTIVE 4. The student should be able to infer from a model that the sun appears to move against a background of stars as seen from the earth during the course of a year.

ACTIVITY

Materials: posterboard or oak tag, paper fasteners

Have the students work in groups to construct one model for each group using the following instructions. Draw a circle with a 7'' radius in the center of a 16'' x 16'' piece of posterboard. From another piece of posterboard, cut out a circle with a 2'' radius to represent the sun, a circle with a ½'' radius to represent the earth, and a strip 1'' x 7''. At one end of the strip, attach the ''sun'' and at the other end attach the ''earth''. Fasten the center of the sun to the center of the circle on the 16'' x 16'' paper using a paper fastener. Shade the half of the earth on the opposite side from the sun. Divide the large circle (the earth's orbit) into quarters labeling the quarters spring, summer, fall and winter on the dividing lines. Place the following constellations outside the earth's orbit: Leo (at Spring), Scorpius (at Summer), Pisces and Pegasus (at Fall), and Gemini (at Winter). You may want to place all 12 of the zodiac constellations around the circle.



EARTH-SUN CONSTELLATIONS

With the students using the model they constructed, have them answer the following questions:

a. Move the earth to the part of the diagram labeled summer. Imagine you are on the small circle that represents the earth, what constellation does the dark side of the earth face? (Scorpius.)

b. What constellation is visible in the summer night sky? (Scorpius)

c. With the earth at summer, look towards and past the sun. In what constellation would the sun appear to be? (Gemini.)

d. Revolve the earth to fall. What constellations are visible at night? (Pegasus and Pisces.)

e. With the earth in the fall position look towards the sun. In what constellation would the sun appear to be? (Leo.)

f. Revolve the earth to the winter position. What constellation is visible in the night sky? (Gemini.)

g. With the earth in the winter position look towards the sun. In what constellation does the sun appear to be? (Scorpius.)

h. Revolve the earth to the spring position. What constellation is visible in the night sky? (Leo.)

i. With the earth in the spring position look towards the sun. In what constellation does the sun appear to be? (Pisces, Pegasus.)

j. Hold the model at eye level and revolve the earth slowly around the sun and look towards the sun from the earth. Does the sun appear to move through the constellations ? (Yes.)

k. What causes this apparent motion of the sun? (The earth's revolving around the sun.)

EVALUATION: Given a model of the earth-sun-zodiac, the student should describe the various backgrounds against which the sun appears.

ERIC

OBJECTIVE 5. The student should be able to name a constellation, describe its mythological background and identify the bright star(s) found in it.

ACTIVITY 1

Materials: overhead projector, construction paper, crayons, books on mythology, star maps, (optional).

Have each student select a constellation from the list below and make a report on the mythological background of their constellation.

Polar	Winter	Summer
Ursa Major and Minor	Orion	Cygnus
Cassiopeia	Canis Major and Minor	Lyra
	Taurus (Pleides)	Aquila
	Gemini	Scorpius
	Augiga	

Fall	Spring
Pegasus	Leo
Andromeda	Bootes
Perseus	Virgo

Using star maps or reference materials, have the students identify the brightest appearing star in each constellation studied in mythology. (Do not list any for the fall sky as none stand out in brightness. Also, although Polaris is not a bright star include it because it is our north star.)

Ursa Minor - Polaris - 1st star in handle of Little Dipper
Orion - Rigel and Betelgeuse
Canis Major - Sirius
Canis Minor - Procyon
Taurus - Aldebaran
Gemini - Castor and Pollux
Auriga - Capella
Leo - Regulus
Bootes - Arcturus
Virgo - Spica

Cygnus - Deneb
Lyra - Vega
Aquila - Altair
Scorpius - Antares

ACTIVITY 2

Print the name of each constellation and each bright star on separate cards. Place the constellation names on the bulletin board and the star names in a box. Using two teams have a race to see which team can match the constellations and stars awarding each correct match with one point as the match is made. The team with the most points is the winner.

ACTIVITY 3

Have the students draw each constellation on a separate sheet of construction paper and punch small holes for the stars. Place the paper on the overhead and project the constellation on the wall. Using a pointer, have the students identify and name the important star(s) in the constellation.

ACTIVITY 4

Construct flash cards of the constellations circling the bright star(s). Write the name of the constellation and star(s) on the back of the card; (see diagrams a and b).

ERIC

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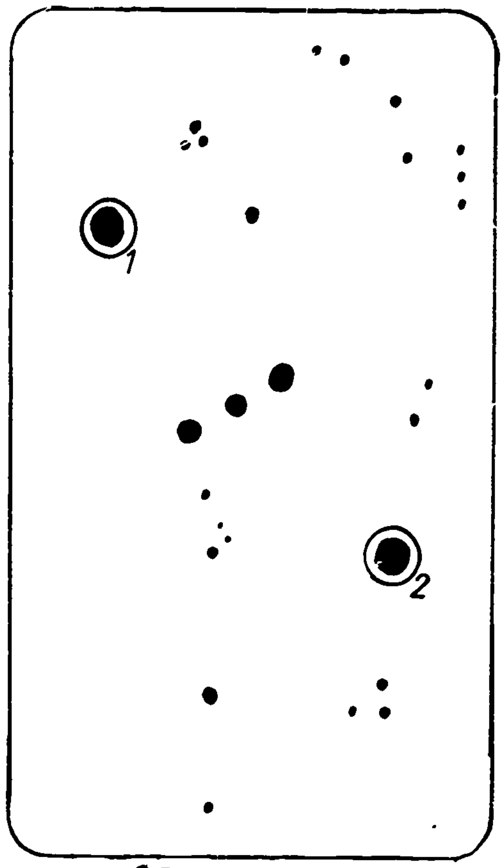
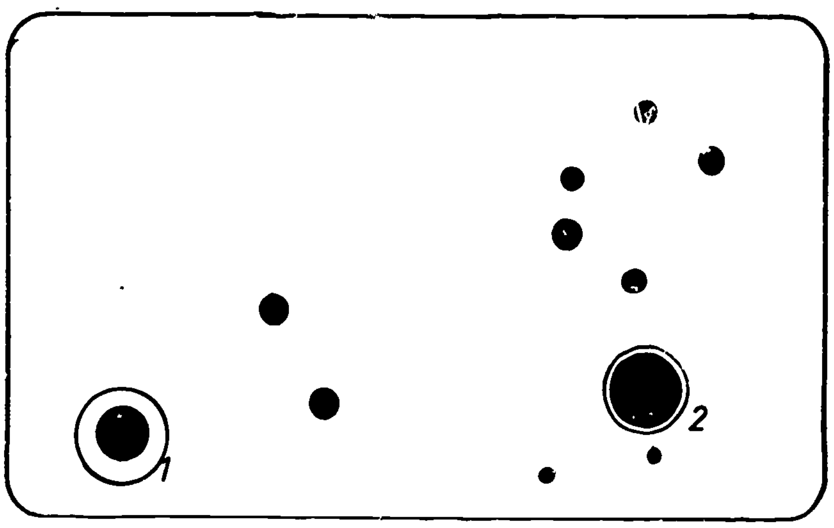


(diagram a.)

ORION
1. Betelgeuse
2. Rigel



(diagram b.)

LEO
1. Denebola
2 Regulus

As a student (or teacher) tells the mythological story of a constellation the class (or individuals) should identify the appropriate constellation.

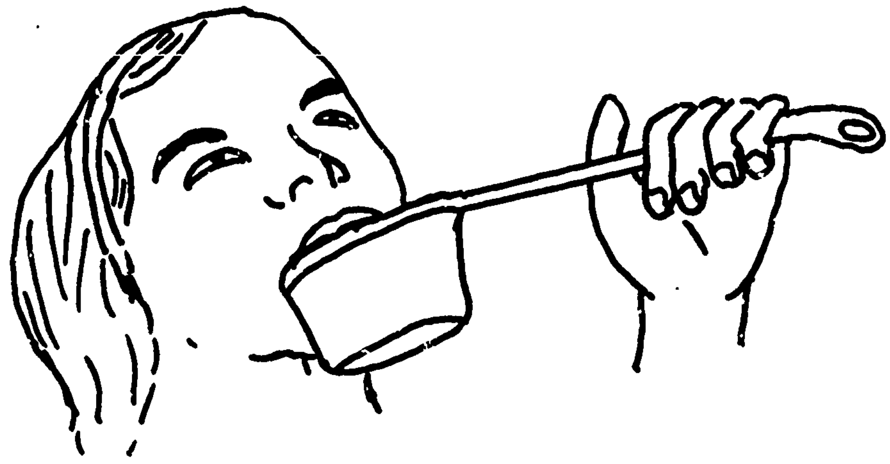
EVALUATION: Given a set of flashcards of the constellations, the student should select one, name it, identify the bright stars and briefly tell the mythological story related to the constellation

OBJECTIVE 6. The student should be able to identify Polaris as the pole star.

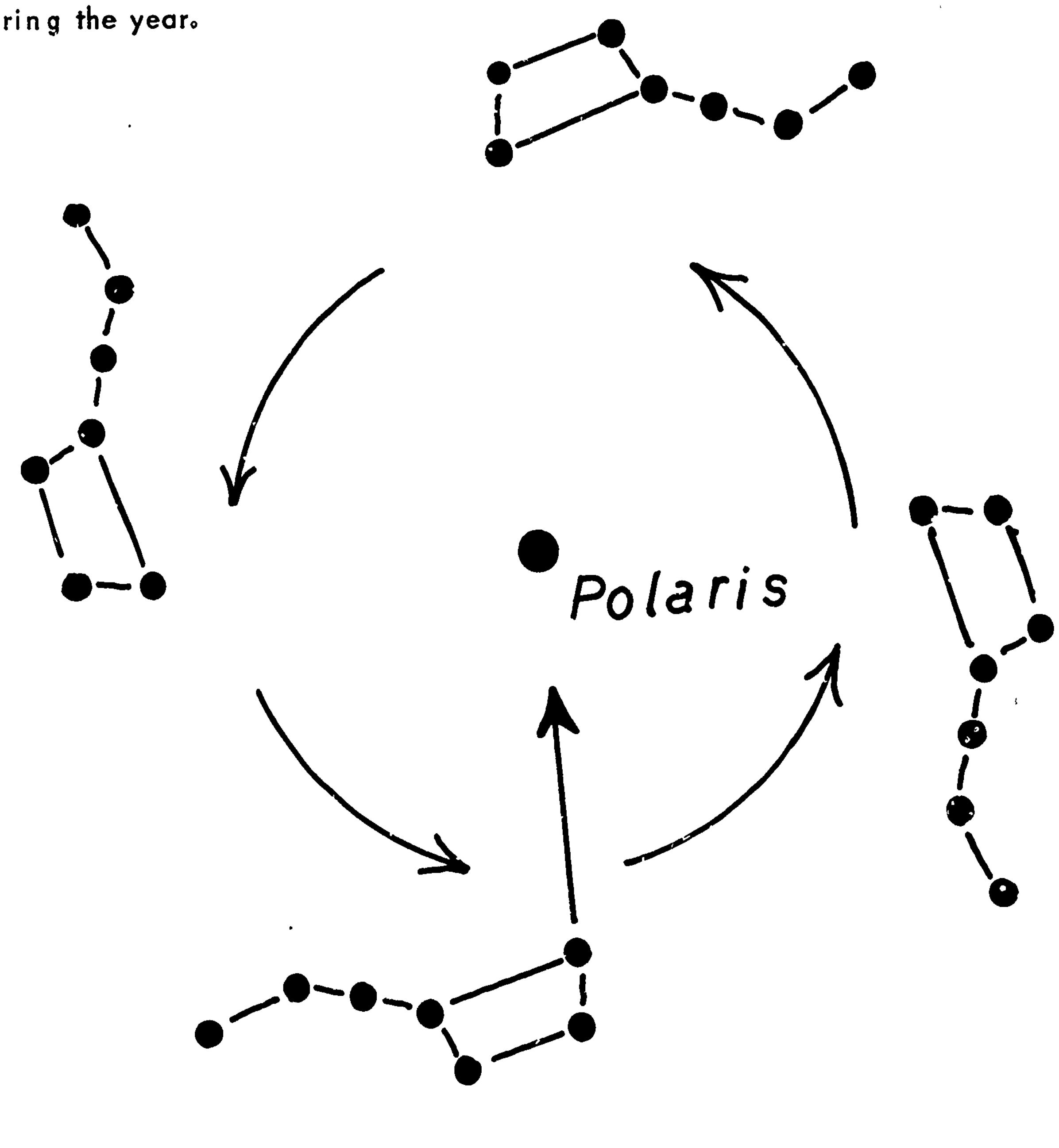
ACTIVITY 1

Materials: dipper (or picture of one), overhead projector, acetate, felt marker

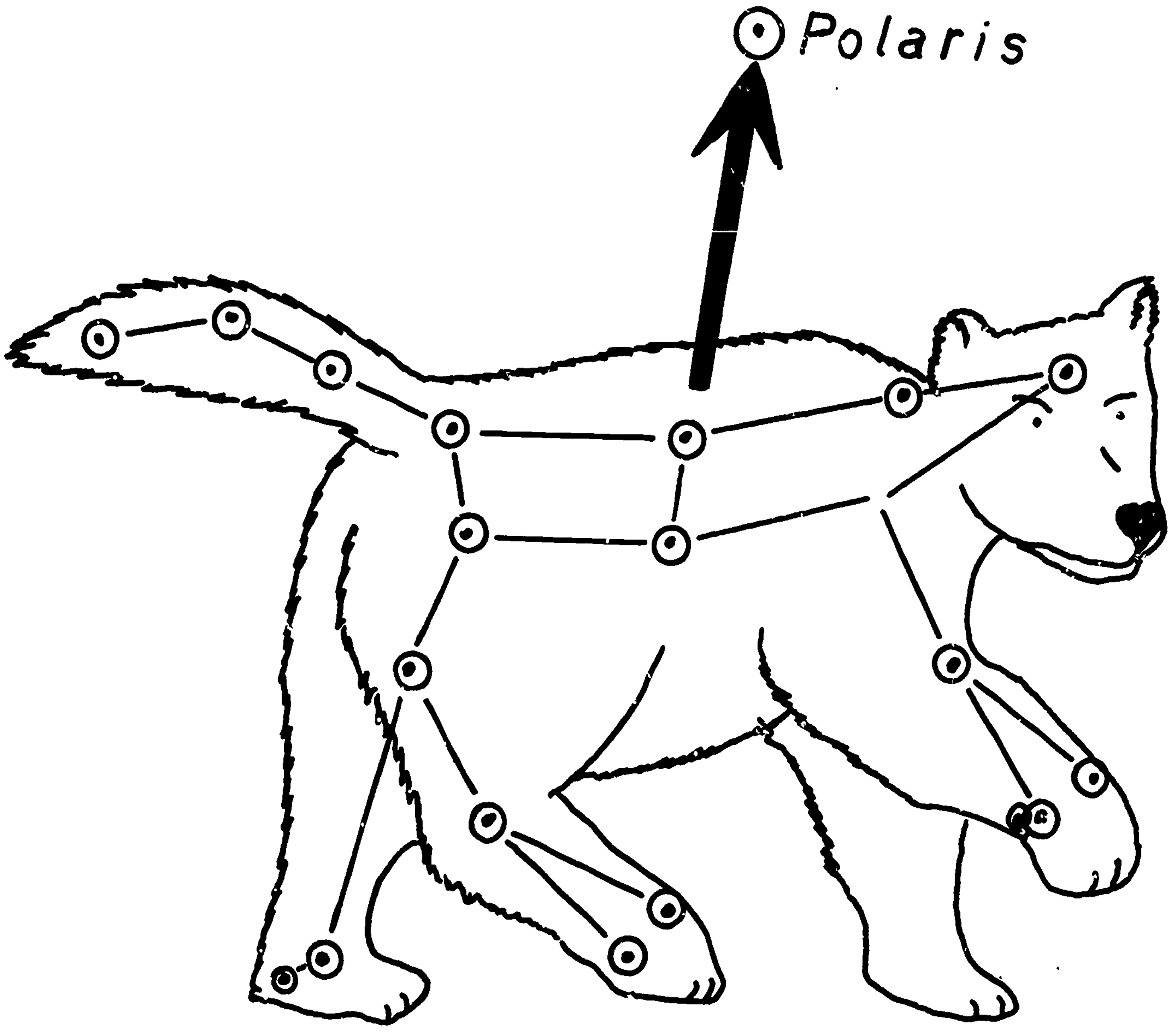
Show the students a dipper or a picture of a dipper and explain that people used dippers to drink from and that part of the shape of the constellation Ursa Major (Big Bear) resembles a dipper.



Make a transparency for the overhead projector showing the dipper and Polaris. Use the transparency to show the two stars that are the "pointer" stars used to locate Polaris (North Star) the star located almost directly over the north pole. Rotate the transparency counter-clockwise around Polaris demonstrating the changes of position of the constellation during the year.



Make another transparency showing Ursa Major and point out the Big Dipper. Give the students the assignment of locating Polaris in the night sky.



ACTIVITY 2

When it appears that it will be a clear evening, give the students this assignment. After sunset, identify the North Star and note its position in the sky. Then select a star that is nearly overhead and note its position. Finally, select a third star that is near the horizon (east or west) and note its position in relation to a tree or other landmark. An hour later, return to the same spot, observe the same three stars and record any change in position on the chart. Repeat this again in another hour.

The next day, compare the observations. Polaris should not have changed position. The overhead star selected should have moved westward. The horizon star should have disappeared if on the western horizon and should have risen higher in the sky if on the eastern horizon. The students may infer that the North Star and stars near it do not set while other stars both rise and set.

FIRST OBSERVATION	RECORD OF OBSERVATIONS ONE HOUR LATER	TWO HOURS LATER
POLARIS		
STAR OVER HEAD (ZENITH)		
STAR NEAR HORIZON (STATE WHETHER EAST OR WEST HORIZON)		

EVALUATION: Given a star chart, the student should identify Polaris and describe the motion of the Big Dipper in relation to it.

MAN IN SPACE

a program for all science students

This program begins with a barrage of images which fill the giant planetarium dome. These illustrations and photos all have to do with man's exploration of his environment. As a typical Cape Kennedy count-down echos through the Star Theatre, the pictures fade from view and the stars appear, leading us to a discussion of the expansion of man's environment from the earth to the sky. The projects which have and will carry man into space are next visualized as we see the relative sizes of the Mercury, Gemini and Apollo rockets and space capsules. These are contrasted with the size of Rochester's own Xerox Tower. An animated effect is used to review the exact sequence of events in Project Apollo to get man to the moon and return him safely to earth. We are then hurled through space to the moon's surface to watch the exciting landing of the first men on the moon in the Lunar Module. The role of spaceprobes in gathering information which allows man to leave the earth and venture into space is next explored. We look specifically at the ways Ranger, Surveyor and Orbiter make Project Apollo possible. The next steps beyond the moon are the planets which are already being explored by our Mariner probes. The hundreds of man-made satellites which whiz around the earth are then typified by looking at the application satellite, Nimbus, which, is saving lives and dollars as it gathers and transmits weather information. Our earth's slow rotation brings the sun into view and serves as our cue to look at the research satellite, Orbiting Solar Observatory, which studies the sun. As we journey to Cape Kennedy to watch a rocket blast off, we return to the opening theme of man's unceasing exploration of his environment.

OBJECTIVES: Man in Space

The student should be able to:

1. infer that when a force is exerted in a given direction, resulting motion will be in the opposite direction.

2. identify the stages of a rocket and their function.

3. identify Robert H. Goddard as the inventor of the liquid-fuel rocket.

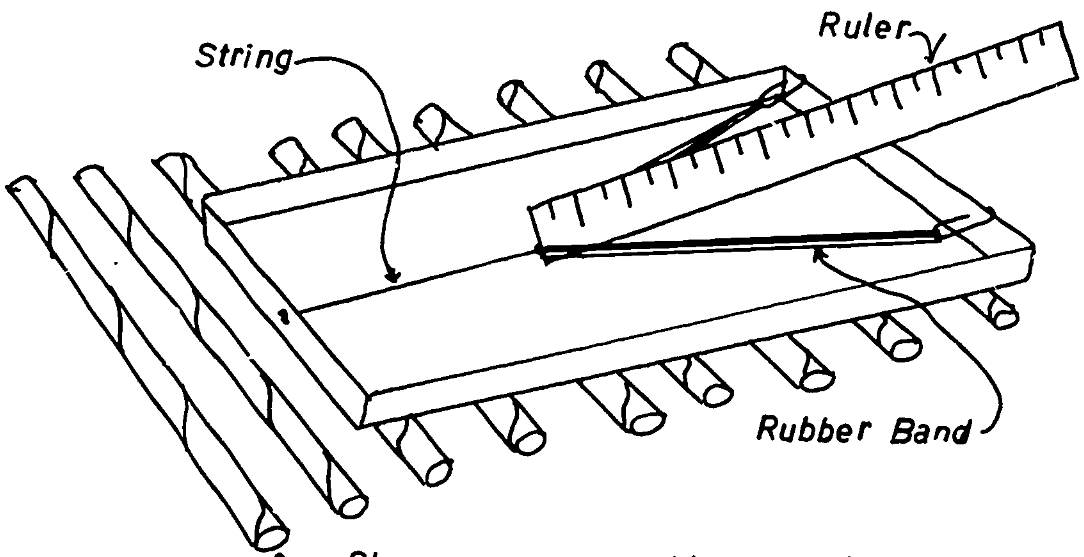
4. describe the major space projects and their contributions to the field of space exploration.

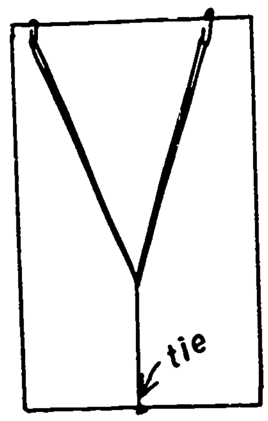
OBJECTIVE 1. The student should be able to infer that when a force is exerted in a given direction, resulting motion will be in the opposite direction.

ACTIVITY 1

Materials: shoebox cover, 2 paper clips, large rubber band, string, ruler, 20 straws (each group of students should have a complete set of materials)

With the students working in small groups, have them hook a paper clip through a corner of the shoebox cove r and loop the rubber band through it. Similarily, hook another paper clip through the corner which is closest to the one where they placed the original clip and loop the same rubber band through it. Make a small hole in the center of the end of the cover opposite the paper clips. Place a piece of string through the hole and tie a knot on the end outside the cover thereby making it impossible to pull it back through the hole. Stretch the rubber band ¾ of the way down the cover and hold it in that position by tying it with the end of the string (see diagram a). Place one end of a ruler in the V formed by the rubber band, resting the other end of it on the box cover.





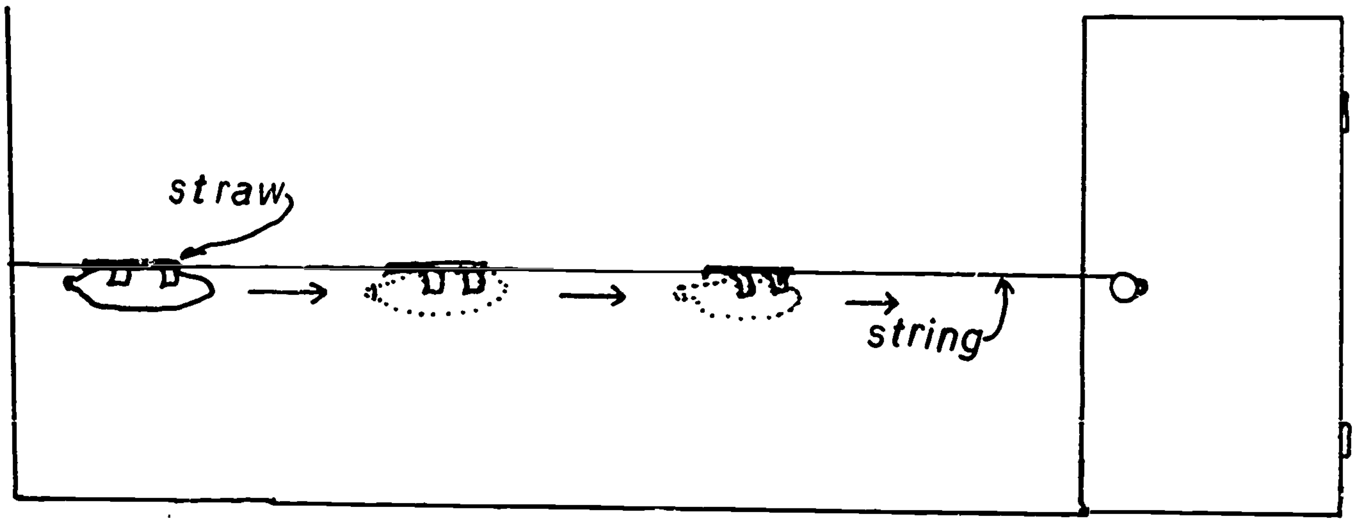
(diagram a.)

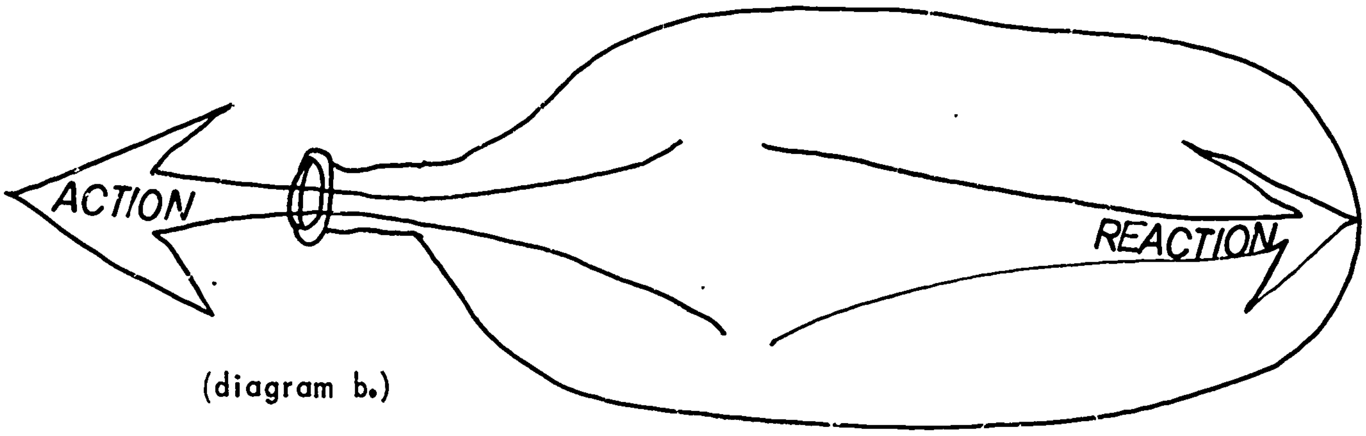
Place twenty straws side by side with about 1'' between each one. Carefully place the cover on one end of the row of straws so the knotted string points toward the rest of the straws in the row. Cut the string and observe the motion of the ruler and cover. The teacher should identify the ''action'' as the motion of the ruler and have the students identify the ''reaction'' (the motion of the cover in the opposite direction).

ACTIVITY 2

Materials: string or thread, balloons, straws, tape

Place a string through a straw and stretch the string fastening the ends of it to opposite sides of the room so the straw can slide the length of the string easily. Place the straw at one end of the string. Inflate a balloon and tape it to the straw so the open end of the balloon is facing the wall. (see diagram b).





(diagram b.)

Release the end of the inflated balloon. Discuss the resulting motions in terms of the air in the balloon pushing outwards in all directions on the balloon. Releasing the balloon allows the air pushing on that part of the balloon to escape leaving the air pushing on the opposite section of the balloon to push the balloon in that direction. This can be explained as an action-reaction within the balloon or as an unbalanced force within the balloon. Relate this to what happens in a rocket.

The students may want to have balloon rocket races in which they vary the size and shape of the balloons and the length of the straws.

EVALUATION: Given a movable object such as a cart, pair of roller skates or scooter, the student should demonstrate the existance of a backward push which makes him move forward.

Given several balloons of different sizes, the student should select the one which would most likely move the straw from activity 2, the greatest distance and he should describe one factor that would effect the distance the selected balloon would travel. (largest balloon, amount of air in balloon affects distance)

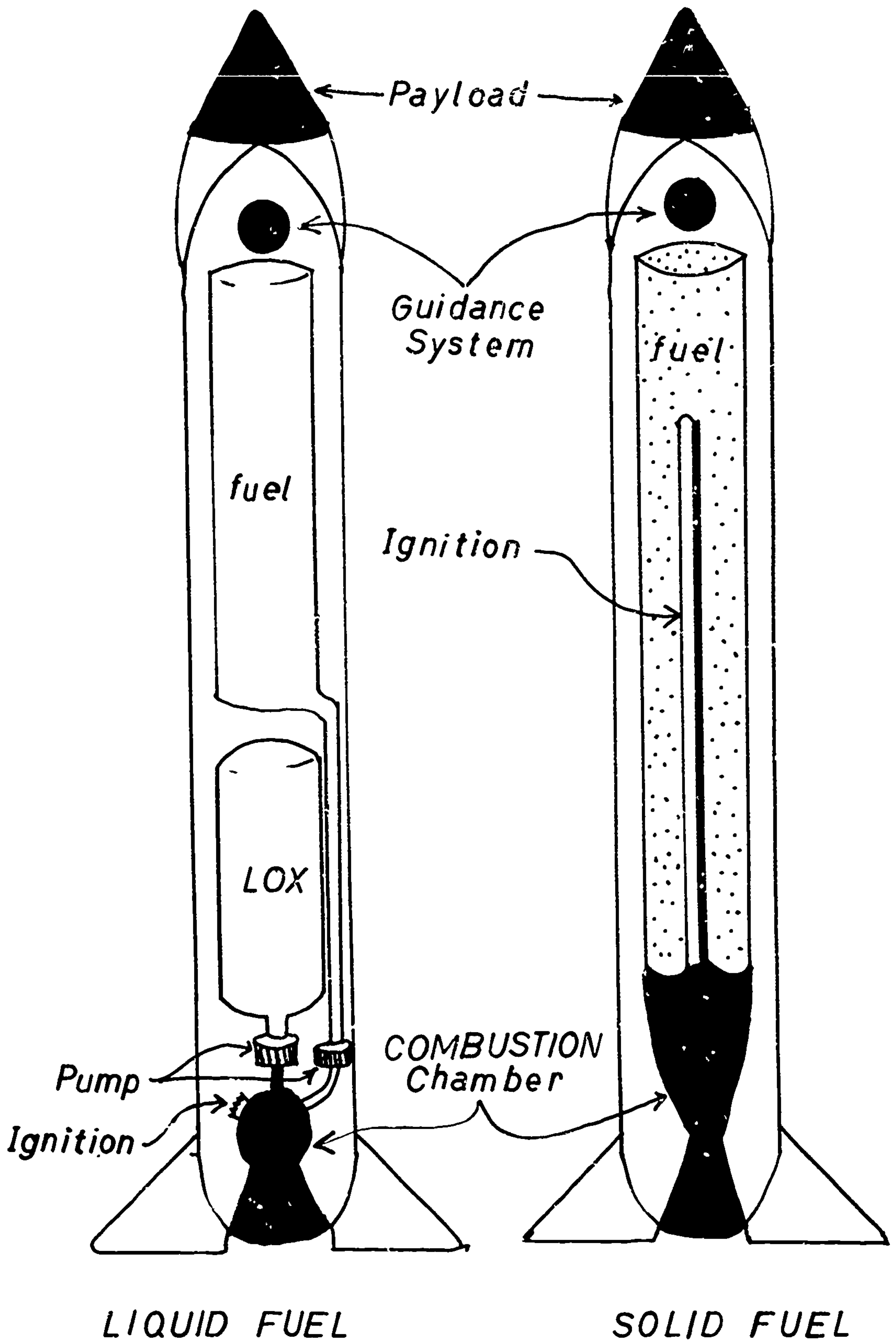
(At this point the teacher should review or do the activities from All About the Planets, Objective 6, dealing with the forces necessary to keep an object in orbit.)

OBJECTIVE 2. The student should be able to identify the stages of a rocket and their function.

ACTIVITY

Materials: reference books, paper, crayons

Have the students collect and discuss pictures of several kinds of rockets. They may make their own diagrams of these rockets and label them.



ROCKETS

EVALUATION: Given a diagram of a 3 stage rocket, the student should describe the function of each stage.

OBJECTIVE 3. The student should be able to identify Robert H. Goddard as the inventor of the liquid-fuel rocket.

ACTIVITY

Materials: resource materials

Using resource materials have the students investigate who Robert H. Goddard was and the role he played in modern rocketry. Discuss their findings in relationship to his work and the era in which he worked. In the lower grades, the teacher may prefer to read a story to the class about Goddard.

Some information appears below which may be of help to you.

Records show that some form of solid-fuel rockets have been in existence since at least 800 B.C. Rockets were used by the Chinese to celebrate holidays and have been used in warfare since the 1700's.

The man given credit for modern rocketry is an American physics professor, Robert H. Goddard, who in 1926 successfully fired a liquid-fuel rocket at Auburn, Massachusetts. He refined his rockets by adding a guidance system and an automatic parachute system to bring recording instruments back to earth safely. He also developed the principle of the multi-stage rocket.

EVALUATION: Given the name of Robert H. Goddard, the student should identify his contribution to modern rocketry.

ERIC

OBJECTIVE 4. The student should be able to describe the major space projects and their contributions to the field of space exploration.

ACTIVITY

Materials: resource materials

In the lower grades, the teacher may want to have the students make a booklet on satellites, space probes and manned flights. Since the reading level of much of the resource material may be beyond the students, the contents may consist of student interpretations of information which the teacher may read aloud about such series as Tiros, Surveyor or Gemini. Students may illustrate their materials through drawings or pictures which they cut from magazines.

For the upper grades, the teacher may prefer to have groups of students research various aspects of the space program. Their findings could then be shared with the class through group presentations complimented by models, bulletin boards or dittoed material.

EVALUATION: Given the names Tiros, Surveyor, Mercury, Gemini and Apollo, the student should describe the purpose of at least three of them.

Some information which may be of assistance to you on these topics follows.

MANNED SPACE FLIGHT

I. PROJECT MERCURY

The purpose of Project Mercury was to orbit a manned spacecraft, investigate man's reactions to and abilities in space flight, and recover both man and spacecraft.

With the exception of the loss of the Liberty Bell 7 which sank, all six missions of the Mercury Series achieved this purpose. The Mercury series began when Astronaut Alan B. Shepard, Jr. was propelled into suborbital flight on May 5, 1961. Each of the subsequent space shots was identical to the first in that all were in the same type of capsule, each carried one man, and the last four employed an Atlas D booster rocket (the first two used a Redstone).

The following chart gives the date, flight time, number of orbits, spacecraft name, astronaut, and significant remarks for all Mercury flights:

	Date	Flight Time (Hrs: Min: Sec:)	Revolutions	Spacecraft Name	Remarks
Project Mercury					
Alan B. Shepard, Jr.	5/5/61	00:15:22	Sub-orbital	Freedom 7	America's first manned space flight.
Virgil I. Grissom	7/21/61	00:15:37	Sub-orbital	Liberty Bell 7	Evaluated spacecraft functions.
John H. Glenn, Jr.	2/20/62	04:55:23	3	Friendship 7	America's first manned orbital space flight.
M. Scott Carpenter	5/24/62	04:56:05	3	Aurora 7	Initiated research experiments to further future space efforts.
Walter M. Shirra, Jr.	10/3/62	09:13:11	6	Sigma 7	Developed techniques and procedures applicable to extended time in space.
L. Gordon Cooper, Jr.	5/15-16/63	34:19:49	22	Faith 7	Met the final objective of the Mercury program-spending one day in space.

II. PROJECT GEMINI

The two-man orbital program known as the Gemini Project was designed to demonstrate that man can: maneuver his craft in space; leave his craft, survive, and do useful work in space; function effectively during prolonged space flights, rendezvous and dock his craft with another vehicle and control his spacecraft during re-entry and descent.

Gemini differed from the Mercury series in the following ways: a larger (two-man) capsule, a more powerful booster rocket (Titan II), and more time in space.

The following chart gives the astronaut's names, date, flight time, number of orbits, flight number, and significance of each Gemini flight.

Project Gemini

Virgil I. Grissom John W. Young	3/23/65	04:52:31	3	Gemini-III	America's first two-man space flight.
James A. Mc Divitt Edward H. White, II	6/3-7/65	97:56:12	62	Gemini-IV	First "walk in space" by an American astronaut. First extensive maneuver of spacecraft by pilot.
L. Gordon Cooper, Jr. Charles Conrad, Jr.	8/21-29/65	190:55:14	120	Gemini-V	Eight day flight proved man's capacity for sustained functioning in space environment.
Frank Borman James A. Lovell, Jr.	12/4-18/65	330:35:01	206	Gemini-VII	World's longest manned orbital flight.
Walter M. Shirra, Jr. Thomas P. Stafford	12/15-16/65	25:51:24	16	Gemini-VI-A	World's first successful space rendezvous.
Neil A. Armstrong David R. Scott	3/16-17/66	10:41:26	6.5	Gemini-VIII	First docking of two vehicles in space.
Thomas P. Stafford Eugene A. Carnan	6/3-6/66	72:20:50	45	Gemini-IX-A	Three rendezvous of a spacecraft and a target vehicle. Extravehicular exercise-2 hours 7 minutes.
John W. Young Michael Collins	7/18-21/66	70:46:39	43	Gemini-X	First use of target vehicle as source of propellant power after docking. New altitude record-475 miles.
Charles Conrad, Jr. Richard F. Gordon, Jr.	9/12-15/66	71:17:08	44	Gemini-XI	First rendezvous and docking in initial orbit. First multiple docking in space. First formation flight of two space vehicles joined by a tether. Highest manned orbit-apogee about 853 miles.
James A. Lovell, Jr. Edwin E. Aldrin, Jr.	11/11-15/66	94:34:31	59	Gemini-XII	Astronaut walked and worked outside of orbiting spacecraft for more than 5½ hours-a record proving that a properly equipped and prepared man can function effectively outside of his space vehicle. First photograph of a solar eclipse from space.

III. PROJECT APOLLO

The knowledge gained from Mercury and Gemini, the wealth of information gleaned from Mariner, Orbiter, and Surveyor, and intensive technological developments are all part of Project Apollo. This project will advance space technology and, in the process, land American explorers on the moon and bring them safely back to earth.

IV. RUSSIAN MANNED FLIGHT

The Soviet space program employs three main bases: Plesetsk, Kap Yar and Tyuratam. The manned flight vehicles have all been launched from Tyuratam. The chart below contains the available pertinent information on the manned flights of the Vostok and Voskhod series.

Name of Ship	Cosmonaut(s)	Launch Date	No. of Orbits
Vostok 1	Yuri Gagarin	April 12, 1961	1
Vostok 2	Geherman Titov	August 6, 1961	17
Vostok 3	A. Nikolayev	August 11, 1962	64
Vostok 4	P. Popovich	August 12, 1962	48
Vostok 5	V. Bykovsky	June 14, 1963	81
Vostok 6	V. Tereshkova	June 16, 1963	48
Voskhod 1	V. Komarov K. Feokistov B. Yegorov	October, 1964	16
Voskhod 2	P. Belyayev A. Leonov	March 18, 1965 (spent 10 min. outside vehicle)	17

SATELLITES

1. Research Satellites

A. SPUTNIK 1 - Oct. 4, 1967 - 1st Artifical satellite of the earth (USSR)

B. SPUTNIK 2 - Nov.,1957 - carried dog named Laika (USSR).

C. EXPLORER 1 - 1st U.S. satellite: discovered the Van Allen radiation belts: launched Jan. 31, 1958.

D. VANGUARD 1 - showed that the earth is pear-shaped: launched March,1958.

E. EXPLORER VI - mapped the Van Allen radiation belts; launched August, 1959.

F. EXPLORER XII - explored space between 180 to 47,800 miles from the earth; launched August 1961.

G. EXPLORER XVII - 1st satelilte to study atmospheric temperature, density, and composition.

H. EXPLORERS XXVI, XXVII, & XXIX - used to gain information on gravity, shape of earth, and to map the earth; 1964-1965.

I. PAGEOS - a geodetic observation satellite

J. OSO I / OSO II > Orbiting Solar Observatory < March ,1962 / February, 1965

K. COSMOS 1 - 5 - March,1962 through May,1962 - conducted investigation of radiation belts and cosmic rays (USSR)

L. COSMOS 6 - 198 - June 1962 through Dec.,1967 - payloads not announced (USSR)

M. ANNA - carried flashing light for mapping purposes; launched October,1962.

N. POLYGOT I - Nov.,1963 - space craft with extensive manuvering capability
POLYGOT II - April,1964 - carried out manuevers in orbit (USSR)

O. ELECTRON I / ELECTRON II } Jan.,1964 - 1st dual Soviet launch { study inner Van Allen radiation belt / study outer Van Allen radiation belt (USSR)

P. OGO I / OGO II > Orbiting Geophysical Observatory < September, 1964 / October, 1965

Q. PEGASUS I / PEGASUS II > For study of micrometerorites < Feb., 1965 / May, 1965

R. PROTON I / PROTON II / PROTON III — Orbiting Physics Labs (USSR) — July, 1965 / November, 1965 / July, 1966

S. INTERNATIONAL RESEARCH SATELLITES

1. ARIEL I / ARIEL II > Study upper atmosphere < April ,1962 / March, 1964 British

2. ALOUETTE I / ALOUETTE II > Studied ionosphere < Sept., 1962 / Nov., 1965 Canadian

3. SAN MARCO - studied atmosphere; launched Dec., 1964; Italian

4. FR-1A - studied the ionosphere to improve radio communication; launched Dec.,1965; French.

II. Application Satellites

A. COMMUNICATION

1. PROJECT SCORE - 1st voice broadcast from space; launched Dec. 18, 1958.

2. ECHO I - 1st passive communication satellite; launched August,1960.

3. COURIER - 1st active communication satellite; launched October ,1960.

4. OSCAR I - broadcasted practice signals for amateur radio operators; launched December, 1961.

5. TELSTAR I - 1st satellite to relay television programs between U.S. and Europe; launched July, 1962.

6. RELAY I - an active relay for radio, telephone, and television; launched December, 1962.

7. TELSTAR II - (similar to item 5) launched May, 1963.

8. WEST FORD - orbiting ring of millions of tiny wires which reflect radio signals; launched May, 1963.

9. SYNCOM II - 1st synchronous satellite; launched July,1963.

10. RELAY II - (same as item 6); launched January, 1964.

11. ECHO II - passive communication satellite; launched January,1964.

12. SYNCOM III - (similar to item 9); launched Aug., 1964

13. EARLY BIRD - 1st commercial communication satellite; launched April, 1965.

14. MOLNIYA 1A (April, 1965), 2A (Oct., 1965), 1C (April, 1966), 1D (Oct.,1966) 1E (May, 1967), IF and 16 (Oct., 1967) - 1st Soviet Communications Satellite

B. METEOROLOGICAL

1. VANGUARD II -first to send weather information back to earth; launched February, 1959.

2. TIROS I - 1st satellite to take detailed pictures of weather; launched April,1960.

3. TIROS II - transmitted weather pictures and measured infrared radiation from the earth; launched Nov.,1960.

4. TIROS III - discovered Hurricane Esther in Atlantic; launched July,1961.

5. TIROS IV - photographed Gulf of St. Lawrence; launched February,1962.

6. TIROS V - mapped ice fields and tropical storms; launched June,1962.

7. TIROS VI - photographed weather over the flight path of Astronaut Walter Schirra; launched Sept.,1962.

8. TIROS VII - sent weather pictures and measured the temperature and density of electrons in space; launched June,1963.

9. TIROS VIII - carried special camera system that transmitted cloud pictures automatically; launched Dec.,1963.

10. NIMBUS I - meteorological space laboratory to continue and expand the TIROS series it replaced; launched Aug., 1964

11. ESSA I, ESSA II, ESSA III - Environmental Survey Satellite - part of meteorological system of weather bureau. (Feb., 1966; Feb., 1966; Oct., 1966)

C. NAVIGATION

1. TRANSIT IB - 1st navigational satellite; launched April 13, 1960.

2. TRANSIT IIA - carried Canadian-built instruments to measure radio interference in space; launched June, 1960.

3. TRANSIT IIIB - 1st satellite to broadcast precise information on its own position; launched Feb.,1961.

4. TRANSIT IVA - 1st satellite to carry a nuclear power souce; launched June,1961.

5. TRANSIT IVB - tested a method of using earth's gravity to keep satellites in proper position; launched Nov., 1961.

SPACE PROBES

1. Programs

A. LUNAR ORBITER - used to gather information needed for eventual manned landing on the Moon. Lunar Orbiters I and II were launched late in 1966. Both orbited the moon and returned close-up photos of the surface as well as other information.

B. LUNA SERIES - USSR - used to gather information about the moon leading to manned landing on the surface. Series started in Jan., 1959 and consisted of 13 launchings, ending in late 1966. Resulted in first photos of the back side of the moon.

C. RANGER - to gain information on surface features, of the moon, needed for manned landings. Rangers I through IX photographed the moon while making hard landings during 1961 to 1965.

D. SURVEYOR - to land and transmit data on environment and surface material of moon. Surveyors I, II, and III executed soft landings to examine the surface and return information during 1966 to 1968.

E. MARINER - designed to fly in the vicinities of and send information about Venus and Mars. Mariners II and IV added much information about solar radiation and micrometeorites in space during 1962 to 1968.

F. PIONEER - long-distance space probes to gather information about the space between Earth and Venus and between Earth and Mars. The program has been in operation from 1960 to 1968.

G. VENUS - probe to Venus with Venus 4 landing on surface. (USSR)

H. ZOND - series of 3 probes the first two of which were unsuccessful and the results of the third are incomplete.(USSR)

I. MARS - Mars probe which lost contact with the Earth en route. (USSR)

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AUDIO-VISUAL MATERIALS

SP - Available for preview at Strasenburgh Planetarium
ESSEC - Available for preview from Earth-Speace Education Center

FILMLOOPS - Ungraded

SP - Film Associates
11559 Santa Monica Blvd.
Los Angeles, California 90025

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140 West 51st Street
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Filmstrip Title - Man Studies the Sky - History of Astronomy and Tools of Astronomy.
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FILMS

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GLOSSARY

Organized by Strasenburgh Planetarium
School Program Title

SUN, MOON AND EARTH

1. cardinal points: the principle directions of a compass, N for north; E for east: S for south and W for west.
2. compass: a device for determining directions by means of a magnetic needle or group of needles turning freely on a pivotal and pointing to the magnetic north.
3. crescent moon: the moon at any stage between new moon and first quarter and between last quarter and the succeeding new moon when less than half of the illuminated hemisphere is visible.
4. day: the time of light between one night and the next.
5. diameter: the greatest distance through a circle or a sphere pasing through its center.
6. earth: the third planet from the sun, the planet upon which we live.
7. east: a cardinal point in the general direction of the rising sun.
8. full moon: the moon at the stage where it is on the opposite side of the earth from the sun and with all of its illuminated hemisphere visible.
9. gibbous moon: the moon at any stage between the 1st quarter moon and the full moon and again between the full moon and the last quarter phase when more than half but not the full illuminated hemisphere is visible.
10. moon: the natural satellite of the earth.
11. new moon: the moon at the stage where it is positioned between the earth and the sun so that none of its illuminated hemisphere is visible.
12. night: the time from dusk to dawn when no light of the sun is visible.
13. quarter moon: the phase of the moon when it has exactly half of its illuminated hemisphere visible.
14. reflector: a polished surface for reflecting light or other radiation.
15. rotation: the turning of a body as if on an axis.
16. scale model: an imitation made to a reduced or increased size.
17. source: a point of origin.
18. sun: the star (luminous celestial body) about which the earth and eight other planets revolve; the star of the Solar System.
19. sunrise: the apparent rising of the sun above the horizon.
20. sunset: the apparent setting of the sun below the horizon.
21. west: a cardinal point in the general direction of the setting sun.

ALL ABOUT PLANETS

1. aphelion: the point of an orbit most distant from the sun.
2. circle: a closed plane curve every point of which is equidistant from a fixed point within the curve.

3. Copernicus: the scientist that concluded that the earth rotates daily on its axis and the planets revolve in orbits round the sun.

4. data table: a list of factual information written in a systematic arrangement.

5. degree: a 360th part of the circumference of a circle.

6. density: amount of material per unit volume.

7. diameter: the greatest distance through a circle or a sphere.

8. earth: the third planet of the solar system upon which we live.

9. ellipse: a closed plane curve in which the sum of the distance from any point on the curve to two internal points (foci) is always the same; a conic section.

10. gravity: the attractive force exerted on a body by another body.

11. inertia: the property of resisting a change in velocity and direction.

12. Jovian: a collective term referring to the four largest planets of the solar system, Jupiter, Saturn, Uranus and Neptune.

13. Jupiter: the fifth planet from the sun and the largest planet of the solar system.

14. Mars: the red planet; the fourth planet from the sun.

15. mass: the amount of matter in a body.

16. Mercury: the smallest of the planets in the solar system, and the closest planet to the sun.

17. Neptune: the eighth planet from the sun.

18. orbit: a path described by one body in its revolution about another body.

19. perihelion: the point of an orbit nearest the sun.

20. perpendicular: being at right angles to a given line or plane.

21. planet: a "wanderer", one of the principal bodies in orbit around the sun.

22. plot: to locate a point by means of coordinates.

23. Pluto: the ninth planet from the sun.

24. position: the point or area occupies by a physical object.

25. Ptolemy: the geographer and astronomer of Alexandria about A.D. 130, who maintained that the earth is at the center of the universe, with the sun, moon and planets revolving around it.

26. retrograde motion: the apparent east to west motion of a planet or comet, opposite to its direct motion.

27. revolution: the motion of one body around another.

28. Saturn: the sixth planet from the sun, noted for its rings.

29. telescope: an instrument for observing objects at a distance either visually or by other means.

30. terrestrial: of or relating to the earth.

31. Uranus: the seventh planet from the sun.

32. velocity: time rate of linear motion in a given direction.

33. Venus: the second planet from the sun, entirely covered by clouds.

34. volume: bulk, space occupied, in cubic units.

EXPLORING THE UNIVERSE

1. astronomical unit: the mean distance from the sun to the earth (about 93 million miles), abbreviated A.U., used as a unit of distance.

2. Doppler effect: apparent change in wavelength or frequencey of light, sound or other radiation produced by a source moving toward or away from the observer.

3. dwarf star: small hot star of high density and low luminosity; lowest level of a main sequence star (do not confuse with white dwarf)

4. galactic star cluster: group of several dozen to several thousand stars having common origin and space motion and found near the galactic plane.

5. galaxy: a vast, usually disk-shaped assemblage of stars, gas and dust; comparable in size with the Milky Way; a system of millions or billions of stars held together by gravity.

6. giant star: highly luminous star hundreds of times larger than the sun and usually having a lower surface temperature.

7. globular star cluster: relatively compact group of stars (10,000 to several hundred thousand stars); distinguished for symmetry and star density, located outside of a galactic plane but inside the "halo".

8. Hubble's constant: factor of proportionality connecting velocities of recession of the galaxies with their distance; equal to about 15 miles per second per million light years; the farther away a body is from an observer, the faster it seems to recede.

9. hydrogen: the simplest and lightest of the element; the most common of all elements in space.

10. interstellar space: space between the stars.

11. Local Group: cluster of about 20 galaxies which includes, among others, our galaxy, the clouds of Magellan, M-31 in Andromeda, and M-33 in Triangulum.

12. luminosity of a star: the apparent magnitude of a star would have at a distance of 10 parsecs;32.4 light years; inherent brightness of a star in terms of the sun's brightness, as would be observed if the two were at the same distance from us.

13. main sequence: diagonal band on a temperature-luminosity graph on which most stars are found.

14. multiple star: two or more stars revolving about each other.

15. nebula: vast cloud of gas between stars; dark nebula also contain dust and obscure stars behind them.

16. planet: nonluminous body moving around a star in a nearly circular orbit, shining by reflected light.

17. quasar: the name of quasi-stellar radio sources. These are objects having the mass of perhaps a million ordinary stars and are located at the edge of the observable universe.

18. red shift: the shift of the dark lines in a spectrum towards the red due to Doppler effect.

19. spectroscope: instrument for viewing the spectra of light sources.

20. spectrum: diagram of electromagnetic energy spread out in sequence from long to short wave length (radio to x-rays).

21. star: a self-luminous gaseous celestrial body whose shape is usually spherical.

22. supergiant star: stars about 100 times brighter than giants.

23. universe: the largest known entity; the cosmos.

24. white dwarf; a star that has the same mass but much smaller diameter than a main sequence star.

MAN IN SPACE

1. action-reaction: the law of physics which states that for every action (force), there is an opposite and equal reaction (force).

2. application: a type of satellite; a satellite which gathers information for practical use.

3. combusion chamber: the area, in a rocket, in which fuel in converted into energy.

4. fuel: the material which is oxidized to produce energy.

5. Goddard: the father of modern rocketry; developed the liquid fuel rocket.

6. gravity; the attractive force exerted on a body by another body.

7. guidance system: the mechanical or electronic instruments which control the flight of a rocket.

8. inertia: the property of resisting a change in velocity and direction.

9. LOX: liquid oxygen.

10. manned flight: any space flight in which the rocket contains a human pilot.

11. orbit: a path described by one body in its revolution about another body.

12. oxidizer: the material used to assist combution of the fuel of a rocket to produce energy.

13. propulsion: the system which is responsible for moving the object of which it is a part.

14. research: a type of satellite; a satellite which gathers scientific data.

15. rocket: missile or vehicle that is propelled by the principle of action-reaction.

16. satellite: a body in orbit around another body.

17. space probe: an instrumented package launched to another body in space to gain information.

18. velocity: time rate of linear motion in a given direction.

SKY SCANNING

1. Big Dipper: a group of stars found in the constellation of Ursa Major that looks like a dipper, the pouring part of which is used to locate the star Polaris.

2. circumpolar stars: stars which appear never to go below the horizon.

3. comets: a small body moving around the sun in an orbit generally of high eccentricity. Comets generate an atmosphere (coma) and a tail as they come close to the sun.

4. constellation: an area of the sky.

5. day: the time of light between one night and the next.

6. horizon: the line where earth and sky appear to meet.

7. magnitude: the brightness of a celestial object as viewed from the earth.

8. meteor: an atmospheric phenomena caused by the rapid entry and vaporization of a solid body in the air.

9. moon: the natural satellite of the earth.

10. myth: a legend or story, usually one that appears to explain a natural phenomenon.

11. night: the time from dusk to dawn when no light of the sun is visible.

12. planet: a "wanderer", one of the principal bodies in orbit around the sun.

13. Polaris: the name of the earth's North pole star.

14. revolution: the motion of one body around another.

15. rotation: the turning of a body as if on an axis.

16. space: the region beyond the earth's atmosphere.

17. star: a self-luminous gaseous celestial body whose shape is usually spheroidal.

18. zenith: the point directly over one's head, altitude 90°.

LIST OF EQUIPMENT AND SUPPLIES BY PROGRAM

(items common to the classroom are not listed)

EARTH, SUN AND MOON
- package of common pins
- basketball
- marble
- beebe (or Kix cereal)
- mirror
- cardboard box
- tape measure
- magnetic compasses
- tennis ball

ALL ABOUT PLANETS
- ball (whiffle, ping pong or rubber)
- string
- empty thread spools
- compasses (drawing)
- tape measure
- protractor
- coat hangers
- styrofoam ball (1'' diameter)

EXPLORING THE UNIVERSE
- logarithmic graph paper (full log 2 x 2)
- electric buzzer
- insulated bell wire (12')
- 1½ volt dry cell (with terminals)
- prism
- spectroscopes (Macallister Scientific)
- chemicals (salt, baking soda, copper sulfate, borax, boric acid)

SKY SCANNING
- star maps (optional)
- constellation pictures (teacher or student made)

MAN IN SPACE
- balloons
- string
- straws
- shoe box covers