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ABSTRACT

GRADES OR AGES: Grades K-6. SUBJECT MATTER: Science; space. ORGANIZATION AND PHYSICAL APPEARANCE: The guide is divided into four units: 1) the sun, earth, and moon; 2) stars and planets; 3) exploring space; 4) man's existence in space. Each unit includes initiatory and developmental activities. There are also sections on evaluation, vocabulary, children's books, and films. The guide is mimeographed and spiral-bound with a soft cover. OBJECTIVES AND ACTIVITIES: Details of activities are given for each concept in the four units. Objectives involve an understanding of the concepts and of the results of the various experiments. INSTRUCTIONAL MATERIALS: Materials required for each activity are described. The extensive bibliography and film list are annotated. STUDENT ASSESSMENT: Samples of evaluation items are included to help the teacher develop an informal testing program. (MBM)

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RESOURCE HANDBOOK - SPACE BEYOND THE EARTH

(A supplement to Basic Curriculum Guide - Science)

Grades K - 6

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SCHOOL CITY OF GARY
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PREFACE

The teaching of science in the elementary school is a responsibility of major significance. Through our efforts pupils should be helped to gain an understanding of science in the development of our culture. Likewise, we should emphasize the development of the ability to write and recognize social uses of science in daily life. In developing the ability to understand their natural environment, the pupils must also have a complete understanding of the process involved.

There is a need to improve teaching and learning in science continuously. New materials of instruction, new teaching approaches, and the continuing responsibility to meet the individual needs of students place great demands on all professional staff members to appraise the quality of teaching and learning in science. This publication represents an effort on the part of staff members within our school system to assist all staff members in improving the teaching and learning in science. It is hoped that all staff members who use this publication will find it to be of value.

Norman R. Turchan
General Elementary Supervisor

A C K N O W L E D G M E N T S

I wish to express appreciation to the members of the Elementary Science Materials Committee for their extra effort in the preparation of this publication. The publication is a composite of materials which have been developed previously, combined with new material. Much of the material presented in this publication is the result of their intensive work and effort.

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THE SUN, EARTH AND MOON

Initiatory Activities

Have the children:

1. Discuss life on earth without the sun. Talk about plants, animals, temperature, light and the atmosphere.

2. Do research on sundials to answer such questions as: Who used them? What do sundials do?

3. Tell about their personal experiences with the heat of the sun: walking barefoot in the hot sand; being sunburned; being in the hot sun on a hot summer day. Draw a picture to go with each story.

4. Report on the spectroscope, an instrument that enables astronomers to analyze the composition of the sun and the stars; the spectrograph, a spectroscope that takes photographs; and the thermocouple, an instrument used to measure the temperature of a star.

5. Report on the work of Joseph Von Fraunhoter.

6. Report on work being done to more fully utilize the sun's radiant energy (solar cells, solar furnaces for homes).

7. Report on the beliefs of the early people who were sun worshippers; such as, the Romans, Greeks, Egyptians, Japanese, and American Indians.

8. Discuss and examine pictures of telling time by the sun.

Developmental Activities

CONCEPT - All objects occupy space.

1. Problem

   What is space?

   Materials

   Water, tubs, tanks or basins, widemouth jar, marbles, sand, alcohol or sugar, chart paper or butcher paper, string, crayons.

   Procedure

   Have a child fill a jar with water and put his fist in the jar. Let him discover that the water overflows because his hand takes up space. Point out that water was pushed out of space where his hand is now.

   Invert an "empty" jar in a tank of water. Does the water rise inside the jar? (No.) What occupies the space in the "empty" jar? (Air occupies the space.)

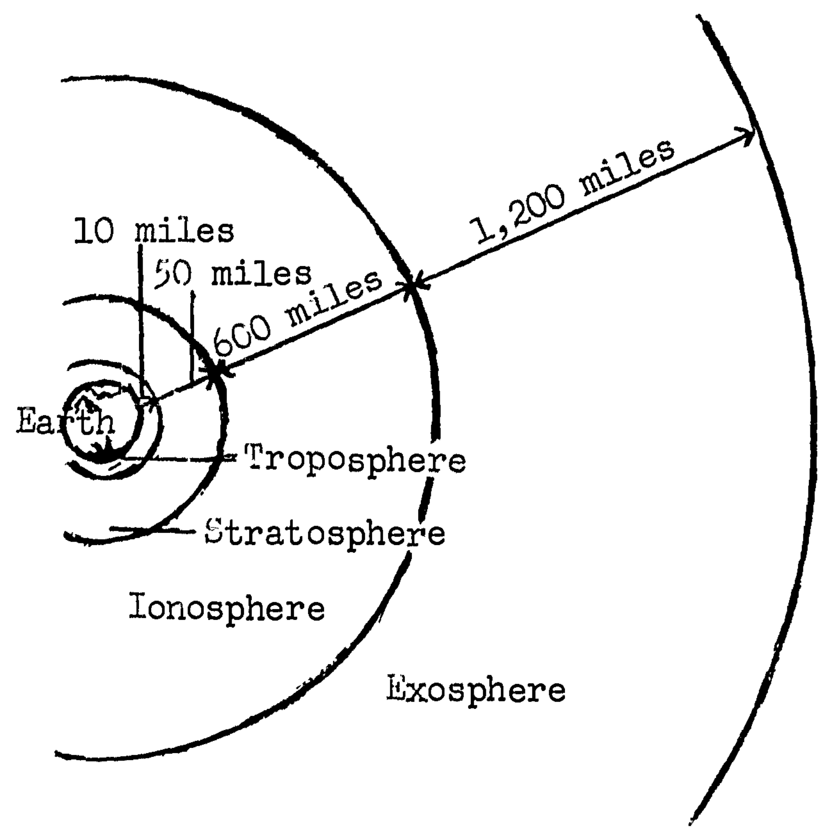
Fill a large, widemouth jar with marbles. Ask the children, "Does the jar look full? Can you see some space left in it?" Have the children add some clean sand and shake the jar, then add more sand. Then ask the children, "Is it full now?" or "Is there any space left?" Have a child add water to the jar. Ask the children if they notice anything coming out of the jar. (They should.) Ask them what they think it is. (Air bubbles) Try adding some alcohol or sugar to the full jar. Bring out that each time they add something, they are filling up space. (Actually, empty space is that dimension or condition in which there is an absence of anything.) Between the grains of sand there was space. Even between the water molecules there was space.

Results

There is space all around us. Help the children generalize that we take up space. Our bodies take up space. The earth occupies space.

Conclusions

All objects occupy space. Space is all around us.



CONCEPT - The sun is a nearby star that is the center of a large system of heavenly bodies that revolve around it.

1. Demonstration

Cut out a large sun from yellow paper. Put a flashlight in the center of it. Darken the room and have it "shine" on the earth (globe). Turn the globe. Can the sun shine on all sides at one time? Turn off the flashlight. Keep turning the globe from west to east. Without its own (earth) light and without light from the sun, what happens? Have the child observe that the globe or earth is turning to cause night and day. Reflect light from a mirror to show pupils how the moon reflects light.

CONCEPT - We seldom see the sun on rainy and cloudy days. Shadows form when things block the light.

1. Problem

What makes shadows?

Materials

Slide projector, black construction paper, white construction paper.

Procedure

Project light from slide projector onto the chalk board. Have each child in turn stand near the board so his shadow will fall on the board. Place black construction paper on the chalk board so child's shadow will fall on it. Next, outline the child's silhouette. As the next child is getting his silhouette drawn have the finished silhouette cut out by previous children and pasted on white construction paper.

Results

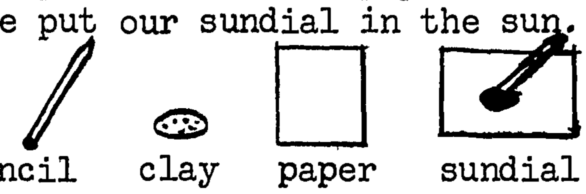
As children are watching the silhouettes being drawn guide them to believe that shadows form when things block the light.

2. Charts, Maps, Graphs

Make experience chart after the children make sundials.

Our Sundial

We made a sundial.
We put a pencil in some clay.
We put the clay on paper.
We put our sundial in the sun.



3. Observe

Take the children outside to notice the position of the sun. Do this in the morning and again in the afternoon. Notice the difference in shadows. Travel through the school and notice those rooms that are bright with sunlight in the morning and then in the afternoon. Encourage them to make a number of observations. They should be led to observe the sun's direction across the sky. As they are ready, introduce the East to West concept.

CONCEPT - The sun is always shining. It is day when our part of the earth faces the sun. It is night when our part of the earth is turned away from the sun.

1. Problem

   Do shadows change?

   Materials

   Butcher's paper, black crayon.

   Procedure

   Lay the butcher's paper on the ground and have a pupil stand next to the paper so that his shadow falls on the paper. Now have another pupil outline his shadow with the black crayon. Repeat the experiment several hours later.

   Conclusions

   Shadows during the day get longer.

2. Observe

   Have the pupils observe that the evening shadows become longer and longer by watching the shadows of trees, houses, etc.

3. Demonstration

   a. Have the children record the night temperature at home with the aid of their parents. On the next day, record the temperature taken from a thermometer that has been placed in the sunshine. Note the difference in temperature. Discuss the difference in temperature between day and night.

   b. In a darkened room, use a flashlight to represent the sun and direct the light of the flashlight onto a large ball or globe in order to illustrate night and day. Have the child observe that the globe or earth is turning to cause night and day. Reflect light from a mirror to show pupils how the moon reflects light.

      Call attention to the fact that sunlight cannot pass through some solid objects; for example, boys and girls, trunks of trees, flags, and walls of buildings. Any object through which light cannot pass will make a shadow. When a cloud crosses the sun, everything becomes darkened. The cloud casts a shadow.

      Discuss why we darken the room for movies and filmstrips.

      Appoint a committee to make a daily observation of the school's flagpole. Some questions to be answered are: Where is its shadow in the morning? Can it help us to tell in what direction is West, East, North, South? Where is the shadow at noontime? In the afternoon when we go home? Where will it be at 5:00 p.m. on a summer day? Why?

Have the children generalize that when a cloud crosses the sun, everything becomes darkened. Thus, it's difficult to see the sun on a cloudy day. Ask the children why we seldom see the sun on rainy days. They should be able to generalize that the clouds are formed before it can rain. Thus, when it rains there are clouds in the sky that block the sun.

4. Field Trip

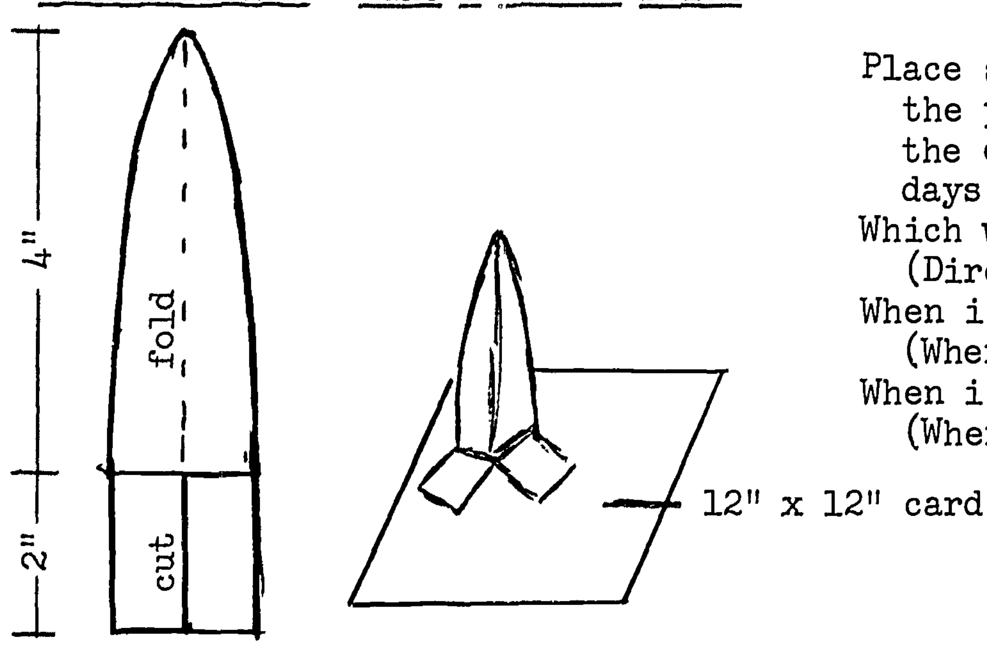
Take the children for a walk on an overcast day to observe if the sun can be seen.

CONCEPT - Shadows are made by the sun changing during the day. The relationship between shadows and the sun is of great importance in the study of time, seasons, and directions.

1. Demonstration

Hammer a long pole or stakes into the ground. Have the children observe the positions of the shadows and the sun in the morning and again in the afternoon. Have some of the children examine the rooms in the school that are sunny in the morning and in the afternoon. Have them observe the change of position of the sun during the day and the change of the shadows.

2. Demonstration - Make a Shadow Stick



Place stick in the sun and mark the point of shadow for hours of the day or for noon of succeeding days.
Which way does the shadow point? (Direction opposite to the sun.)
When is the shadow longest? (When the sun is low in the sky.)
When is the shadow shortest? (When sun is high in the sky.)

3. Observe

Take children outside on a sunny day and have them observe their shadows. Have them notice how much taller their shadows look in the morning than at noon. Use a light to represent the sun. Move it from east to west, from high to low, so that the children will see the changing lengths of their shadows. This works best in a darkened room.

CONCEPT - The sun gives us warmth and light; helps make rain which supplies water to plants and animals.

1. Demonstration

Place some metal objects in the sun and some in the shade. After 20 to 30 minutes have them feel the objects and explain the difference in their temperatures.

Results

Metal objects in the sun get warm.
Metal objects in the shade stay cool.

Conclusions

The sun gives us warmth.

2. Demonstration

Take two thermometers; place one in the sunlight and place one in the shade. After a few minutes, note the difference in the temperature readings.

Results

The thermometer in the sunlight will have a higher temperature reading.

Conclusions

The sun gives us warmth.

3. Problem

How does the angle of the sun affect the weather?

Materials

Light bulb, extension cord, globe, piece of tape.

Procedure

Draw an orbit on the floor, elliptical in shape. Place a light in the center. Prop up a light bulb on an extension cord to represent the sun. Place a piece of tape where Gary would be on the globe. Place the globe on the circle and have the slant pointing to an imaginary North Star. Do not change this position as the globe is moved around the orbit. As the globe moves around the circle notice that different parts of the globe are lighted up since the axis is tilted. At one point the North Pole is lighted. Half way around the circle, the North Pole receives no light at all, but the South Pole is lighted. The angles of light which strike the tape are different as the globe revolves.

Results

Slanting rays bring winter weather; vertical rays bring summer weather.

4. Demonstration - Showing Cause of Seasons

Materials

A large ball, black paper.

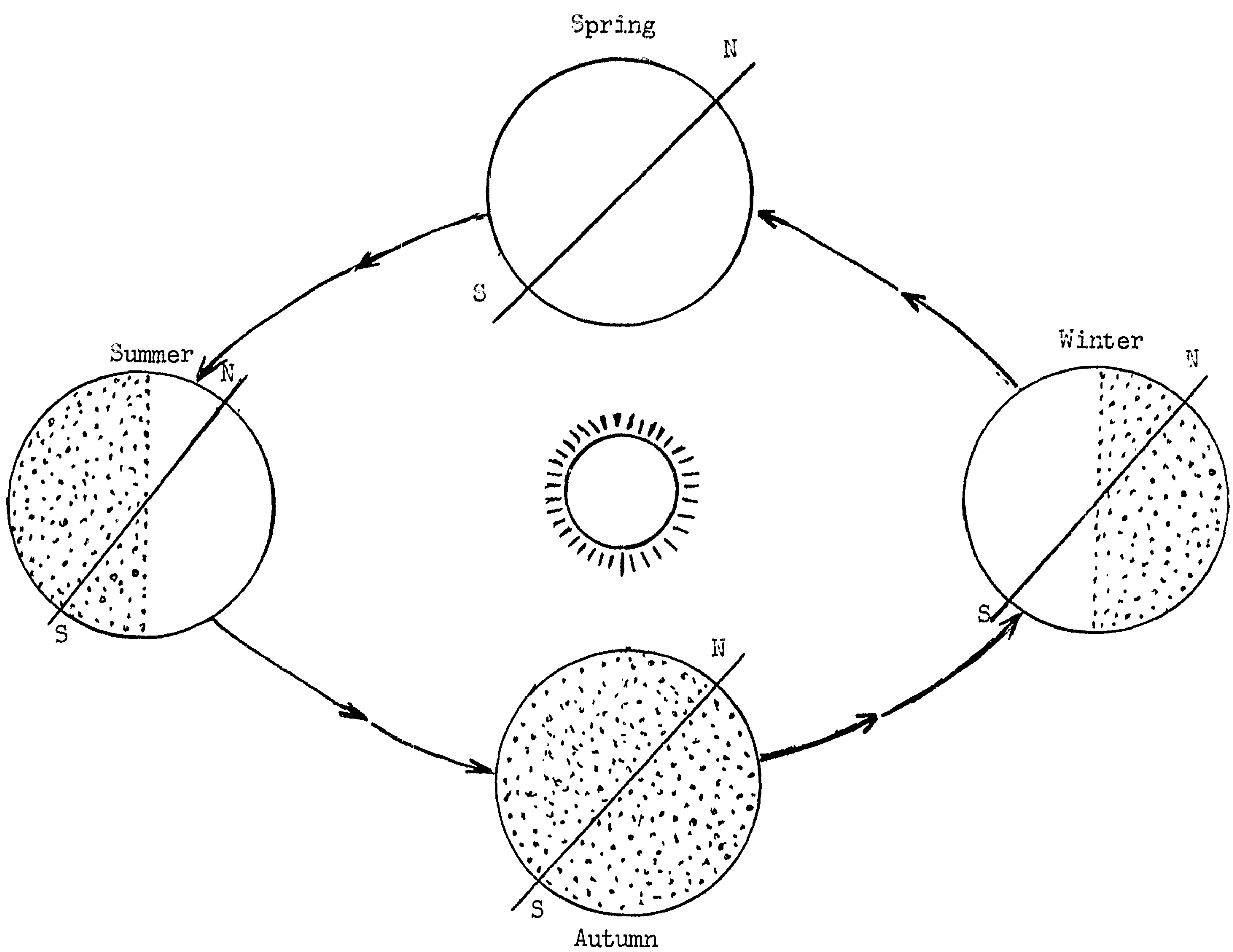
Procedure

Wrap a large ball in black paper. (Black will become warm quicker than white.) Place the ball in the sunlight. Which part gets warmer? Why? The part receiving the direct rays is warmer than the part receiving the slanted rays.

Results

Slanting rays bring winter weather; vertical rays bring summer weather. The change in seasons is caused by the change in the way the sun's rays strike the earth as it moves around the sun.

CAUSE OF THE SEASONS



The direction of the sun's rays changes from 23-1/2 degrees north of the equator (summer in northern hemisphere) to 23-1/2 degrees south of the equator (winter in northern hemisphere) and the length of time the sun shines per day in a given locality changes because of the inclination of the earth's axis.

5. Demonstration

Place at one end of a large blackboard a small arc of a great circle to represent the sun. Place at the opposite end a small circle, not over an inch in diameter, to represent the earth. From the arc that represents the sun trace some rays out across the blackboard in different directions; make clear that the sun is not a circle but a huge ball giving out heat in all directions. Only a minute part of the total heat reaches earth; the rest goes out into space in all directions.

The emphasis at this point need not be on the relative sizes of earth and sun, but on demonstrating that a small body, such as earth, at a great distance from another body which gives off heat, actually receives but a minute part of the total heat.

6. Demonstration

Place a small ball in one corner of the room and a light, such as an electric light, in the opposite corner. Show how the light gives off light and heat in all directions but only a small part of the light and heat is received by the ball. This again shows that the earth (the ball) receives only a very small portion of the light and heat given off by the sun (the electric light).

CONCEPT - The amount of energy received by a section of the earth depends upon the angle at which the sun's rays strike the ground.

1. Problem

What is the effect of slanting rays?

Materials

Black construction paper, two thermometers, books.

Procedure

Do this on a warm, sunny day. Take a large piece of construction paper and fold it in half so that each half is 12" x 9". Staple a paper pocket on each half with strips of paper about 4" x 10". Place a thermometer in each pocket. Prop it up in the sunlight. Place one book under one half, and several books to hold the other half in a vertical position. The sun will strike the upper half of the paper straight down, or in vertical rays. The lower half is receiving slanting rays. After a few minutes, remove the thermometers and read the temperatures. Which part was warmer? The vertical light was warmer than the slanted light. Why?

Results

Slanting rays bring winter weather; vertical rays bring summer weather.

2. Demonstration

Use a piece of black paper. Hold a strong flashlight directly over it about ten inches from the paper. With white chalk outline the area illuminated. Repeat the action keeping the light at the same distance from the paper, but this time tip the flashlight so that the rays are slanted. Outline the area illuminated with white chalk.

The following answers to the questions should result in the comprehension of correlation between angle of sun ray and intensity of heat.

a. Which area is larger?

b. Which area seems brighter?

CONCEPT - All satellites, natural or artificial, travel around the sun in fixed orbit.

1. Problem

How do satellites stay up?

Materials

Ping-Pong ball, scotch tape, rubber bands.

Procedure

Drop the Ping-Pong ball on a table top. Scotch tape the rubber bands (interlocked to the Ping-Pong ball. Slowly swing rubber bands, with ball attached in a circular motion. Note the distance from your hand. Increase the speed of circular swing. Note the distance in this case. Discuss why the Ping-Pong ball falls to the table top and why the distance from the hand increases as the ball revolves at a greater speed.

Results

There are two forces acting on the Ping-Pong ball. One is the force of gravity which tends to pull the ball to the center of the earth. The second is the centrifugal force which forces the ball away from the center of the earth (or hand, in this case). When these two forces are balanced, they will stay at a given distance.

The Ping-Pong ball will fall to the table top. As the ball moves slowly, it revolves a certain distance from the hand. As the speed is increased the ball moves farther from the hand.

CONCEPT - The earth is a natural satellite of the sun. The earth's circumference is 25,000 miles.

1. Problem

Is the earth round?

Materials

World globe, toy ship.

Procedure

Place globe where children can see that it is round. Hold globe steady with one hand. Take the toy ship with the other hand and move it on the globe away from the children until it moves out of sight.

Results

The toy disappears from the children's view.

Conclusions

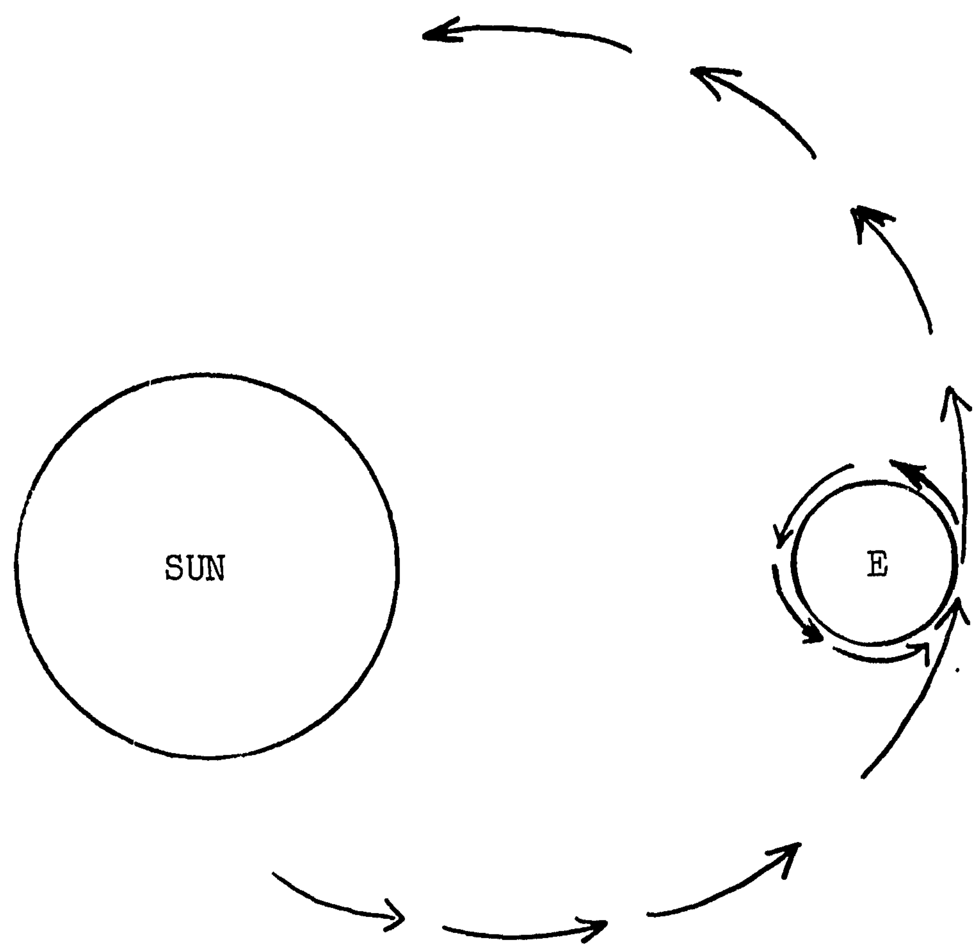
When objects disappear over the horizon it is an indication that the earth is curved.

2. Observe - Solar Position Change

Take the children outside the school in the morning and the afternoon. Notice the difference in shadows. Travel through the school and notice those rooms that are bright with sunlight in the morning and then in the afternoon. Discuss the sun's direction across the sky. Introduce the east to west concept.

3. Draw

Have children draw the earth and sun. Use arrows to show the movement.



4. Demonstration

Have one child stand to represent the sun and have another child represent the earth showing how the earth is spinning and moving around the sun at the same time. Discuss the time it takes for the earth to turn (rotate) one full time (24 hours).

Explain that the earth is also going around (revolving) the sun while it is rotating on its axis.

5. Make Models

Have children set a stick in a mound of clay. Place in an area exposed to sunlight. Have children mark the direction and lengths of the shadows at various times.

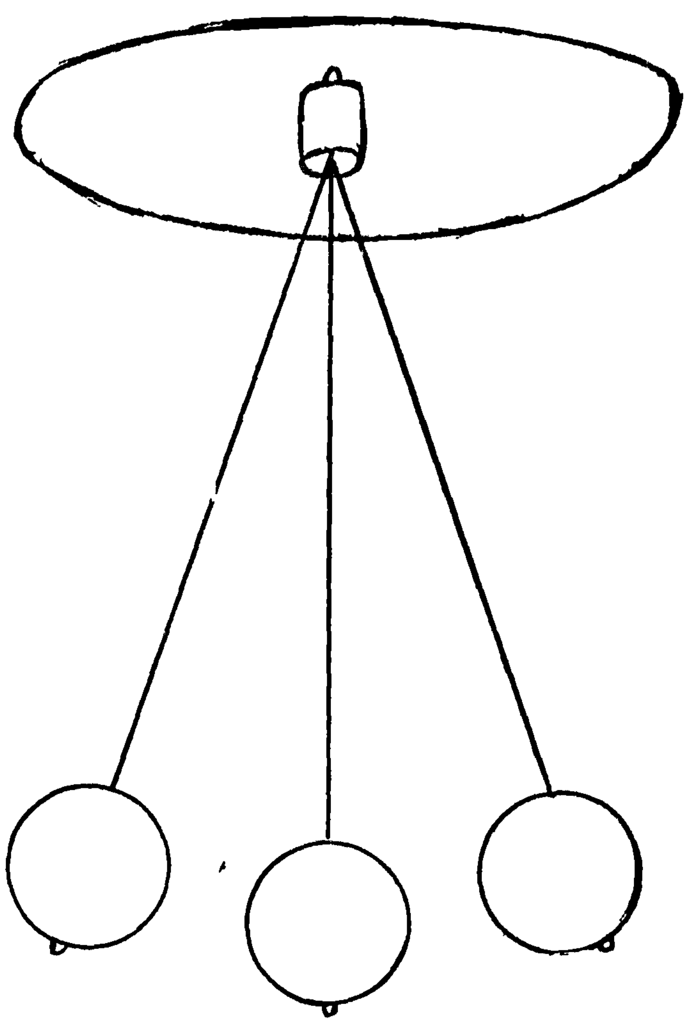
6. Draw (Explain to the children)

The Puco Pendulum

One evidence that our earth is a rotating sphere is the Puco Pendulum Experiment which is performed by attaching a long wire cable holding a swinging pendulum from a high dome. The path of the swinging pendulum is recorded on a device placed directly below the pendulum. From the recordings the following observations can be made:

1. The path of the swinging pendulum moves, and it moves an equal distance in the same direction each hour.

2. It can be concluded that, since there is no force to change the path of the pendulum, the turning of the earth causes the path to change.



CONCEPT - The rotation of the earth causes day and night.

1. Problem

What causes alternating periods of daylight and darkness on the earth?

Materials

Modeling clay, pipe cleaner or short stick, flashlight, world globe.

Procedure

With a lump of modeling clay, secure a stick figure or flag to a world globe. (If a globe is unavailable, a white volleyball will do.) Place the lump of clay at the spot on the globe where you are located. Darken the classroom. Use a flashlight, projector lamp, or unshaded electric lamp to simulate the sun. Rotate the globe slowly.

Results

As the light falls on the globe, help the children see that not all the globe is illuminated at the same time. Have them observe what happens when the stick figure comes into "daylight." Ask the children, "Does the figure cast a shadow?" (Yes.) "How does the shadow change as the earth turns?" (It seems to move.) "What causes day and night?" (The rotation of the earth.) "Which way should the globe be turned to make the sun 'rise' in the east and 'set' in the west?" (From west to east.) "Does the sun really rise, or does it only appear to rise while the earth is turning?" (It appears to rise.)

Conclusions

Day and night are caused by the rotation of the earth.

CONCEPT - The tilting of the earth's axis causes sunlight to strike the earth at different angles as the earth revolves around the sun.

1. Problem

What is the effect of the earth's tilted axis?

Materials

Flagpole or other permanent pole, paint, large piece of paper.

Procedure

Have the children keep track of the shadow cast by a pole over a long period of time. If it is possible, paint markings of the shadow's position directly on the surface of the playground. If not, recording them on a large piece of paper will do. The children should note the exact location of the pole's shadow at the same times each day, marking the length and position of the shadow on the paper. Have them compare the length of the shadow at various times during the day. Also, have them compare the positions and lengths of the shadows at the beginning of the school year, during the winter, during the spring, and at the end of the school year.

Results

How do these lengths change? (The shadows grow longer until the first day of winter, December 22, and then grow shorter until the first day of summer, June 21.)

Conclusion

The earth's axis must be tilted in order for the shadow to change its length. If the axis were not tilted, the shadow cast by the flagpole would always be the same length.

2. Problem

What is the effect of the earth's tilted axis?

Materials

World globe, modeling clay, lamp, pipe cleaner or short stick, yardstick.

Procedure

Place an unshaded lamp in the center of a darkened room. Have the children attach a small stick or a figure made of pipe cleaners to a world globe. (If the globe's axis is not tilted, it will be necessary to tilt it for the first part of the activity.) Ask the children to place the globe so that its axis is tilted toward the "sun" and to measure the shadow cast by the stick. Then have them move the globe to the other side of the unshaded bulb, placing it exactly the same distance from the lamp as it was before. Suggest that they tilt the axis of the globe away from the "sun" and measure the length of the shadow. Was the shadow longer when the axis was tilted toward or away from the "sun?" (When it was tilted away from the "sun.")

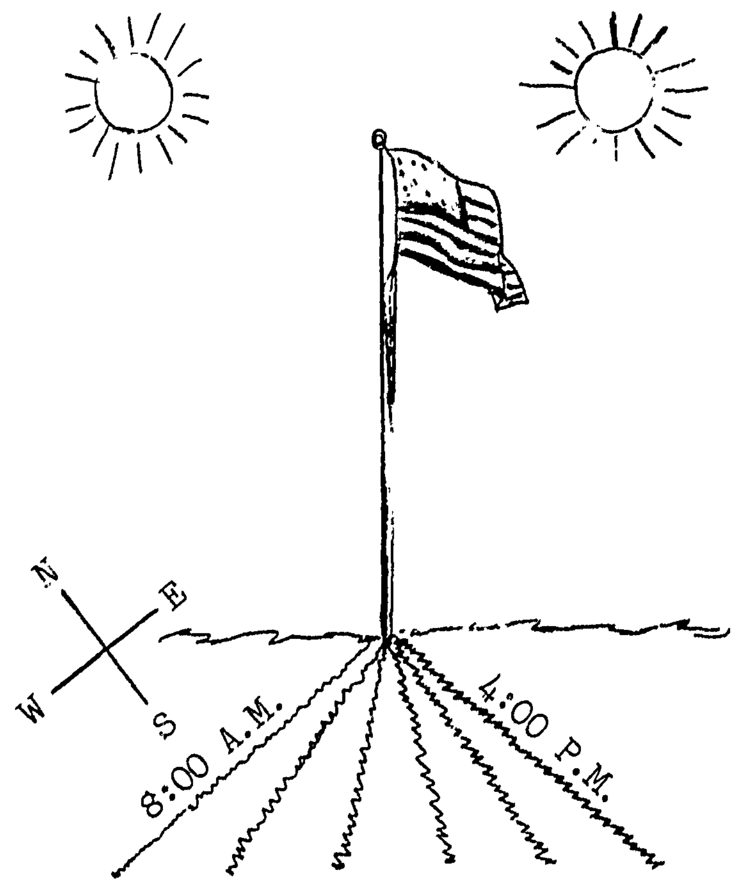
Now have the children repeat the activity, measuring the length of the shadows cast on both sides of the "sun," without tilting the axis - that is, the axis of the "earth" should now be parallel to the axis of the "sun." Do the lengths of the shadows differ? (No.) How do the shadows' lengths compare when the globe is tilted and untilted?

Results

The shadows are longest when the globe is tilted away from the "sun" and shortest when it is tilted toward the "sun."

Conclusions

The earth's axis must be tilted, just as the globe's was, in order for the shadow to change its length. If the axis were not tilted, the shadow cast by the flagpole would always be the same length.
(See illustration on the following page.)



CONCEPT - Different weather conditions and different plant and animal habits come with the changing of the seasons.

1. Problem

Why do seasonal changes occur on the earth?

Materials

Unshaded lamp to represent the sun, four world globes (one will do if no more are available), modeling clay or masking tape.

Procedure

Set the unshaded lamp on a table in the middle of the room. Darken the classroom. If four world globes are available, set them on the north, east, south, and west sides of the lamp and about eight feet away. If four globes are not available, let the children stand and hold the globe consecutively in each position. Keep the earth's axis pointed north at all times. A corner of the ceiling can serve as the North Star. Spin the globes in the correct direction and help the children notice how the "sun's" light strikes the "earth" differently at each position. Locate your position on the globe with a lump of clay or piece of masking tape. As each globe spins, help the children notice how much night strikes your location.

Results

Ask the children, "In which position of the earth's journey around the sun does our city get the most sun? The least sun? In which position do we have winter? Summer? Autumn? Spring?"

Conclusions

The tilting of the earth's axis affects the amount of sunlight striking the earth as it travels around the sun. This is partially responsible for the changing of the seasons.

2. Problem

Why are our summers hot and winters cold?

Materials

Flashlight, chalk.

Procedure

Hold flashlight about six inches away from the blackboard with the rays falling straight on the board. Trace around the edge of the light.

Hold flashlight the same distance from the board, but with the rays falling at a slant. Trace around the edge of the light.

Compare the area of the two drawings on the board. Answer such questions as:

Does the same amount of heat and light leave the flashlight over each area?

Does the same amount of heat and light fall on each area?

Does the same amount of heat and light fall on any one point in each area?

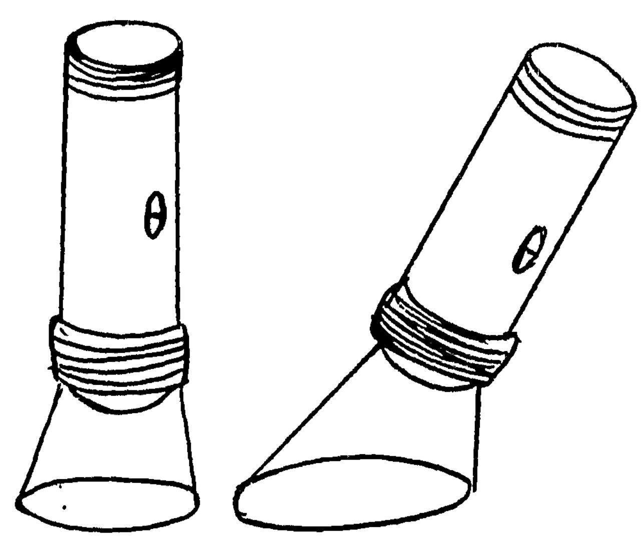
In which area are the heat and light most concentrated?

In which area would a given point receive the most light and heat?

When must the sun's rays fall most directly on us, summer or winter?

Conclusions

Since we receive more light and heat in the summer than in winter, the sun's rays must fall more directly on us in summer than in winter, making our summers hot and our winters cold.



3. Problem

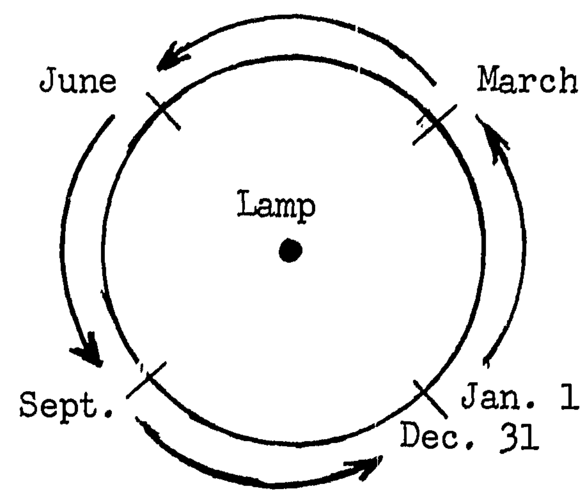
What causes the changes in season?

Materials

Lamp, extension cord, chalk

Procedure

Draw a circle on the floor with chalk (about 3 ft. in radius). Put a lamp in the middle of the circle. Mark the four seasons on the floor. Have children walk counter-clockwise around.



Results/Conclusions

We pretend that it takes about 365 days for children to walk all the way around the sun. Have four children wearing signs for fall, winter, spring, and summer, stand on the season marks on the circle. The child walking around the sun will pass each season. The earth will experience all seasons in one revolution around the sun.

4. Problem

Will a seed grow if it is frozen?

Materials

Bean or corn seed, small container, dirt.

Procedure

Have children plant seed in a container. Put in freezer. Check to see if it grows.

Mention that light will also affect results.

Have a control plant that is not frozen.

Results/Conclusions

The seed put in the freezer does not grow.

Many plants will not grow in frozen ground.

New plants do not start growing in the winter.

5. Charts, Maps, or Graphs

Make a chart of birds that children see in September, December, and April. Which birds stay in Gary all winter?

6. Observe

Have children observe broad-leaved trees in the school area. What changes do the trees make when the seasons change?

7. Charts

Have children bring in or make pictures of the fall season for a classroom chart. Add more pictures as the seasons change. Greeting cards are a good source for these pictures (Christmas, Easter, Mother's Day, Father's Day).

8. Observe

Starting in September, have children observe the fall season and the changes that are taking place. Do this with each change of season during the school year.

CONCEPT - The sun shines on the moon!

1. Problem

Does the moon reflect the light it receives from the sun?

Materials

Small ball, aluminum foil, a lamp.

Procedure

Cover a small ball with aluminum foil. Have a child hold the ball up with one hand. The ball represents the moon and the child, the earth. Have another child turn on a lamp behind the boy holding the ball. The lamp represents the sun. Turn out all other lights.

Results

The lamp's light will shine on the ball and the ball will reflect light.

Conclusions

The sun shines on the moon; the moon reflects some of the light it receives from the sun.

2. Maps, Charts, or Graphs

Have the children list under the headings - Light Giving Objects and Light Reflecting Objects - the following or similar objects under their appropriate titles: moon, Mars, sun, Venus, shooting stars (meteors entering atmosphere), earth, stars.

3. Research

Have the children note a commercial calendar on which the phases of the moon have been marked. Arrange colored cutout disks on a blue background to show the position of the earth and the moon in relation to the sun. Have children read legends about the moon. Have them check each night for a month to see whether the calendar was correct in its predictions. Have them report their findings to the class.

4. Demonstration

You can demonstrate how the moon shines by reflected light as follows: have a child hold a flashlight to represent the sun; have another child hold a mirror, to represent the moon, which reflects light to still another child representing the earth.

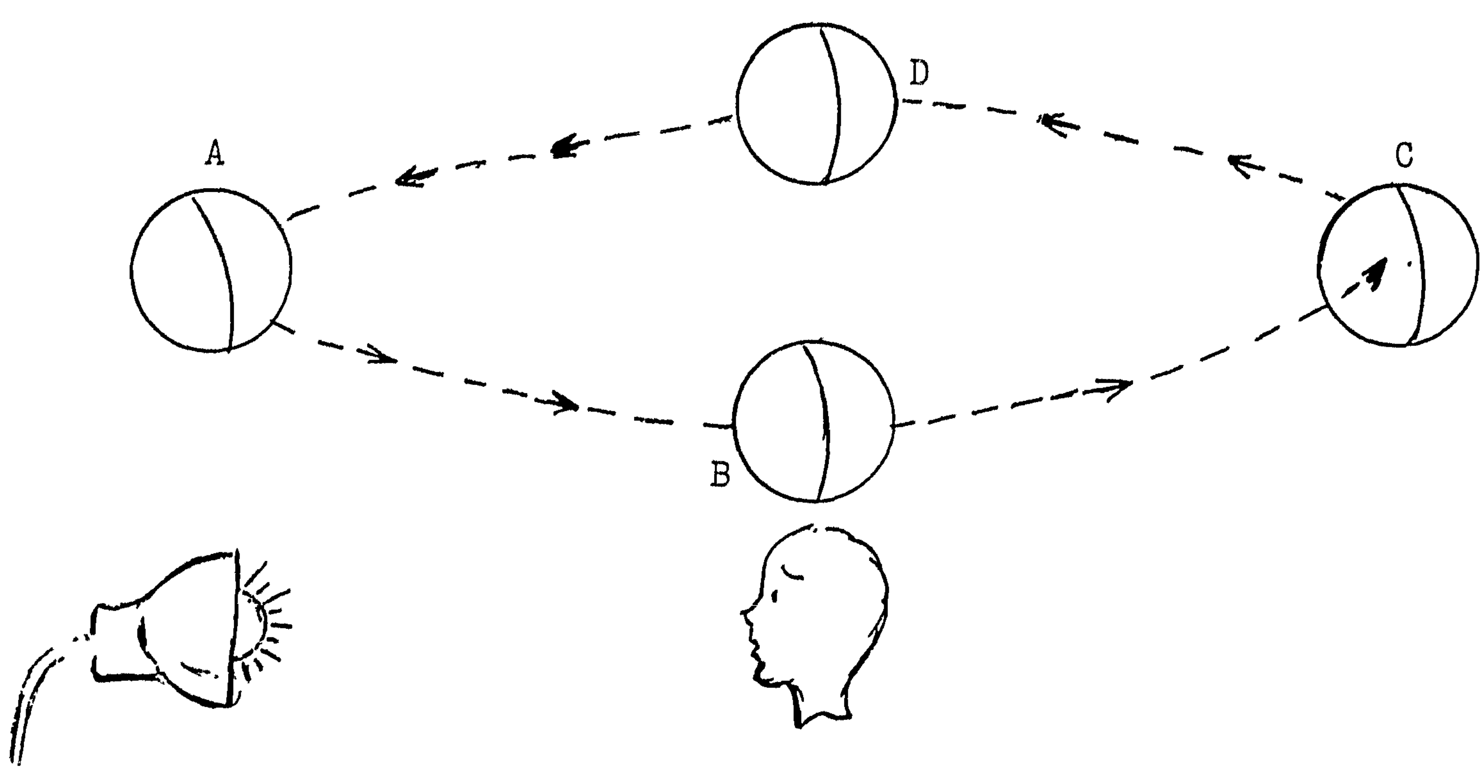
5. Bulletin Board

Cut the weather clipping from the daily newspaper showing the moonrise and moonset each day. On a board chart place the time of the moonrise daily. Have the children notice the time difference at the end of a two week period. Encourage the children to notice patterns of time changes.

6. Demonstration

Paint half of a tennis ball yellow and the other half black. Run a pencil through it to demonstrate how the moon makes the change from new to full to dark as it rotates on its axis in the course of the month.

The Phases of the Moon



The light represents the sun illuminating the moon. The boy's head represents the earth and its position. As the ball (the moon) moves around the boy's head, various amounts of it appear to be lighted. In position A as the ball is moved, only a thin slice of light appears and we see the new moon begin to appear. As the ball moves to position B, the amount of lighted portion increases to first quarter. In position C the moon is full. As the ball is moved to position D, the lighted area grows smaller to the third quarter.

CONCEPT - The moon is a natural satellite of the earth. One revolution of the moon around the earth takes a month.

1. Problem

How does the moon travel?

Materials

Globe, flashlight, chalkboard, three cards (one with earth, one with moon, one with sun).

Procedure

Discuss with the class concepts of rotation (spinning on its axis), revolution (moving around another body), day and night, and how the lengths of a day, month and a year are determined. Use the flashlight and the globe to explain day and night. Have three children come to the front of the room and explain the relative movements of the earth, moon, and sun. Let one be the sun, one the moon, and the other the earth. Have each child go through the motions of his celestial body.

Results

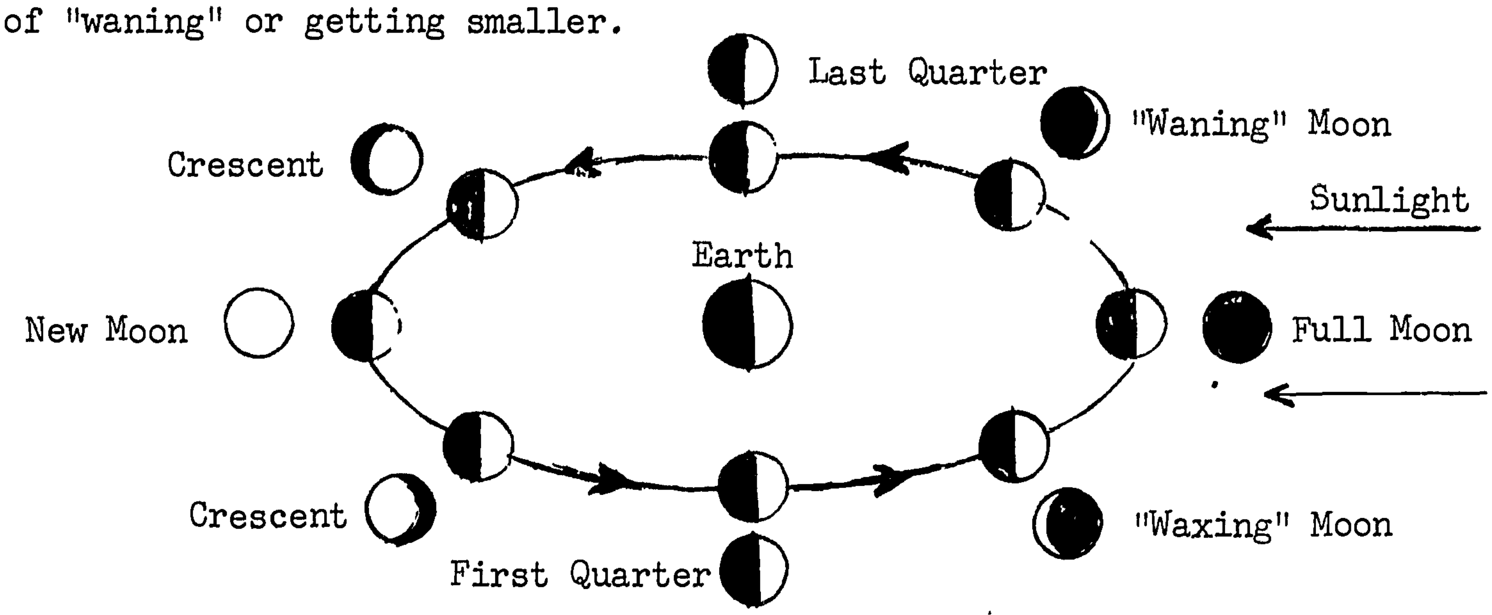
Children will become more aware of the effect the sun and moon have upon the earth.

Conclusions

The moon travels from west to east around the earth. It travels completely around the earth from one full moon to another. This takes approximately 27 days.

2. Demonstration

Cut two large circles from construction paper, one yellow and one green. Demonstrate the appearance of the moon on earth by placing the green circle (earth) over the yellow circle (moon). When the two circles are together, the moon is not visible. This step can be used to demonstrate the "new moon" stage. Soon a very small portion appears; it is crescent shaped. Show the phases up to the full moon. This movement is called "waxing" of the moon. After the full moon appears the moon begins the movement of "waning" or getting smaller.



3. Drama

Have children demonstrate a lunar eclipse with three pupils who will represent the sun, the earth, and the moon. The child (sun) will hold a lamp or flashlight and direct the light on the earth. Fasten a 12 inch circle of white paper to a ruler to represent the earth, and a 3 inch circle of black paper to represent the moon. The pupil (moon) always faces the earth as he walks around. Have the pupils explain what happens.

4. Bulletin Boards

Have a display of the different phases of the moon in the correct positions around the earth. Label the phases.

5. Make Models

Have a committee make a papier-mâché relief replica of the moon. Observe lights falling on it and notice how the rough areas cast shadows. Have some children make clay models of the moon to help show the different kinds of mountains and craters. Use a flashlight to show the kinds of shadows produced by the surface irregularities. Have a committee make a model of the moon phases. This may be done with either Ping-Pong balls or plastic foam. From a sheet of plastic foam (¼ or ½ inch thick) cut out several circles with a cookie cutter. Insert light but rigid wire into each disk and arrange them in an arc. Black tempera paint may be used to paint out the unilluminated part of the moon. If Ping-Pong balls are used they may be painted similarly to represent the phases of the waxing and waning moon. A heavy block of plastic foam makes a good stand for this model and is a material into which wires may be inserted easily.

CONCEPT - Much is already known about the moon.

1. Problem

What are some of the facts that we know about the moon?

Procedure

Make a list of the children's questions about the moon. Have them do research to find not only the answers but also how we know what we know. Help them look in books and other reference sources, seek answers from others who know, watch motion pictures and television, write to sources, and conduct experiments and demonstrations. Have the children develop a chart, such as the one shown, to show questions that can be answered through reading, experimenting, measuring, etc. Which questions have no answers as yet? For which questions must more data be gathered?

Results/Conclusions

Many facts are already known about the moon, but many others remain to be discovered.

QUESTIONS AND ANSWERS ABOUT THE MOON

Questions About the Moon	Some Possible Answers (Hypotheses)	How Does Man Know? Some ways to find out, using tools, experiments, knowledge, resources, etc.
How far is it to the moon?	About 240,000 miles	Radar: sending light signals to the moon and recording time for the light to make a round trip.
What is the diameter of the moon?	About 2,106 miles	Use triangulation. Hold a coin between the eye and the moon. Find how far away it must be held to eclipse the moon completely. Measure the diameter of the coin and the distance from the eye. Can these proportions help determine the moon's diameter?
Does the moon have a magnetic field?	?	Magnetometer must be sent aboard spacecraft to vicinity of the moon.
Is there life on the moon?	?	?
Does the moon have gravity?	Yes	1/6 that of the earth. All bodies have a gravitational pull at the surface, according to their mass and size. (Mass of moon is about 1/80 mass of earth.)
Is there atmosphere on the moon?	?	?
Is there water?	?	?
What is the moon made of?	?	?

CONCEPT - The moon's surface contains craters of unknown origin.

1. Problem

   What is known about the moon's craters?

   Materials

   Pictures of craters on the moon and the earth.

   Procedure

   Have the children collect pictures of various volcanoes on the earth. Suggest Paricutin, Vesuvius, and Mauna Loa to start as a beginning. Ask them to collect pictures of places on earth where there has been considerable volcanic activity, such as Hawaii, Craters of the Moon National Park, and the Azores. Have them compare these pictures with pictures of the moon's surface. Do the children notice any similarities or differences? Ask if they think the moon's craters were caused by volcanoes.

Have the children collect pictures of craters that were caused by giant meteors impacting the earth, such as those in Arizona and South Africa. Ask them to compare these with the pictures of the moon's surface. Do the children think meteors caused the moon's craters?

Results/Conclusions

The moon's surface is covered with craters. The origin of the craters is unknown.

2. Problem

What is known about the moon's craters?

Materials

Ruler, compass for drawing circles, paper, pencil.

Procedure

Help the children draw circles to scale, showing the size of the moon's craters. Using the same scale, have them draw circles showing the size of several of the earth's volcanoes. How do they compare in size? (The moon's craters are larger.) What is the size of some of the meteor craters on the earth? (Very large.) Suggest that the children draw them, using the same scale, and compare them with the moon's craters.

Results/Conclusions

The moon's surface is covered with craters. The origin of the craters is unknown.

CONCEPT - The motions of the earth and the moon can align them in such a way that their position relative to the sun will cause an eclipse.

1. Problem

What is an eclipse?

Materials

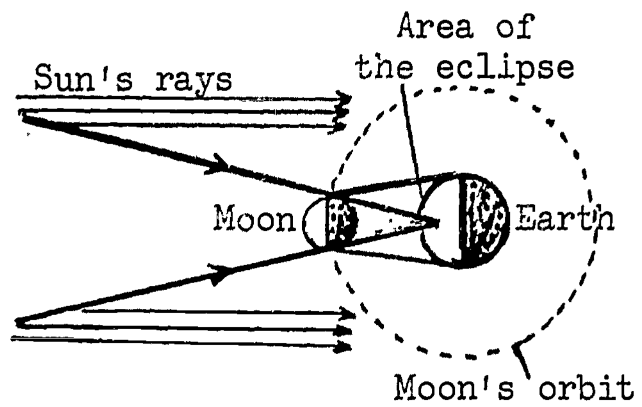
Lamp, tennis ball, string.

Procedure

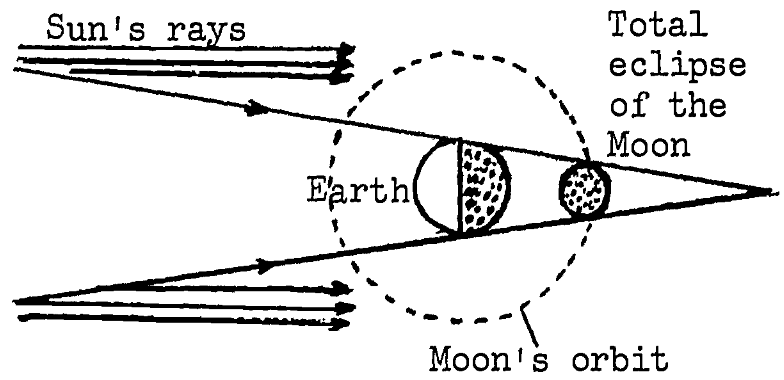
With an unshaded electric lamp in the center of the classroom to represent the sun, have several children sit in a ring around the light. Tie a tennis ball to a string to represent the moon. Tell the class that each child's head represents the earth. Have one child suspend the "moon" in front of each child's eyes and move it around his head. Can the children determine which way the moon should revolve? (The moon revolves in a counterclockwise direction.) As the ball comes between the child's eyes and the electric lamp, part of the "sun's" light is blocked, causing an "eclipse of the sun." This is called a solar eclipse. Call the children's attention to the shape of the ball against the "sun's" light. Have the child holding the "sun" bring the ball behind the seated child's head. Now the "moon" should be in the shadow of the "earth." Since there is no sunlight reflected to the "earth," this is an "eclipse of the moon." This is called a lunar eclipse.

Results/Conclusions

A solar eclipse occurs when the moon passes between the sun and the earth, preventing some of the sunlight from reaching the earth. A lunar eclipse occurs when the earth passes between the sun and the moon, preventing some of the sunlight from reaching the moon.



SOLAR ECLIPSE



LUNAR ECLIPSE

2. Demonstration - Eclipses

Materials

Two pencils or fine knitting needles, modeling clay, a flashlight.

Procedure

From the modeling clay make models of the earth and the moon (1 inch in diameter for the earth; $\frac{1}{4}$ inch in diameter for the moon). Put one of the models on each needle. Use a flashlight to represent the sun.

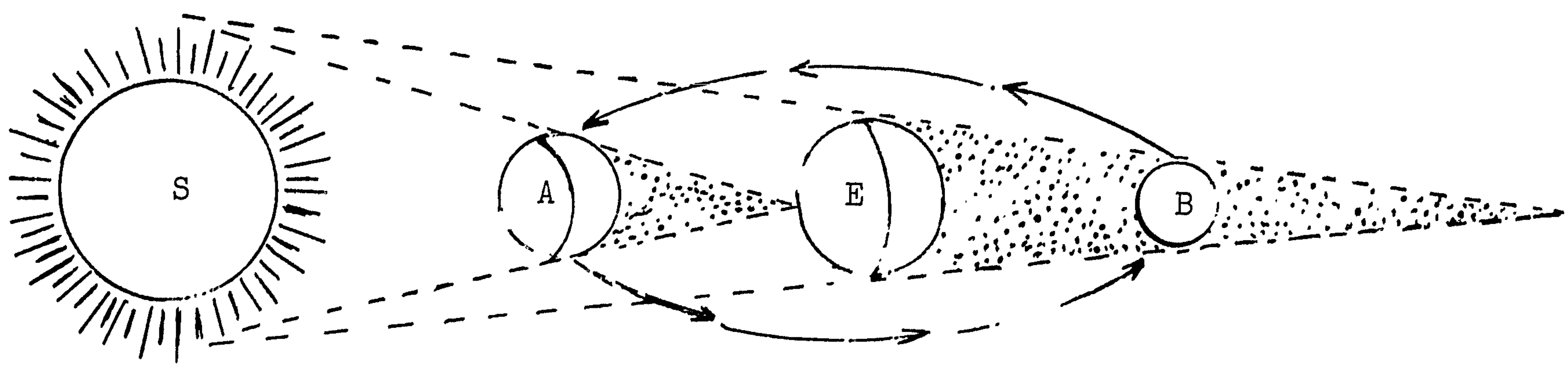
Have the room darkened and have one child turn on the flashlight. Have another child hold the model of the earth in the light of the flashlight. Hold the moon model between the earth model and the flashlight so that it throws a shadow on the earth. We have an eclipse of the sun when the real moon is between the earth and the sun and throws a shadow on the earth.

Move the moon model until it is in the shadow of the earth model. When the real moon, in its journey around the earth, comes into the earth's shadow, there is an eclipse of the moon.

Lift the moon model upward a little way. Before you move it upward very far, it is no longer in the earth's shadow. Put it in the earth's shadow again. Then move it downward. Before you move it downward very far, it is no longer in the earth's shadow. Moving the moon model in this way will help you undertand why we do not have an eclipse of the moon every time the moon travels around the earth. Sometimes the moon is too high and sometimes it is too low, to be in the earth's shadow when it is on the opposite side of the earth from the sun.

In the same way you can show with the models why there is not always an eclipse of the sun when the moon is between the earth and the sun. It is sometimes too low to throw a shadow on the earth, and sometimes too high.

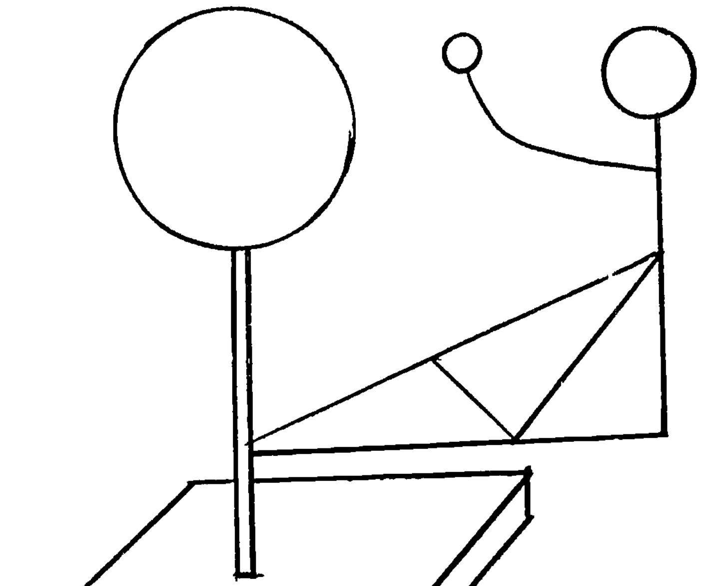
CAUSES OF ECLIPSES



Key: S represents the sun. A and B represent the moon. E represents the earth.

When the moon is at position B, it is in the shadow of the earth and is consequently eclipsed (an eclipse of the moon). When it is in position A, it hides the sun (an eclipse of the sun).

HOW TO MAKE A SIMPLE PLANISPHERE



You will need an old floor or table lamp, a wire coat-hanger, 3 hairpins, a rubber ball about 3 or 4 inches in diameter, and a rubber ball about 1 inch in diameter.

Assemble materials as they are shown in the drawing.

Use the planetarium for showing the class:

The causes of seasons (revolution of the earth around the sun)

The cause of night and day (rotation of the earth on its axis)

The cause of moon phases and eclipses (revolution of the moon around the earth)

CONCEPT - The earth's rotation makes the sun appear to move across the sky.

1. Problem

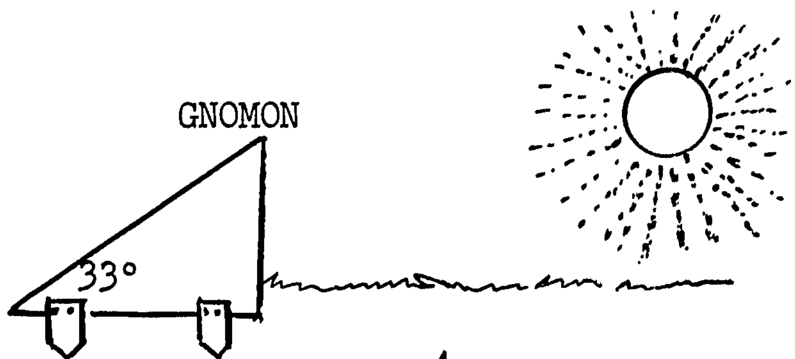
How can the movement of the earth be used to tell time?

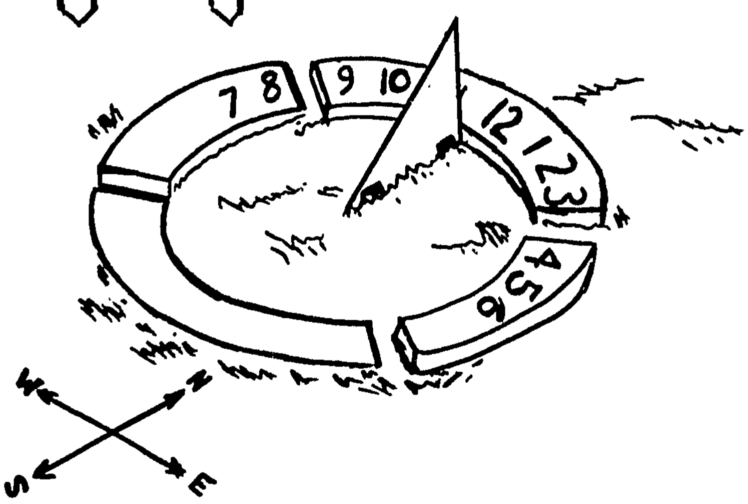
Materials

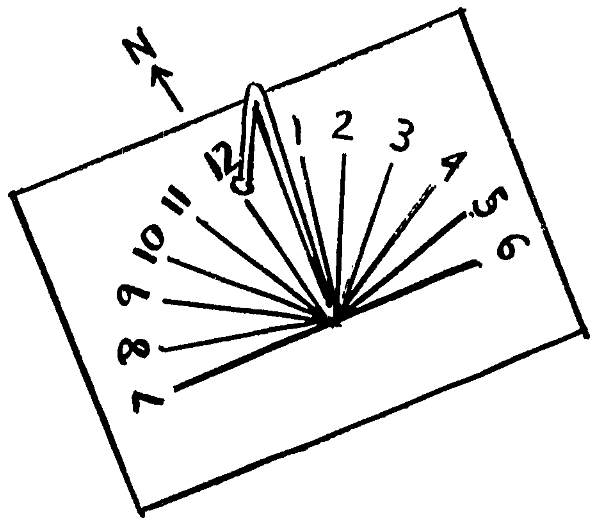
Knitting needle or strong wire, cardboard or soft wood (1 foot square), 4 quarter-circle edging blocks from a nursery or building supply store (the kind used to line flower beds and separate them from lawns), piece of redwood or cedar about 1 foot wide and as long as the radius of the circle of edging blocks, nails, small pieces of scrap redwood or cedar.

Procedure

Have the children place the four curved edging blocks in a circle in a protected but open spot on the schoolyard. The center of a garden plot is excellent. For the center of the sundial you will need a gnomon. To make this, cut the piece of wood at the same angle as the number of degrees of latitude that your school is north or south of the equator (about 33° in Los Angeles, about 40° in New York City). Children can do research in an atlas or almanac to find the location of your town. Help them use a protractor to draw this angle. Nail some stakes to the wood so it will stand firmly in the center of the sundial. Place the gnomon in position so that the point of the angle of the wood at the center of the circle points directly south. When the shadow cast on the circle is at its thinnest, the time is exactly noon, sun time. Each time the shadow widens by 15 degrees, an additional hour has passed. Mark each hour on the sun dial.







A more simplified sundial can be made by inserting a knitting needle or similar strong wire into a heavy, 1-foot-square piece of cardboard or soft wood. If desired, the knitting needle may be bent to the angle corresponding to your latitude.

Take the sundial out of doors or to a window sill. Follow the procedure of marking the cardboard where the needle casts its shadow, precisely at each hour of the day.

Results

Have children list some reasons why the sundial is not a suitable time-keeper. Some children may wish to read further about other time-keeping devices. Early civilizations had methods for keeping track of time. Can the children find what they were?

Discuss with the children how a sundial would differ if it were south of the equator or on the equator. What effect does bending the gnomon to the angle of your location on the earth have on the sundial? Could you make a sundial out of your school's flagpole? Some children may wish to do research in an encyclopedia or other book to explain other types of time: sidereal time, Earth time, and real time.

Conclusions

The rotation of the earth makes the sun appear to move.

CONCEPT - Certain words have meaning only in relation to other words--discovering relativity in temperature.

1. Problem

How can the idea of relativity be introduced?

Materials

Three bowls, heated water, tap water, ice water.

Procedure

Place bowls containing heated water, tap water, and ice water on your desk. Have a child put his hand in the tap water. Ask the child, "Is it warm or cold?" If he says, "warm," have him put his other hand in the heated water. Does he still think the tap water is warm? If he says, "cold," have him compare the temperature with that of the ice water. Help the children see that the temperature terms we use are relative. Such words as warm, cold, tall, heavy, far, and near are all relative depending upon your point of reference. Ask the children if they can think of other words that have meaning only when they are related to a given location, time, or degree.

Results/Conclusions

Some words have meanings only in relation to other words.

CONCEPT - The appearance of objects is relative.

1. Problem

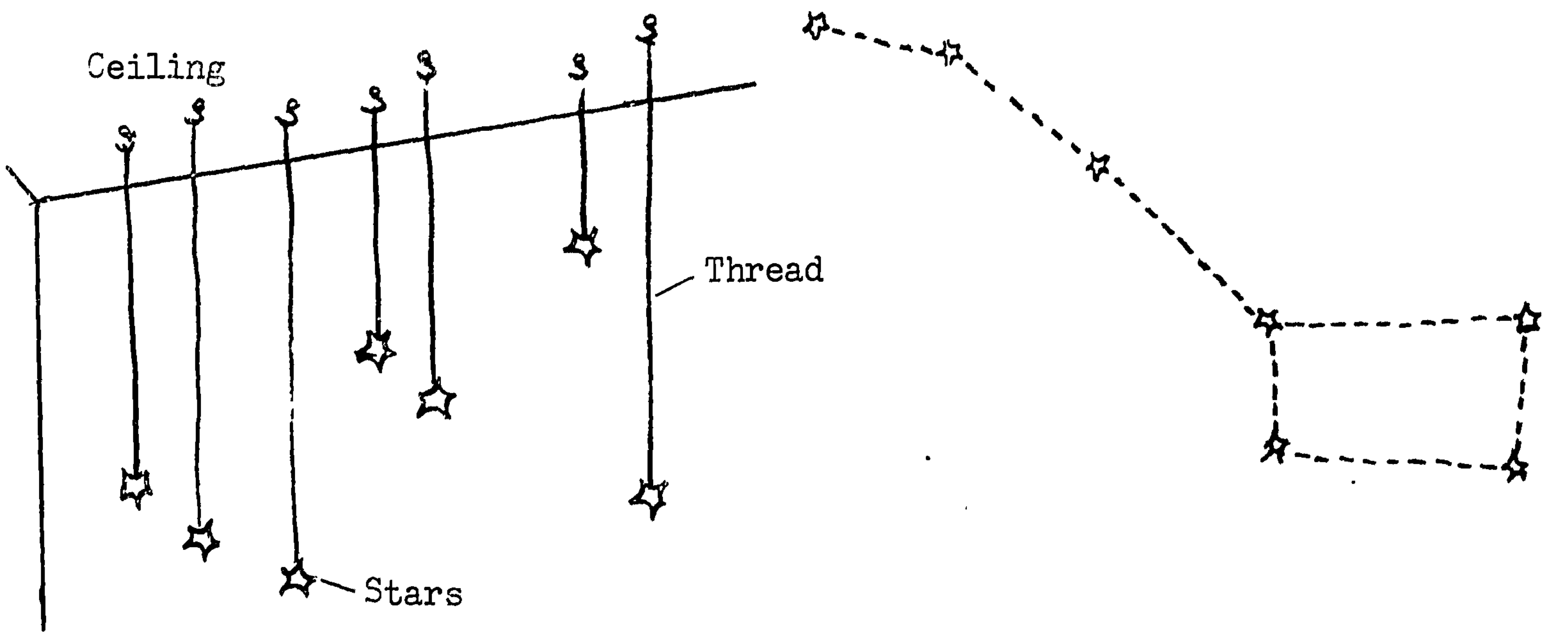
Why is the appearance of objects relative?

Materials

Thread or string, paper, ladder, pins or tacks.

Procedure

To form the shape of the Big Dipper constellation, suspend round pieces of paper representing stars by strings or thread from the classroom ceiling. The strings should be of different lengths. Try to make the constellation cover about a four-foot radius. Have children look up to the ceiling from their chairs or desks. They will see the familiar constellation, the Big Dipper, which will look something like the one shown in the illustration. Have each child draw exactly what he sees. The children will find that each picture differs slightly, depending upon where the artist was sitting in the room. To some the dipper will appear to "hold water," to others it will look as if it is pouring water out, and to others it will appear to be standing on one end. Now have several children go out "into space" by standing on a ladder, a chair, or a desk. Have them view the constellation from various points in the room. Again, ask them to draw what they see. Their drawings may look something like the illustration.



Results

Have the children compare their second drawings with what they originally saw from "the earth" (the floor). Ask the children, "Which is the top of the dipper? Which is the bottom?" (There is none. It all depends on where you are on the earth or in space.)

Conclusions

The appearance of stars and constellations viewed from space will be different from the way we are used to seeing them from the earth.

CONCEPT - Motion is a relative phenomenon.

1. Problem

How can relativity in motion be shown?

Materials

Chalkboard eraser, ball, chair.

Procedure

Ask a child to stand on a table, ladder, or chair and drop a chalkboard eraser to the floor. Have three children act as observers. One should stand on the table with the child who drops the eraser. Another should stand or squat on the floor. The third should lie on his back on the floor close to where the eraser falls. Each of the observers should describe the path of the eraser as seen from his vantage point.

Ask three other observers to trace the path of a ball as it is rolled across the room or playground in a "straight" line. Spin the ball in an attempt to make it curve as it rolls along its path.

Results

Compare what each observer sees.

Conclusions

The moti-n of an object can be described only in terms that are relative to the p nt from which the motion is observed.

CONCEPT - Distances to stars can be determined by studying their light. The farther away a light is, the fainter it seems. Therefore, distances can be calculated by the relative brightness of stars.

1. Problem

Does the brightness of a light source decrease with its distance from an observer?

Materials

Two identical flashlights, slide or filmstrip projector, yardstick, chalk, photographer's light meter.

Procedure

Have one child draw on a chalkboard a horizontal line one yard long and mark off thirty-six 1-inch intervals on it. Place the projector exactly 1 foot from the chalkboard and turn it on. Ask another child to focus the light on the horizontal line. How many inches of the line are lighted? Move the projector back 1 foot. Now how many inches does the light cover? Can the class find the area of the square of light? Move the projector back another foot and measure the distance covered by the light again. Has the amount of light hitting the chalkboard changed? (No. It has just spread out and therefore seems dimmer.) Have the children make a table of distances and areas of the rectangles of light on the chalkboard. The area of the rectangle of light is found by multiplying the width of the rectangle by its height. This amount will vary for each projector and lens.

Next place a slide or filmstrip in the projector. Shine the picture on the wall from a distance of 2 feet. Move the projector back to 6 feet. Now move it as far away as possible. When is the picture the brightest? (When the projector is closest.) When is it the dimmest? (When the projector is farthest from the wall.) Has there been a change in the amount of light produced? (No.) Why does the light become dimmer when the projector is moved back? (It is spread over a greater area.)

Results

Obtain a light meter. Take readings of the light falling on the chalkboard when the projector is various distances away. Have the children make a table of the readings and the distances at which they were measured.

Conclusion

Although the brightness of a light source may not change, it appears brighter or dimmer according to its distance away from an observer. Thus, distances to stars may be measured by comparing their light intensities.

CONCEPT - The apparent path of the sun is called the ecliptic.

1. Problem

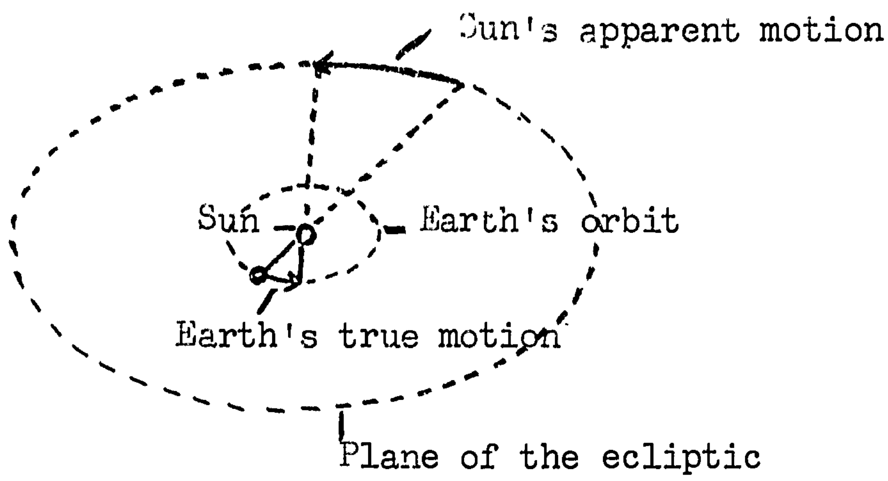
How can it be shown that the earth revolves about the sun, and the sun appears to follow a path in the sky?

Materials

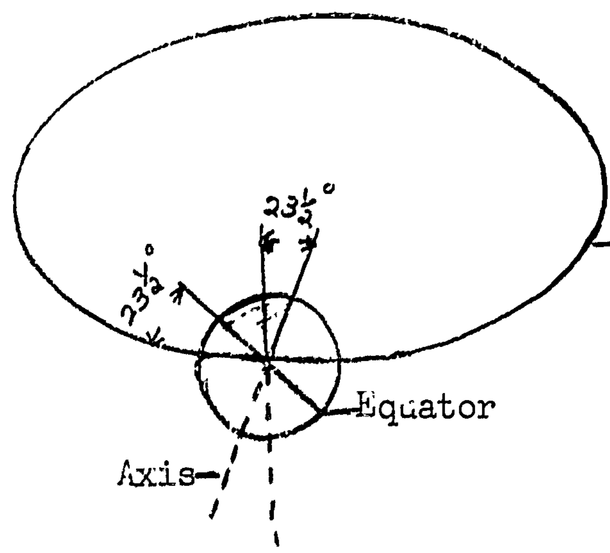
Protractor, paper, pencil, ruler.

Procedure

The children may do the following to show the plane of the ecliptic. Have them draw a verical line on a sheet of paper and then, using a protractor, draw an angle of $23\frac{1}{2}$ degrees. Next, ask them to center a large coin, such as a half-dollar, over the angle and draw a circle. Have them extend the lines of the angle, draw a diagram of the earth and the angle at which the axis is tilted, and draw in the equator. Finally, ask them to measure the angle between the equator and a line drawn parallel to it.



After the children have completed their drawing, ask such questions as: "What is the angle at which the equator is tilted?" ($23\frac{1}{2}$°.) "If the line of the axis were extended into space, what star would it intercept?" (The North Star.) If the horizontal line were continued into space around the sun, it would trace the path of the sun around the earth.



Results

This is called the ecliptic and the plane in which it lies is called the plane of the ecliptic.

Conclusion

The apparent path of the sun about the earth is called the ecliptic.

CONCEPT - The path of the earth around the sun is an ellipse.

1. Problem

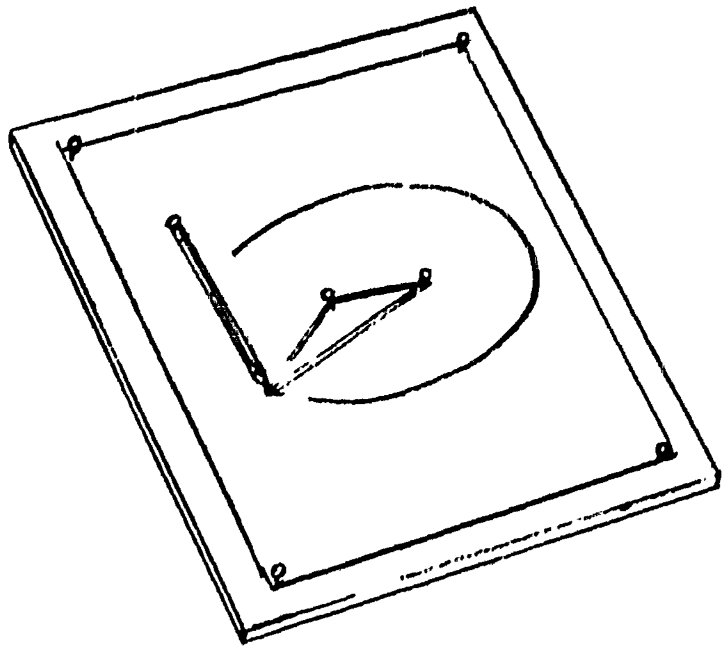
What is the shape of the earth's orbit?

Materials

Large sheets of paper, pins, pinning board, large drawing board or heavy tag board, string, pencils.

Procedure

The orbits of the earth, the moon, and the other planets and their moons are ellipses. To help the children find out more about ellipses and how they differ from circles, have them pin a large piece of paper, about 18 inches by 24 inches, on the bulletin board or on a piece of heavy cardboard, with two pins near the middle of the paper, about 4 inches apart. Then have them tie string about 1 foot long into a loop, place the loop over the pins, and pull the string taut with a pencil. Ask them to draw a line, using the string to guide the pencil.



Result

The result will be a true ellipse. Each pin represents a focus of the ellipse. Have the children draw several ellipses, varying the distances between the pins. What kind of figure is produced when the pins (foci) are right next to each other? (A circle.)

Conclusion

The path of the earth around the sun is an ellipse.

STARS & PLANETS

Initiatory Activities

Have the children:

1. Observe the night sky and try to locate some constellations, the North Star. Use the Big Dipper in locating the North Star.
2. Arrange gummed stars on a piece of dark blue paper in the form of some of the constellations.
3. Form committees to work on the various planets in conjunction with the model of the Solar System. Each group is to do research on a particular planet, using sources for research materials; library, magazines, children's private books, etc.
4. Bring in pictures, charts, and clippings from magazines, of the Solar System for display.
5. Read some of the legends about some of the constellations.
6. Discuss ancient people's beliefs about the Milky Way and other stars.
7. Estimate the time it would take to count the 40,000 million stars which some scientists believe are in the Milky Way.
8. Report on the recent work of Karl Jansky with the radiotelescope. How does this type of telescope work?
9. Read stories by Jules Verne and other writers for enjoyable exploration into the area of space.
10. Contrast the conditions necessary to sustain life found on earth with those of other planets. Find out what is being done by space programs in this area today.

Developmental Activities

CONCEPT - Scientists differ in their theories about the origin of the Solar System.

1. Research

   Have various committees each do research on a different origin of the planet theory. Then at a given time each committee will defend its theory using charts, drawings, and scientific knowledge that it has researched. Displays may be made of the work of the various committees.

2. Information for Teachers

Molecules of gas around a planet are held by the gravity of the planet. If the planet is unable to maintain an atmosphere, life would not be encouraged. Some of the main known characteristics of planets are listed below.

a. Mercury: The side facing the sun is estimated to be very hot, as high as 770°F. Since the same side of this planet always faces the sun, the side away from the sun has an estimated temperature of 400°F. Mercury has little or no detectable atmosphere. Mercury rotates only once each revolution.

b. Venus: The atmosphere of this planet contains large amounts of carbon dioxide, with recent observations revealing water vapor. No traces of free oxygen have been found, however. It is difficult to determine the surface temperature of it because of the dense clouds that interfere with telescopic and photographic methods of observation.

c. Mars: Oxygen is rare on Mars. Its shallow atmosphere contains mostly nitrogen. The average temperature of this rotating planet is about -60°F. The seasonal formation and melting of polar ice caps indicate the presence of water. The diameter of Mars is about half that of the earth.

d. Neptune: This planet has an atmosphere composed of methane and ammonia gases. Its average temperature is -330°F. Neptune's orbit period is 165 years and it rotates every 16 hours.

e. Pluto. Neither surface details, atmospheric gases (if any), nor satellites have been observed. Because of its distance from the sun, its temperature is probably never above -348°F. The distance of this planet from the earth has deterred man's learning much about it.

CONCEPT - The planets differ in size.

1. Problem

What is the relative size of the planet Earth as compared to the other eight planets in the Solar System?

Materials

9 balls of various sizes

Procedure

If the sun were about the size of an average classroom, the rest of the planets would be about these sizes:

Mercury - marble   Venus - tennis ball

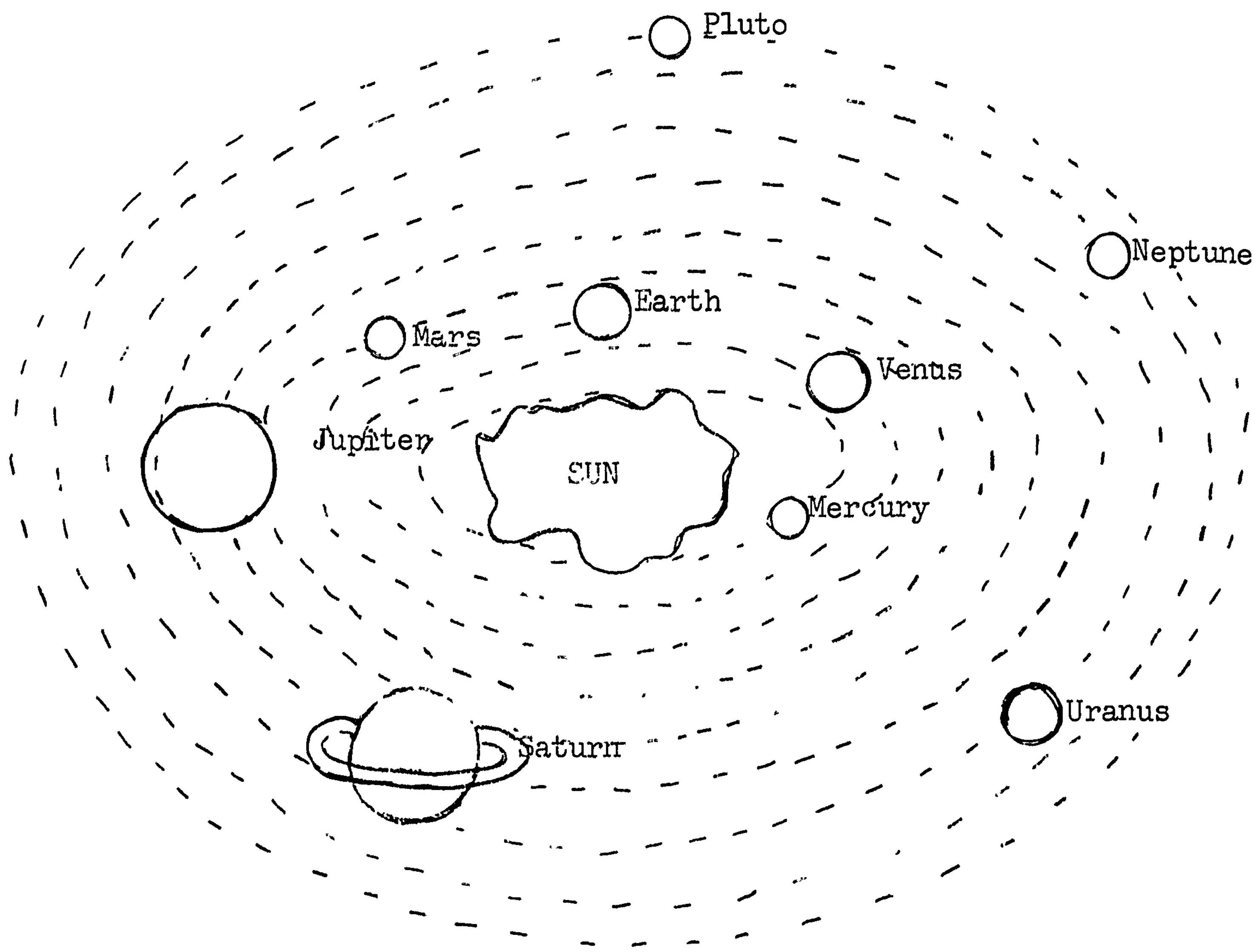
Earth - tennis ball
Jupiter - basketball
Uranus - baseball
Pluto - marble
Mars - ping-pong ball
Saturn - volleyball
Neptune - baseball

Have the children set these various balls and marbles into the positions they occupy in the solar system and label each. Discuss with the class which member of our Solar System is largest. What other planet is about the same size as the planet Venus? Why do such huge objects as the Sun appear small from far away? (The farther away an object is, the smaller it appears.)

Result/Conclusion

The Earth is a relatively small planet.

THE SOLAR SYSTEM



CONCEPT - Our Solar System is part of the Milky Way Galaxy, a tremendous grouping of stars, which is only one of many galaxies.

1. Research

   a. Have the children report on the contribution of Galileo, Kepler, Lowell and Newton to man's knowledge of the universe.

   b. The Egyptians believed that the Milky Way was a river used by the spirits of the dead Pharoahs to sail their boats. Later, before the advent of high power telescopes, people thought of the Milky Way as a mass of gas and dust.

   c. Scattered among the stars in the galaxy are huge clouds of gas and dust called nubulae. In some areas where there is a nearby star, the atoms of gas and dust may be excited into giving off light, thereby becoming a bright nebula (the radiation, heat, from a near-by star causes increased electron activity and glowing; reflection also accounts for some illumination).

2. Maps, Graphs, and Charts

   Obtain a picture of a star map of the Milky Way Galaxy and locate the Solar System. Use the opaque projector.

3. Demonstration

   a. Stress the fact that man is a very, very small part of the universe; characterize his position in the universe; ____________, School City of Gary, County of Lake, State of Indiana, Continent of North America ; Western Hemisphere, Planet Earth; Solar System; Galaxy, Milky Way; Universe.

   b. Demonstrate man's position in the universe by taking one grain of sand from a large container. Note that there may be thousands or millions of grains of sand in the container. In like manner, our planet earth is but one of an infinite number of celestial bodies in the universe just as is the grain of sand compared to all the sand in the jar.

   c. Take a small balloon and mark dots all over with a pen. Inflate the balloon and observe the positions of the dots as the balloon expands to demonstrate the concept of the vastness of space and expanding universe.

   d. Suggest that some pupils carry on research about the theories relating to the origin of the universe. This may be a good science fair project.

   e. Place many marbles on a table in a cluster arrangement so that no marble is less than an inch away from another marble. Slowly move away from the cluster of marbles. The farther back, the closer the marbles of "stars" appear to be. When looking at the Milky Way the stars seem to be very small and almost next to one another. They seem close together because they are so far away. This will show that although the stars appear close together, they are separated by great distances.

4. Resource Person

You will probably be able to find an amateur or a professional astronomer in the community who will be willing to share his knowledge of the night sky with the children.

CONCEPT - The universe is made up of many star systems of galaxies.

1. Maps, Graphs, Charts

An enlarged chart placed on the bulletin board may enable the children to understand the vastness of space.

Discussion about the chart should emerge, answering such questions as:

a. What is the Milky Way? Our galaxy.

b. What is a galaxy? A system made up of billions of stars.

c. Where is our Solar System located? Note the circle on the Milky Way.

2. Research

Have the children look up: signs of the zodiac; reports on planetoids, comets, meteors and meteorites; where some of the largest telescopes are, such as Mt. Wilson, Palomar Observatory; constellations, such as Cepheus, Draco, Taurus, Auriga, Cetus, Aries, Pisces, Andromeda, Perseus, and Pegasus.

Do research on astrology and astronomy, Aristarchus, Ptolemy, Copernicus, Kepler, Galileo, Newton, and reflecting telescope.

3. Draw

Have the children draw pictures of the zodiac signs and place in order (circle) on the floor around an unshaded lamp. Let a tennis ball represent the earth. The children will quickly see why at different seasons we see different constellations.

4. Make Models   Umbrella Planetarium

Use an old umbrella. Let the tip of the umbrella where the ribs converge be the North Star. This is also the end of the handle of the Little Dipper. On the inside make the outline of the Little Dipper with squares of masking tape or adhesive disks. Then place the Big Dipper with the pointer stars in its bowl pointing toward the North Star. Opposite this design place Cassiopia and add Cepheus and Draco in the appropriate positions. Let the children work under the raised umbrella. When the umbrella is held overhead the star groups should look much as they do outdoors.

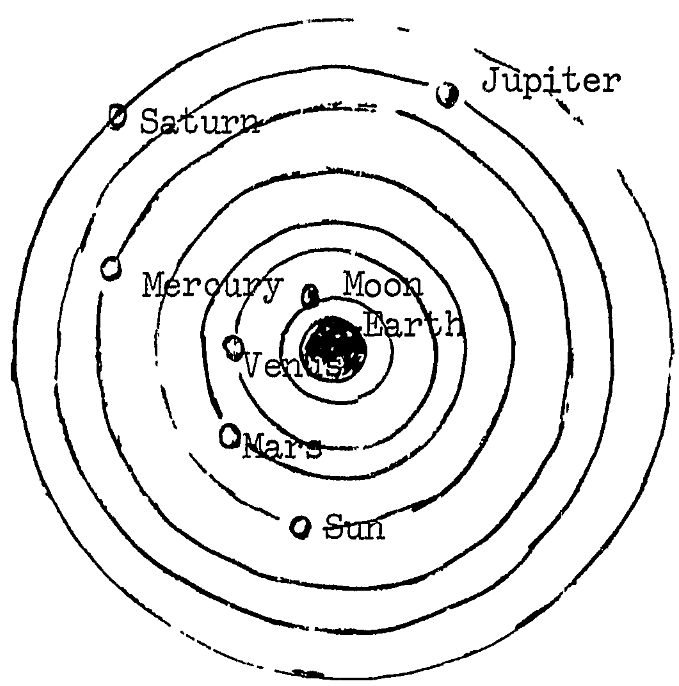
5. Demonstration   To Show the Relationship between the Constellation and the Rotating Earth

Take an old globe and after making holes at the North & South Poles, slip it over the rod of the umbrella. Take a piece of modeling clay or other marker and put it on the globe to indicate where you are. Ask the children to pretend that they are standing on the globe, looking up at the sky, that is, at the inside of the umbrella (open). Now turn the globe to demonstrate why the constellations each night appear to move about Polaris.

CONCEPT - Planets, planetoids (asteroids), moons, comets, and meteors are all part of the sun's family, the Solar System.

1. Draw

Place a diagram of Ptolemy's theory of the universe on the chalk board. Contrast this diagram with one of the Solar System.



2. Discuss

Discuss and account for the difference in the number of planets on the two diagrams.

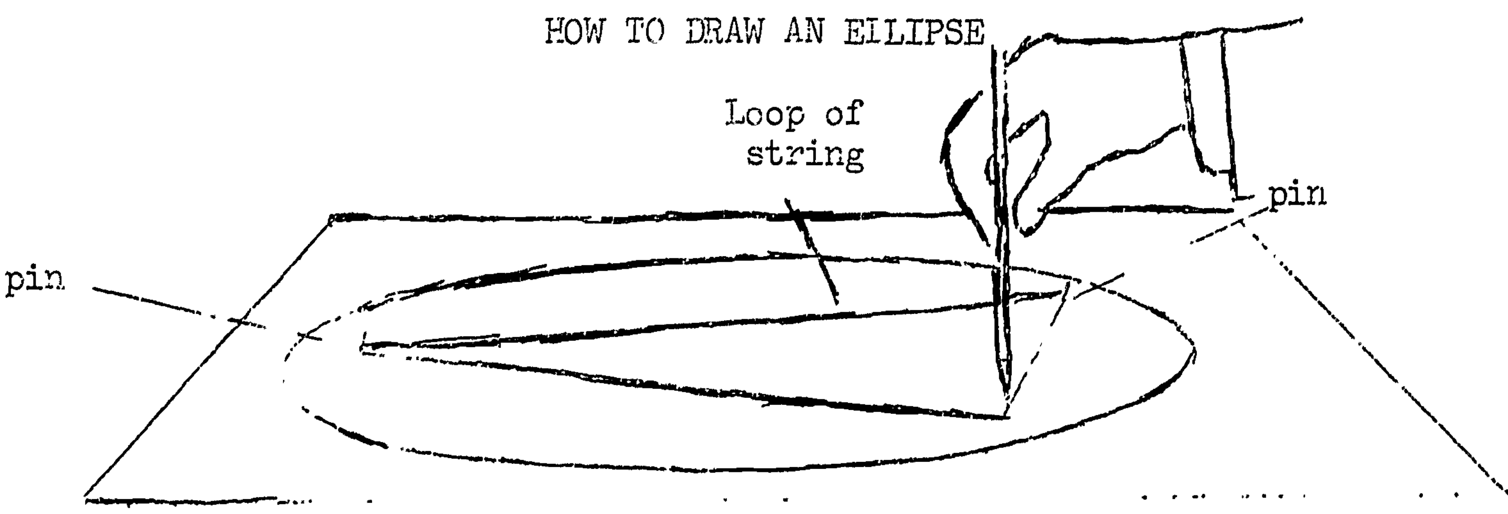
How did the work of Copernicus affect the Ptolemaic Theory?

How have recent discoveries affected present understanding?

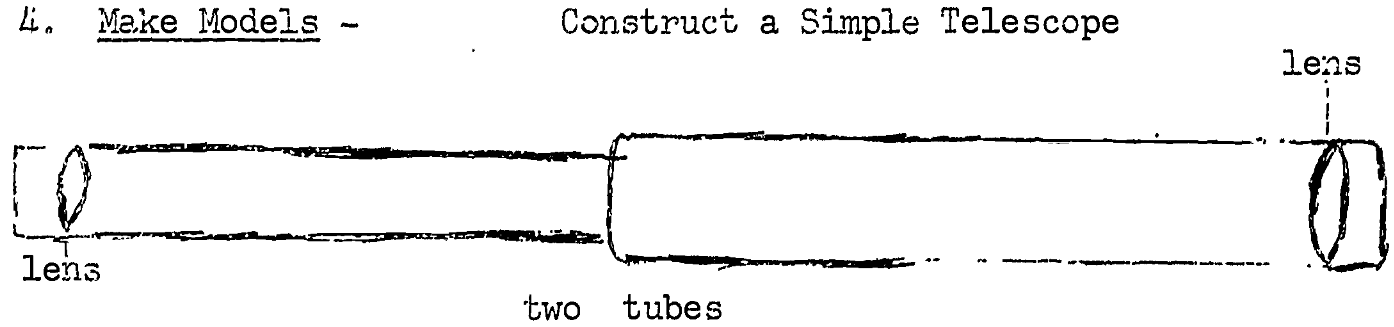
3. Demonstration

Stress the fact that the orbits of the planets are elliptical. Have pupils draw ellipses by using two pins or thumbtacks and a loop of string. Stick two pins through a piece of paper that rests on a wooden surface. Place the loop of string over the pins and, keeping the string stretched with the point of a pencil, describe the curve around them. The orbit of the earth and that of every other planet is a curve of this kind.

HOW TO DRAW AN ELLIPSE



4. Make Models - Construct a Simple Telescope



Use two cardboard tubes, one sliding closely into the other. Attach a small thick convex lens near the opening of the small tube. Attach a large, thin convex lens near the opening of the large tube. Look at a distant object through the smaller eyepiece lens. Slide the tube in and out until the object comes into clear, sharp focus. Assemble so the lenses are at opposite ends of the tube.

CONCEPT - Stars shine during the day, but we don't see them because their light is obscured by the brightness of the sun.

1. Problem

Why can't the stars be seen during the daylight hours?

Materials

Flashlight, lamp

Procedure

Let a bright electric lamp represent the sun. Have the children compare the brightness of the lamp in a darkened room and in a well-lighted room. Take the lamp out of doors during a sunny day. Does it look as bright as it did in the classroom? (No.) Have one child view the lamp from across the schoolyard. Does it look as bright from a great distance? (No.) Then hold the flashlight next to the bright lamp. Is the flashlight beam clearly distinguishable next to the bright lamp? (No.)

Results

What happens to the stars during the day? Do they still shine? (Yes.)

Conclusion

Why can't we see them? (Their light is obscured by the brighter light of the sun.)

[illegible] - The earth is the third planet from the sun.

1. Problem

Where is the location of the earth's position in the Solar System?

Materials

Tape measure, paint, stop watch

Procedure

There are nine known planets in the Solar System. Have the children look in a book on planets and the Solar System to find the distance of each planet from the sun. Discuss with them what would make a logical and usable scale of miles so that proportionate distances could be measured on the schoolyard. In the following table of distances, 1 inch equals 1 million miles.

Measure these distances away from a central, open spot and mark the position where each planet would be. Have a child stand on the point designating each planet to get an idea of the planet's location. Can the children align themselves in their proper order from the sun? Let another child serve as the sun. Have the children walk around the "sun," keeping in their orbits. How long does it take for "Mercury" to go around the "sun"? For the "earth"? For "Neptune"? For "Pluto"? Using a stopwatch one child can record the time it takes for each "planet" to revolve around the "sun."

Results

The children should find out that the farther the planet is from the sun, the longer it takes to make a complete revolution.

Conclusions

There are nine known planets revolving around the sun. Earth is the third planet.

Planet (arranged in order from the sun)	Approximate distance from the sun (millions of miles)	Distance on the schoolyard (feet)
Mercury	36	3
Venus	67	6
Earth	93	8
Mars	141	12
Jupiter	483	41
Saturn	886	74
Uranus	1783	149
Neptune	2792	232
Pluto	3666	309

CONCEPT - Light waves need no carrier; they travel across a vacuum.

1. Problem

Is visible light a form of radiant energy?

Materials

Clear electric lamp bulb

Procedure

Have the children examine a clear glass electric light bulb that is lighted. Point out that this is similar to a star burning in space. What forms of energy does the electric light give off? (Light and heat.) Can the children see the light it produces? (Yes.) Have a child place his hand close to the bulb. Does he feel another form of energy? (Yes.) What is it? (Heat energy.) What is inside an electric light bulb? (A filament, which is in a vacuum.) Why is it in a vacuum? (If the bulb is to burn for prolonged periods, the filament must be in a vacuum so that no oxygen from the air can oxidize it.)

Results

What carries the heat and light from the filament through the vacuum and the glass? (Nothing. Radiant energy needs no carrier.)

Conclusions

Light needs no carrier. It travels in a vacuum. It is detected only when something is placed in its path to absorb and/or reflect the radiant energy. In this case, the child's hand absorbs some of the radiant energy.

CONCEPT - Heat energy can travel through a vacuum, such as space.

1. Problem

Is heat energy another of the forms of radiant energy?

Materials

Electric iron, world globe, thermometer, chart paper

Procedure

Have the children place a thermometer in the direct sunlight and take a reading. Then place the thermometer in a shady spot and again take a reading. Keep a record of the readings and compare them.

Results

What does the thermometer record in each place? (The amount of heat energy.) What energy comes to the earth from space?

Conclusion

Heat energy can travel through space.

CONCEPT - A light year is a convenient unit to measure distances in space; it is the distance light travels in one year.

1. Teacher Information — Measuring Light-Year Distances

If you want to find out how many miles there are in a light-year, you can do it this way:

a. Multiply the distance light travels in one second (186,000 miles) by 60. This tells you how far light travels in a minute. 11,160,000 miles.

b. Multiply your answer by 60 again. This tells how far light travels in an hour. 669,600,000 miles.

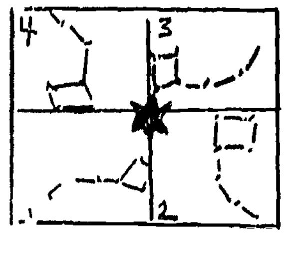
c. Multiply that answer by 24. This tells you how far light travels in one day. 16,070,400,000 miles.

d. Now multiply that answer by the number of the days in a year (365). This answer tells you how many miles there are in a light year. 5,865,696,000,000 - about 6 trillion miles.

This can be a good activity of correlation between math and science. Have the children discover each step before doing it. Thus, it will be more meaningful to the children.

2. <u>Draw</u>

Have the children draw observations of night sky. Have each child to draw a circle and divide it into four parts. Place a star in the center of the circle. This is the North Star. In each of the four parts have the children draw the Big Dipper. They are to be sure the pointer stars are in line with the North Star. Number your dippers, one, two, three, four. Have the children observe the night sky. They are to hold the paper so that the dipper 1 is in the same position as the Big Dipper in the sky. Mark the time. Have the children mark the time for the position of each Big Dipper. This may not necessarily be done in one night.



3. <u>Field Trip</u>

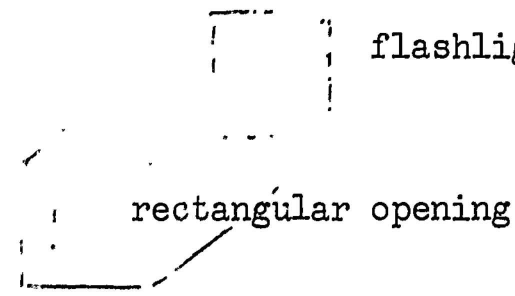
If possible, have the children visit a planetarium or observatory.

4. <u>Bulletin Boards</u>

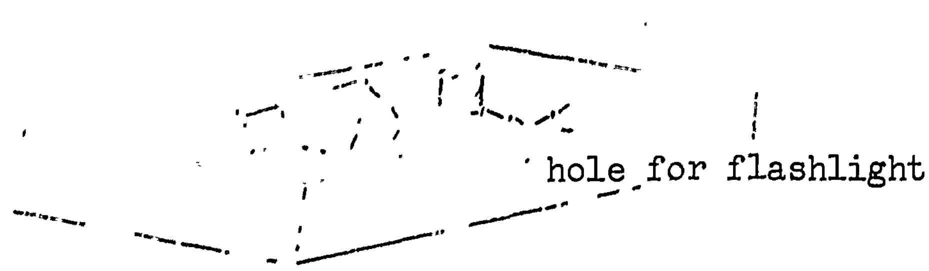
Have the children cover a bulletin board with black construction paper to represent outer space or the night sky. Have them cut out the number of white circles needed to represent the stars in their particular constellation from the drawings they made previously. It would be best if the children work in pairs. Each group is to place and label a constellation on the bulletin board.

5. <u>Make Models</u> Construct a Constellation

Cut a rectangular opening in one end of a shoe box and a circle in the center of the opposite end through which a flashlight can be inserted. Cut rectangles of black paper slightly larger than the opening in the shoe box. Using a pencil or sharp object, punch holes in the black paper to represent stars of a specific constellation. View the cards of the constellations. Remind the pupils that stars in the same constellation are at different distances from the earth.



Construct a larger constellation viewer by using a dress or suit box.



Solar System

Materials

Yellow modeling clay, a piece of heavy wire long enough to reach across the room, several feet of fine wire, a large sheet of tagboard, paper clips.

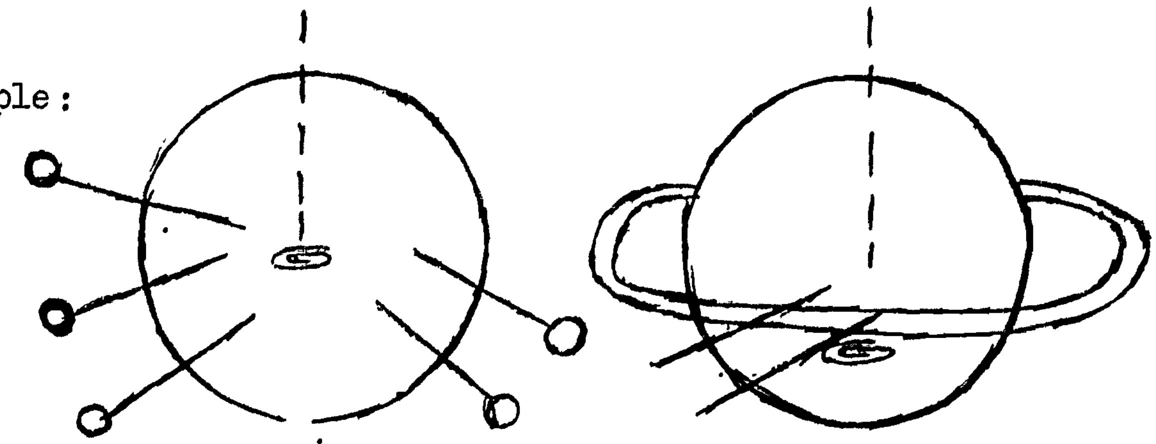
Procedure

To represent the earth use a ball of clay $\frac{1}{4}$ inch in diameter. Then from the chart find out how large the other planets should be made. Example: Mars 1/8", Jupiter 11 times 1/4" or 2 and 3/4 inches in diameter.

Saturn differs from all the other planets in having a ring around it. Make the ring from tagboard about an inch wide. The diameter of the inner circle of the ring should be greater than that of the model of Saturn. Push 3 paste sticks into the model of Saturn to make a support for the ring. Place the ring on them.

As soon as you have made the models of the planets, run pieces of fine wire about a foot long through them so that they can be hung up. In each of the larger models, fasten a paper clip to the end of the wire to keep the model from falling off. Bury the clip so that it doesn't show.

Example:

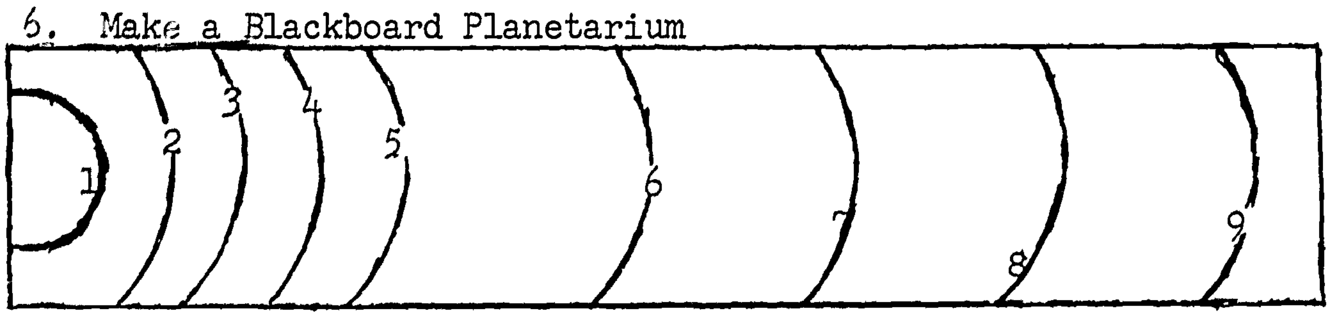


The sun, if made of clay on the same scale as the planets, would be too big and heavy. Cut a circle out of tagboard to stand for the sun. It will be 108 times ¼ or 27 inches in diameter.

Fasten the heavy wire across as high above the floor as possible. Fasten the sun circle to the wall at one end of the wire. Use the chart to find out where to hang the earth and other planets.

Make tiny balls of clay, for moons of planets. Fasten them to planets with short pieces of fine wire.

6. Make a Blackboard Planetarium



Number & Name of Planet		Distance from Sun in Millions of Miles	Distance to be Measured from left side of Blackboard
1.	Mercury	36	1 3/4 in.
2.	Venus	67	3 1/4 "
3.	Earth	93	4 3/4 "
4.	Mars	141	7 "
5.	Jupiter	483	2 ft.
6.	Saturn	886	3 ft. 7 in.
7.	Uranus	1783	7 " 5 "
8.	Neptune	2791	11 " 6 "
9.	Pluto	3671	15 " 3 "

(Scale: 1 inch = 20 million miles)

EXPLORING SPACE

Initiatory Activities

Have the children:

1. Read a poem about airplanes, the stars, or the moon; listen for and discuss sound words, rhyming words, and words which tell pictures.

2. Invite a speaker to discuss modern communications; illustrate at least three kinds of communications used in their homes, industry, transportation, and space projects.

3. Listen to a series of weather reports and note how they are presented.

4. Read a book or story about space; have each child give an oral book report to the class.

5. Listen to a guest speaker; take a field trip to a planetarium; form committees with each committee reporting on three facts that were learned.

6. Plan and present an assembly program on space exploration.

7. Read chart stories about the work at an airport, project Gemini, or weather and meteorological satellites.

8. Do independent reading and report on legends and myths connected with flight.

9. Select a topic such as communications satellites and read a news story, feature article, and an interview connected with the subject and discuss them with the class.

10. Differentiate between fact and fiction by reading science fiction books, comparing them with factual materials from authentic scientific sources.

11. Prepare word lists using the names of planets or space projects and using each word in a sentence.

12. Write captions for scrapbooks on the earth, solar system, moon, constellations or satellites.

13. Plan a class book on space studies. Let one committee prepare an outline for each chapter; another write the material; another prepare the captions; another the table of contents and indexes.

14. Read an article about a satellite to the class; have the children take notes, organize the information into an outline, and then write a brief summary.

15. Write newspaper articles: a story about a recent launching, an interview with a civic personality about space exploration, a review of a scientific book, or a feature article on the benefits of space research.

16. Bring newspapers to class and show how many different kinds of information on space can be found.

17. Make a class calendar for a particular month and record facts about the moon's shape, color, and when it can be seen in the daytime.

18. Look at photographs of the moon taken through a telescope and discuss the patterns.

19. Observe and record the weather each day for a two month period; have the children note and discuss cloud formations on cloudy and sunny days.

20. Tell about the latest launch at Cape Kennedy and form committees to report on the various phases; e.g., the spacecraft, its use, the launch vehicle, the countdown, the personnel, recovery or landing, etc.

21. Keep informed about current events by reading articles on space exploration in magazines as well as newspapers. Have them bring articles and pictures about the latest launching to class for a bulletin board display.

22. Collect materials about the practical benefits of space exploration and then discuss the points of view expressed by various sources.

23. Devote an entire issue of the school newspaper to "space."

Developmental Activities

CONCEPT - Astronomers use a spectroscope to determine the chemical composition of the stars and of the atmosphere of other planets.

1. Problem

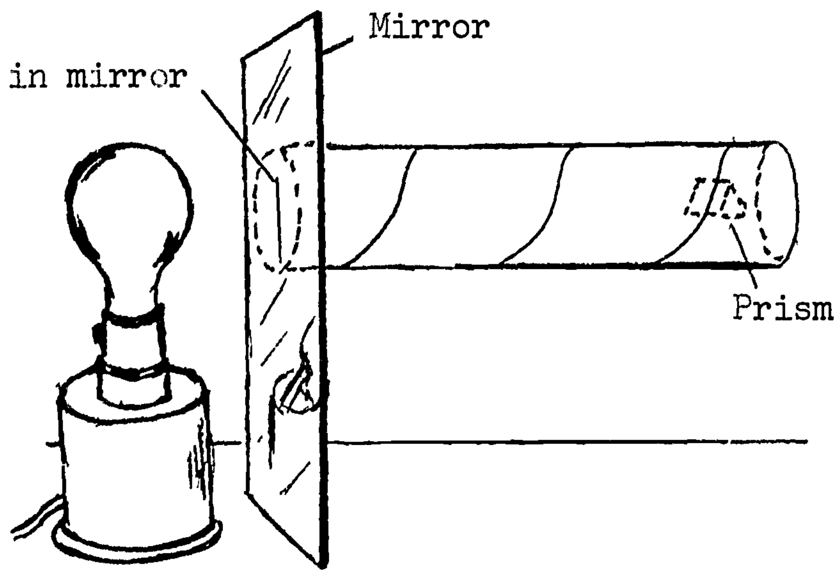
How is a spectroscope used?

Materials

Small mirror, mailing tube, adhesive or masking tape, light source, diffraction grating, prism, glue, aluminum foil, razor blade, rubber band.

Procedure

Have the children make a fine scratch ½ inch long on the silvered side of a small mirror. The line should have clean, sharp edges. Have them fasten the mirror to one end of a mailing tube and then cut a hole in the tube so a prism may be inserted. Let them hold the end of the tube with the slit in front of a light source, look through the open end of the tube, and adjust the prism to give a broad spectrum. (This can be determined only by maneuvering it until the desired clarity is reached.) Then tape the prism in position.



Now suggest to the children that another way to build a spectroscope is with a diffraction grating. A diffraction grating is a transparent piece of glass or plastic on which thousands of parallel lines have been etched. These lines serve to break up the light into a spectrum as does a prism. (Diffraction gratings may be obtained very inexpensively from scientific supply companies.)

Have the children glue a diffraction grating to the end of a mailing tube or other round cardboard tube and then place some aluminum foil over the other end. Make a narrow slit in the aluminum foil with a razor blade. Have a child hold the diffraction-grating end of the tube up to his eye and look through the slit at a light source, rotating the aluminum foil until a spectrum is seen. Fasten the aluminum foil in place with a rubber band.

Results

Light from an incandescent lamp will give a continuous spectrum, that is, the colors will blend from red to violet without interruption. However, under conditions of low pressure, each element when in its incandescent gaseous state will produce a spectrum with a unique pattern of bright lines. For each element, there will be a bright line spectrum, and each bright line will be in a definite position in the spectrum.

If the light from an incandescent substance under high pressure is permitted to pass through a cooler gas at low pressure, the spectrum will be marked by dark lines. Each dark line will occupy the same position as a bright line in the spectrum as above. Either the dark line spectrum or the bright line spectrum may be used to identify the elements in the gas.

Conclusion

By taking pictures of the spectrum produced by a star, and comparing them with spectrographs produced by known elements, we can determine what a star is made of.

CONCEPT - The Doppler effect is the name given to the shift of the position of spectral lines when the light source is either receding from or approaching the spectroscope.

1. Problem

What is another type of information that can be obtained through the use of the spectroscope?

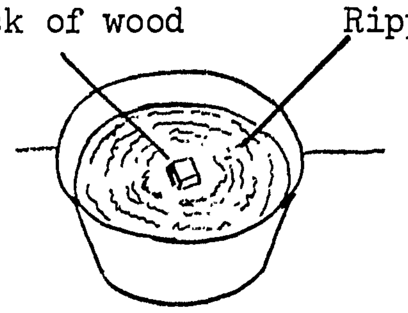
Materials

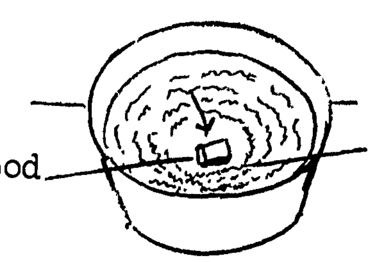
Bicycle, transistor radio, block of wood, pan of water.

Procedure

The children can experience hearing the Doppler effect by lining up along the edge of a sidewalk. One child, riding a bicycle, should move swiftly past the row of students as he sings, yells, or plays a transistor radio loudly. Have the children listen for the change in pitch as the rider passes.

Another example of the Doppler effect can be seen with ripples in a tub of water. Have a child float a small block of wood in the center of a pan of water. Let another press lightly on the block and watch the pattern of the ripples emanate in rings from the center. Now have the child give the block a slight forward motion. Do the children see how the ripples are closer together in the direction of movement?





Result

Now make the point that light energy also comes to us in waves. These waves tend to bunch up in the direction of movement, just as the ripples do. Explain that, by comparing the bands in a light spectrum of a star with a known spectrum, we can see a slight shift in the bands to one side or another. This shift indicates that the light is moving toward or away from the slit in the spectroscope. Light from a source moving toward us will cause a slight shift to the shorter violet end of the spectrum, while light from a source moving away will cause a shift toward the red end.

Conclusion

The Doppler effect is the shift of waves so that they are either close together or farther apart, depending upon the relative movement of the source and receiver of the waves. Astronomers use the shift in the spectrum to determine whether a light source is moving toward or away from the earth.

CONCEPT - Some space probes carry instruments such as the magnetometer, to detect the magnetic fields around other planets.

1. Problem

What are the types of equipment carried by space probes?

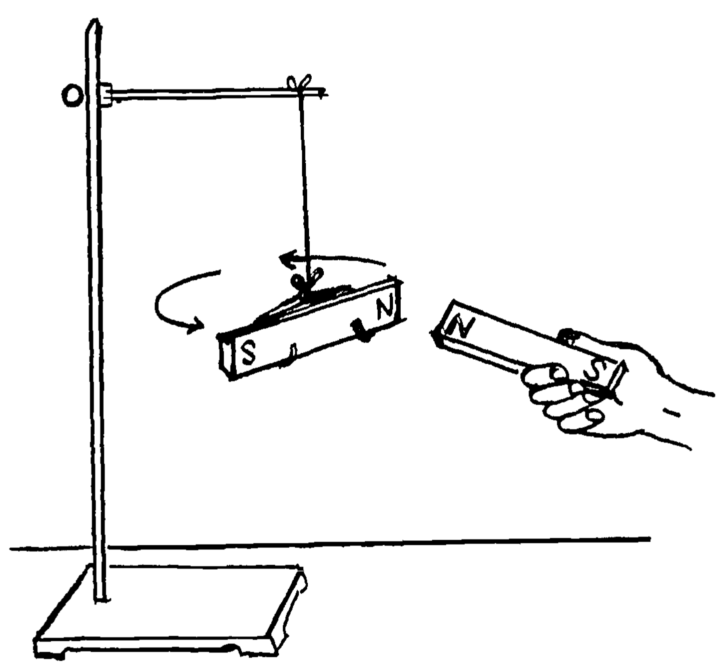
Materials

Two bar magnets, string, compass.

Procedure

The children can make a magnetic field detector simply by constructing a free-moving magnet. (This, incidentally, is also the principle of the compass.) There are many ways to do this. One way is to suspend a bar magnet by a string and allow it to rotate freely. When it stops, have the children note the direction in which it points, then tap it gently to cause it to swing again. When it stops, ask them to note the direction in which it is aligned. Is it the same as before? (Yes.) Why? (The magnet has aligned itself with the earth's magnetic field.) Have the children bring a second magnet close to the first magnet. What happens? (The first magnet moves.) Why? (The magnetic fields of the two magnets interact.) Ask the children, "Do you think the same thing would happen if the magnetometer were placed near Mars? Venus? Near the moon?"

Some children might try to detect magnetic fields of objects on earth. Sometimes a piece of steel or iron equipment that has been left undisturbed for a long period of time will become magnetic. The metal legs of a table or chair may become magnetized. Establish that a compass will move when brought near a magnetic field by bringing one near a magnet. Move the compass around the magnet and have the children observe the movement of the compass needle. Why does it move? (The needle is a small magnet, and its magnetic field interacts with that of the magnet.)



Results

Have the children bring a compass close to the top of a steel table leg or steel cabinet. Note the direction in which the compass needle points. Let them move the compass to the bottom of the leg. What happens to the compass needle? (If the legs of the table are magnetized, the compass needle will swing around to point in the opposite direction as it is moved from the top to the bottom.) Let the children test the other table legs. Do they observe the same thing happening to the compass needle? (They should.) Have them test various metal objects.

Conclusion

A magnetometer is used to detect the magnetic fields around the other planets in the solar system.

CONCEPT - There may be life on other planets.

1. Problem

What are ways to explore whether there is life on other planets?

Materials

Pyrex Petri dishes, plastic refrigerator boxes, or other clear containers that can be sterilized and sealed.

Procedure

Have the children sterilize several of the containers by boiling or steaming them (as is done with nursing bottles) for about 20 minutes. Into each container, let a child pour enough agar or liquid gelatin to cover the bottom to 1/8 inch. Cover the containers and allow them to cool. Have another child take several 8-inch pieces of damp string that also have been sterilized and drag them over the lawn, across the soil, or over the classroom floor. Ask the child to place them in the dishes of agar or gelatin. Save one container of nutrient to use as a control. Cover each dish and allow them to remain in a warm place for several days. Do not open them, but have three children observe each dish every day, keeping a record of their observations. Do they notice any life appearing on or around the string on the gelatin? (Bacteria, molds, or yeasts may begin to grow on the nutrient.) Do any forms of life grow on the control nutrient? (No.) Would this experiment prove that all living things that are on the nutrient have been detected? (No. There may be organisms that live on other nutrients and organisms that live at other temperatures.)

Results

Develop with the class such questions as: What do living things need to grow? What do they take from their environment to grow? What do they give back to the environment? What do animals need for growth? What do plants need? (Develop the concept of the exchange of carbon dioxide and oxygen between plants and animals in the processes of respiration and photosynthesis.)

Conclusion

Life may exist on other planets. Space probes can carry instruments to detect this life if it exists.

CONCEPT - The earth pulls things down toward it. This is called the earth's gravity.

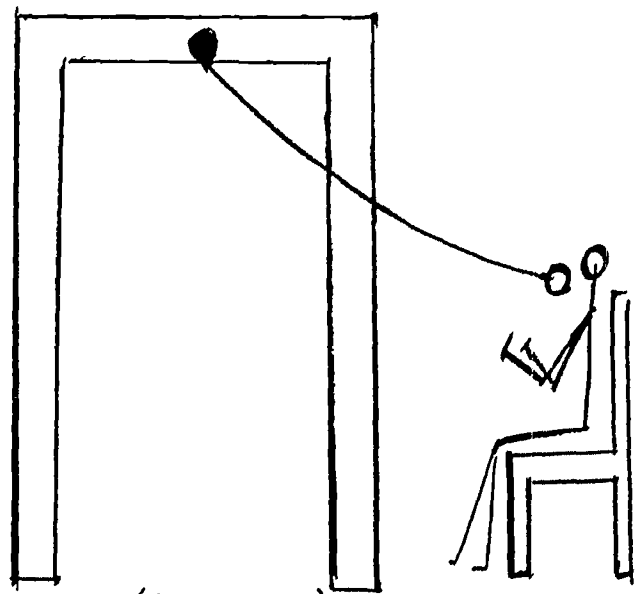
1. Problem

What is gravity?

Materials

Ball, string, chair, tape.

Procedure



Hang the ball in a doorway (see the illustration). Hold the ball to your nose. Let the ball go. Sit still. What makes the ball go away from your nose? (Gravity.)

How far will it go? Will it come back?

Results/Conclusions

The ball will swing back and forth.

Gravity is constantly exerting a pull on the ball.

Research

Make a report on Sir Isaac Newton, an English scientist who discovered some important facts about gravitation.

2. Problem

How much does gravity pull on you?

Materials

Small cardboard box, large rubber band, ruler, thread, marbles.

Procedure

Place the ruler on a table so that about 3 inches extend beyond the table. Place a pile of books on the rest of the ruler so that it will not topple over during the experiment. Insert one end of the rubber band into a paper clip and loop the other end of the rubber band over the protruding end of the ruler. Then insert into the lower end of the paper clip a loop of thread attached to the sides of the cardboard box. Make a pointer by bending one end of the paper clip into a horizontal position. Now add marbles, one by one, and notice how the rubber band stretches. You may make your own scale by putting a narrow strip of white cardboard underneath the ruler and let the rest hang down with the box empty, marking with black crayon the point where the pointer touches zero. As marbles are added to the box the rubber band stretches. Label each mark to denote how many marbles are in the box. You now have a balance with marbles as a unit of weight.

Conclusions

The stretch of the rubber band clearly shows the pull of gravity on the marble.

3. Demonstration

Have a child hook a ball to a string. Hold the string out as far as your arm goes.

Make the ball go in a circle.

(The earth's gravity is still pulling down, but the ball has moved up a little.)

Make the ball go faster and faster. The earth's gravity never stops pulling it down. But the ball stays up if it keeps moving fast. Now let it go slower and slower. What does the earth's gravity do to the ball?

NOTE

A satellite is not attached to string but receives its initial speed from a launch vehicle.

CONCEPT - "Down" is toward the earth. "Up" is away from the earth.

1. Problem

Is it easier to move a ball "down" or "up"?

Procedure

Have a child simply drop a ball. Then have the child try to get the ball to go up. He will have to work to make the ball go "up." Does he have to work to make the ball come down?

Results/Conclusions

The ball goes "down" with only the force of gravity working on it. It takes "work" to make the ball go "up."

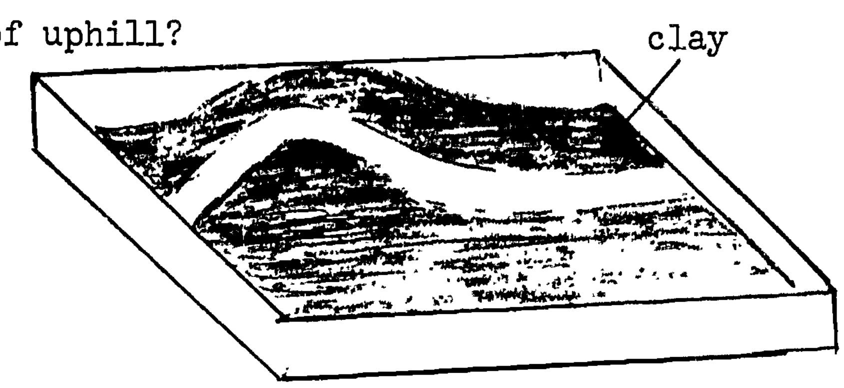
Gravity is pulling on all objects. It is easier for an object to go to the earth than for it to go away from the earth.

2. Problem

Why does water go downhill instead of uphill?

Materials

Pan, water, clay or dirt.



Procedure

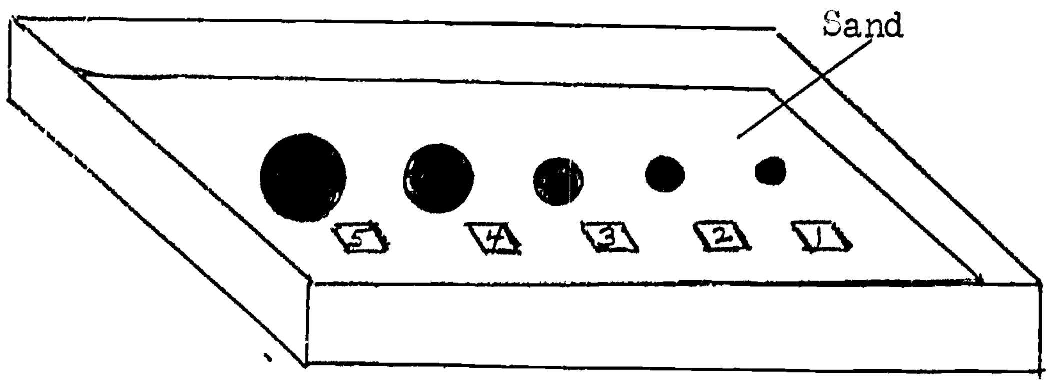
Make a hill in the pan with clay or dirt. Spread it out so that there is a gradual slope. Make a path for the water to go down. First, put water at the low part of the pan. Does it go up? (No.) Then pour water on the high part (hill). Does the water go downhill? (Yes.)

Results/Conclusions

Water goes downhill.

Water flows downhill because of the earth's gravity.

3. Problem



Does the mass of an object (size and weight) affect its gravitational pull?

Materials

Five steel balls of different sizes, box of sand.

Procedure

Have the children drop the steel balls into the sand. Have each ball labeled with a piece of tape (1, 2, 3, 4, 5).

Put a tag in front of each ball showing its number.

Remove the balls and observe which ball made the biggest hole. (Measure and record.)

NOTE

Make sure all balls are dropped from the same height.

Results/Conclusions

The biggest ball will make the largest hole. The bigger the mass, the more gravitational pull is exerted on it.

Record Facts

Balls	Distance Dropped	Weight of Balls	Size of Hole
1			
2			
3	if you wish	if you know	
4			
5			

Which made the largest hole?

Which made the smallest hole?

CONCEPT - Everything has gravitation. The more mass to a substance the stronger its gravitation. The greater the distance between two things the weaker the gravitation between them.

1. Problem

Do similar objects, falling from the same height, hit the floor at the same time?

Materials

Two 12 inch rulers, two pennies.

Procedure

Place a 12 inch ruler obliquely at one corner of a table top. Let one end of the ruler project over the edge of the table and have the other end about one inch from the edge. Place a penny on top of the projecting end of the ruler. Place a second penny on the table between the other end of the ruler and the edge of the table. With the flat part of another, strike the projecting end of the first ruler sharply, using a horizontal motion. Draw the second ruler back quickly as soon as you have struck the first ruler.

Results

One penny falls straight to the floor while the other travels in a long arc. They both hit at the same time.

Conclusions

Everything has gravitation.

CONCEPT - The earth's pull [illegible] toward its center.

1. Problem

How can the gravitational attraction of the earth be demonstrated?

Materials

Bathroom, balance, spring, and laundry scales; various objects for measuring; string and weight for a plumb line; pipe cleaners; world globe; ball or other unbreakable objects; modeling clay

Procedure

Each child can find out how much gravitational force the earth is exerting on him by weighing himself and recording his weight. Explain to the class that a person's weight is a measure of the earth's pull on his body. If a child registers a weight of 100 pounds, the earth is pulling at him with a force of 100 pounds. Using various scales--balance, spring, and laundry scales--measure various objects to find the amount of gravitational pull on each.

Next, the children can discover that gravity attracts all objects toward the center of the earth by dropping a ball or other unbreakable object. Have the children observe the direction of fall.

Have them also construct a plumb line by attaching a weight to a string. Suspend the string so that it will swing freely. When it stops swinging, let the children observe it to see if the string is perpendicular to the ground. Ask them in what direction gravity is pulling on the weight. (Straight down.) What if the plumb line were on the other side of the earth? Would it hang in the same direction? (Yes.)

Results

Using modeling clay, attach pipe-cleaner figures to a world globe. Help the children determine the direction of the force of gravity if a person (represented by a pipe-cleaner figure) were to drop an object. These activities will help the children to see that the attraction of gravity is generally toward the center of the earth.

Conclusion

The earth's gravitational attraction pulls objects toward the center of the planet.

CONCEPT - If a great enough force is exerted in a direction opposite to the gravitational force exerted by the earth, an object can rise.

1. Problem

How can the earth's gravitational attraction be overcome?

Materials

Large ball.

Procedure

Have a child hold a ball at arm's length. Ask the children, "Is the earth pulling on the ball?" (Yes.) "How much?" (The force is the weight of the ball.) "Is the child overcoming the force of gravity on the ball?" (Yes. Otherwise, the ball would be falling.) When his arms tire, let the child release the ball. "Does it fall?" (Yes.) "Why?" (The earth attracts the ball toward the center of the planet.) Now have him throw the ball gently into the air. As the ball goes up, does it travel against the pull of gravity? (Yes.) What did the child apply to the ball to make it overcome the gravity for a brief period? (A force.) Have the child throw the ball harder. Does the ball go higher? (Yes.) Why? (He has applied a greater force.) See who in the class can throw the ball the highest. Could anyone throw the ball into space? (No.) Why? (No one can apply a force great enough to overcome the earth's gravitational force indefinitely.)

Results

As the children throw the ball into the air, can they determine the point at which the ball begins to fall back to the earth? (Yes.) Why does the ball fall back? (The ball travels upward because it has initially been given enough upward push by the child to exceed the downward pull of the earth's gravitational attraction. The gravitational pull, however, eventually overcomes the child's push, and the ball therefore returns to earth.)

Conclusion

The pull of gravity can be overcome by exerting a sufficient force in the opposite direction.

- To overcome the earth's gravitational attraction, large amounts of energy must be expended.

1. Problem

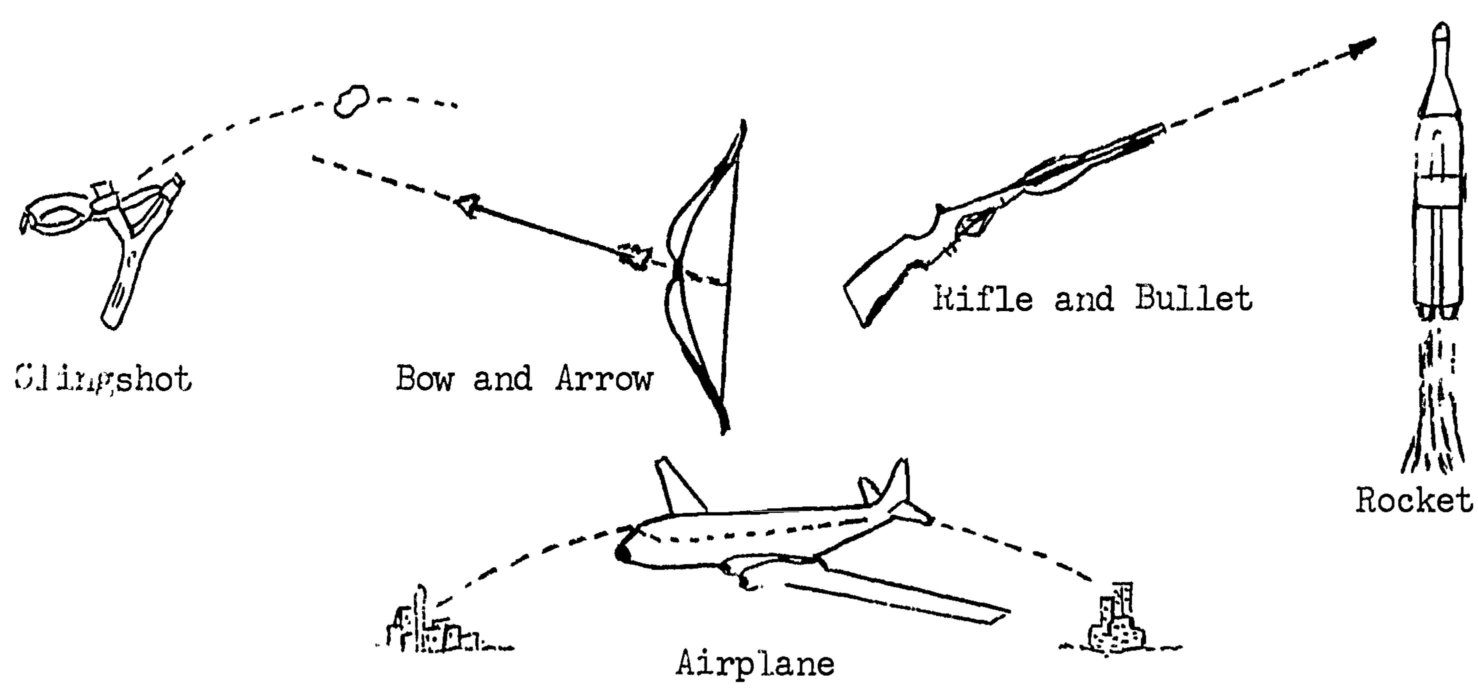
How can machines be used to overcome the attractional force of the earth?

Materials

Candle, jars, baking soda, broom straw or wood splinter, hydrogen peroxide.

Procedure

Explore with the children the sources of energy for various machines with which they may be familiar. On what principle do they operate? Which of these energy sources do the children think would be feasible to power a space vehicle? Which would not? Why not?



Could a jet airplane go into space? (No.) What does a jet engine need to operate? (Oxygen.) Any engine that uses a fuel such as gasoline or kerosene must also have a source of oxygen (oxidizer) available to combine with the fuel. Kerosene and gasoline use oxygen from the atmosphere. Is there oxygen in space? (No.)

Results

To supply answers to these questions, let the children place a candle (fuel) inside a jar in an upright position and light the candle. Then have them place the lid tightly on the jar and observe what happens to the candle's flame. (It should go out in a short time.) Why? (The candle uses some of the oxygen in the jar to burn.) The candle serves as the fuel to combine with the oxygen in the air inside the jar. If a jet engine approaches the outer limits of the atmosphere, where the oxygen supply becomes slight, what will happen? (The fuel will have nothing with which to combine and therefore will not burn.)

Pose the question, "Where can an engine obtain a supply of oxygen in space?" (To venture into space, where there is no oxygen, it must take a supply of oxygen along.) Explain that this might be in the form of pure oxygen or oxygen in combination with other elements. Many compounds in our environment contain oxygen. In some cases this oxygen in compounds can be taken into space along with the fuel (kerosene).

Have the children pour about 1 inch of hydrogen peroxide into a small bottle and add a teaspoonful of ordinary baking soda. Then ask them to place a piece of cardboard over the top of the jar and set it aside for about five minutes. Explain that the tiny bubbles escaping from the peroxide are bubbles of oxygen. Light a broom straw or wooden splinter. Blow out the flame so the straw or splinter just glows. Put the glowing straw or splinter into the bottle and notice what takes place. (The straw should burst into flame.)

Conclusion

Many machines help us overcome gravity. A great deal of energy is required to overcome gravity completely. An engine that burns fuel must take its own oxygen into space with it, for there is no oxygen in space.

Machine	Energy Source
Automobile	Gasoline and oxygen
Jet airplane	Kerosene and oxygen
Nuclear submarine	Nuclear (uranium)
Locomotive	Diesel fuel and oxygen
Electric motors	Electricity
Cordless electric razors	Electric storage batteries
Steam engine	Steam

CONCEPT - Inertia keeps moving things going.

1. What is inertia in motion?

Materials

Paper, block of wood, thumbtacks, a coin.

Procedure

Press two thumbtacks into the block of wood. Put a coin next to the tacks. Fasten another block of wood near the center of the table. Push the block of wood that has the coin on it. Try to hit the other block.

Results/Conclusions

The coin moves forward since an object in motion cannot stop moving by itself. It has inertia. The block stops since it was pushed against the other block, but the coin did not hit anything so it continues to move. Thumbtacks do not continue to move because they are fastened to the block.

An object in motion stays in motion unless acted upon.

2. Observe

Have a child run fast and stop suddenly. What happens? His body is in motion and will continue to go forward. His feet will stop because of friction and the force he applies. What force finally stops the body?

Talk about a car stopping suddenly. Why does the car skid? It is in motion and tends to keep going forward. What happens to the objects inside the car?

3. Demonstration

Have children bring in a baseball (soft). Throw the ball. It is in motion and will not stop until a force stops it. The hand that catches the ball is the force that stops it. The hand actually pushes on the ball in the opposite direction.

4. Demonstration - Possible Objects

Materials

Toy that has wheels, toy that has no wheels, small wooden box (about the size of the toy), marble, an orange, smooth-surfaced table, sand or dirt.

Procedure

Have children place objects, one at a time, on the flat, smooth surface. Do the articles stay where they are placed? Now take the objects that will roll and set each in motion. Does it keep moving? Try to set the objects that do not roll into motion. What happens? Repeat the experiments putting some rough materials on the surface (sand, dirt). Ask:

"On which surface did we need to use more force to make something move?"

"On which surface did the objects need less force to make them move?"

"To stop them?"

Try these same experiments with a slanted surface.

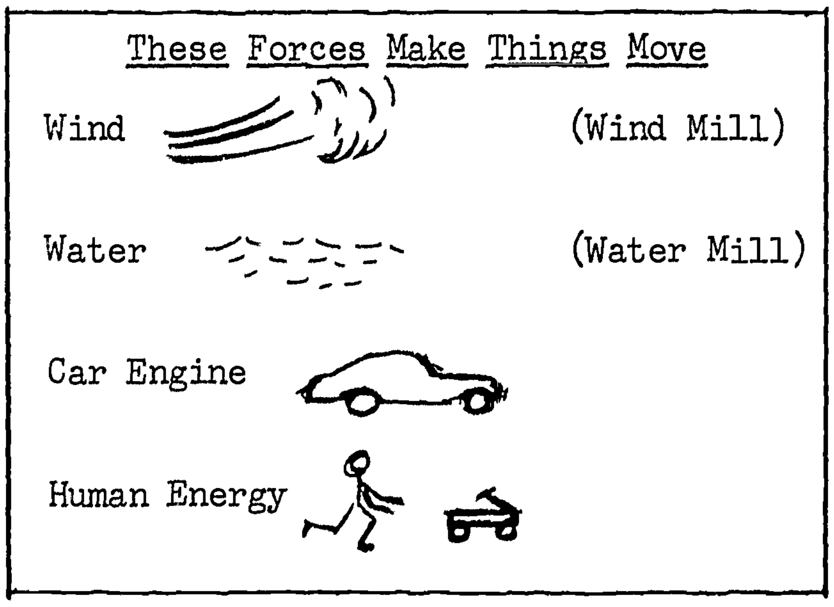
5. Discussion - Riding in a Car

What happens when the car stops suddenly? Which direction does the passenger keep going? What stopped the car? What will stop the passenger? (Safety belt, windshield; or the passenger may use his hands.)

The passenger is in motion, and he stays in motion until something stops him.

6. Charts, Maps, or Graphs

Have the children make a chart of as many kinds of forces that they can think of.



Make children tell you what force makes each object go:

Pinwheel
Top
Ball
Kite
Air Conditioner
Sail Boat
Train
Skates

7. Demonstration

Have children demonstrate pulls and pushes (as many as they can do in the classroom).

PULLS	PUSHES
Open a window (depending on the type).	Open a door.
Drop an eraser (gravity pulls).	Roll a ball.
Raise a window shade.	Throw a ball.
Lift the desk.	Walk (Your feet push against the floor.)
Lift a book.	Write with a pencil.
Take a tack out of the bulletin board.	Blow up a balloon.

CONCEPT - Inertia is a for e that keeps things that are at rest where they are.

1. Problem

   Can you set an object into motion with a force?

   Materials

   Pinwheel, toy car, box, marble.

   Procedure

   Set object on a completely flat surface. Ask the children to observe the object. Is it in motion? The answer should be "no." Have one child try to set the object in motion without applying a force. Children may try to:

   1. Tip the surface -- gravity would be the force.

   2. Blow on it -- this is a push.

   3. Use another object to hit it -- push.

   4. Move the surface -- this would be action-reaction. The surface moving is the action. The object moving back is the reaction.

   Results/Conclusions

   The object will not move without a force being applied to it.

   Inertia is the force that keeps things that are at rest where they are.

2. Problem

   What is inertia at rest?

   Materials

   Paper, block of wood, thumbtacks, a coin.

   Procedure

   Put the block of wood on the table on top of the paper. The block of wood is still and remains still. When you pull the paper from under it, you are neither pushing or pulling it.

   Results/Conclusions

   The block of wood does not move because it has inertia. It was not moving in the beginning.

   An object at rest stays at rest unless set in motion.

3. Observe

Have the children observe all the objects in the classroom and all the objects that they can see outside the window that are at rest. What could set these objects in motion?

4. Demonstration

Have two toy wagons; put a lead sinker in one. Try pushing the loaded wagon and the empty wagon with the same force. Which wagon moved farther? (empty wagon)

The empty wagon's inertia of rest was less than the loaded wagon. To move the loaded wagon the same distance as the empty wagon, you would have to overcome a greater inertia and therefore would need a greater force.

[illegible] - How can you demonstrate the centrifugal effect?

1. Problem

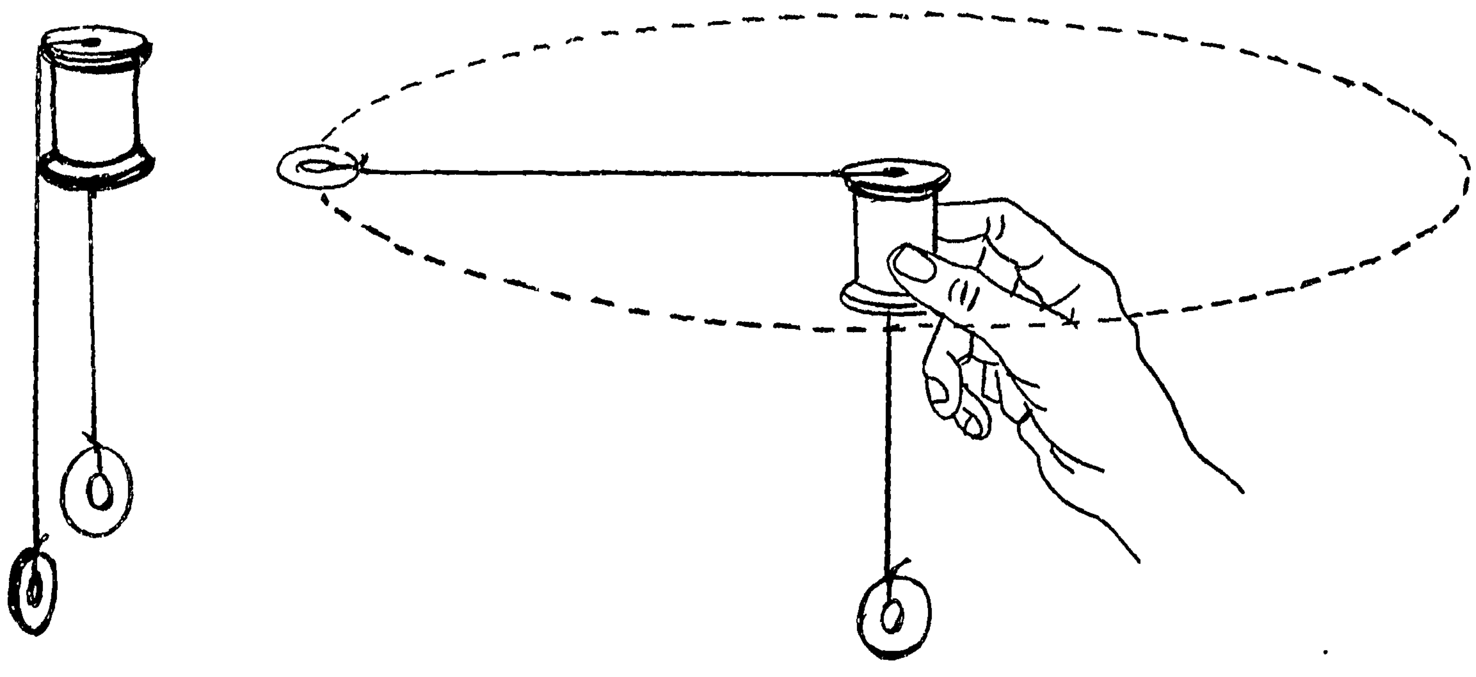
What is centrifugal effect?

Materials

Two rubber washers, string, empty spool of thread or firm paper tube.

Procedure

Securely tie a rubber washer to the end of a string that is between two or three feet in length. Push the other end of the string through the hole of a spool of thread or a firm paper tube. Then securely tie another washer to the end of the string. Leave several inches of string hanging from the top of the spool, keeping the spool upright, make it go rapidly in a circular motion while you hold the lower washer steady, then let go of the lower washer.



1. 2.

Results

The upper washer moves farther away from the spool. The lower washer is being lifted by the motion of the upper washer.

Conclusions

The upper washer pulls the lower washer when it is going faster than the pull of gravity.

CONCEPT - Between the earth's two magnetic poles there is a magnetic field including the earth and the poles themselves.

1. Problem

Does a magnet have a field of force?

Materials

A strong bar magnet, large flat-bottomed glass dish, thin wood strips or books, thin piece of cork, steel pin.

Procedure

Support the large flat-bottomed glass dish by thin strips of wood. Place the bar magnet so that the North Pole lies directly under the center of the dish. Magnetize a steel pin as a North Pole and thrust it vertically through a thin slice of cork. Put enough water in the dish so that the head of the pin will float clear of the bottom. Place the cork and pin at various places near the N pole of the magnet and observe the line of motion of the pin.

Results

The vertical needle with the N pole down moves along a line of force from north to south.

Conclusions

This indicates that a magnet does have a field of force. The path that an independent north-seeking pole would take in moving from the N pole to the S pole of a magnet is known as the line of force.

CONCEPT - A magnetic compass worked because the earth is a magnet having two ends.

1. Problem

How can we make a compass?

Materials

Magnet (horseshoe or bar shaped), paper clips, brads, tacks, needle, cork, dish of water, square sheet of paper (2 inches larger than the dish).

Procedure

Stroke a needle in one direction with a magnet until the needle becomes magnetized. Test it on the clip, etc. Trim a slice from a bottle cork and float it in the dish of water. Place the needle across the cork. Mark one corner of the paper N for north, the opposite S for south, the corner on your right E for east, and the one on your left W for west. Set the saucer on the paper and allow the needle to come to rest. Lift the saucer without disturbing the needle and move the paper around until the N and the point of the needle are in line. Move the cork and the needle so they point to various directions; release so the cork and needle swing freely.

Results

The needle and cork swing around in a north-south line. This can be tested by having other compasses in the classroom. The floating magnetized needle is a compass.

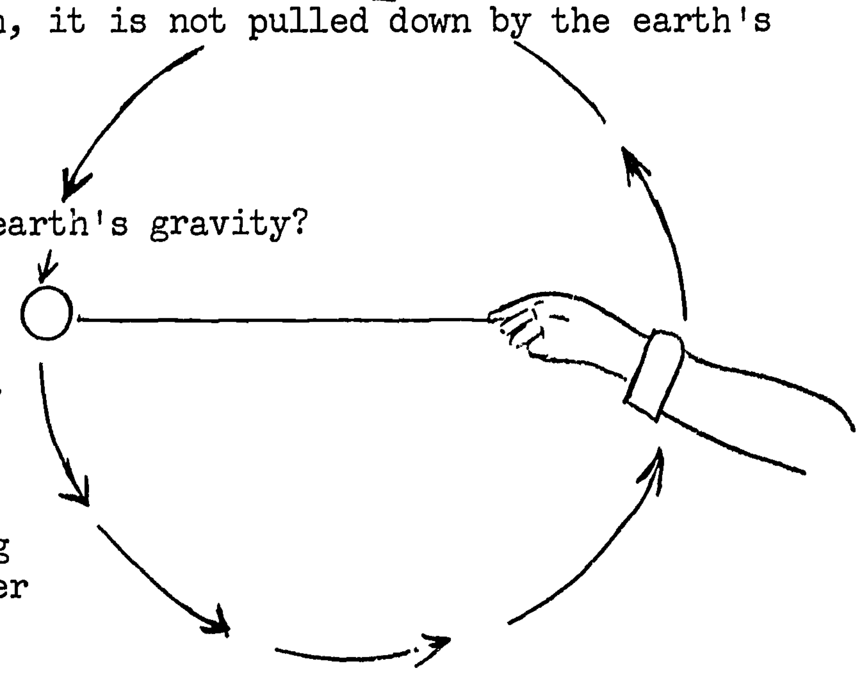
Conclusions

A needle can be magnetized by rubbing it on a magnet in one direction only. It acts as a compass in that it continues pointing north as the dish is moved.

CONCEPT - If a satellite moves fast enough, it is not pulled down by the earth's gravity.

1. Problem

How does a satellite escape the earth's gravity?



Materials

String or long rubber band, ball.

Procedure

Take the ball and tape the string to it. Hold the end of the rubber band and swing the ball around your head as shown.

Observe the ball as it goes around. Try starting and stopping the ball. Try changing the speed of the swinging.

Results/Conclusions

If the speed is great enough, gravity will not pull the ball down.

Conclusions

You can overcome the earth's gravitational pull by exerting a force greater than the force of gravity.

Tell the children that if a satellite travels at 25,000 m.p.h., it can escape earth's gravity.

Materials

Globe, small object to represent spacecraft.

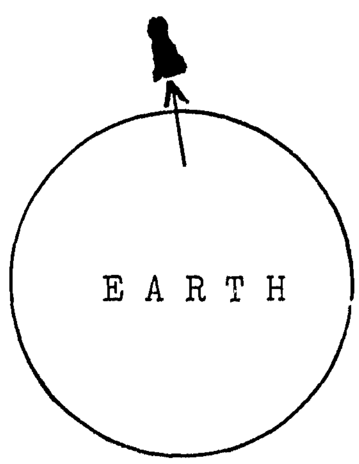
2. Demonstration

Show that once a satellite escapes the earth's gravity, it slows its speed (slow to 18,000 m.p.h.) and goes into a circular orbit around the earth because of the earth's gravity. As the craft slows down, earth's gravity can exert a great pull.

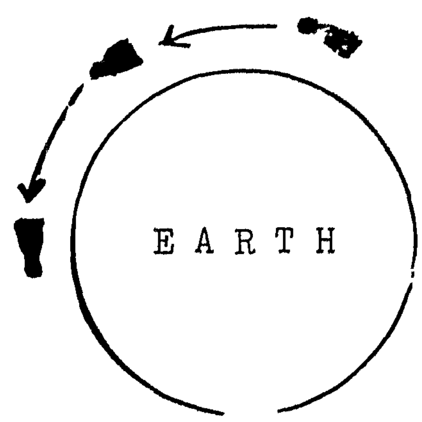
Space craft

25,000 m.p.h.

(7 m.p. second)



Escape Velocity



18,000 m.p.h.

Orbital Velocity

CONCEPT - Light is composed of waves of differing lengths; each color is a wave of a different length.

1. Problem

Is light composed of waves of differing length?

Materials

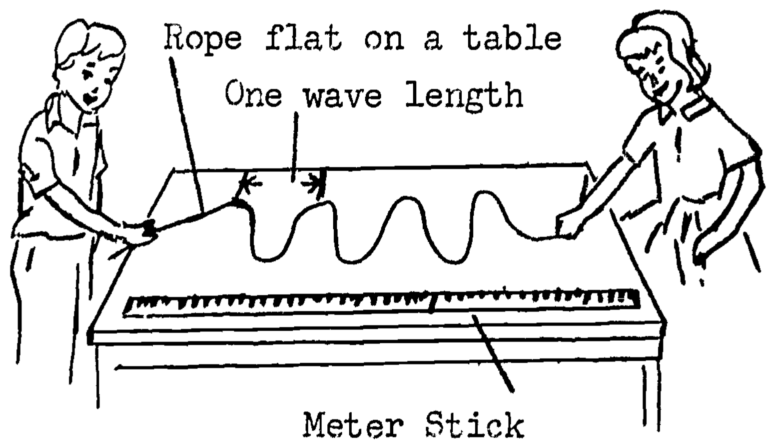
Jump rope, meter stick.

Procedure

Place a jump rope on a table. Have the children move it back and forth "snake" fashion to cause waves in it, then stop it so that it lies on the table in waves. Have the children measure the distance from the top of one wave to the top of the next. This is one wavelength.

The length of a wave of light is measured in angstroms. An angstrom is $\frac{1}{1 \times 10^{10}}$ meter, or one ten-billionth of a meter. Have the children find one meter on the meter stick. Then have them find one-hundredth of a meter (centimeter) and one-thousandth of a meter (a millimeter). Can the children imagine how long one angstrom is? (One ten-billionth of the meter stick.)

Red light's wavelength is between 6,500 and 8,000 angstroms; violet's is about half that, or 4,000 angstroms. It is this small difference in wavelengths that our eyes translate into different colors.



Results/Conclusions

Light is composed of waves of differing lengths. Each color is a wave of different length. Red light has the longest wavelength. Violet light has the shortest wavelength.

CONCEPT - A prism can spread light into a spectrum.

1. Problem

How can the wavelengths of light be spread into a spectrum?

Materials

Various sizes of prisms, flashlight, paints and crayons, wrapping paper, 3 pieces of window glass cut accurately into rectangular shapes approximately 4 by 8 inches, waterproof tape, aquarium cement, water, alcohol, baking pan or tray, plaster of paris, needle, mirror or shiny key.

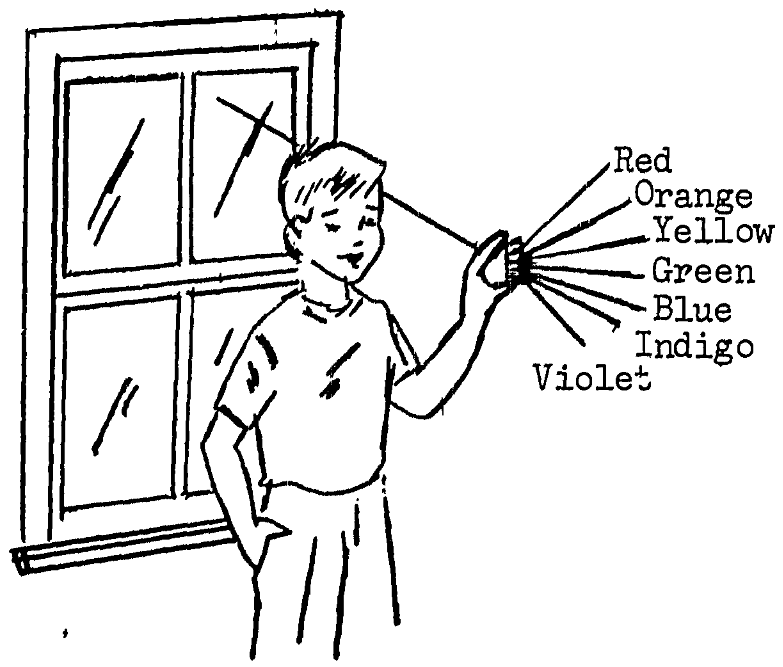
Procedure

Ask a child to stand by a classroom window through which the sun is shining. Have him hold a prism in the sunlight and turn it until the colors of the spectrum appear on the ceiling or walls of the classroom. Can children describe the colors? Let the children try various sizes of prisms. What effect does prism size have on the size of the spectrum obtained? (The bigger the prism, the bigger the spectrum.) Have the children try a light source other than the sun, such as a projector or flashlight.

Help the children mix paints and find crayons to match the colors of the spectrum. Let them make a large spectrum in the classroom by painting the colors on a long piece of wrapping paper.

Next, suggest that the children build a prism. This may be done by taping together the three rectangular pieces of glass in the shape of a triangle. Set one open end of the triangle into a pan of wet plaster of paris and allow it to remain in the pan until the plaster has hardened. The prism must be made waterproof, and this can be accomplished by sparingly applying clear aquarium cement. Fill the prism with water. Have the children project a light through the water prism. Allow them to experiment by varying the amount of light passing through the prism.

Next, place black waterproof tape over the lens of a projector, allowing only a thin slit of light to shine onto the prism. Have the children try reflecting the light from a mirror, a needle, or a shiny key. They might also try other liquids in the prism, such as alcohol. The light is refracted at different angles with each. Which produces the best spectrum?



Results/Conclusions

A prism breaks white light into its component wavelengths.

CONCEPT - Rocket engines work on the principles described by Newton's third law of motion which states, that for every action there is an equal and opposite reaction.

1. Problem

How can Newton's third law be shown?

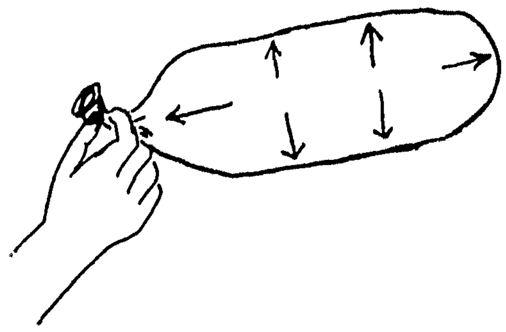
Materials

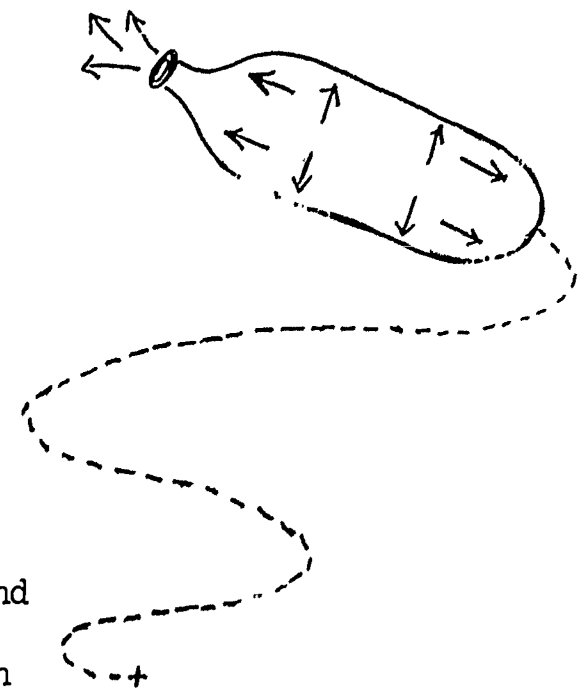
Two pairs of roller skates, large ball, rubber balloon.

Procedure

Have a child put on a pair of roller skates and throw a ball over his head to another child. Does the child on roller skates move? In what direction? Why? Try the same thing with both children on roller skates as they play catch. What happens? (The children move apart.) Can the children devise other demonstrations of this phenomenon?

A rubber balloon can serve as a simple rocket engine. Examine a balloon with the class. Then have a child inflate it, hold it above his head with the end closed, and then release it. Let the children observe what happens.





Results

The balloon will probably fly across or around the room. Why? (The gas inside the balloon is exerting pressure in all directions. When the balloon is released, the air is allowed to escape out one end. Since the action of the escaping air is in one direction, the balloon will travel with equal force in an opposite direction.

Ask the children to collect pictures of, and to explain examples of, the action-reaction principle at work in a variety of ways. For example, have them explain the following:

Lawn sprinklers: Water rushing out in one direction causes motion in the opposite direction.

Rifle or cannon firing: A rifle or cannon fired in one direction causes a "kick" in the opposite direction.

The children can experience the action-reaction principle themselves. When they ride in a car, bus, train, or airplane, and it starts or speeds up, they can feel the backward thrust when the vehicle moves forward. Can they identify other instances when they have experienced the action-reaction principle?

Conclusion

For every action, there is an equal and opposite reaction. This is the principle of the rocket engine.

2. Problem

Will gas under pressure provide push or thrust?

Procedure

Wrap a teaspoonful of baking soda in a small piece of tissue paper and place in the inside of a small bottle. Place the bottle on two round pencils or dowel rods. Place about a tablespoonful of vinegar in the bottle and cork it loosely.

Results

The reaction between the baking soda and vinegar produces a gas. This gas (which occupies more space) in turn forces the cork from the bottle. The force or thrust is produced by the greater pressure on the inside surface opposite the pushed-out cork.

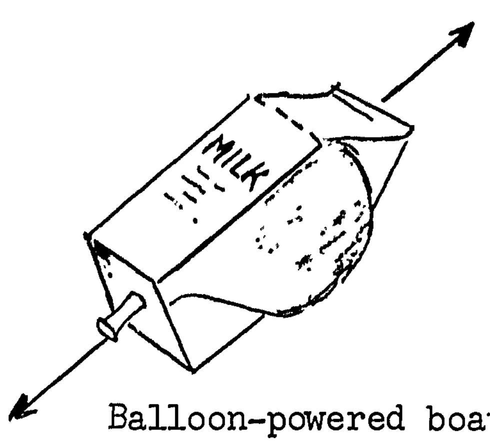
Conclusion

For every action there is an equal and opposite reaction.

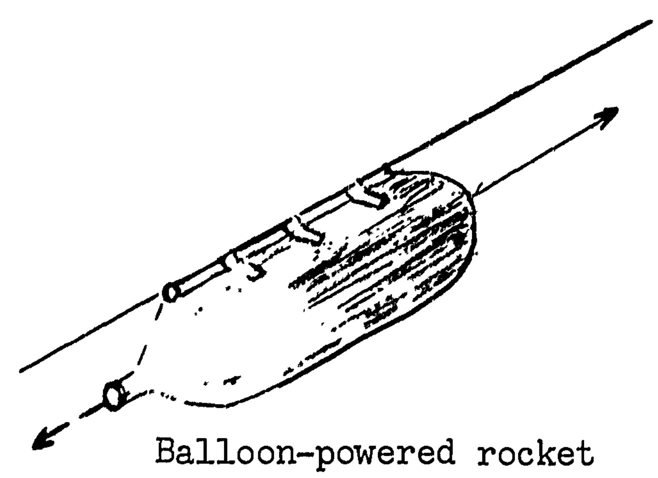
3. Demonstrations

Have the children build the following action-reaction engines.

Balloon-powered boat: Have a child cut a milk carton in half lengthwise, and puncture a hole in the bottom side near the edge. Next, he should insert a glass tube into the hole and attach the balloon to it with a rubber band. Then another child can inflate the balloon and place the boat in a tub of water. Does it move? (Yes.) In what direction? (In a direction opposite to that in which the air is escaping.) Can the children note the difference in speed when the open end of the glass tube is under the surface of the water? (The "boat" moves more quickly when the tube is out of the water.) Why? (The air escapes more quickly.)



Balloon-powered boat


Balloon-powered rocket

Balloon-powered rocket: Using cellophane tape, a child can attach a drinking straw to the side of a long balloon. Then he should pass a thin wire through the straw and attach one end of the wire to a school fence, post, or door handle. Next, have him pull the wire taut and attach the other end to an object on the opposite side of the room or yard. After inflating the balloon he should release it suddenly. Let the children observe the balloon's movement in relation to the direction of the escaping air.

Have the children devise other vehicles that use the air escaping from a balloon as the source of power. In each case, what is the vehicle's direction of movement in relation to the direction of the escaping air? (Explain that this is what is meant by action and reaction. The action of the air rushing out one end of the balloon causes a reaction, or movement, in the opposite direction.)

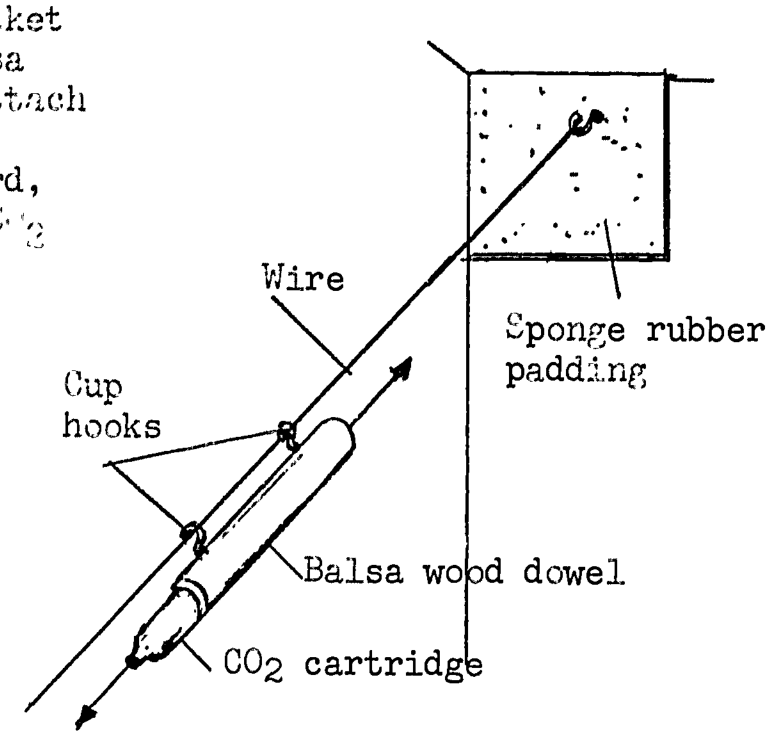
The simple machines the children can design by using balloons as the source of power are not very powerful, however. They do not go far or travel very fast. Pose these questions for the children to consider: How can more powerful and efficient machines be built? What happened when too much air was placed in the balloon. Would a metal container be strong enough to allow the storage of more gas under greater pressure? If the gas escaped more rapidly, would the rocket go farther?

The children can devise other types of machines in which there is a more efficient use of the action-reaction principle in the following ways.

One way is to tie an electric fan on a roller skate. When the fan is turned on, in what direction does the skate move? In what direction does the air move?

Another way is to obtain from a hobby store several carbon dioxide (CO_2) cartridges and a spring-powered puncturing needle to pierce the ends of the cartridges. Many types of rocket ships (air frames) for the cartridge may be constructed using mailing tubes, balsa wood, or plastic containers. Ask the children to design and construct their own rocket ships. (Elements of safety must be kept in mind when choosing materials and propellants.)

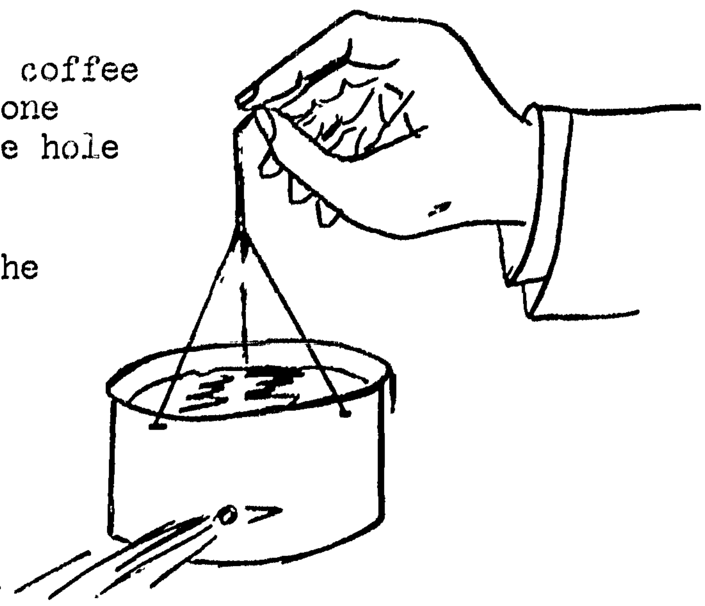
Suggest that one way to construct a rocket ship is to hollow out the end of a balsa wood dowel to hold a CO_2 cartridge. Attach two cup hooks in the top of the dowel. String a wire taut across the schoolyard, and hang the rocket on it. Place the CO_2 cartridge in the end of the dowel, and puncture it. Be sure the other end of the wire is padded with sponge rubber or cloth so the balsa wood rocket will cause no damage on impact.



Suggest to the children that another way of increasing rocket energy is to use a fuel that will generate a large amount of expanding gas. To do this, they should obtain a flat bottle, some round pencils or $\frac{1}{4}$ inch dowels, some vinegar, baking soda, and a cork. Have them place one tablespoonful of baking soda in the bottle, add 2-3 ounces of vinegar, and place the cork loosely in the opening. Ask them to lay the flat side of the bottle on the dowels and observe the action of the cork and the reaction of the bottle. (The cork pops out in one direction, and the bottle rolls along the dowels in the opposite direction.) Why? (The children can see the bubbles in the vinegar. The bubbles are carbon dioxide gas, generated in the reaction between the baking soda and the vinegar. When the pressure of the gas in the bottle builds up sufficiently, the gas forces the cork out of the bottle. When the gas flows out of the bottle, action-reaction causes the bottle to move forward.)

4. <u>Demonstration</u>

The following materials are needed: water, cord, coffee can, hammer, small nails.



Punch a small hole in the side of the coffee can at the bottom. Bend the nail to one side so the water will pour out of the hole at an angle. Then remove the nail.

Fill the can with water and observe the can as the water leaks out.

Discuss the following questions:

a. How does Newton's Third Law apply here?

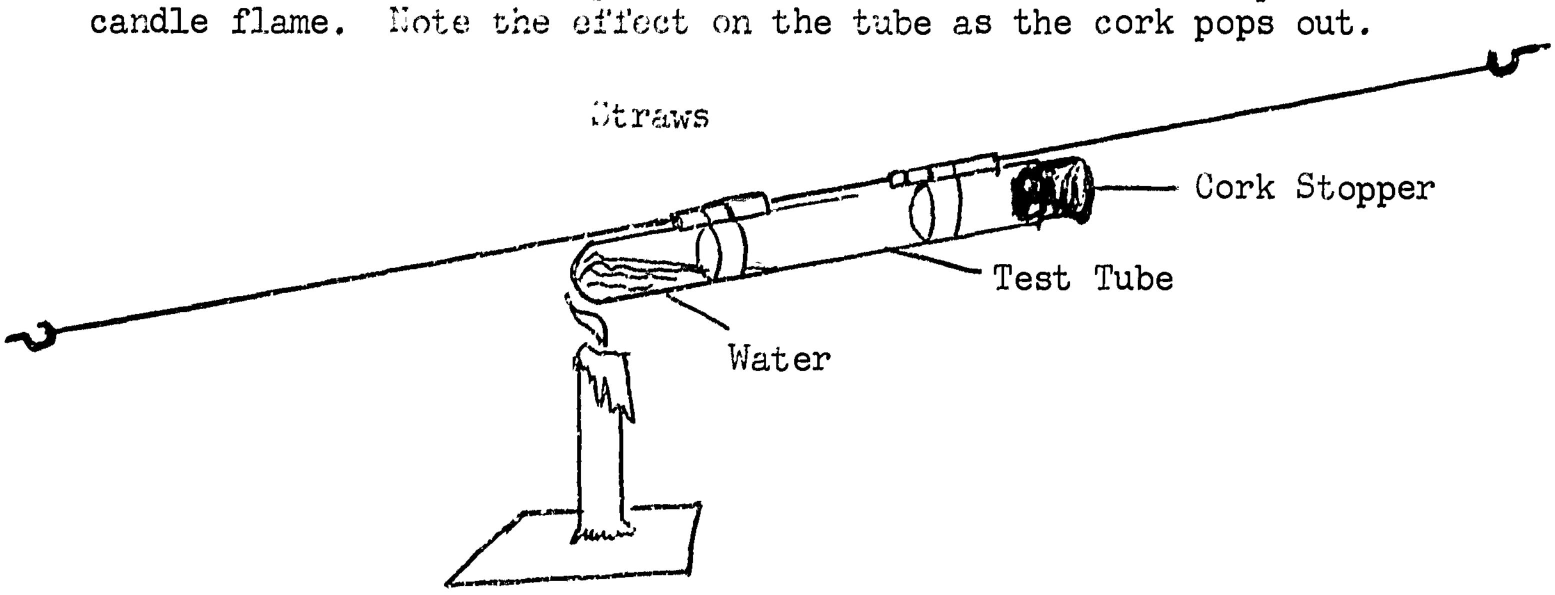
b. From what you have seen, how can we turn a satellite with a supply of liquid or gas?

c. How can you modify this experience so that you may use steam?

5. <u>Demonstration</u>

The following materials are needed: water, small test tube with cork, candle, thread, ring stand, Vaseline.

Set up materials as shown in the illustration. Lubricate the cork with Vaseline. Place a tablespoonful of water in the tube and place over the candle flame. Note the effect on the tube as the cork pops out.



Discuss the following questions:

a. How does this illustrate Newton's Third Law?

b. What is the similarity between this and a rocket engine?

CONCEPT - The thrust of a rocket propellant is the amount of force it produces.

1. Problem

How is the thrust of a rocket propellant measured?

Materials

Garden hose, rotary lawn sprinkler, toy rocket or balloon, balance or fulcrum scale, weights.

Procedure

On the school playground or at their homes, help the children begin to learn the meaning of thrust by letting them observe and feel the thrust produced when water passes through a garden hose. Lay the hose across a large expanse of lawn. Connect the hose and slowly turn on the water, until the faucet is completely open. Have children observe the action of the hose. As the amount of water that passes through the hose increases, the hose should begin to move. In what direction does it move? The children should hold the hose and feel its motion forward. Why does the hose tend to move? Do the children notice any difference as more water passes through the hose? (The more water, the greater the movement of the hose.) Attach a rotary lawn sprinkler to the hose. Gradually turn on more water. Notice the speed of the lawn sprinkler. Does it move faster or slower as the amount of water increases? (Faster.)

The children may wish to contact the water company to find out the water pressure in their particular location. They may also wish to measure the inside diameter of the hose. Will a larger hose cause the sprinkler to turn faster? (Yes.) How is water pressure measured? (Water pressure is measured in pounds.) Point out to the children that the thrust of a rocket is also measured in pounds. This can be shown in the following way.

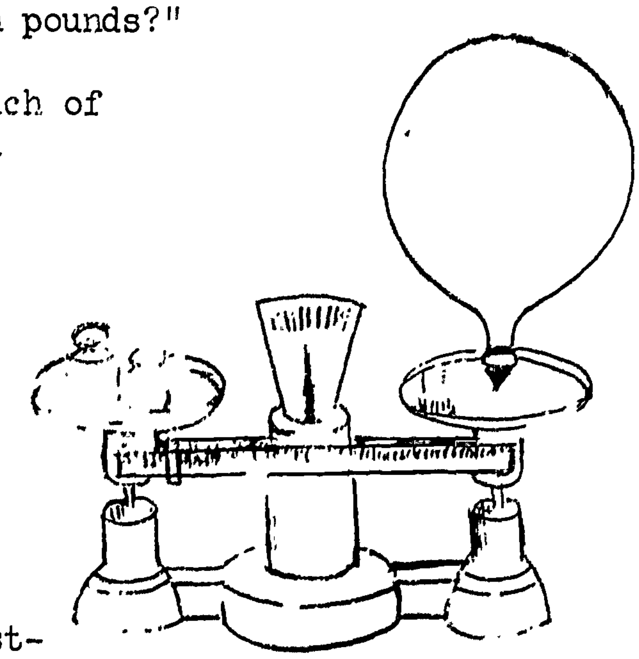
Thrust may be measured with a balance scale. Have the children inflate a balloon (or turn on a toy rocket motor) and hold it directly over the scale. Adjust the scale so that several ounces of weight are on one side. Firmly holding the balloon over the other weight pan, release the nozzle, allowing the air to escape against the balance pan. How many ounces or pounds of thrust does each rocket engine or balloon exert on the scale? Experiment with various amounts of weight to find the amount of thrust exerted by the escaping gases.

Explain that a large rocket may produce 150,000 to 500,000 or more pounds of thrust. Have the children look in newspapers or in books about rockets to find out how many pounds of thrust various rocket engines produce. Then ask them to make a chart showing the name of the rocket, the weight of the rocket, and the amount of thrust in pounds it produces.

Develop with the children the idea that if a rocket weighs 5 tons, this means that the earth's gravity is pulling down on this rocket with 5 tons of force. In order for the rocket to rise, it must overcome that pull of 5 tons toward the center of the earth. Therefore, the rocket's thrust must exceed 5 tons (10,000 pounds) in order to rise. Ask the children, "If a rocket weighed 500,000 pounds, how much thrust would it need to rise? What if it weighed a million pounds?"

Extending Ideas: Ask the children which of the following rockets they think would achieve the greatest height. Why?

Rocket weight	Thrust
500,000 pounds	500,500 pounds
500,000 pounds	750,000 pounds
500,000 pounds	1,000,000 pounds



Naturally, rockets that produce more thrust in relation to their weight will travel faster and higher. Some children may wish to compute the thrust-to-weight ratios of various rockets on the chart. Which has the largest thrust in relation to weight?

Results

Explain to the children that in order for the rocket to overcome the earth's gravity and pierce the atmosphere, its fuel must burn long enough to lift the rocket high above the earth. Certain fuels perform better than others. Better fuels develop more pounds of thrust for each pound of propellant and will burn for longer periods of time. The measurement of this aspect of a fuel's performance is called its specific impulse.

For example, if 1,000 pounds of rocket propellant produces a thrust of 5,000 pounds, and it burns in 60 seconds, what is the specific impulse of this fuel?

$$\text{Specific impulse} = \frac{\text{thrust x burning time}}{\text{weight of propellant}}$$

$$\text{Specific impulse} = \frac{\text{5,000 pounds x 60 seconds}}{\text{1,000 pounds}}$$

$$\text{Specific impulse} = \frac{\text{300,000 pound-seconds}}{\text{1,000 pounds}}$$

$$\text{Specific impulse} = \text{300 seconds}$$

What would be the specific impulse of a rocket that produced 1 million pounds of thrust and was loaded with 75,000 pounds of fuel that burned for 120 seconds?

Conclusion

The thrust of a rocket is a measure of the energy of its fuel. The specific impulse is a measure of the amount of thrust a propellant will produce for each pound of propellant burned per unit of time.

CONCEPT - The mass ratio of a rocket is a measure of the final speed it will achieve. The higher a rocket's mass ratio, the greater will be its speed.

1. Problem

What is the concept of "mass ratio"?

Materials

Water, water rocket, scale.

Procedure

The children can determine the mass ratio of a toy rocket by weighing it before it is launched and after it returns to earth, and comparing the difference in weight. A water rocket can show this well. Weigh a rocket filled with water. Launch it, and weigh it again.

Results

What was the weight of the water? If the rocket weighed 1 pound before launch and $\frac{1}{2}$ pound after launch, the rocket would have a mass ratio of 2.

$$\text{mass ratio} = \frac{\text{weight before}}{\text{weight after}} = \frac{1}{\frac{1}{2}} = 2$$

Ask: Is water a good propellant? (It is not very good because of its heavy weight.) Lighter-weight fuels are more desirable because they produce a higher mass ratio. Can the children think of some lightweight elements that might be used for fuels? (Oxygen, hydrogen, and fluorine.)

Conclusion

The mass ratio of a rocket is its weight before launching divided by its weight after it returns to the earth. The greater a rocket's mass ratio, the greater will be its final speed.

CONCEPT - There are several types of rocket propellants; liquid, solid, and hypergolic.

1. Problem

What are some of the different types of rocket propellants?

Procedure

Some fuels are solid propellants--the fuel and the oxidizer are packed together in a solid state. (Actually, it is more like putty.) When they are brought to a high enough temperature by a spark, they ignite, and a gas is released.

Liquid propellants, such as kerosene and liquid oxygen (LOX), are ignited when they are combined to form a gas. Perhaps the children would like to make a chart showing various liquid fuels and the oxidizers with which they combine:

FUEL	OXIDIZER
Aniline	Nitric acid
Hydrazine (N_2H_4)	Nitric acid
	Nitrogen tetroxide (N_2O_4)
Kerosene	Oxygen
Alcohol	Oxygen

Hypergolic fuels do not need a spark to ignite them. They combine automatically when the fuel and the oxidizer are together.

Launch vehicle	Stages	Propellant fuel and oxidizer	Thrust	Remarks
Scout	5	Solid	366,600	Sounding rocket
Atlas	1	Liquid	367,000	Used in Mercury Program
Centaur	2	H_2-LOX	397,000	First rocket to use liquid hydrogen
Saturn V	3	Liquid	7,500,000	Most powerful booster

CONCEPT - Inertia is the tendency of a body at rest to remain at rest or of a body in motion to remain in motion in the same direction unless acted upon by some outside force.

1. Problem

Why does a satellite assume the orbit that it does?

Materials

Glass, small rubber ball or marble.

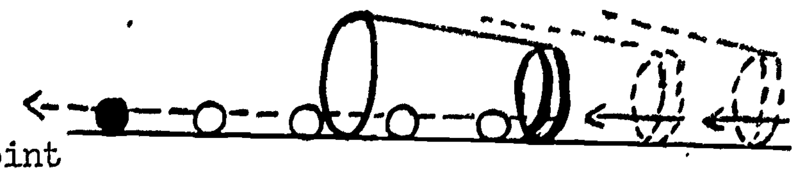
Procedure

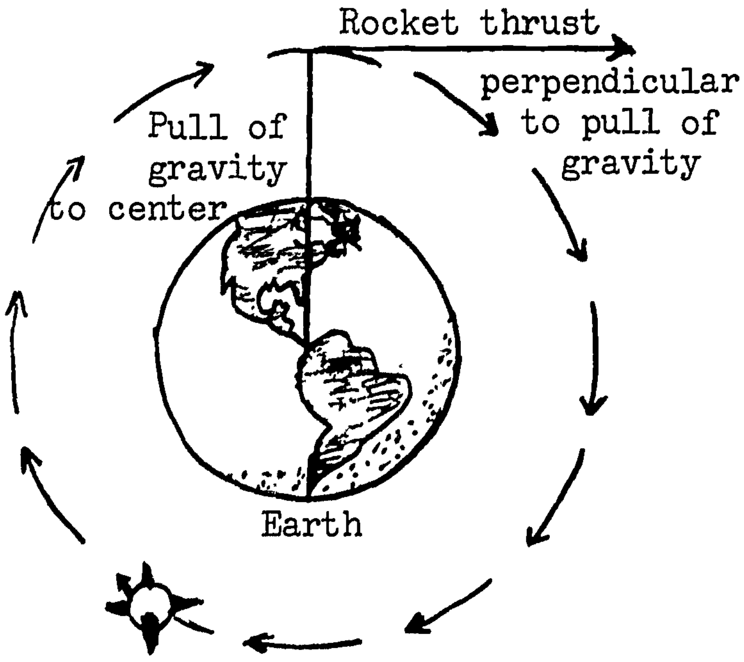
Have a child place the marble or ball inside the glass and, with the glass on its side, move it swiftly along the surface of a table. Let him stop the glass suddenly and observe the motion of the marble.

Ask the children why the marble continued to move across the table even after the glass had been stopped. What forces were acting on the marble? (Mostly inertia.) Did the marble ultimately come to rest? (Yes.) Why? (The marble and glass were set in motion. The glass was stopped, but the inertia of the marble kept it moving. Firally the force due to friction slowed the marble to a stop.)

Results

Now make the point that a rocket takes the satellite to a point in space in a similar manner.





Satellite falls into orbit

There the rocket gives the spacecraft enough speed (about 17,500 miles per hour) to remain in orbit. The rocket also gives the spacecraft direction. The direction should be about perpendicular to the pull of gravity. The combined effect of the spacecraft's inertia of motion and the gravitational pull of the earth results in a circular path of the spacecraft around the earth.

Conclusion

Inertia is the tendency of a body at rest to remain at rest or a body in motion to continue in motion (in the same direction and at the same speed) unless acted upon by an external force.

CONCEPT - A spacecraft's flight path is determined by its inertial tendency and the gravitational forces acting upon it.

1. Problem

What are the forces that determine a spacecraft's flight path?

Materials

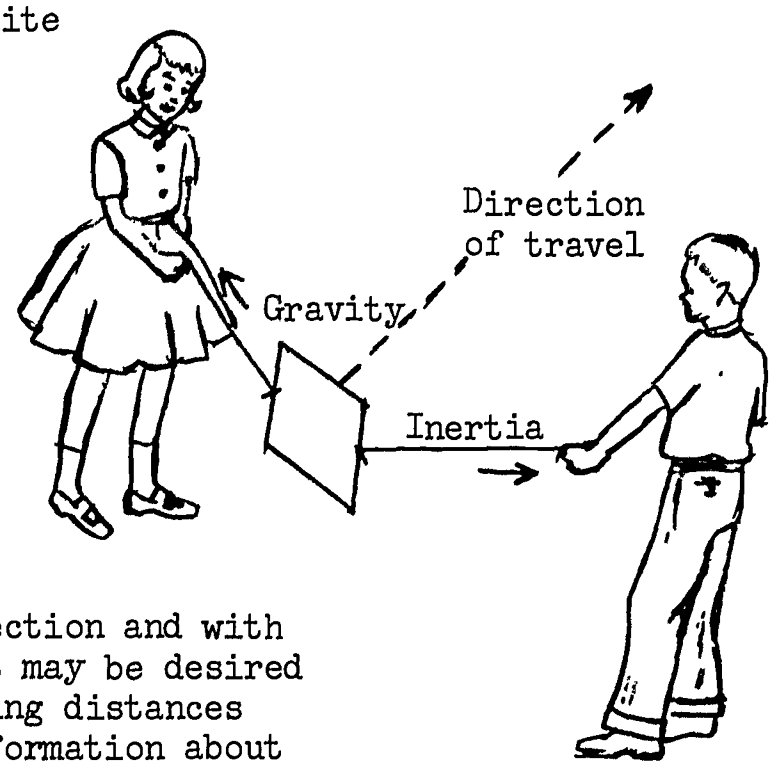
Three foot length of string or twine, ball or other unbreakable object, two equal lengths of rope, carton (filled with dirt or rocks to give it weight).

Procedure

Attach a length of rope to each end of the weighted box. Ask one child to pull on one rope in one direction. Have another child pull the other rope in a direction that is at a 90° angle to the pulling of the first child. In what direction does the box travel?

Discover what happens if the 90° angle is changed; if one child pulls with more force than the other; if one child pulls faster than the other. In each of these cases, the direction of the box's motion will be changed.

Likewise, the path that the satellite takes is dependent upon the force and direction that the rocket initially exerts upon it.



Result

If the satellite is moving at just the right speed and in the precise direction to balance the earth's gravitational pull, the spacecraft will follow a circular orbit around the earth. However, it is very difficult to make a rocket go in such a precise direction and with such exact speed. Furthermore, it may be desired that the satellite travel at varying distances from the earth so as to gather information about conditions at various altitudes. Therefore, orbits are elliptical. The shape and size of the ellipse depend on the speed and direction of the spacecraft.

If the spacecraft travels at less than 17,500 miles per hour, it will be suborbital. If it achieves a speed faster than 17,500 miles per hour (orbital velocity), it will go into orbit around the earth. If the launch vehicle can achieve a speed of approximately 25,000 miles per hour, it will escape the earth's gravitational force and go into deep space, perhaps to the moon or the other planets.

Conclusion

The two factors that determine a spacecraft's flight path are its inertial tendency and the gravitational forces acting upon it.

CONCEPT - A spacecraft may travel in one of four possible flight paths - a circle, an ellipse, a parabola, or a hyperbola.

1. Problem

What are the paths in which a spacecraft may travel?

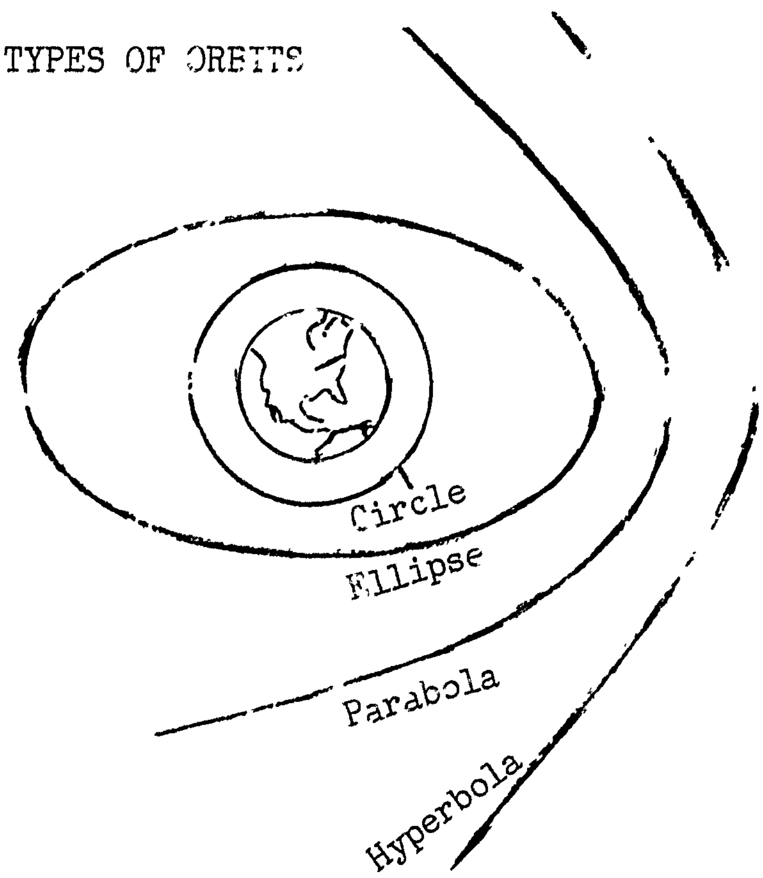
Materials

Cone-shaped paper cups, construction paper, scissors, tempera powder, ink or rubber stamp pad, cutting tool or single-edged razor blade.

Procedure

Discuss with the children the following problem: If the spacecraft escapes the earth, what trajectory will it follow? Explain that a satellite may follow one of four different flight paths: a circle, an ellipse, a parabola, or a hyperbola. All earth satellites travel in ellipses. A vehicle that achieves about 25,000 miles per hour (escape velocity) will go into a parabolic flight path. If it goes faster than escape velocity, it will follow a hyperbolic path.

TYPES OF ORBITS



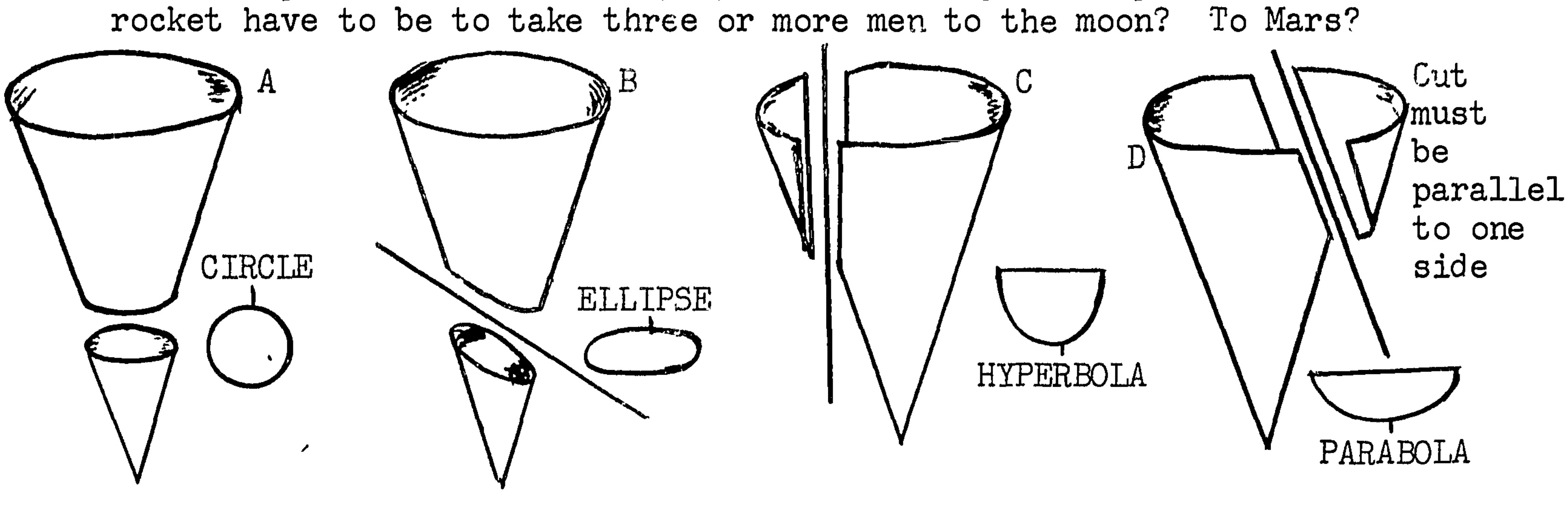
Have the children cut circles, ellipses, parabolas, and hyperbolas out of construction paper. What do they notice about the shapes? Is it really possible to cut out a complete parabola or hyperbola? (No.)

Point out that another way to illustrate circles, ellipses, parabolas, and hyperbolas is with cone-shaped paper cups. Using a single-edged razor blade or other sharp cutting tool, cut the cone in planes as shown. Examine the edge that has been cut. You may wish to dip this edge in dry tempera powder, ink, or on a rubber stamp pad and print the resulting shape on paper. Label the shapes correctly.

Result

What is the difference between a hyerbola and a parabola? A circle and an ellipse? Help the children see that circles and ellipses are closed, while hyperbolas and parabolas are open.

Help the children see that the flight path that a spacecraft takes is dependent on its velocity and direction. At a speed less than orbital velocity, it will only fall back to earth. If it achieves orbital velocity, it will travel around the earth. If it exceeds orbital velocity, it will escape the earth and go into deep space. What gives the spacecraft enough thrust to achieve the proper flight path? What effect does the satellite have on the size of the rocket? Discuss with the children the relative sizes of the rockets needed to place a large, heavy satellite in orbit and a small spacecraft into a deep-space trajectory. How powerful does a rocket have to be to take three or more men to the moon? To Mars?



Conclusion

A spacecraft may follow any one of four flight paths - a circle, an ellipse, a hyperbola, or a parabola.

CONCEPT - A high degree of precision is required in aiming a spacecraft at the moon.

1. Problem

How difficult is it to send a spacecraft from the earth to another heavenly body?

Materials

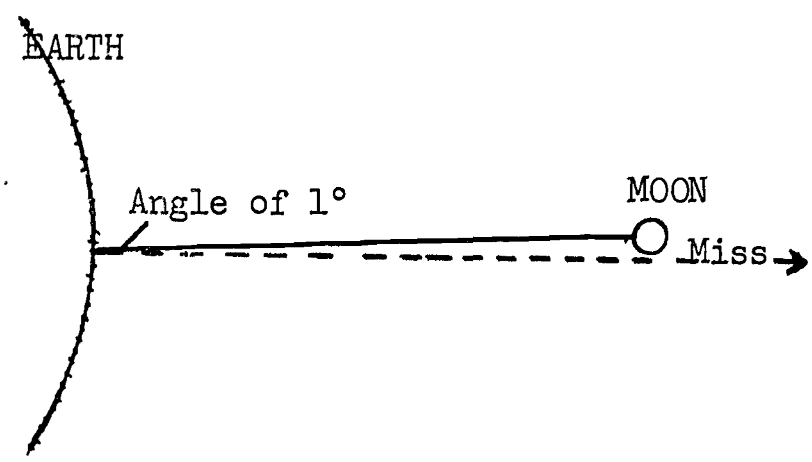
Small ball, long piece of wrapping paper, protractor, rulers, yardstick.

Procedure

On a large piece of paper, draw two lines at right angles. Place a circle on the horizontal line close to the edge of the paper to indicate the moon. Using a protractor, measure an angle of 1° from the right angle. Extend a line through the 1° mark to the edge of the paper. This would be the path of the spacecraft if an error of only one degree was made. Measure the line's distance from the moon. This indicates how the spacecraft would miss the moon if such an error were made.

Result

If each inch equaled one million miles, by how many miles would the spacecraft miss the moon at one degree of error? The children should see that a slight error would cause a miss of a great many miles. The farther away the target, the greater the error would be.



Besides the need for accurate computation of the vehicle's trajectory, there are many other factors that can cause the vehicle to deviate from its flight path. The walls of the rocket are comparatively thin. When it is filled with many gallons of liquid fuel, it has a tendency to wobble and vibrate. The children can experience this sensation when they attempt to carry a large tub of water across the playground. Impact by meteors, winds in the atmosphere, the unequal pull of gravity at the various altitudes from the earth, the gravitational attraction of other objects in space, small imperfections in fuels and mechanisms--all of these can cause the launch vehicle to vary from its desired path.

Conclusion

A great deal of precision is required to send a spacecraft from the earth to any other heavenly body.

CONCEPT - Guidance systems stabilize the flight path of a spacecraft.

1. Problem

Why do spacecrafts require guidance systems?

Materials

Balloon, long, thick soda straw, broom, rubber band.

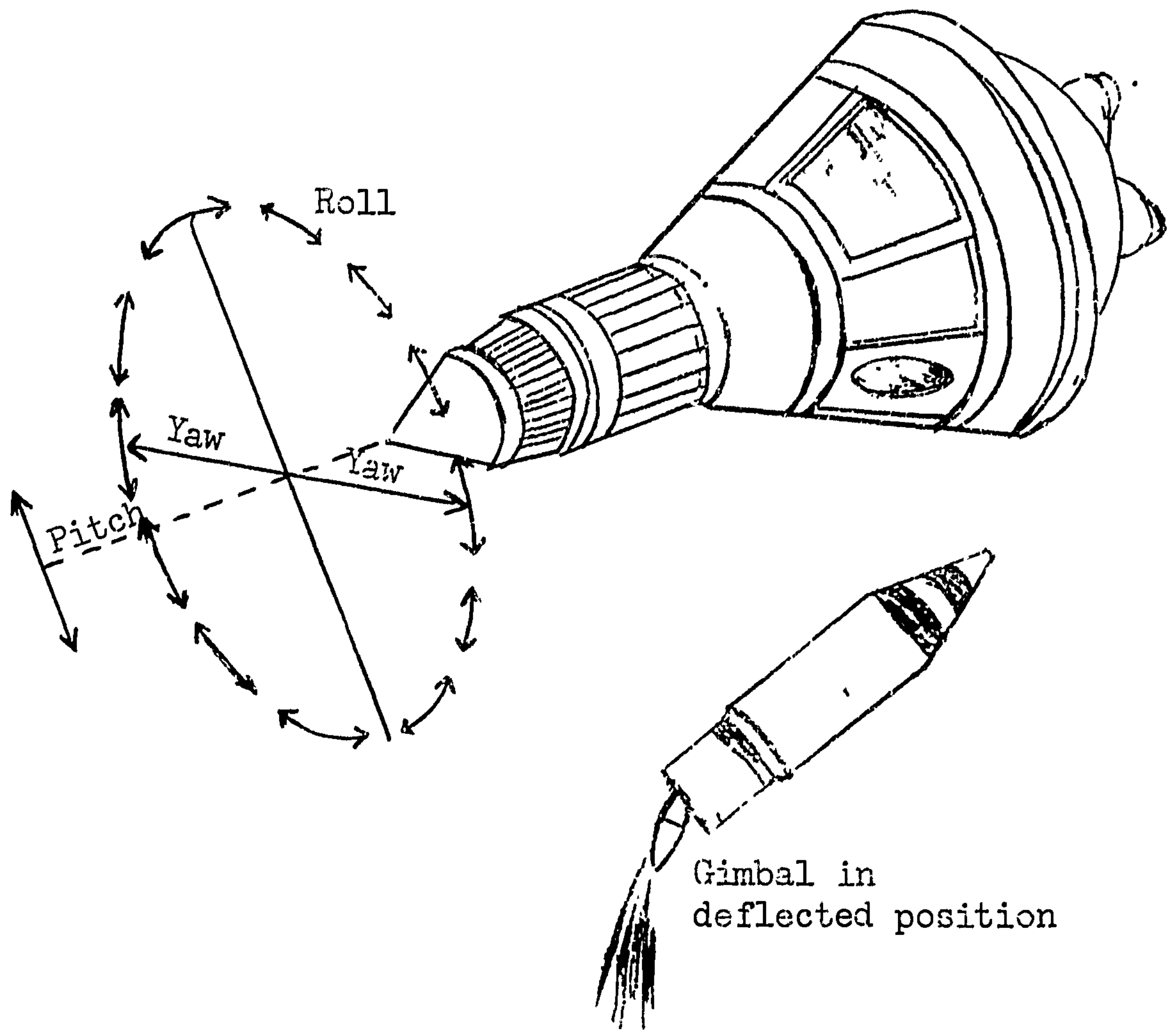
Procedure

Have a child blow up a balloon and release it. Note the path it follows. It does not move in a straight line because it has no guidance system. To give the balloon a rudimentary guidance system, attach a long, thick soda straw to the nozzle of the balloon with a rubber band. Blow the balloon up and release it once again. Does it travel in a straighter path? (It should, for the soda straw tends to stabilize it.)

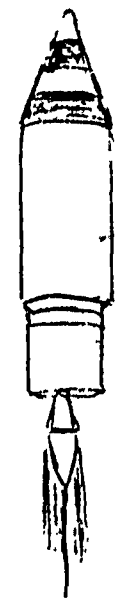
Introduce the following terms to the children for their study of stabilization.

Roll is a rotating motion. Yaw is a side-to-side motion. Pitch is an up-and-down motion.

Ask the children to theorize about ways in which they think the spacecraft can be stabilized so as to control these motions and be directed into proper flight paths.



Gimbal in deflected position



Gimbal in neutral position

Explain that an airplane is stabilized by the movable vanes in its wings and tail. These deflect the air to cause the airplane to climb, dive, and turn. Arrange to take the class to an airport. Have the children observe the elevators, ailerons, and rudder of model or actual airplanes. Describe what happens when elevators in the tail section are up and down. (The airplane goes up when the elevators are up and down when the elevators are down.) Describe what happens when a plane banks. In what position must the ailerons be to bank left? Right? (Left aileron up, right aileron down, the plane banks to the right, and vice versa.)

Since there is no air in space, would it be possible to use elevators and ailerons on rocket ships? (No.) Could the children devise a method to stabilize a rocket, using this same principle? Suggest that one way is to insert vanes or rings (gimbals) into the exhaust nozzle of the rocket to act as a rudder. The expanding gases that are escaping from the rocket can then be deflected in any direction.

The children may now have some understanding of air coolers, and air conditioners. Many of these have wind deflectors in front of the fan that cause the air to be deflected in a certain direction.

Point out that these guidance systems are used during the <u>initial guidance</u>, while the rocket engines are still burning fuel. However, when no more gas is created to escape through the gimbals, how can the spacecraft be maneuvered?

Result

After the engines have stopped firing (burnout), the spacecraft is in free flight. It is falling around the earth or coasting to another planet or to the moon. What can be used to keep or send the spacecraft in its proper direction? Encourage the children to speculate and suggest ideas as to how this might be done.

The children may now have some understanding that, to control the vehicle in space, a system of small corrective jets or rockets is employed. The amount of thrust needed for correction is small. Ask the children why they think this is so. (Because the inertia of motion is balanced by the force of gravity, resulting in a state of weightlessness. There is no atmosphere to cause friction. There are no other forces to change direction. Therefore, it takes only a small force to change the direction of the spacecraft.) These small jets might use hydrogen peroxide or nitrogen under pressure. When the direction must be altered, small thrusts are exerted in one direction, which moves the craft in the opposite direction. By this means roll, pitch, and yaw can be corrected. In addition, by the same process, the spacecraft may be turned over or in the opposite direction.

Conclusion

In order to guide the spacecraft in a proper orbit, a guidance system must be employed. This may include gimbals in the engine. Small rocket engines are used to attain and maintain a proper orbit. They are also used to overcome pitch, roll, and yaw.

CONCEPT - Spinning the spacecraft on its axis as it travels tends to stabilize its flight path.

1. Problem

How can a spacecraft be stabilized?

Materials

Piano stool or swivel chair, bicycle wheel, iron rod, bicycle, toy tops or other spinning toys.

Procedure

A child can experience this stabilization effect through spinning by standing on a well-oiled piano stool or swivel chair and attempting to turn himself around. He may find that as he attempts to move in one direction, the stool or chair moves in the opposite direction.

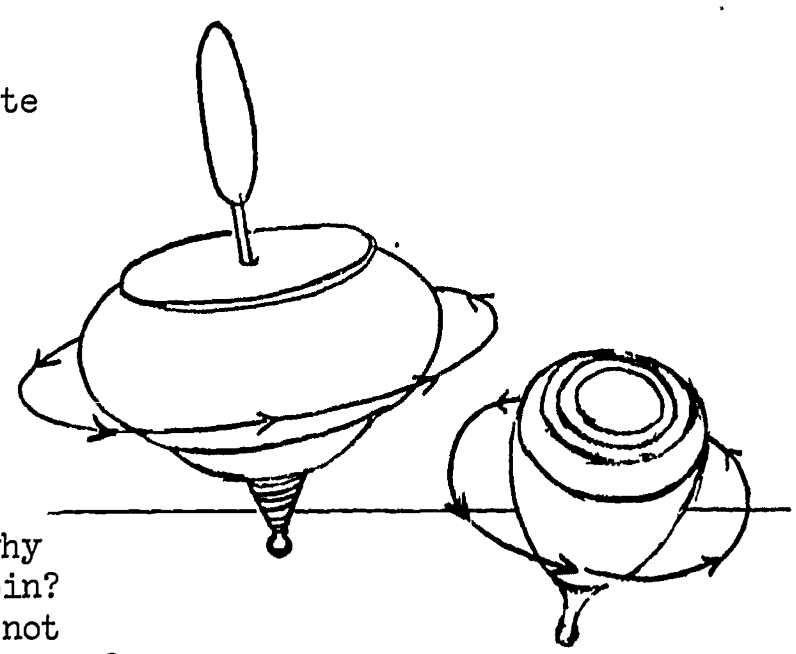
Another way to experience this is by spinning a large wheel. Place an iron bar or rod through the hub of a bicycle wheel (or perhaps the axle could be extended) so that a child may hold the wheel in his hands. Have him spin the wheel while holding the handles. Seat a child on the piano stool or swivel chair. Have the child hold his feet off the floor and twist the spinning bicycle wheel sharply. What happens? (It resists turning.)

Result

Encourage the children to manipulate and experiment with tops. Have them try balancing tops on strings and on the edges of tables.

Tops and other spinning toys can help the children understand spin stabilization. Ask them why tops remain upright while spinning but fall when they stop.

Can the children speculate as to why a space station will be made to spin? Can they guess why the earth does not wobble much as it travels through space?



Conclusion

Spinning a spacecraft around its axis is another way of stabilizing its flight path.

CONCEPT - Inertial guidance systems use gyroscopes, for the spinning gyroscope is very stable.

1. Problem

How are gyroscopes used to achieve spin stabilization?

Materials

Gyroscope, rubber bands, heavy nails, board (10" x 4" x ½"), hammer.

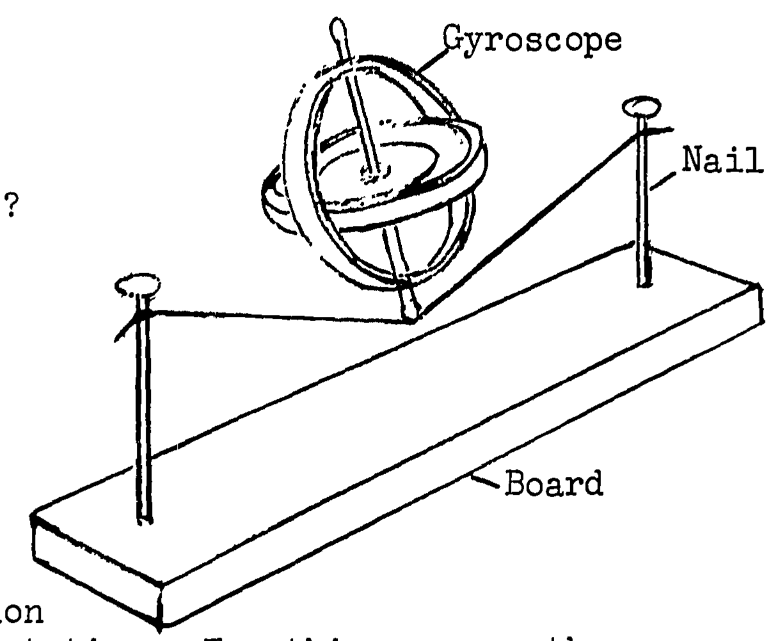
Procedure

Construct a simple guidance system as follows: Hammer a large nail into each end of the board. Attach the rubber bands to each end of the gyroscope and around the nails. The gyroscope should be suspended freely. Then have a child spin the gyroscope.

While the gyroscope is spinning, have the child tilt the wooden base into various angles and positions. Let the children observe the motion of the gyroscope. What happens? (A spinning gyroscope resists any force that acts to change the position of the gyroscope along its axis of rotation.)

Result

Since the spacecraft might move in any of three motions (roll, pitch, and yaw), how many gyroscopes would be needed to correct these movements? (Three.) Can the children decide how three gyroscopes might be mounted so that their axes of rotation would be in three different planes?



Conclusion

A spinning gyroscope resists any force that acts to change the position of the gyroscope along its axis of rotation. For this reason, three gyroscopes can be used to stabilize the flight path of a spacecraft. One gyroscope must be used to correct the roll, the second to correct the pitch, and the third to correct the yaw.

CONCEPT - An accelerometer is used to measure changes in the speed of the spacecraft.

1. Problem

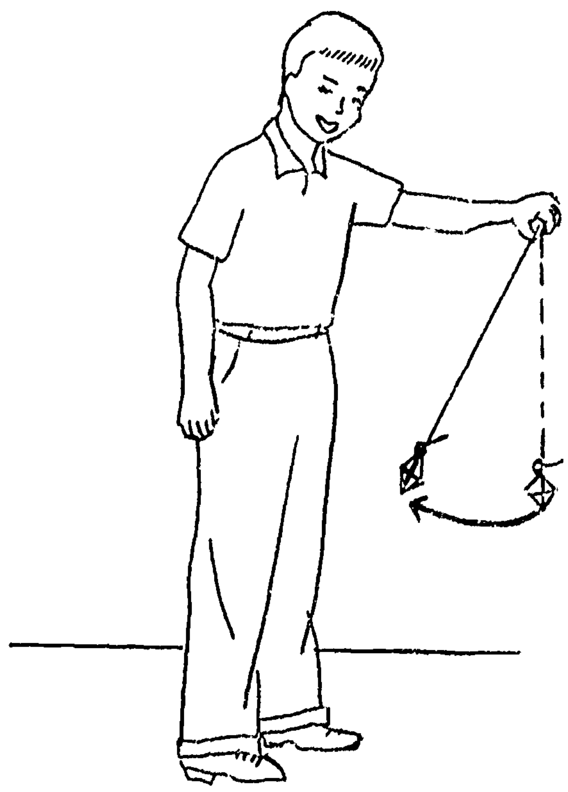
How can the speed of a spacecraft be measured?

Materials

Weights, string, paper, roller skates or bicycle.

Procedure

The principle of an accelerometer can easily be seen by suspending a weight from a string. Have a child hold the string, allowing the weight to hang freely. When the string and weight come to rest, have the child thrust his hand forward and observe the motions of the weight.



Variations may be tried by placing the child holding the string on roller skates or on a bicycle. In each case, as the vehicle is moved faster or is started, the weight has a tendency to remain stationary. It will, therefore, appear to swing back. Have the children try moving it gently and rapidly. Notice how the weight tends to remain in the same location even when the string is moved.

Result

By placing a calibrated card behind the string, the children can measure to what extent the weight is deflected. The faster it moves, the greater the deflection that will be noticed. The children may wish to build their own accelerometer. Perhaps they could mount such a device on the rocket-powered vehicles they constructed previously.

Conclusion

An accelerometer measures deviations in the speed of a spacecraft.

CONCEPT - Staging vehicles enable us to increase payload capabilities.

1. Problem

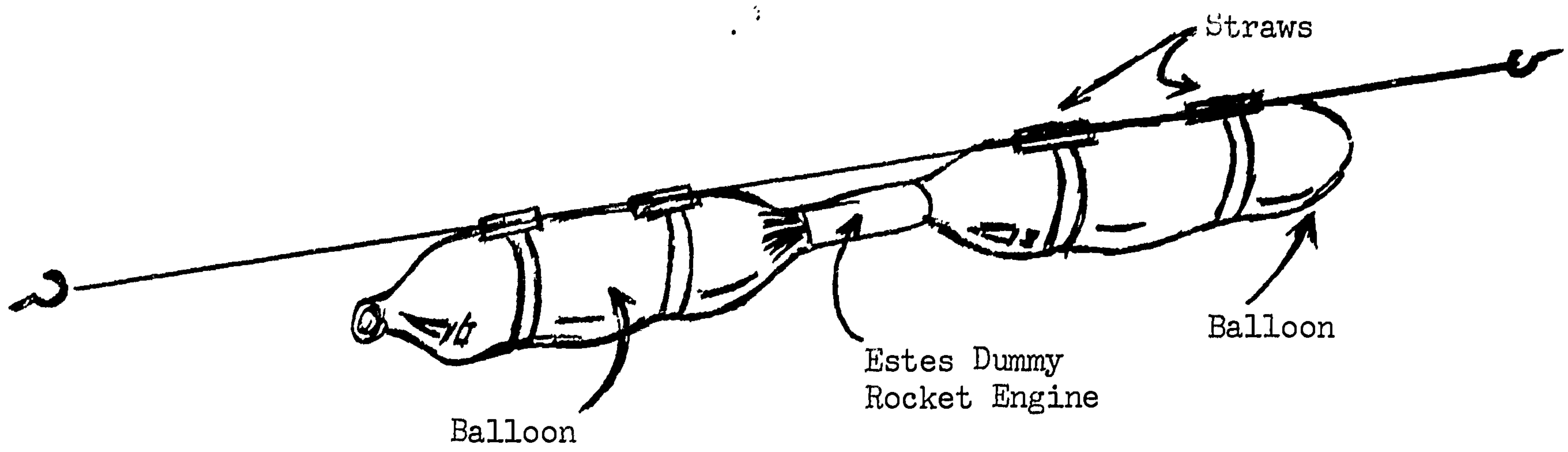
How does staging increase payload capabilities?

Materials

Two or three long balloons (6 inches or more), hooks for attaching line, plastic straws, tape, nylon fishing line, Estes dummy rocket engine, three bricks.

Procedure

Attach line between two points (the longer the better). Insert dummy rocket engine into nozzle of an inflated balloon. Push an uninflated balloon to the depth of one inch into the dummy rocket engine and inflate the balloon. Include a third balloon for a third stage if desired. Attach balloons to straws (short pieces) with tape close together. Slide over line. Release the first balloon which will push the others ahead of it. Discuss advantages of staging with reference to gravity, atmospheric density, etc.



Results/Conclusions

Why do the stages become successively smaller rather than the other way around? What advantage is there to dropping the stages as their fuel is consumed? Relate what you have seen to rockets and fuel tanks (full or empty).

2. Thought Problem

One truck, one jeep, and one motorcycle, each with a range of 200 miles need to be transported. The gas tanks are full and sealed. How would you get them across a desert to the nearest oasis 600 miles away?

3. Demonstration

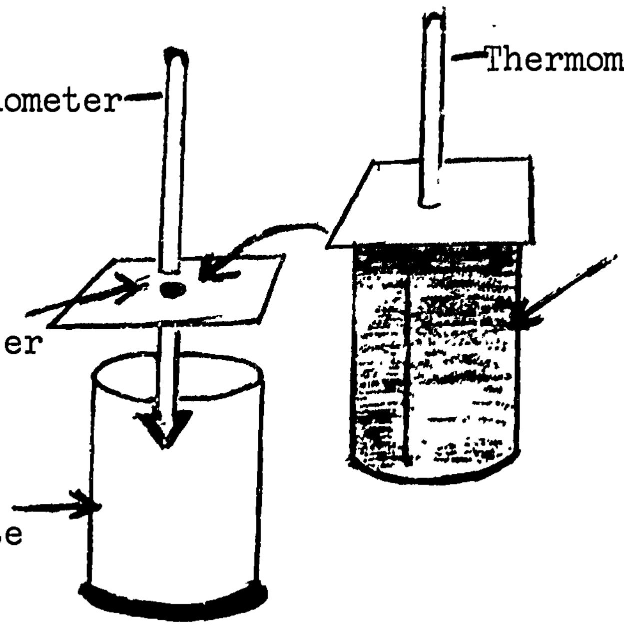
Stack three bricks on top of each other. Lift all three from the floor. Drop the lower one. Does it require as much energy to continue lifting the remaining two bricks? Continue to raise the bricks, dropping the second and third bricks. What do you observe?

CONCEPT - The amount of radiant energy different materials absorb or reflect varies greatly according to their surface color.

1. Demonstration

The following materials are needed: tin cans, 2 lab thermometers, light cardboard, paint (white and black spray paint), heat lamp, 2 candles, rubber bands.

Paint one of the cans white and the other black. Allow to dry. Suspend the thermometers in the cans through holes in the cardboard; the bulb must not touch the can. Direct a heat lamp at the cans so that the rays shine directly on the cans but not on the thermometers. Record the different temperatures. Touch the cans and note the difference in temperatures. After a brief cooling-off period, light two candles and attach them to the sides of the cans. Direct the heat lamp at the cans again. Observe what happens to the candles after a short period of time.



Discuss the following questions:

a. If intermediate colors (yellow, pink, red, etc.) instead of white were used, how do you suppose the temperatures would be affected?

b. What colors should be used for propellant tanks?

c. Why doesn't the Titan II have varying colors as does the Saturn II?

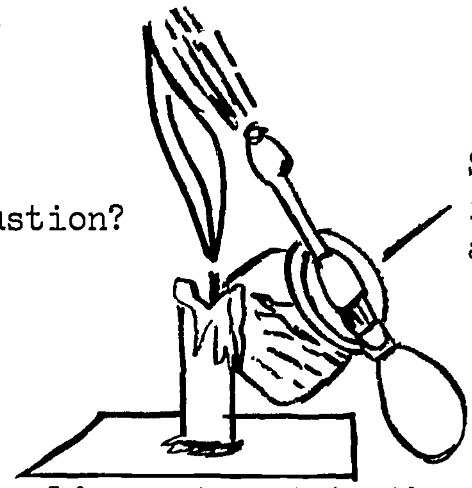
d. What other reasons can you think of for using other paint patterns of color?

CONCEPT - By increasing surface area, you increase ignition and burning rate.

1. Demonstration

The following materials are needed: beaker, alcohol, spray bottle, candle mounted on cardboard, evaporating dish, wood splinter.

Plunge the burning splinter into the beaker of alcohol. Light an evaporating dish of alcohol and observe the burning rate. Light the candle and let the wax drop on the cardboard. Mount the candle in the wax before it cools. Holding the spray bottle parallel to the flame, spray the alcohol across the flame (keep the spray back from the flame two or three feet). Note the reaction.



Discuss the following questions:

a. By spraying the alcohol, why did you get such instant combustion?

b. How might this concept affect the design of a rocket motor?

c. If your clothing were on fire and the only liquid nearby was an open vat of gasoline, would you jump into the vat? Why or why not?

CONCEPT - A high concentration of oxygen is necessary to support efficient combustion in rocket engines on earth and in space.

1. Demonstration

The following materials are needed: hydrogen peroxide, manganese dioxide (the black powder from the inside of a new flashlight battery cell), a drinking glass, broom straw, wood splinters, cardboard.

Pour about one inch of hydrogen peroxide into a drinking glass and add a small amount of manganese dioxide. Place a piece of cardboard over the top and notice the bubbles that escape from the hydrogen peroxide. These are bubbles of oxygen gas. Light a broom straw or wood splinter and blow it out. Put the glowing straw or splinter into the gas and notice how the oxygen affects the action.

Discuss the following questions:

a. Why do we use pure oxygen in rockets instead of air?

b. Why do we use pure oxygen in liquid form at 297°F rather than gaseous oxygen at room temperature?

c. Consider volume vs. temperature.

MAN'S EXISTENCE IN SPACE

Initiatory Activities

Have the children:

1. Prepare a list of questions about an announced television program on a space event and report on the aspect that interested them the most.

2. Study pictures of several spacecraft, noting the differences and similarities of various details.

3. Collect different kinds of maps for a wall display. Discuss the kinds used for various purposes and what kind would be needed for a flight to the moon.

4. After listening to an assembly program on space exploration, such as the NASA Spacemobile, discuss the part they liked best.

5. Devote a "Show and Tell" period to the contributions made by our astronauts.

6. Dramatize a space trip with a simple skit of two or three characters.

7. Develop a picture dictionary of aerospace terms.

8. Provided with a library corner containing a variety of books on aerospace subjects that include history, biography, autobiography, the classics, science fiction, poetry, and plays.

9. Write imaginative paragraphs about space: how the satellites got their names; how the earth looks from a space capsule; the landscape of the moon or planets; pictures that the constellations make.

10. List several ideas for original stories or poems: what it is like to ride in a spacecraft; a trip along the Milky Way; how it will feel to land on the moon; how the wind helps us; a day at a tracking station.

11. Use as subjects for descriptive paragraphs pictures such as a spacesuit, aircraft, the Andromeda Galaxy, etc.

12. Check the derivation of various aerospace terms in the dictionary. Follow with word lists relating with specific programs, e.g., communications, astronomy, weather, and using them to increase understanding of word formation.

13. Plan a bulletin board on airplanes, including types from the earliest models to the SST and V/STOL.

14. Locate on a large map of the moon with colored pins the areas man has photographed. Place photographs and related materials around the border and connect to locations with string.

15. Collect pictures of means of transportation or vehicles used in exploration from the horse to space capsules; choose pictures that also show how man has to adapt to different conditions, e.g., clothing, weather, etc.

16. Plan a radio program based upon current space news, interviews with famous space scientists, a new invention, or a broadcast from a tracking station.

17. Choose a space subject that lends itself to dramatization and develop it into a one act play. Subjects could be: an interplanetary trip; a passenger from mythology; a flight in the X-15; episodes in the development of the airplane; an imaginary trip to the moon.

18. Develop the library corner with many types of books on one space subject; such as, flight, its history, early myths, biographs of the Wright brothers, the X-15, stories about the astronauts, an imaginative flight to the moon.

19. Select and dramatize passages from story books about lunar and interplanetary flight.

20. Collect materials about the practical benefits of space exploration and then discuss the points of view expressed by various sources.

21. Prepare a list of questions about a variety of space projects, then decide in which kind of reference book the answer would be found. Have the children look up the answers and report to the class.

Developmental Activities

Concept - Man can survive in space only if he has an atmosphere similar to that on earth.

1. Problem

   Why must air pressure be maintained inside a space capsule or a space suit?

   Materials

   Glass of water, heavy cardboard, 1-gallon can with tight fitting lid, hot plate, bottle of carbinated beverage, tight-fitting cork or stopper, Pyrex nursing bottle, balloon, rubber band, pan of water.

Procedure

How much pressure is being exerted on the earth? Have the children find out the normal pressure of air at sea level. (About 14.7 pounds per square inch.) This means that the weight of a column of air one inch square and extending upward to the edge of space would be about 14.7 pounds. How many pounds per square foot is this? (2,116 pounds per square foot.) As we go to higher altitudes, does the amount of air in the column above us decrease? (Yes.) What effect would this have on pressure? (It would decrease.)

If there is 14.7 pounds of pressure against each inch of our bodies, can the children calculate the total amount of pressure over our entire body surface? The children can soon realize that there are many tons of air pressing on our body surfaces at all times. Why are our bodies not crushed under this tremendous weight? (There is an equal pressure of air inside our bodies that is pushing out.) We exist in a narrow zone on earth where pressure is such that man's bodily functions can be carried on. What happens when this balance in pressure is upset? (Man dies.)

To observe the effects of high pressure, have the children pour some water in the can to a depth of about ½ inch and heat it to boiling. Allow the water to boil a few minutes to remove the air inside the can. Then cap the can tightly and remove it from the hot plate. Observe what happens when it cools. To speed up the cooling process, the can may be placed under cool water. (The walls of the can should cave in.) Why? (The air pressure outside the can is greater than the air pressure inside the can.) How was the air pressure inside the can changed?

To observe the effects of low pressure, open a bottle of a carbonated soft drink. Let the children notice what happens as soon as the lid is removed. Why do bubbles rise? Why are there no bubbles visible when the lid is kept on? Recap the bottle with an airtight stopper. What happens to the bubbles? (A gas has been dissolved inside the drink. When the drink is kept under pressure, the gas remains dissolved. When the pressure is removed, the gas turns to vapor and boils, or bubbles away.)

Point out that there is gas in man's body; it is in the form of oxygen, nitrogen, and carbon dioxide in our joints, lungs, stomach, cells, blood, and intestines.

Now apply this situation to man in space by asking: What would happen to man if he ventured outside his zone of comfortable pressure? How high can man climb without feeling the effects of low pressure? How deep in the ocean can man descend without taking along protection from too much pressure? What are the "bends"? Some children may have experienced high pressure when they tried to swim deep in a lake or pool. Some may have felt their ears "pop" when they drove high in the mountains. Why must airplanes be pressurized to keep passengers comfortable? What would happen if the pressure outside our bodies were removed, as it would be in space?

Close the neck of the balloon so that the air pressure inside the balloon equals the air pressure outside. (Do not blow it up; just blow it so the walls stand out.) Tie it with a rubber band. Put about ½ cup of water in the baby bottle and place it in a pan of boiling water. Place the pan on the stove and heat until the water inside the baby bottle begins to boil. When the water is boiling fast, drop the balloon into the bottle and cap the bottle tightly. Remove it from the pan and hold it under a stream of cool water. What happens to the balloon inside the bottle? (It expands.) What has happened to the pressure inside the bottle? (The pressure inside the bottle has decreased, and the air inside the bottle has decreased, and the air inside the balloon has expanded to equalize the pressure.)

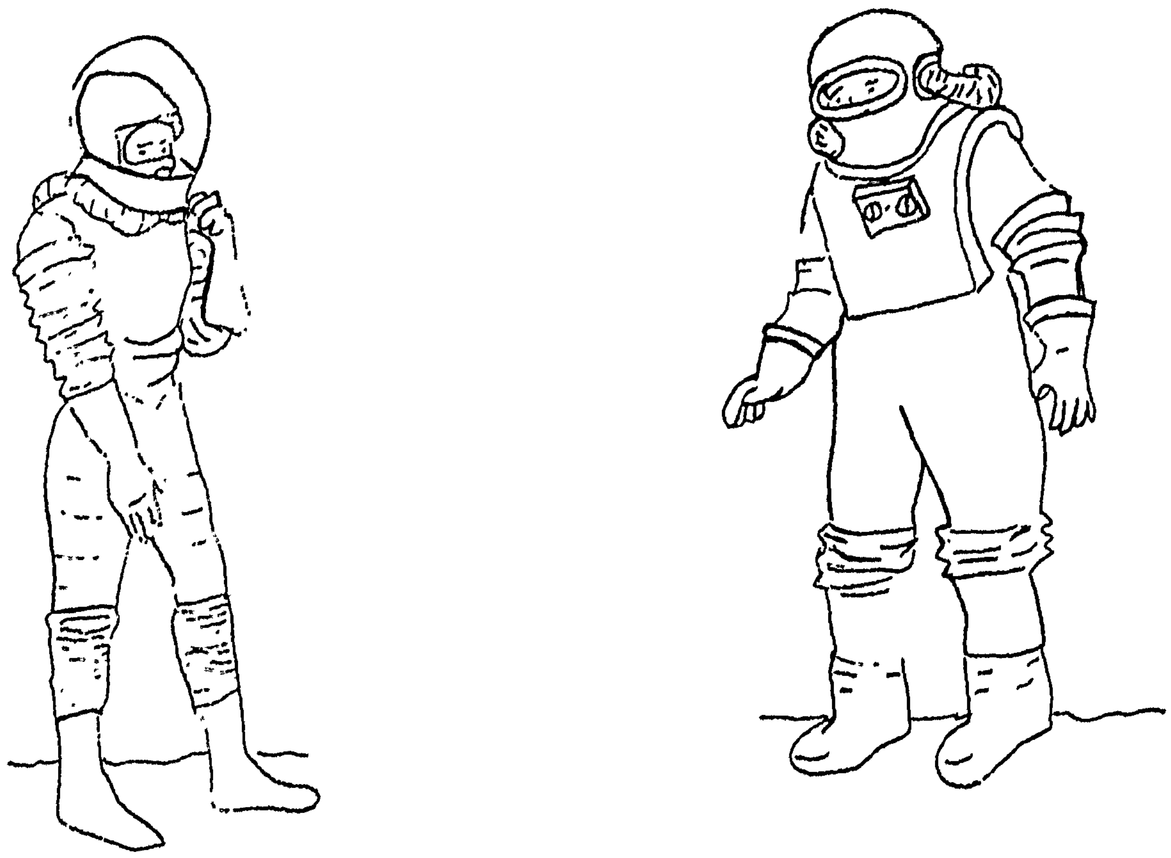
What would happen to man in space if there were no protection from lack of pressure? From these activities (and others), the children may predict that the gas inside his body would expand so that he might blow up. The gas that is dissolved in his body would soon come out of solution and escape ("bends"). His body fluids would boil. Therefore, the question becomes: How can man be protected from lack of pressure? The children may wish to speculate as to how this might be done: capsules, space suits, etc.

The children will be aware by now that, in any case, man must take with him some device to maintain or exert nearly normal pressure on his body. For high-altitude space travel, space suits of a soft fabric may be used; the walls of these suits can contain expandable air pockets so that pressure can be exerted against the space traveler's body. However, for deep-space or lunar exploration, this soft material might not be adequate protection against the dangers of radiation and speeding meteorites. Actually, the space suit might resemble a small spaceship: constructed of rigid material, air conditioned, pressurized, and supplied with oxygen. The children may enjoy discussing such questions as the following: What are the disadvantages of so clumsy a suit? How will man move, pick up things, and work in such a suit? Have the children collect pictures of various types of space suits to aid in their discussion. They may wish to design suits according to their own specifications.

Results/Conclusions

Man requires an air pressure of about 15 pounds per square inch in order to survive. To maintain this pressure in space, man must wear a pressurized space suit or remain in a pressurized capsule.

(See illustration on next page.)



CONCEPT - If man were to take untreated food into space, it would spoil before he had an opportunity to eat it.

1. Problem

Why must the food that man takes into space be specially treated?

Materials

Various foods, including meat, bread, and milk; jars; dishes.

Procedure

Allow milk to stand out all day and overnight. Moisten a piece of bread and allow it to remain uncovered in the room for one day. Cover it and place it in a dark, warm place for several days. Examine its condition. Place a small piece of meat and some water in a tightly covered jar. After several days, examine its condition.

What is done to preserve our foods? Discuss with the school's cafeteria manager or dietitian methods of preserving: refrigeration, drying, pickling, irradiating, freezing, etc. Have the children discuss whether any of these would be useful to the space traveler. Point out to them that one method of preservation is by freeze-drying. In this process, foods are frozen and the ice crystals are removed by sublimation; that is, they pass directly from the solid to the gaseous state, without passing through the liquid state. This greatly reduces the weight, and the flavor is not altered noticeably.

Have a group of children weigh the food they eat in one meal; in one day. If it takes 516 days for a round trip to Mars, how much might the food weigh for a crew of three men? How big would the space capsule and the rocket have to be to accommodate this much food? Can the children devise some ways of reducing the bulk and weight of the food?

How can foods be packaged for space travel? Let the children examine various containers for foods. Consider and discuss these problems: Would the containers we use be useful in space? Have the children examine cans, milk cartons, plastic squeeze bottles, glassware, etc. Would any of these be suitable to take into space? How would they be disposed of when emptied? Can the children devise disposable or edible containers for foods (for example, sausage casings, sugar packing around candies, and edible fruit skins)?

Results

The children may wish to inquire further into the problem of preparing foods. Have them discuss such problems as these: How can food be prepared in space? Can it be heated or cooked? How can it be removed from its package during weightlessness? Can it be shaken out? How can small bits and pieces be handled by a man in a space suit? How can liquids be poured? Have the children examine squeeze bottles and pipettes for transferring liquids.

Have the children examine the contents of various dietary supplements that doctors recommend for reducing of gaining weight. How are they packaged? Do they constitute a total diet? Some children may visit a food market to look for dehydrated foods and make a list of them. Can a balanced diet be planned by using only dehydrated foods?

The children may wish to apply their findings in devising a simple meal for the space traveler. How much food would be consumed by a man in one day? How long can man go without food? How much will this food weigh? How will it be stored and eaten?

Conclusions

Man must take his food with him into space. The food must be preserved to keep it from spoiling.

CONCEPT - A manned spacecraft must be made self-sustaining.

1. Problem

How can a spacecraft be made into a closed system?

Materials

Aquarium, fish, water plants, jar.

Procedure

Fill a jar with aquarium water and invert it in the aquarium over the water plants. Place the aquarium in the sunlight and have the children observe any bubbles that may rise in the jar. What are they? (Oxygen.) Where do they come from? (Plants.)

One type of plant that may be feasible to use for food in space is the algae. These green plants sometimes grow inside the aquarium and are found growing in ponds.

Grow some algae in the classroom. Place the aquarium in the sun. (An aerator that circulates air and water through the tank improves conditions for growth.) After several days, have the children observe the green algae growing in the aquarium. Can the children notice an increase in the green material as the algae grow and multiply? Let them observe the algae under a microscope if one is available. Do the fish eat the algae? (Yes.) Could man eat the algae? (Yes.) Could algae be used as a source of food? (Yes.)

Here is a recipe for algae cookies:

4 tablespoons chlorella (algae) powder (obtainable from biological supply houses)

2 cups flour | 4 tablespoons shortening

½ tablespoon salt | 3/4 cup milk

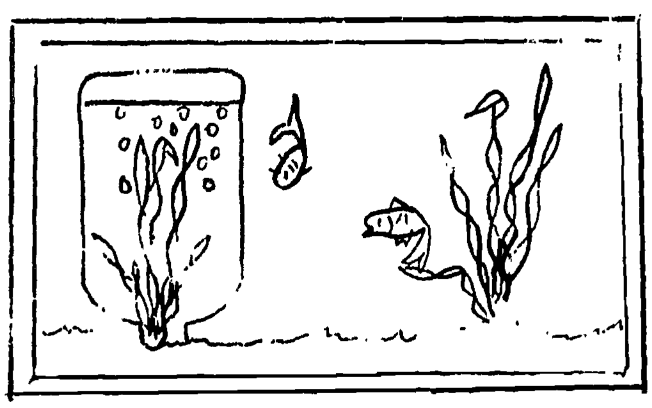
3 tablespoons baking powder

Cream shortening. Add sifted dry ingredients and milk. Roll out in ½-inch thick sheets. Spread with mixture of sugar, cinnamon, and butter. Roll up, slice into pinwheels, and bake at 350° for 10-15 minutes. The children may wish to devise other recipes.

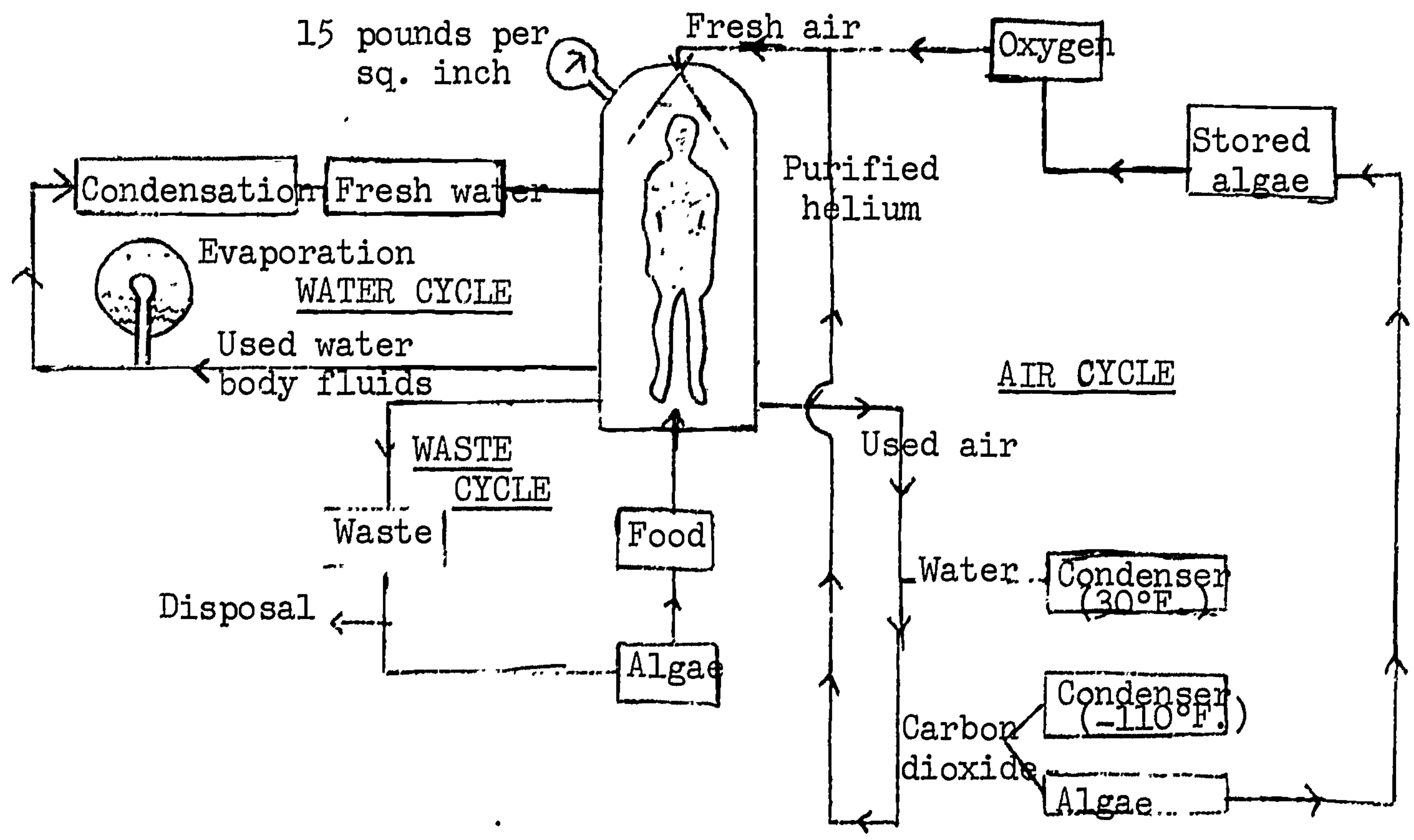
Can man live on algae alone? Can algae supply air? How would algae be supplied with nutrients for growth? There are many problems related to meeting man's needs for food, air, and water in space. Help the children see that man must take these elements with him or become part of the system that produces them.

Results/Conclusions

Through the use of green plants, such as algae, a spacecraft can be made self-sustaining. The plants would use up carbon dioxide and provide oxygen, and water could be recycled and distilled.



LIFE SUPPORT SYSTEM



CONCEPT - A cloud chamber may be used to detect cosmic rays.

1. Problem

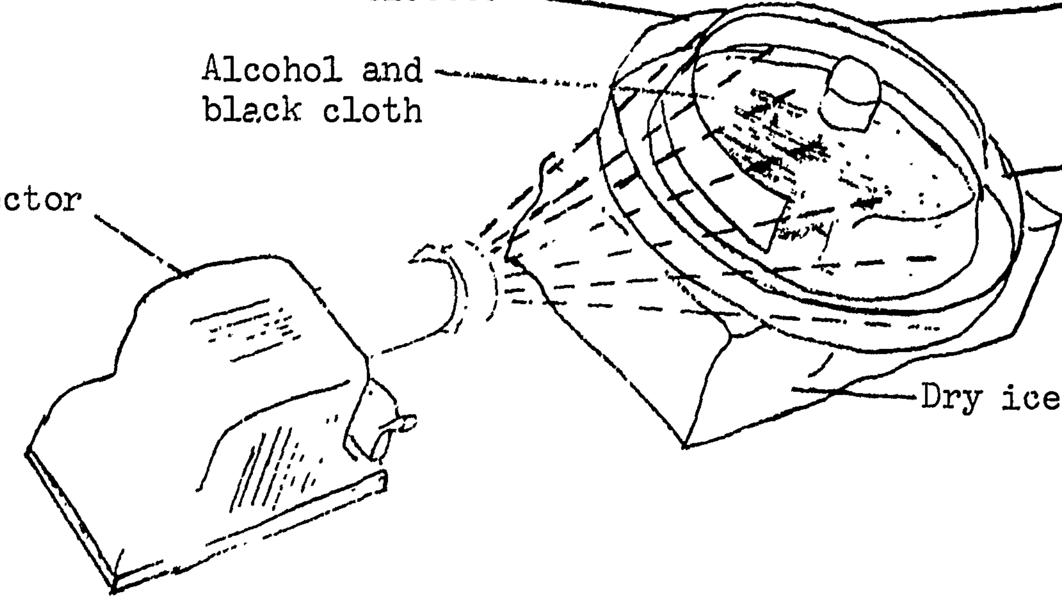
   How can radiation be detected?

   Materials

   Dry ice, alcohol, metal baking dish or pie pan, blotter, black cloth, transparent plastic cake cover or glass beaker, flashlight, radium watch dial, strips of various metals.

   Procedure

   A simple cloud chamber may be constructed to detect the presence of cosmic rays. Cut a round piece of black cloth to fit the bottom of the baking dish. Pour some alcohol in the baking dish until the cloth is more than soaked. Cut the blotter into a long, wide strip so that it lines the inside of the plastic cake cover. Leave about a 1-inch opening in the blotter so that it does not completely line the cover. Place the baking dish with the alcohol directly on the dry ice. Place the cover over the baking dish, with the blotter standing in the alcohol. Darken the room and shine the projector or flashlight through the slit in the blotter. Soon, as the alcohol is absorbed by the blotter, a cloud will form inside the cake cover. Have the children look down through the top of the plastic cake cover, through the beam of light passing through the cloud. Careful observation may reveal white streaks, 2 or more inches long, in the cloud. What are these? (Cosmic ray trails.) Where do they come from? (They are the trails of condensation left when a cosmic ray passes through the cloud. Cosmic rays come from space all the time.) How do they pass through the walls of the classroom? If they can pass through the walls of the classroom, can they pass through a human being? What effect might this have on us?



Hold a watch dial painted with radium close to the cloud chamber. Do the children notice an increase in the number of white streaks? What causes this? (Radiation from the radium.) Place strips of various metals between the watch dial and the cloud chamber. Does this decrease the number of white streaks? Place various substances and materials between the watch dial and the cloud chamber. Which seems to stop the cosmic rays the best? Encourage the children to speculate as to how man might be protected from cosmic rays in space. (This is called shielding.)

Develop the activity by explaining that man also needs protection from X rays. Let the children examine an X ray photograph. Help them understand that X rays pass through the body, and that an overdose destroys the flesh. Invite an X ray technician, dentist, doctor, or nurse to discuss the effects of X ray radiation and precautions used in the hospitals.

Results/Conclusions

Man must be protected from the radiation in space.

CONCEPT - Man must devise special ways to cope with his weightlessness and that of other things when he is in space.

1. Problem

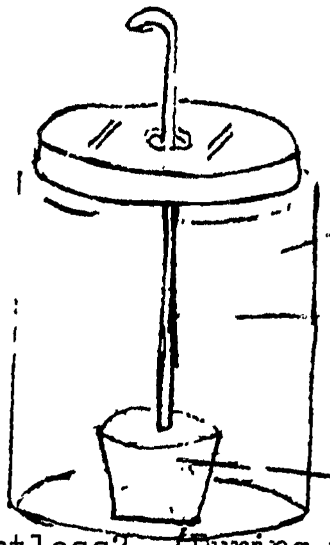
What is meant by the condition of weightlessness?

Materials

1-quart fruit jar, cork, coat-hanger wire, water.

Procedure

Suggest that the children make a bottle in which a submerged cork will not float. Have them take a quart fruit jar, bore a small hole in its metal cover, and fasten a cork to a piece of coat-hanger wire so that the cork can be held at the bottom of the water in the jar. If the wire is released while the jar is on the table, the cork promptly rises to the top; it is buoyed up by the water. But if you climb to the top of a tall ladder and release the jar at the same instant you release the cork, you will find the cork does not rise until the jar reaches the bottom, where someone catches it. The cork then promptly comes to the top. (Be sure that all safety precautions have been discussed. It might be wise to let the jar fall onto an outstretched blanket, held at the corners by four children.)



When does man in space become weightless? (During the coasting stage, after the rocket engines have stopped.) Why? (The space vehicle is either sufficiently beyond the pull of the Earth's gravity, or the Earth's gravity is counterbalanced by the rocket's forward thrust. Therefore, the spacecraft and everything in it are weightless.)

How does the weightlessness affect man? Ask the children if they have ever dreamed they were falling. How did they feel? Ask the children to think about what would happen if the man in a spacecraft were to push against the wall, jump, or raise his hands during the weightless state. Will man expend as much energy during weightlessness?

Other questions that children might like to consider are: How would man eat or drink during weightlessness? What would happen to the circulation of the blood? What would happen to the carbon dioxide that man exhales during weightlessness? How could food be prepared? How would mar sleep? Man himself must venture into space to try to find the answers to some of these questions.

Results/Conclusions

Weightlessness occurs when the spacecraft is either beyond the pull of the earth's gravity or when the earth's gravity is counterbalanced by the rocket's forward thrust. Man must be prepared to cope with weightlessness when he ventures into space.

CONCEPT - G-forces are caused when an object is accelerated.

1. Problem

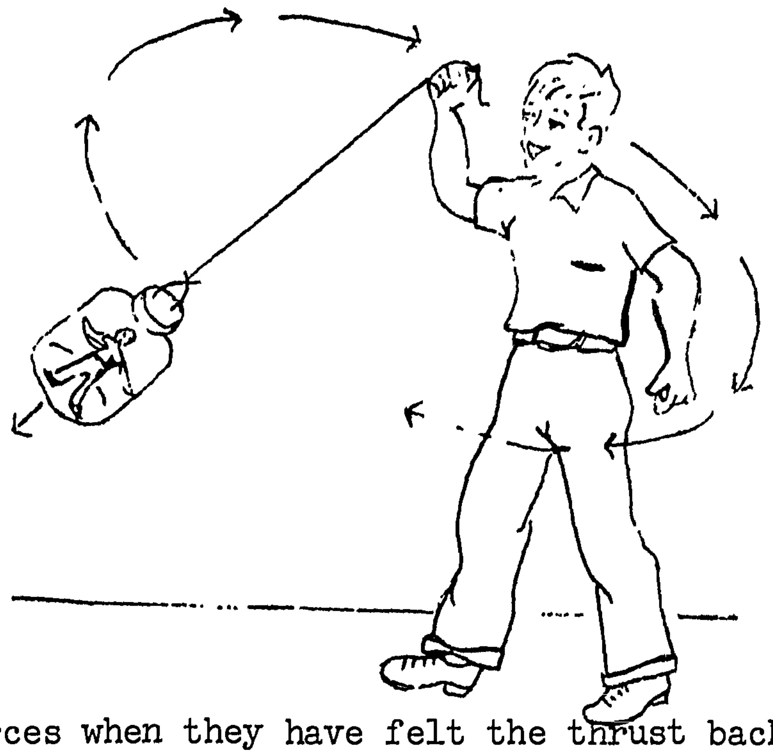
What are G-forces?

Materials

String or wire, small doll, 1-quart jar with tight fitting lid.

Procedure

Have a child place the small doll in a jar. Punch two holes in the lid of the jar and thread and tie a wire or heavy string through it. Have the child screw the cap tightly on the jar and whirl it around his head. Let the class observe what happens to the doll inside the jar. Is the doll forced to the bottom of the jar? (Yes.) Why? (Because of inertia.) Explain to the children that, as man leaves the earth, the forces of the rocket motors must be great enough to take the rocket to its destination. This terrific acceleration acts to cause tremendous pressures (G-forces) on the astronaut. (Under a force of 1G, a man's weight is normal; with a force of 2G's, his weight is twice normal; with a force of 3G's, his weight is three times normal; etc.) The children have experienced an



increase in G-forces when they have felt the thrust backward as a car or plane accelerates rapidly. During a launch, the astronaut will experience about 3.5G's. Man has withstood up to 45G's for brief moments in specially designed equipment. One way to overcome G-forces is to have the astronaut lie down so that the G-forces will be more evenly distributed over his body.

Discuss with the children how a chair might be designed to be comfortable for space travel. Of what should it be made? What position should it be in? How big should it be?

Bring to the children's attention the following problem: how will man react to the conditions of extended space flight? A spaceman can withstand G-forces, the vibration of the launch vehicle during take-off, weightlessness, confinement, and special foods for given periods of time. But how will he react to isolation for extended periods? Will he be able to live with fear?

Results

Discuss with the children how they would feel if they were shut in a small, dark place for an extended period of time. Discuss their reaction if they have ever been lost. How would they feel if they knew they were constantly being observed with a camera, and many thousands of people were watching?

What are the qualifications for being an astronaut? One group of children might do research into the lives of the astronauts. What are their qualities? What common types of experiences have they had? What What are some of their significant home, school, and career experiences?

How should teams be chosen to explore space? What should their qualities and competencies be? Develop standards for cooperation in space.

Plot a sociogram of the class. Ask the class to choose two other "astronauts" with whom they would venture into space.

Can the children suggest activities for spacemen while they are alone for weeks, months, and years? How have astronauts occupied their time in orbital flights? What experiments have they conducted. What did they wish to find out about space? What did they wish to find out about space? What would the children like to find out about space.

Summarize this discussion by helping the children to see that man lives in relation to his environment. On earth we take from and give to the environment. Thus, life processes are accomplished and maintained. When man ventures away from his natural home, the factors on which he is dependent must be supplied, and he must be protected from hazards. Thus, in order to understand man's necessities in space, we must understand man on earth. To supply him and protect him is one of the major challenges of the space age.

Conclusion

Man must cope with G-forces, weightlessness, and other abnormal conditions when venturing into space.

CONCEPT - A freely falling object accelerates at the rate of 32 feet per second every second.

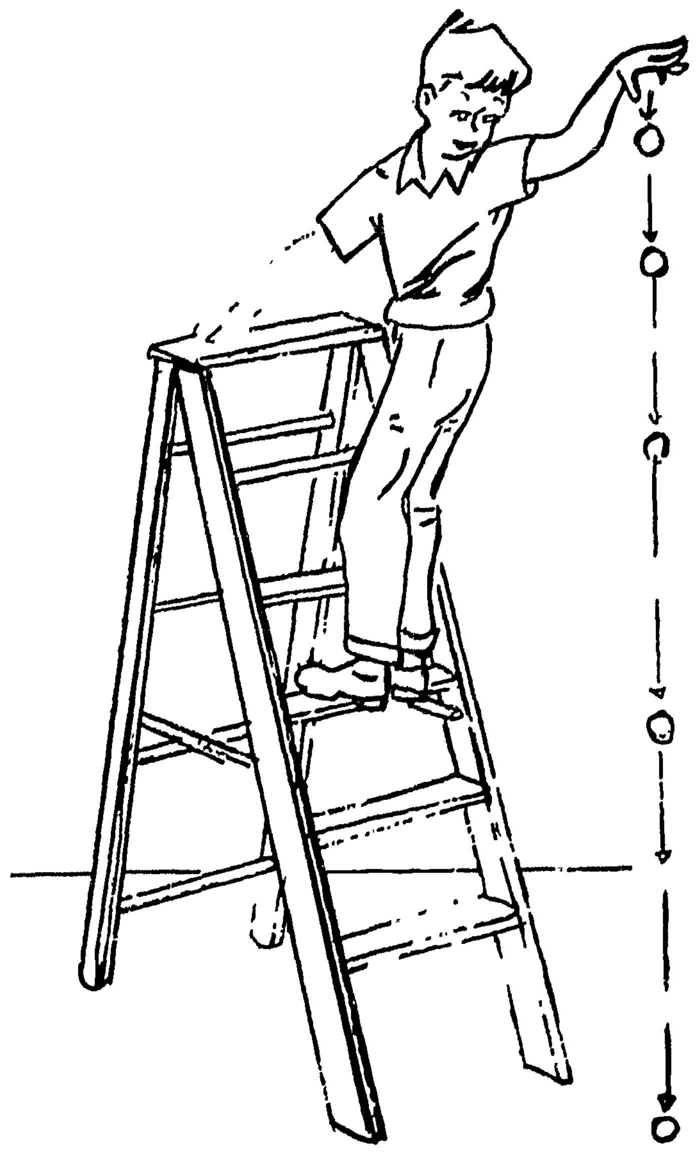
1. Problem

How can the acceleration of a freely falling object be shown?

Materials

Five spools, 15 feet of narrow ribbon, stepladder or high table.

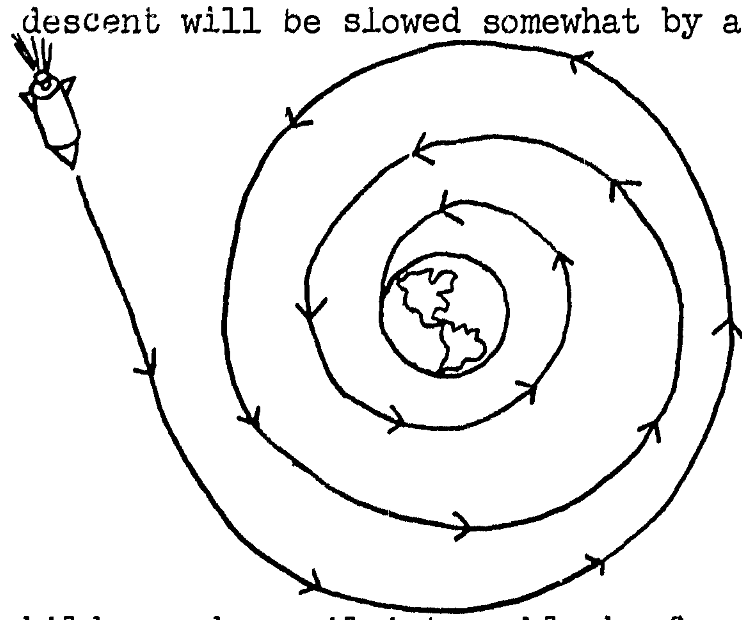
Procedure



Have a child thread the ribbon through the spools and tie the spools at unequal, measured intervals-----1 foot, 3 feet, 5 feet, 10 feet, and at the end. Have him stand on a stepladder, chair, or table and hold the ribbon so that it hangs straight down. Ask him to release the ribbon and have the class listen closely for the "clicks" as the spools reach the floor. Did all the spools "click" at the same time? (No.) Did they "click" at regular intervals although the spools were spaced unequally? (Almost.) Did they "click" with inequality similar to their spacing? (No.) The children should observe that although the spools are not evenly spaced, the "clicks" are almost evenly spaced. The spool that fell the greatest distance increased its speed as it fell so that it "caught up" somewhat with the other spools.

Explain to the children that the rate of acceleration is 32 feet per second each second, and that this means that the longer a body continues to fall, the greater its speed will become. To find the distance a body will fall in a given amount of time, some children might like to work with the equation $d = 16t^2$, where d represents the distance a body will fall from a stationary position in the time t. For example, in 10 seconds a body will fall 16×10^2, or $16 \times 100 = 1,600$ feet.

Since a spacecraft's speed will tend to increase rapidly as it falls toward the earth, man may wish to have it return to the earth in a spiral trajectory, such as the one shown in the illustration. In this way, instead of falling freely and accelerating very rapidly, the spacecraft's descent will be slowed somewhat by air resistance and frictional forces.



Have a child pound a nail into a block of wood, then feel the nailhead. How does it feel? (It should feel warm.) Likewise, as the spacecraft collides with air molecules, the surface of the vehicle will get warm.

Ask the children to rub two surfaces together, such as their hands, a block of sandpaper, etc. What is the effect? (They become warm.) Why do the surfaces become heated? (Because of friction.)

Pump a tire pump rapidly. Have the children feel the bottom of the cylinder. How does it feel? (It whould feel hot.) What effect does compressing air have on its temperature? (It increases the temperature.)

Results/Conclusions

A freely falling object accelerates to great speeds quite rapidly. A body in free fall accelerates at the rate of 32 feet per second each second.

CONCEPT - As a spacecraft enters the dense layers of the atmosphere, friction and compression will cause its temperature to increase tremendously.

1. Problem

Why does a spacecraft become heated as it falls through the atmosphere?

Materials

Block of wood, hammer and nails, sandpaper, tire pump.

Procedure

Discuss meteors, or shooting stars. What are they? Where do they come from? Why do they flare rapidly across the night sky? Why don't many more of them strike the earth? (Most meteors are completely burned or vaporized before they get within 50 miles of the earth. Their great speed sets up friction that heats them beyond their melting point.) How is a space capsule like a meteor? How can it enter the atmosphere without being burned up, as a meteor is?

Explain that even as airplanes fly through the air, their surface temperature increases. At the speed of sound (700 miles per hour) the temperature increases by about 95°F. The X-15, an experimental rocket plane, has reached a surface temperature of about 1,200°F. Discuss with the children what they think will happen to the spacecraft as it enters the atmosphere at 17,000 miles per hour and at 25,000 miles per hour. At 17,000 miles per hour it may reach a surface temperature of 3,000°F. At 25,000 miles per hour it may reach a temperature of 7,000 to 10,000°F.

Encourage the children to suggest ideas as to how this tremendous heat might be overcome. How can a spacecraft withstand such high temperatures without disintegrating or melting? How can man survive such temperatures?

The children will no doubt deduce that one way is to construct the spacecraft out of special materials. Can the children think of certain materials that withstand high temperatures? Encourage them to search in the kitchens of their homes to find materials used at high temperatures. Have them make a list of materials found, such as Pyrex, ceramics, aluminum, iron, Pyroceram. They should try to find out the temperatures at which these substances melt.

Results/Conclusions

Friction and the compression of air tend to increase the temperature. The entry surface of a spacecraft will be heated tremendously by friction and resistance.

CONCEPT - The shape of the re-entry craft can reduce the effects of friction and air resistance on the entry surface.

1. Problem

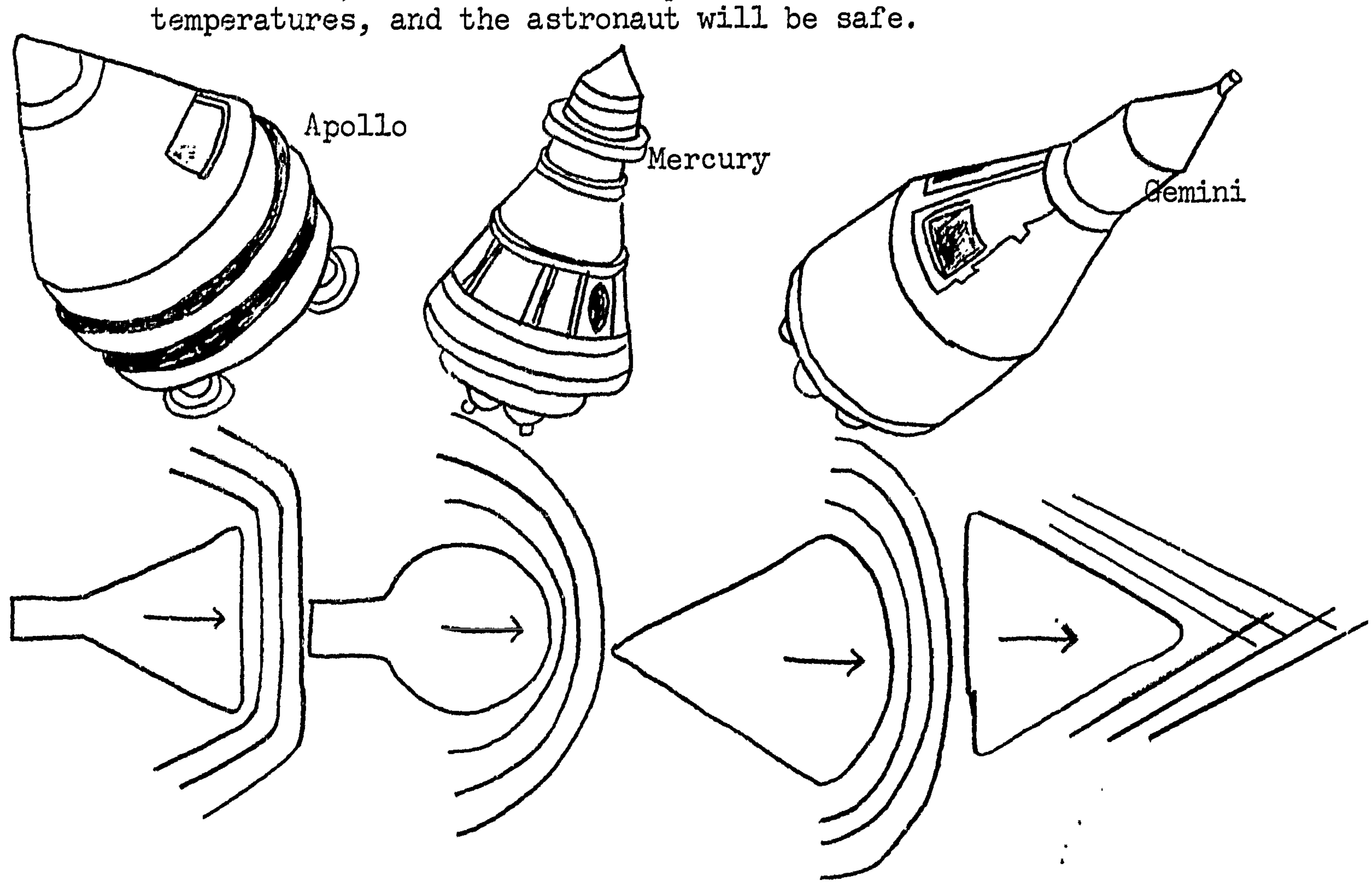
How can the re-entry craft be designed to reduce pressure and friction?

Materials

Balsa or soft wood; items of various shapes, such as light bulbs, toys, catsup bottles, and coffee carafes, to serve as spacecraft; 2 Pyrex test tubes, nursing bottles, or flasks; 2 thermometers; paraffin or candle wax; hot plate; pan of water.

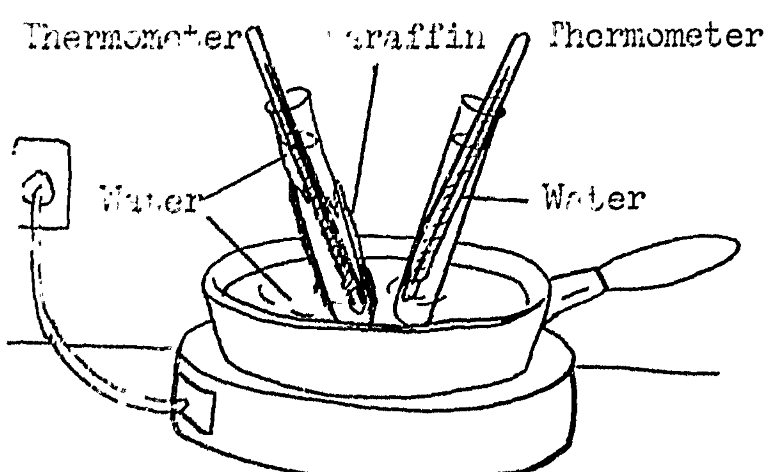
Procedure

Help the children model various shapes of spacecraft. Let them float objects of various shapes in a tub of water or push them through the sand in a sandbox. As the objects move forward, be sure the children notice the ripples that result. Which shape allows the water or sand to flow along the sides? Which shape compresses the ripples in front? Therefore, which shape would be best for re-entry? The children will see that if the spacecraft can be shaped in such a way as to allow the heat to be built up on one surface, and that surface will resist or absorb heat, the rest of the spacecraft will then withstand the high temperatures, and the astronaut will be safe.



Point out that this special surface is called an ablation (or heat removal) shield. It is designed to absorb much of the heat built up by the compression of air in front of the spacecraft. The ablation shield actually melts away under these conditions. But as it melts and burns, the heat is carried away with it-----away from the man in the space capsule. The children can understand in the following way how this works.

Have the children melt some paraffin or candle wax and dip one test tube, nursing bottle, or flask into the wax repeatedly, until a thick coat covers the outside of the container. Place a thermometer in the coated container and one in the plain container, and add equal amounts of water to each. Place each container in a pan of water and heat. Observe the relative changes in temperature inside the two containers as they are heated. (The container coated with wax should remain cooler as the wax melts away.) In the same way, the spacecraft will remain cooler as the ablation material melts away. Let the children find the ablation shield in pictures of space capsules. What would happen to the capsule if the ablation shield did not enter the atmosphere first?



Results/Conclusions

The re-entry vehicle can be designed in such a way as to reduce the effects of pressure and friction by using an ablation shield, which reduces the heat on the surface of the re-entry vehicle by melting away.

CONCEPT - The re-entry vehicle must be slowed down in such a way as to overcome both the heating caused by friction and air resistance and the G-forces that result from too rapid a slowing down.

1. Problem

How can the speed of the re-entry vehicle be reduced?

Materials

Large piece of poster paper or tagboard, catsup bottle or similarly shaped object, pieces of heavy bond paper, cloth or tissue paper, string, weights, deep tub of water, hammer and stakes.

Procedure

Drag Decay: The atmosphere helps reduce the space capsule's speed. This is called drag decay. To demonstrate the manner in which drag decay works, choose the two fastest runners in the class for a race. Pin a large sheet of paper on one child and then have them run the race. Is it more difficult for the child with the paper to run fast through the air with a large, flat surface in front of him? Why? (Because of air resistance.)

In the same way, the shape of the spacecraft will also tend to slow it down. To illustrate this, have a child drop the catsup bottle into the deep tub of water. He should drop it first with the pointed side (top) down. In which position does the object go deeper into the water? (When the pointed side is down.) Have the children observe how the object's speed slows as it passes into the water.

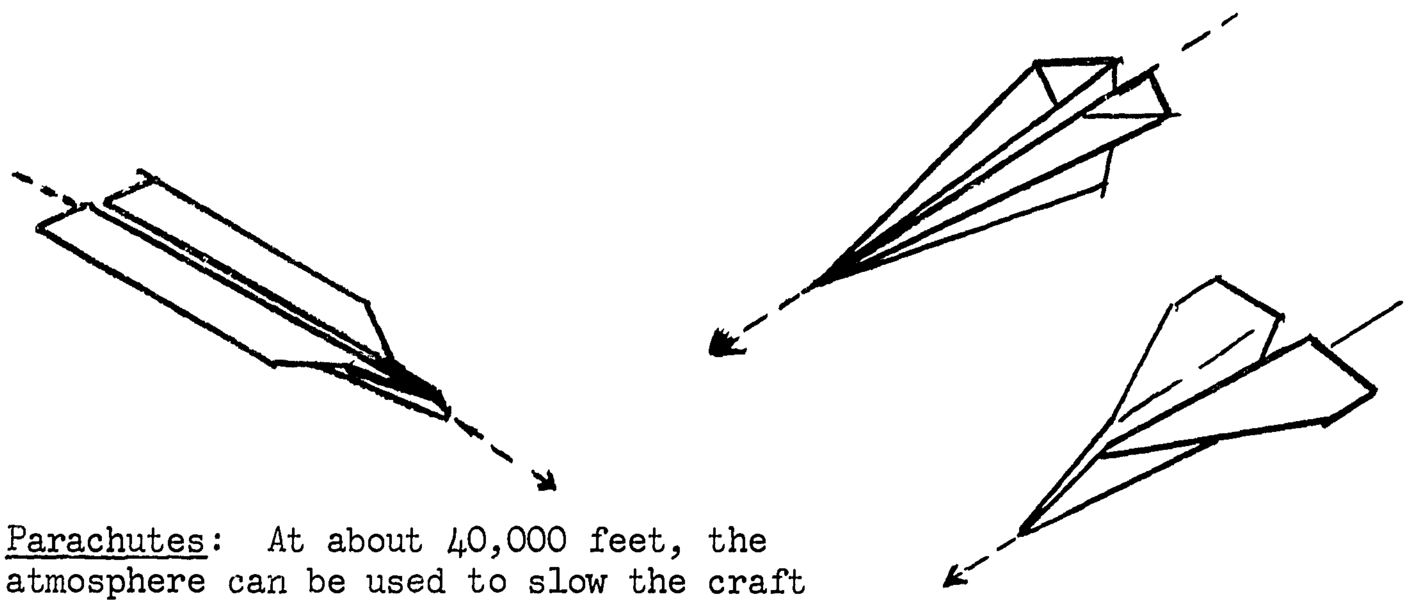
Another means of illustrating drag decay is to have the children pound wooden stakes of various shapes into the ground. Which shape is more difficult to pound, the pointed or the flattened? (The flattened.) From these experiences, can the children suggest how its shape might help slow the spacecraft?

Retrorockets: Another way to slow the spacecraft is to use retrorockets. Retrorockets are small but powerful rockets that are fired in the direction of movement. These serve to brake the spacecraft and slow it down. (Review the principle of action--reaction.) The retrorockets slow the spacecraft to below orbital velocity. What happens to the spacecraft when it is traveling slower than 17,500 miles per hour? (It returns to earth.) Review the section on orbits. What effect will such rapid deceleration have on man? (The reduction of speed from 25,000 miles per hour to about 150 miles per hour in such a short time could be harmful to men.)

Wings: Some spacecraft may be equipped with wings that will allow them to be maneuvered like a conventional airplane upon re-entry into the atmosphere. The wings will provide "lift" so that the descent toward earth can be made slowly and accurately.

To demonstrate this, have the children construct gliders by folding sheets of paper. See which glider sails the farthest. Let them experiment with many types of wings to see which provides the greatest lift.

Suggest that the children locate information about various winged re-entry spacecraft, such as the X-15. How are they constructed? How is it planned that they will re-enter the atmosphere and land? The children might also locate information about lifting bodies, such as the M-2 and M-3. How do they provide lift although they have no wings? How will they re-enter and land?



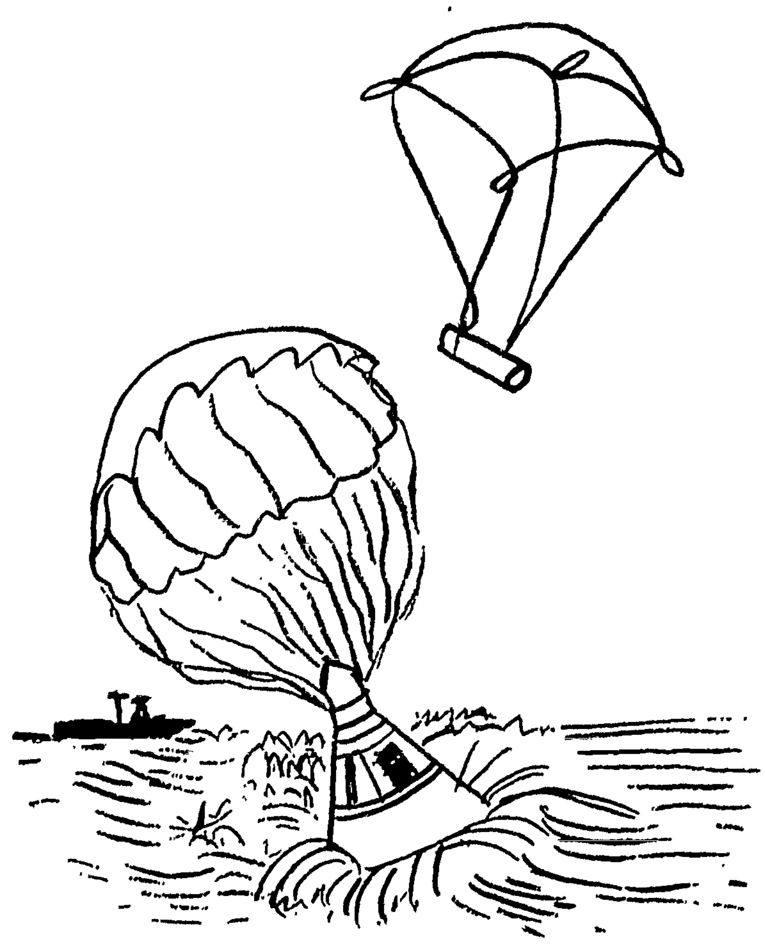
Parachutes: At about 40,000 feet, the atmosphere can be used to slow the craft by means of a parachute. The children can construct parachutes out of cloth or tissue paper. Have them attach a string to each corner of the cloth and tie all the strings to a weight or rock. Let them throw the weighted parachute into the air. (Be sure that safety precautions are observed.) The air will fill the parachute, and it should glide slowly to the earth.

Now the children are ready to consider where on the earth would be a suitable landing place. What type of surface would provide a soft landing? Encourage their theories.

How might the need for numerous re-entries be lessened? Can the children think of ways man could be provided with necessities to remain in space for longer periods of time? Could an environment be created for living on the moon? What would be needed? What materials are already there that man could utilize? How can man find out what materials are there?

Some children may wish to design a space station that would provide a base for refueling, rest, and research. How might the space station be designed to provide a comfortable environment?

Review with the children what they have learned so far. Point out that much research and experimentation must be done to solve the problems of re-entry. Returning man safely from space is dependent on his ability to slow, maneuver, and control the spacecraft through the barriers of heat and atmosphere.



Results/Conclusions

Drag decay, retrorockets, wings, and parachutes are some of the means used to slow re-entry vehicles.

CONCEPT - In the search for life forms on other planets, it is necessary that we "sterilize" our spacecraft so that if we do detect life it will not be a form carried by our own exploring devices.

1. Demonstration

The following materials are needed: dry beans (soaked overnight in water), four ½ pint milk bottles, water, iodine (3%), alcohol (70%), Lysol.

Place beans in each bottle and cover with water. Add the following to each bottle: bottle A - iodine; bottle B - alcohol; bottle C - Lysol; bottle D - nothing. Stopper the bottles with cotton and allow to stand in a warm place for two or three days. Examine the bottles periodically for cloudiness and odor.

Discuss the following questions:

a. How do you account for any change in color or odor in each bottle?

b. What difference might we have noted in the results if we had used a sterile bottle? Changed the temperature?

c. Would sterilization of the beans have helped?

d. Now consider the problems involved in the decontamination of spacecraft before they are launched. Make a list of possible methods which could be employed.

CONCEPT - Meteoric material in outer space - space hazards (Micrometeoroids)

1. Demonstration

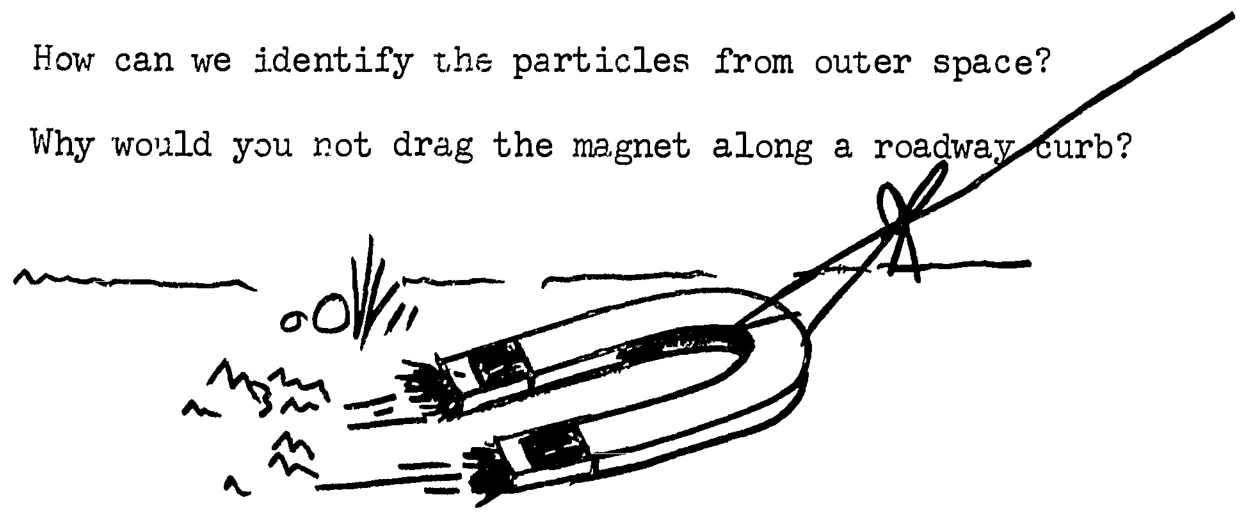
The following materials are needed: string (3 to 4 feet), strong U-magnet, microscope.

Attach string to magnet. Have the children drag the magnet across the lawn or field allowing the magnet to collect any material that might be attracted to it. Observe the material collected -- about 5% to 10% will be meteoric. Observe some of the particles under a microscope. Note the kinds of structure.

Discuss the following questions:

a. How can we identify the particles from outer space?

b. Why would you not drag the magnet along a roadway curb?



CONCEPT - Because small particles travel through space at tremendous speeds, they are easily able to penetrate a spacecraft.

1. Demonstration

The following materials are needed: paper and plastic straws of different sizes, raw potato.

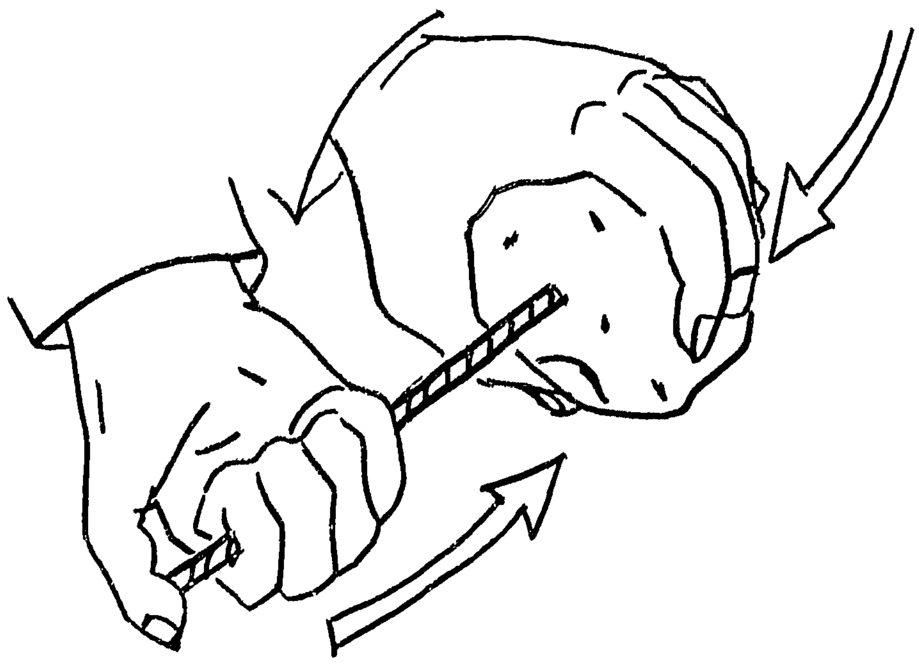
Hold the potato in your hand (between the thumb and index finger). Do not hold it in the palm of your hand. With the straw in the other hand, try to drive the straw through the potato. If after a few trys you have no success, try covering the end of the straw with your thumb in order to trap an air column. Just before you attempt to pierce the potato with the straw, bring the potato quickly toward the straw. Repeat, using different sizes of straws.

Discuss the following questions:

a. Relate this activity to particles traveling in space.

b. How do size and speed affect the ability of the straw to penetrate potato?

c. Devise methods by which spacecraft might be protected from meteoroids traveling in space.



CONCEPT - The extreme intensity of visible light in space often requires the use of mechanical aids to enable astronauts to see.

1. Demonstration

The following material is needed: flashlight (2 cell only), felt tip marker, mirror, various colors of cellophane.

Look at the pupils of your eyes in the mirror. Cover one eye while observing the pupil of the other eye. Move the flashlight so that it shines into one eye at an angle -- move it away quickly; observe the action of the pupil. Repeat, moving the light back and forth quickly. Try this on another person and observe the reaction of their pupils. Now try using the different colors of cellophane and make a filter for the flashlight. Repeat the above procedures for shining the light into the eye. Print a word on the lens of the flashlight with the felt tip marker. Determine the cellophane color which when used as "sunglasses" allows you to read the word most easily.

Discuss the following questions:

a. Discuss reasons for reaction of eye pupils when subjected to the bright light.

b. Which cellophane color(s) reduces the pupil reaction most? Why does this happen?

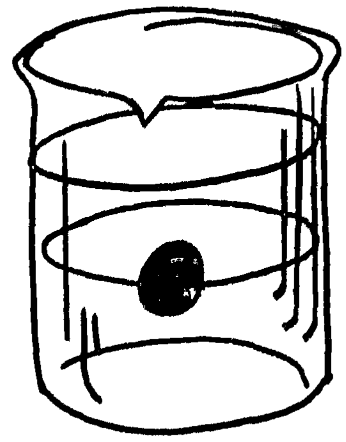
c. What possible methods might be used to provide protection for astronauts' eyes and still allow for greatest visibility?

CONCEPT - Liquids behave differently in a weightless condition.

1. Demonstration

The following materials are needed: olive oil, rubbing alcohol, pencil, beaker (250 cc), water.

Fill the beaker about $\frac{1}{4}$ full of water. Add a few drops of olive oil (making sure that the oil is together and not scattered). Add alcohol very slowly using a pencil until the sphere of oil appears to be suspended in the water and alcohol solution. Take a pencil and break up the oil globule into many smaller ones. Notice the shape they immediately assume.



Discuss the following questions:

a. Considering the nature of the action of the olive oil as demonstrating how liquids behave in a weightless condition, make a general statement that could be applied to the behavior of all liquids in space.

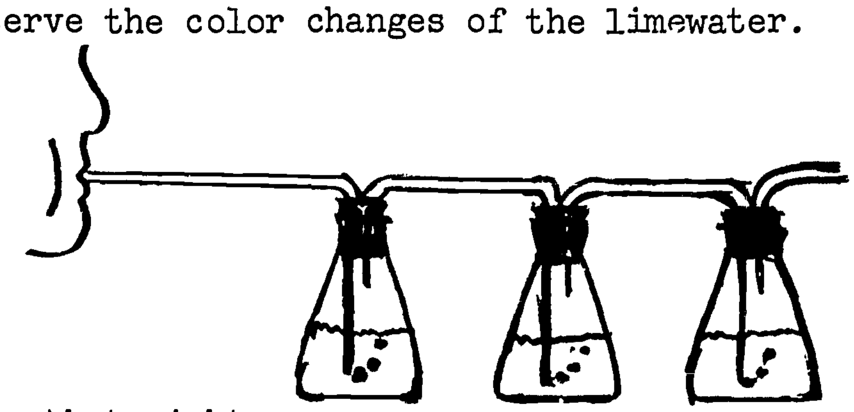
b. How might weightlessness interfere with the following:
   - food and water storage?
   - capsule housecleaning?
   - digestive process?
   - fuel storage and pumping?
   - others?

CONCEPT - It is necessary to remove carbon dioxide from the cabin atmosphere within a manned spacecraft.

1. Demonstration

The following materials are needed: three $\frac{1}{2}$ pint milk bottles (or flasks), glass tubing, rubber tubing, three 2 hole stoppers that fit the bottles, limewater.

Assemble the glass tubing, rubber stoppers, and rubber tubing as shown in the diagram. Add enough limewater to each flask to cover the end of the longer glass tube. Exhale a couple of breaths through the proper tube as indicated in the diagram. Observe the color changes of the limewater.



Discuss the following questions:

a. How do you account for the color change?

b. Why use more than one flask?

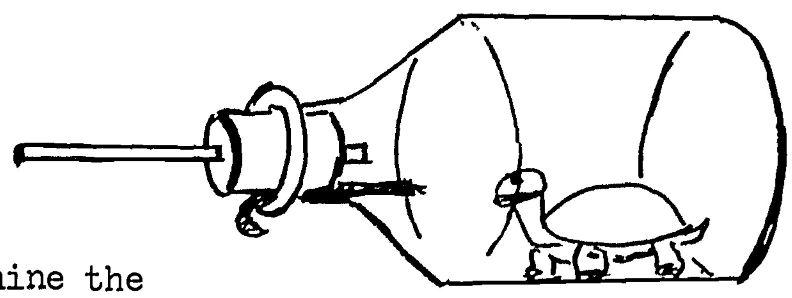
c. Describe a similar system that might be used in a manned space capsule.

CONCEPT - It is necessary to know the amount and rate of oxygen usage in manned spacecraft in order to properly regulate the cabin atmosphere.

1. Demonstration

The following materials are needed: $\frac{1}{2}$ pint milk bottle, pipe cleaners, ink, 1 hole rubber stopper, calcium hydroxide, small animals (mouse, cockroaches, crickets, grasshoppers, salamanders, etc.)

Place animal(s) in bottle. Place a pipe cleaner soaked in calcium hydroxide down into the bottle (CaOH absorbs carbon dioxide). Insert the glass tubing into the stopper allowing approximately 2/3 to extend above the top. Now stopper the bottle tightly in such a manner that the pipe cleaner still remains suspended. Apply a minute amount of ink to the tip of the glass tube -- wipe off the excess. Observe the movement of this ink marker.



Discuss the following questions:

a. What causes the ink marker to move?

b. Is it possible to determine the amount of oxygen used by the animal?

c. How can we improve our indicator tube to show rate of consumption?

d. Are there other factors which could affect our results using this apparatus? List them.

e. Manipulate the bottle in such a manner as to cause a change in rate and amount of oxygen usage. List other influences you can use on the bottle to cause these changes.

f. Relate your answers to the above questions to problems in maintaining proper cabin atmosphere in manned spacecraft.

CONCEPT - Astronauts traveling in space must take similar earth environment with them.

1. Demonstration

The following materials are needed: three bottles or jars with tight covers, aquarium plants, aquarium snails, aquarium water.

Fill the three bottles with aquarium water. Into each jar place the following: jar A - aquarium plants, jar B - aquarium snails, jar C - plants and snails. Add more aquarium water so that each jar overflows. Cover each jar tightly and allow them to stand at room temperature in an averagely lighted room for a few days. Observe periodically.

elodea | snail | elodea and snail

Discuss the following questions:

a. What is the condition of the living organism in each jar after 3 to 5 days?

b. Considering the basic environmental needs of a living organism, i.e., food, oxygen, temperature, light, etc., explain the cause of the resulting conditions in each jar.

c. Relate each jar to possible conditions in a manned space capsule.

d. Discuss reasonable conditions you believe should exist in a manned space capsule and explain the reason for including each.

CONCEPT - The evaporation of a liquid causes cooling ("Space Suit - Air Conditioning").

1. Demonstration

The following materials are needed: fan, water, alcohol, acetone, small squares of gauze, two thermometers with the same reading.

Rub water on a large area of the hand or arm. Fan the wet area and note the results. Tie the gauze about the bulb of one thermometer and wet it. Place the thermometers side by side. Direct the fan at them. Observe the result. Rub water on the back of one hand and alcohol (or acetone) on the other. Hold both in the fan stream. Note and record the apparent difference in temperatures.

Discuss the following questions:

a. Why is it that some of the evaporating liquids leave your hand feeling cooler?

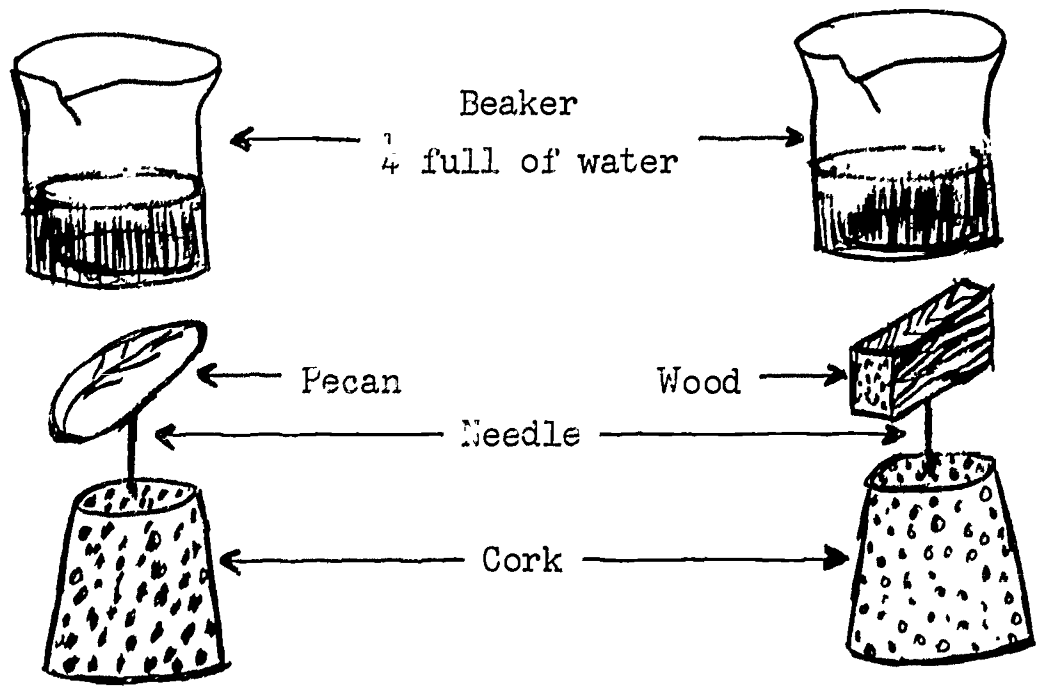
b. How do you think this principle can be applied to a space suit? A manned space capsule?

c. Discuss possible design of such an air conditioning system.

CONCEPT - The diet of an astronaut must be specially considered to anticipate the amount of heat energy released in the normal digestion of food versus the amount needed in a weightless, inactive space environment.

1. Demonstration

The following materials are needed: two large corks, pecan nuts, two needles, two beakers (250 cc), water, piece of dry, soft wood, ring stands, two thermometers.

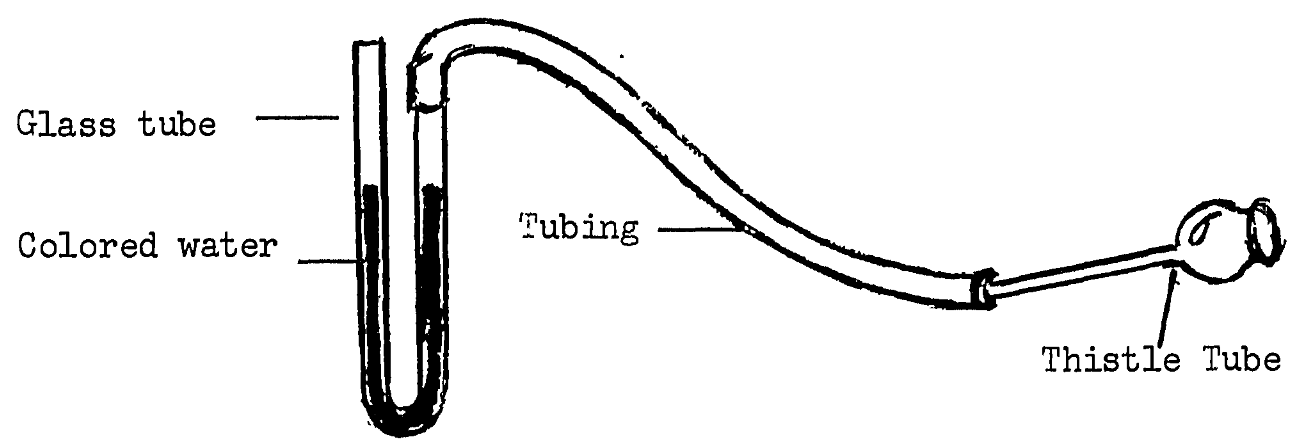


Place a needle in each cork and mount the pecan nut on the point of one needle and the piece of wood on the other as shown. Place each beaker on a ring stand at the same level. Fill the beakers one-quarter full of water which is of the same temperature. Set fire to both the nut and the wood and place under the beakers. Record the highest temperature reached by each and the length of time each burned.

CONCEPT - Certain body activities of animals and man can be monitored and measured as they orbit the earth in their spacecraft.

1. Demonstration

The following materials are needed: water, colored with ink; U-shaped tube or 2 glass tubes plus rubber tubing; thistle tube; rubber or plastic tubing; ring stand or wooden holder.



Half fill a manometer tube with water (a u-shaped tube made from two pieces of glass tubing and a short length of rubber tubing - see diagram). Attach a length of rubber or plastic tubing which has a two inch funnel on the end. Press the funnel over the carotid artery in your neck, beside the windpipe, or over your heart on the left side of the chest. Observe the action of the liquid in the tube.

Discuss the following questions:

a. What is this instrument actually measuring?

b. How could it be improved so that we could compare one animal with another?

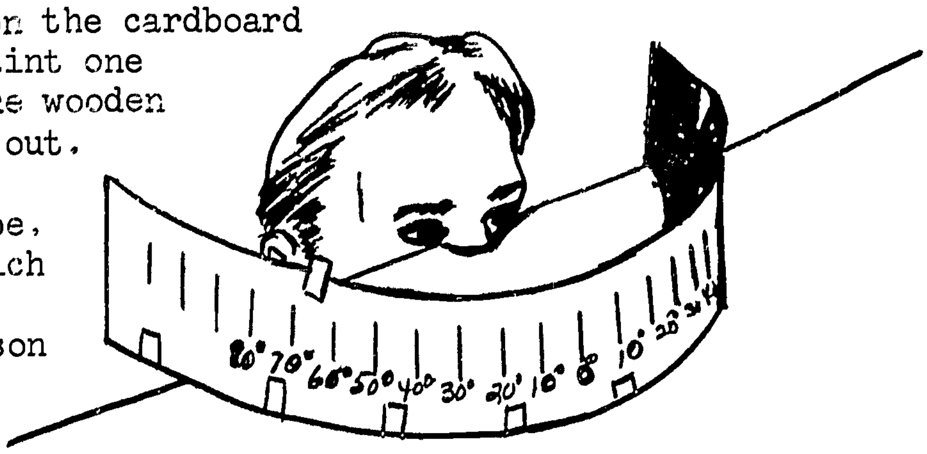
c. If the funnel was being used in a manned spacecraft, how could we get the change in liquid level back to scientists on the earth?

d. Discuss body changes of astronauts which should be sent back to earth-based scientists and devices that could be used in doing this.

CONCEPT - Location and operation of instrumentation in spacecraft is partially dependent upon the astronaut's field of vision.

1. Demonstration

The following materials are needed: strip of cardboard 45" x 4", metal or wire clips, felt tip marker or ball point pen, 3/4" round, wooden base cut in half equaling 18" in radius, black paint, ruler, thumbtacks.



Prepare a scale of degrees on the cardboard as shown in the diagram. Paint one side black. Thumbtack to the wooden base so the scale is facing out. Identify "0" by use of a metal marker or piece of tape. Fashion two more markers which can be moved along the top edge of the cardboard. Person being tested should sit so that the nose is in the groove in the baseboard; he should look directly at "0" marker while markers are moved along the scale until they just disappear from view. (Do not look at the moving markers, only at the "0" marker.) Read number of degrees as field of view for each eye. Prepare a chart of your group.

Discuss the following questions:

a. Are both eyes usually the same?

b. At what point in your field of vision can you detect the slightest movement?

c. What effect does wearing glasses have?

d. Relate astronaut activities which might be dependent upon field of vision.

<u>EVALUATION</u>

Included here are samples of evaluation items which could be used in developing your own informal testing program. These suggested types of items cover the particular science area that has been developed in this section of the handbook. This also means they could be used to help develop informal testing to cover large areas of information (monthly, mid-year, end-of-year testing). These are by no means complete tests as such. You will have to adapt and develop items to meet your particular class's own individual needs and differences.

I. Write the number of the word group in column A in the space before the item in column B that it best matches.

Column A		Column B
1. Day and night are the same length	(4)	Polaris
2. Orbit of planet	(1)	Equinox
3. Largest object in the solar system	(2)	Ellipse
4. The North Star	___	Circle
5. Revolves around the sun	(5)	Planet
	___	Shooting star
	(3)	Sun

II. Place a T in front of each true statement. Place an F in front of a false statement.

(F) 1. Space begins at about three miles above the earth.

(F) 2. Space is a place of great blinding light.

(T) 3. Space is neither hot nor cold.

(F) 4. Space is filled with an endless, humming noise.

(F) 5. Rocket motors do not need oxygen from the air around them to burn their fuel.

III. For each distance in column B, find the number of miles in column A. Number the distance the same as the number of miles in the distance.

Column A		Column B
1. about 24,000,000,000,000 miles	4	distance from earth to sun
2. about 25,000 miles	1	distance between earth and the nearest star (other than our sun)
3. about 186,000 miles	2	distance around earth at the Equator
4. about 93,000,000 miles	3	distance light travels in one second

IV. Which of the two words or phrases in the parentheses is the one that should be used? Draw a line under it.

1. The earth rotates on its (north pole, axis).
2. The earth rotates from (east to west, west to east).
3. Rotation of the (earth, sun) causes day and night.
4. The earth turns on its axis once every (365 days, 24 hours).
5. The earth's axis is always (straight, tilted) toward the plane of its orbit.

V. Underline the correct answer in each of the following sentences.

1. The earth makes one rotation in

   a. 12 hours b. 24 hours c. 32 hours d. $365\frac{1}{4}$ days

2. The summer solstice comes on

   a. May 21 b. June 21 c. July 21 d. August 21

3. The shortest day in the Southern Hemisphere is

   a. December 21 b. April 21 c. June 21 d. September 21

4. The largest planet is

   a. Mercury b. Venus c. Earth d. Jupiter

5. The planet closest to earth is

a. Mercury b. Venus c. Mars d. Saturn

VI. Write the name of the planet that

1. is closest to the sun. (Mercury)
2. is farthest from the sun. (Pluto)
3. is about the same size as the earth. (Venus)
4. is the largest of the planets. (Jupiter)
5. travels around the sun in 365 days. (Earth)

VII. For each definition in column A, find the word it defines in column B. Number the word the same as the definition.

Column A

1. Heavenly body with a star like center and a cloudy tail of light
2. Small planets
3. Heavenly body whose name means "wanderer" and which travels around the sun
4. Mass of stone or metal that comes toward the earth from outer space
5. Any heavenly body except the moon, the planets, comets, and meteors
6. Heavenly body around which the planets revolve

Column B

2 planetoids
4 meteor
5 star
6 sun
3 planet
1 comet

VIII. A list of terms is given below. Select the term from the list that goes with each statement. Write the term in the space before the statement.

Archimedes Lunar eclipse Copernicus Solar eclipse
Horizon Zenith Ptolemy

1. (Copernicus) solar system theory
2. (Horizon) where land and sky seem to meet
3. (Ptolemy) fixed-earth hypothesis

4. (Solar eclipse) moon between earth and sun

5. (Lunar eclipse) earth between moon and sun

IX. Underline the correct answer in each of the following sentences:

1. The distance between the earth and the sun is about ________ miles.

   a. 240,000 b. 73 million c. 83 million d. 93 million

2. Bodies that do not have regular orbits are ______________.

   a. planets b. comets c. meteors d. asteroids

3. A star in our solar system is ______________.

   a. the sun b. the moon c. the North Star d. Mercury

4. Light waves travel at a speed of about ________________________.

   a. 186 million miles per minute b. 186 million miles per second

   c. 186 thousand miles per minute d. 186 thousand miles per second

5. A radio message to the star nearest our solar system would arrive in about ____________________.

   a. 240,000 seconds b. 4 years c. 4 hours d. 8 years

X. Complete the following sentences:

1. During the winter months the sun rises each morning a bit farther to the (north).

2. It takes the moon about (29) days to revolve around the earth.

3. The Big Dipper moves slowly across the sky toward the (west).

4. The earth revolves around the sun in $(365\frac{1}{4})$ days.

5. The first day of spring in the Southern Hemisphere falls on (Sept. 21).

XI. Write the number of the word group in column A in the space before the item in column B that it best matches.

Column A	Column B
1. Moving around another body	(3) Rotation
2. Gives off light	____ Comet
3. Turning on an axis	(4) Meteor

4. "Shooting star"

5. Rotates once during a revolution

(1) Revolution

____ Meteorite

(5) Moon

____ Star

XII. A list of terms is given below. Select the term from the list that goes with each statement. Write the term in the space before the statement.

1. (Comet) has a long, glowing tail
2. (Newton) laws of motion
3. (Meteorite) a meteor that reaches the earth
4. (Einstein) theory of relativity
5. (Galaxy) group of billions of stars

Meteorite   Planetoid   Comet   Newton   Archimedes   Galaxy
Einstein

XIII. Complete the following sentences.

1. The scientist who discovered that the orbits of the planets are elipses was (Kepler) .
2. Small bodies that travel in orbit around the sun in a belt between Mars and Jupiter are called (planetoids) (asteroids) .
3. The planets are kept in their orbits by (gravitational) force.
4. The first astronomical observations through a telescope were made by (Galileo) .
5. Our galaxy is known as the (Milky Way) .

XIV. Underline the correct answer in each of the following sentences:

1. In a lunar eclipse (a) the earth is between the sun and moon (b) the moon is between the sun and the earth (c) the sun is between the earth and the moon (d) the earth and the moon are the same distance from the sun.

2. The most familiar constellation seen in north latitudes is (a) the Big Dipper (b) Leo the Lion (c) the Great Dog (Canis Major) (d) the Milky Way.

3. An important constellation seen in southern latitudes is (a) Orion (b) the Southern Cross (c) Cassiopeis (d) the Little Dipper.

4. A star that keeps an almost constant position in the sky is the (a) North Star (b) Dog Star (c) Vega (d) Rigel.

5. The pull of gravity on the moon is (a) about 6 times more than on earth (b) about 1/6th as much as on earth (c) $\frac{1}{2}$ as much as on earth (d) not known.

XV. Complete the following sentences:

1. The moon is about (1/4 million) miles away from the earth.

2. The distance around the earth is about (25,000) miles.

3. Besides the earth, there are (how many more?) (8) planets.

4. The lack of atmosphere on the moon is due to the moon's low (gravity).

5. The pull of the moon on the water in our oceans and seas causes (tides).

XVI. Which one of the two words or phrases in the parentheses is the one that should be used?

1. As the earth travels in its orbit around the sun, changes in (seasons, day and night) occur.

2. During the (summer, winter) season, the sun is straighter overhead than at any other time.

3. Near the (Northern Hemisphere, Equator) there are no great seasonal changes.

4. One revolution of the earth around the sun takes (365 days, 24 hours).

5. Our entire solar system is speeding through space with the Milky Way (Galaxy, Constellation).

6. When it is winter in the Northern Hemisphere, it is (winter, summer) in the southern half of the earth.

7. Sun rays that spread out over more space (give as much, do not give as much) heat as the direct rays.

8. During the summer months, the farther north you travel in the Northern Hemisphere, the (warmer, cooler) the weather.

9. The closer to the (Equator, North Pole) the greater is the depth of atmosphere through which the sun's rays must travel.

10. The greater the depth of atmosphere, the (more, less) heat reaches the earth.

11. Our sun is just one of (several, millions) of stars making up our star system.

12. Scientists believe there are (no, many more) star systems far beyond our own.

13. The (Equator, hemisphere) is an imaginary circle around the middle of the earth.

14. An (axis, Equator) is a straight line around which something turns.

15. (An Equator, A hemisphere) is half of the earth's surface.

XVII. Place a T in front of each true statement. Place an F in front of each false statement.

(T) 1. Because the moon is the heavenly body nearest the earth, man's first journey into space will probably be to the moon.

(T) 2. A rocket reaching the moon would have trouble coming in for a landing because the moon has no atmosphere to slow down the rocket.

(F) 3. Because of the earth's gravity, the nearer a returning rocket got to the earth, the slower it would travel.

(F) 4. Most of a rocket's fuel would be used up after the rocket reached airless space.

(T) 5. Rocket ships carrying passengers must be sealed off from all outside conditions.

(T) 6. Without some way to get oxygen, man could not live over ten miles above the earth.

(T) 7. A rocket must travel 24,000 miles an hour to escape the pull of the earth's gravity.

(F) 8. Even in the sunlight, the moon's surface is 250 degrees below zero.

(T) 9. The higher up an airship goes, the thinner the air becomes.

(T) 10. Cosmic and ultraviolet rays are always moving through space.

(F) 11. A man weighing 200 pounds on earth would weigh at least 350 pounds on the moon.

(T) 12. Fuel is a substance that can be burned.

(F) 13. Friction causes objects to move toward the center of the earth.

(F) 14. A satellite is a small body around which a planet revolves.

(T) 15. Atmosphere is the air that surrounds the earth.

XVIII. Complete each of these sentences by drawing a line under the correct word or phrase that belongs in the blank space.

1. The sun is a (star) . (star, planet, meteor, constellation)
2. The smallest planet is (Mercury). (Venus, Mars, Mercury, Earth)
3. The planet most like the earth is (Venus). (Saturn, Venus, Pluto, Neptune)
4. The largest planet is (Jupiter). (Earth, Mars, Saturn, Jupiter)
5. The planets get their light from the (sun). (volcanoes, moon, stars, sun)
6. The planet having the most atmosphere is (Jupiter). (Venus, Mars, Jupiter, Earth)
7. The planet that moves fastest around the sun is (Mercury). (Jupiter, Mercury, Mars, Uranus)
8. The planet having the largest number of moons is (Jupiter). (Jupiter, Neptune, Saturn, Mars)
9. Galaxies are made of (stars). (stars, meteors, dust, comets)
10. The groups of stars which we see in the sky are called (constellations). (galaxies, constellations, meteors, planetoids)

XIX. Place a T in front of each true statement. Place an F in front of each false statement.

(T) 1. One side of the moon is hot, and the other is cold.

(F) 2. We have a full moon one week after we have a new moon.

(F) 3. Our moon is larger than any other moon in the solar system.

(F) 4. The moon is about one half as large as the earth.

(T) 5. The light we get from the moon is reflected sunlight.

(F) 6. An eclipse of the moon happens only when we have a new moon.

(T) 7. Many stars are larger than our sun.

(T) 8. First magnitude stars are the brightest stars.

(F) 9. Anyone with good eyes can see about one million stars.

(T) 10. One side of the moon has never been seen.

(F) 11. The dark parts seen on the moon are water.

(T) 12. Planetoids are really very small planets.

(T) 13. The sun is many times larger than the moon.

(F) 14. The North Star is the brightest star in the sky.

(T) 15. A light-year is the distance light travels in one year.

(F) 16. White stars are not as hot as orange-colored stars.

(F) 17. The surface of the moon changes faster than does the surface of the earth.

(T) 18. During the night the stars seem to move from east to west.

(F) 19. All planets have the same kind of atmosphere.

(F) 20. The path of a planet around the sun is called an eclipse.

XX. Place a T in front of each true statement. Place an F in front of each false statement.

(T) 1. The gravitational pull of the earth on an object equals the weight of the object.

(F) 2. Gravity pulls objects toward the outer edge of the earth.

(T) 3. Atmosphere is held to the earth by the force of gravity.

(F) 4. The farther an object moves away from the center of the earth, the more it weighs.

(F) 5. The perigee is the point in a satellite's orbit where it is at its greatest distance from the earth.

(F) 6. Deceleration means an increase in speed.

(T) 7. Besides fuel, rocket engines must carry the oxygen that is necessary for combustion.

(T) 8. Multistage rockets are used because a single rocket cannot carry enough fuel to escape the earth's gravitational pull and reach outer space.

(T) 9. In order to escape the pull of gravity, a rocket needs more fuel at the beginning of its flight.

(T) 10. As a satellite's orbits get smaller, it moves closer to the earth.

(F) 11. In outer space rockets are able to use oxygen from the surrounding air to burn fuel in their combustion chambers.

(F) 12. The heavier an object is, the faster it will be pulled toward the earth.

(T) 13. Backward pull during acceleration is measured in "gravities" or "G's."

(T) 14. The human body can best withstand acceleration in a reclining position.

(F) 15. Friction keeps a satellite in orbit.

XXI. Complete each of these sentences by drawing a line under the correct word or phrase that belongs in the blank space.

1. ______________ is the science of space flight.

   Geometrics   Aerodynamics   Astronautics   Hydraulics

2. A man weighing 180 pounds on earth would weigh ___________ pounds at a height of 4,000 miles above the earth's surface.

   720   0   1440   45

3. ______________ force is the force tending to impel an object outward from a center of rotation.

   Centrifugal   Gravitational   Mechanical   Electrical

4. A ______________ is an object launched into an orbit around the earth.

   missile   rocket   satellite   jet

5. Weightlessness occurs when centrifugal force equals the force of ______________.

   deceleration   combustion   gravity   compression

6. An eliptical orbit is ______________ in shape.

   oval   round   angular   circular

7. The path of a body revolving around another body is its ______________.

   apogee   satellite   ellipse   orbit

8. ______________ is the heaviness that a body has because of the pull of gravity.

   thrust   weight   velocity   friction

9. ______________ established the law of gravitation.

   Galileo   Copernicus   de Vinci   Newton

10. A ______________ is an object that is hurled or shot forward.

   satellite   missile   space station   craft

VOCABULARY

One of the strongest keystones of scientific efficiency lies in its vocabulary. The scientist says things precisely, accurately, and briefly. Probably one of the greatest quarrels the science teacher may have with the elementary level teaching today is vocabulary. The science teacher can have no use for vocabulary that is not precise and accurate. Precision in vocabulary is necessary for understanding and meaning of the concept or process being learned.

The words listed below are the basic vocabulary for the indicated area of study. After each word has been introduced, its meaning is to be maintained and extended at each succeeding level of study.

asteroid
astronaut
axis
balloon
comet
constellation
crater
direct force
earth
ellipse
equinox
frame of reference
galaxy
glacier
gravitational force
hypothesis
indirect force
Jupiter
laws of gravitation
laws of motion
light-year
lunar eclipse
Mars
Mercury
meteor
meteorite
Milky Way
moon
Neptune
orbit
parachute
phases
planet
planetoid
Pluto
revolution
rocket
rocket engine
rotation
satellite
Saturn
solar eclipse
solar system
solar system theory
solstice
sphere
spring tide
tidal day
tide
triangulation
Uranus
universe
Venus

CHILDREN'S BOOKS

Books are a very essential part of the instructional materials in elementary schools which provide superior learning experiences for children. The selection of these books poses a difficult problem for librarians, teachers, and administrators because the science field is broad and increasing in scope, and elementary school science programs are varied in nature. Some of the more common specific difficulties in choosing books are (1) finding materials which deal with the varied interests of children; (2) locating material which gives information correlated with the local school district's instructional guides; (3) finding books of appropriate reading difficulty; and (4) selecting the best books from the many available. The following list gives help related to the first three difficulties presented. Indirectly, it also helps with the fourth, for the best books cannot be selected until they are located. Further, the brief annotations should be of help in determining which books may be best for a given class. Finally, time should be saved in the selection of a "best" list if some information about the reading difficulty of available books is provided. It is hoped that this list will suggest for elementary teachers books that are supplementary to basic text series, and that these books will have value either as sources of information or for recreational reading.

It is always hazardous to specify an exact grade placement for a book because of variations in pupil reading ability in any class group, and because of different uses made of books. Consequently, the lowest grade levels for pupil use are indicated. At lower levels these same books may be useful if the teacher reads to the children.

Adler, Irving. Seeing The Earth From Space; What The Man-Made Moons Tell Us; illus. by Ruth Adler. Day, 1961. $3.75.
"This book reports actual results of both Russian and American satellite launchings. Findings in regard to the shape of the earth, gravity, density of electrons, temperature of the upper air, and the Van Allen radiation are described and interpreted. Some of the original illustrations are retained."

Adler, Irving. The Stars; Steppingstones into Space; illus. by Ruth Adler. Day, 1956. $3.50.
"What stars are, how old they are, their paths through space, how we are able to weigh them and discover their content and other facts about them. Accurate and up to date. Line drawings and photographs. More detailed than most teen-age astronomy books. Text difficult at times and may discourage average reader."

Ames, Gerald. First Days of the World; illus. by Leonard Weisgard. Harper, 1958. $3.50. (4-6)
"Follows the history of the earth, from the origin of the solar system (Laplace theory) to the emergence of modern mammals."

Branley, Franklyn M. A Book of Planets For You; illus. by Leonard Kessler. Crowell, 1961. $3.75. (2-4)

"The nine planets that go around our sun are described in this book. Their sizes, temperatures, characteristics, and satellites are explained in easy terms. Simple experiments show how the planets revolve and rotate, where they are located in relation to each other. A very good science book for the primary level: straight information, no talking down or popularization, print that is large and clear, and illustrations that are (with a few exceptions) an amplification of the text. Dr. Branley combines his professional competence with a deft ability to present material in a style that is crisp without being dry."

Branley, Franklyn M. The Big Dipper; illus. by Ed Emberley. Crowell, 1962. $2.95. (k-3)

"The author gives directions for locating the Dipper, tells what we know about this famous group of stars, and gives some of the folklore and legend connected with the Dipper. While the scope of subjects exceeds that indicated by the title, it is not too complicated for the age of the reader. The text is, however, not always clarified by the illustrations."

Branley, Franklyn M. The Moon Seems to Change; illus. by Helen Borten. Crowell, 1960. $2.95. (k-2)

"A science picture book which, in the most elementary terms, discusses the size of the moon and its distance from the earth and explains the reasons for the phases of the moon. A home experiment is included. Text and drawings are well integrated, sentences are short, and the vocabulary is easy. While the book will be useful with first and second grades it is better suited for reading aloud to preschoolers."

Branley, Franklyn M. The Sun, Our Nearest Star; illus. by Helen Borten. Crowell, 1961. $2.95. (k-2)

"This book about the sun, our only daytime star, describes its size, shape, and characteristics. It tells why the sun is necessary to our lives. A good science book for beginning independent readers in which the author successfully establishes a few basic facts with lucidity and with no digression. At the end of the book, the facts that have been learned are recapitulated. Some of the illustrations, although handsome, are ornamental rather than informative."

Branley, Franklyn M. What Makes Day and Night; illus. by Helen Borten. Crowell, 1961. $2.95. (k-2)

"The author describes the mechanics of earth's rotation and the apparent changes in the position of the sun that result from the rotation. Clearly and simply he gives an explanation of day and night. . .sunrise and sunet. Although the text is easy enough for a second-grader to read, an adult would have to explain and supervise the directions given, and Helen Borten's illustrations are much too freehand to give the accuracy a child demands."

Branley, Franklyn M. What The Moon Is Like; illus. by Bobri. Crowell, 1963. $2.95. (1-3)
"A simplified description of the surface and atmosphere of the moon with a prediction of man's exploration there. Dr. Branley explains lunar seas and craters, mountains and valleys. . .Unified first science text, with illustrations that are helpful."

Brenna, Virgilio. The Moon; illus. with photographs and drawings. Golden Press, 1963. $3.95. (5-7)
"A close-up view of the moon; what is known and what lunar explorers may find. Discusses the origin, substance, motions, physical features, changes, and future of the moon. Includes many photographs, 44 of which are color photographs of scale models which, based on scientific observation, were made especially for the book."

Crosby, Phoebe. Junior Science Book of Stars; illus. by William E. Preston. Garrard, 1960. $1.98. (3-5)
"Day and night, the seasons, and the phases of the moon are explained in easy language. Gives some basic facts about the planets and the stars, and tells how to find and recognize several important constellations."

Darby, Gene. What Is A Season; pictures--Lucy and John Hawkinson. Benefic Press, 1959. $1.80. (k-2)
"This book which explains the cycle of seasons begins with spring when days are growing longer and plants and animals are becoming more active. Seeds are sprouting and many animals have their young. Summer brings growth and in fall there is maturing and preparation for another winter. The author uses a vocabulary of only 129 words for the text."

Dietz, David. All About The Universe; illus. with diagrams by John Polgreen and with photographs. Random House, 1965. $1.95. (5-7)
"The telescope, spectroscope, and radio telescope, the principal means by which the universe is surveyed, and the solar system, stars, nebulae, and galaxies are described. . .There are also chapters on the current theories of the origin and future of the universe. For its price, this book is extremely good value. It is ably written and well illustrated. It gives one a general view of the universe as modern astronomy is revealing it. The age group for which it is aimed ambitiously spans 10 to 15. Younger readers may find the book a bit advanced, but it will not let them down by giving 'kiddy' explanations of the wonders of the cosmos. Older readers will find the treatment sketchy, but by no means childish."

Fenton, Carroll Lane. Worlds in the Sky; illus. by the authors, Carroll and Mildred Fenton. Day, 1963. $3.29. (4-6)
"A factual account of the seasons, eclipses, the earth's rotation and related phenomena. Covers considerable territory dealing with the earth, the solar system, the stars, and the universe in general. The Fentons use a fine, clear style, with no wasted words, and cover this tremendous subject for the young very cleverly in a brief space. Their diagrams and drawings are splendid."

Freeman, Mae. Fun With Astronomy Random House, 1953. $1.95 (4-7)
"A practical introduction to the science of astronomy in which a child by means of simple experiments can understand the principles involved in day and night and seasonal changes; how to make a sundial; how to find distances from the earth to other heavenly bodies; how to chart the planets or model them to scale, and how to make a sun camera. Excellent photographs and diagrams In our opinion this book stirs the imagination and awakens the interest of the reader to follow up on astronomy. The young reader may, indeed, want to duplicate the experiments described in the book "

Freeman, Mae and Ira The Sun, The Moon and The Stars; illus. by René Martin. Random House, 1959. $1.95 (2-4)
"An introduction to astronomy which presents some basic facts about the earth, sun, moon, planets, and stars in . . . an easy-to-read, clearly printed text, and satisfactory drawings. Should stimulate the primary reader, as well as some in older grades. Experiments to show the pull of gravity and the rotation of the seasons are valuable in the classroom "

Gallant, Roy A. Exploring The Sun; illus by Lee J. Ames. Garden City Books, 1958. $2.[illegible] (5-7)
"This book tells you what the sun does for mankind. Without this 'rather ordinary' star there could be no life of any sort on our planet. It also tells you not only many amazing facts about the drama of its death billions and billions of years from now. No youngster (or grown-up, either) can fail to be fascinated by the large, clear, and attractively-colored illustrations. . .The reader will find in a few pages an extraordinary wealth of information."

Gallant, Roy A. Exploring The Universe; illus. by Lowell Hess. Garden City Books, 1956. $[illegible].95. (5-7)
"The beliefs of ancient civilizations, theories and discoveries of early astronomers, present day concepts and facts about the universe, and research methods are discussed in clear, interesting text and striking colored illustrations in an oversized book."

Haber, Heinz. Stars, Men and Atoms Golden Press, 1962. $3.99.
"An examination of what man now knows about the universe in comparison to what he first knew and of what there is still left to discover, with explanations of both atomic structure and Einstein's theory of the nature of the universe. Should appeal to older children and to adults alike."

Joseph, Joseph Maron. Point to The Stars; illus. with photographs and line drawings. McGraw, 1963. $3.95. (4-6)
"This book can be taken outdoors by the stargazer and used as a guide. By using the unique 'Face and Point' directions and the variety of star maps, young people can identify not only the constellations, individual stars and planets, but artificial satellites also. Folklore of the constellations is included "

Lauber, Patricia. All About The Planets; illus. by Arthur Renshaw. Random House, 1960. $1.95. (4-7)
"What astronomers have learned about the earth and its fellow planets, the origin of our solar system and the likelihood of life on other planets. There is an excellent discussion of the 'canals' on Mars and of the possibilities of life there; of new knowledge concerning the atmosphere and the temperature of Venus; of the discovery of Pluto and possible planets beyond it."

Ley, Willy. The Exploration of Mars; illus. by Chesley Bonestell. Viking, 1956. $5.95. (5-7)
"The first portion of this book gives a comprehensive account of existing knowledge of Mars, based on the writings and astronomical observations from the time of Johannes Kepler to the present. The authors, experts in the field of rockets and the theory of space travel, then outline a plan for an exploring trip to Mars, adhering strictly to known facts regarding the solar system. Reproductions of paintings by Chesley Bonestell add materially to the interest of the work and the appeal to all types of readers."

Mayall, Newton. Sky Observer's Guide; A Handbook for Amateur Astronomers; paintings and diagrams by John Polgreen. Golden Press, 1959. $3.95. (5-7)
"This is a guide for younger sky watchers telling how to recognize and find interesting features of stars and planets. With instructions for the use of binoculars and telescopes, and sections on astronomical terms, photography, etc. The book can be used best by those who are amateur astronomers of sufficient enthusiasm to get or build a small telescope."

Moore, Patrick. Telescopes and Observatories; illus. by Clifford Bayley and Susan Benson. Day, 1962. $2.50. (3-5)
"The author explains how lenses and telescopes work and describes many kinds of telescopes, ranging from the simple hand-held telescopes used by sailors to the huge, immensely powerful instruments used by astronomers--the scientists who study the stars. He also gives directions for making a simple telescope; and lastly, emphasizes the importance of observatories to the advancement of knowledge."

Moore, Patrick. The Picture History of Astronomy. Grossett, 1961. $5.95
"The author surveys the history of astronomy from prehistoric times to the present. After tracing the development of astronomy as a science through the contributions of individual astronomers, he describes earth's solar system, the stars, and galaxies, explains the techniques of modern telescopy, spectroscopy, and radio astronomy, discusses theories about the origin of the universe, and considers recent progress in the direct exploration of space by rocket probes, artificial satellites, and manned space craft."

Munch, Theodore W. What Is a Solar System; pictures by Berthold Tiedemann. Benefic Press, 1959. $1.80. (2-4)
"This is a presentation of the six types of bodies that comprise our solar system--sun, planets, moons, planetoids, comets, and meteors. Emphasis is placed upon the planet and their relationship to the sun

and each other. Their size, composition, weight, atmosphere, and orbits are clearly explained."

Page, Lou Williams. A Dipper Full of Stars: A Beginner's Guide to The Heavens. Follett, 1964. $3.50.
"Information on the stars and planets, the constellations, the Milky Way, meteors and comets, and the myths and legends about them which the ancients believed."

Polgreen, John. The Earth in Space; illus. by John and Cathleen Polgreen. Random House, 1963. $1.95. (2-5)
"During an imaginary trip, the planet Earth as seen from outer space is described in clear, simple language with clarifying illustrations and diagrams. The guided trip included visits to all planets, the moon, and other parts of the Milky Way. Explanations of meteors, satellites, galaxies, and forces are given showing the place and part Earth has in the solar system."

Ravielli, Anthony. The World is Round; illus. by Anthony Ravielli. Viking, 1963. $3.50. (2-5)
"An explanation of why the earth seems flat and of ways in which man has uncovered evidence that supports his belief that the earth is round. The history of the changing concepts of the earth's shape is briefly sketched in clear text and beautiful pictures in color. A handsome science picture book for the early elementary school ages."

Reed, W. Maxwell. Patterns in The Sky:The Story of The Constellations; illus. by D. F. Levett Bradley. Morrow, 1951. $4.00.
"Here are explanations and detailed star charts showing how to find the twenty-five most familiar constellations. There are interesting astronomical facts about each one and the mythological stories of their names. The book is written in. . .friendly, informal style."

Rey, H. A. Find The Constellations. Houghton, 1954. $3.95. (3-6)
"This book shows you how to recognize the stars and find the constellations. It is a book to be used indoors and outdoors, all the year round. It gives you views of the sky as if you were looking out at night through a huge observatory window. Using practical methods for star recognition. . .the author describes the constellations of the Northern Hemisphere, the stars of first magnitude and the planets. There are Quizzes, Time tables, a sky chart, a number of 'Sky views,' a bibliography, and an excellent index-glossary. Mr. Rey has the faculty of making stargazing sound as if it were the most exciting and worthwhile hobby imaginable. . .includes a discussion of space travel in relation to the stars. . .A 'must' for public and school libraries and a wonderful book for an individual or a family to own. In addition to detailed drawings of all the constellations this book contains 40 charts showing the sky, throught the year, not only for our mid-northern latitudes but as far north as Alaska and as far south as Australia and New Zealand. The latter part of the book is slightly more complicated, explaining eclipses, celestial mechanics, the phases of the moon, procession of the equinoxes, etc."

Schneider, Herman. You, Among the Stars; illus. by Symeon Shimin. Scott, 1951. $3.50. (2-5)
"Discussion of basic concepts of astronomy (up and down, night and day, rotation and revolution; etc.), and simple answers to the child's first questions--'Why is the sky blue?', 'Where does the sky end?', 'Why don't the stars light up empty space?'. Examples are those of everyday experience. Not at all complicated, it is for the youngster as soon as he or she becomes interested and curious about these wonders, and illustrations are really helpful."

Schneider, Leo. Space in Your Future; illus. by Gustav Schrotter. Harcourt, 1961. $3.75. (5-7)
"Informally and with the use of a number of experiments a science teacher describes the earth, the solar system, and the stars, explains the tools of the astronomer, and discusses space exploration and travel. Appendixes include a listing of eclipses, sources for star charts, and a list of planetariums in the U. S. Much of the information is available elsewhere, and some is already outdated by recent Russian and American space flights, but the clarity of style and attractiveness of format make this a useful addition to science collections."

Schloat, G. Warren. Andy's Wonderful Telescope. Scribner, 1958. $2.97. (4-7)
"A photo story in three parts. Part I tries to put the Solar System and the Universe into perspective for the early teen-ager; Part II tells the story of the telescope and the actual workings of a small one; Part III describes some of the objects as they are seen through such a four-inch reflecting telescope. The ingenious photographs are often dramatic and more convincing than words or even simple drawings could be. They have a three-dimensional quality and provide a direct matching with our experience that makes the point startingly clear. The book should be most useful to teachers who wish to get some of the astronomical facts of life across to their pupils. The clarifying experiments performed by Andy, the boy in the photographs, are easy to do and add interest and value to the book."

White, Anne Terry. All About The Stars; illus. by Marvin Bileck. Random House, 1954. $1.95. (4-7)
"The text explains the laws which control the universe and in particular, the relationship between the sun, earth and other planets. It also considers the possibility of future space travel and of new discoveries. Simply and beautifully told story of the heavens as seen and increasingly understood by our scientists as they improve telescopes and clarify thinking."

Wyler, Rose. The New Golden Book of Astronomy: An Introduction to The Wonders of Space; illus. by John Polgreen and George Solonevich. Golden Press, 1965. $3.99.
"The latest theories about the phenomena of the heavens are simply and clearly explained. The book describes gravity, seasons, tides, the beginnings of our solor system, how stellar distances are measured, the telescopes in use today. This large, attractive book effectively explains its subject, and offers ample material on the planets, nebulae, and space travel."

Zim, Herbert S. Comets; illus. by Gustav Schrotter. Morrow, 1957. $2.95. (4-6)
"All the known facts about comets are discussed and current speculations about them are considered. This is clear, concise and interesting and modern space-minded children will be fascinated by what he has to tell about the curious 'habits' of comets and some of the reasons people many years ago used to be afraid of them."

Zim, Herbert S. Shooting Stars; illus. by Gustav Schrotter. Morrow, 1958. $2.95. (3-6)
"An explanation of meteors and meteorites: how they enter the earth's atmosphere, how they differ from each other, how men observe them and what is known and not yet known about shooting stars. Some of the famous meteor showers that have occurred are described, as are the astronomical phenomena that are demonstrably related to meteors. It will fascinate the youngsters for whom it is meant. . .The illustrations are profuse, clear, and excellently done."

Zim, Herbert S. Stars: A Guide to The Constellations, Sun, Moon, Planets and Other Features of The Heavens; illus. by James Gordon Irving. Golden Press, 1956. $2.99.
"A gem of a field guide for the novice, this little book tells how to scan the heavens, where to look and when. Authoritative, carefully organized, here is a wealth of data for quick reference. Divided into three sections: stars, constellations, and solar system. Every page is beautifully illustrated. . .Binding good for the size. Recommended. Contains detailed charts of northern, southern, circumpolar and seasonal skies and individual constellation pictures."

Zim, Herbert S. The Sun; illus. by Larry Kettelkamp. Morrow, 1953. $2.95. (4-6)
"This volume gives data on the sun, its weight, size, etc., sunspots and how they affect earth, plant growth, and heating. . .and a clear statement of the atomic energy principle. A fascinating and solidly factual, though brief, study of the sun, easily read by younger children but of interest to a wider audience. Suggestions, with diagrams, for simple experiments give everyday significance to the subject. The sketches on each page are clear and well labeled."

Zim, Herbert S. The Universe; illus. by Gustav Schrotter. Morrow, 1961. $2.95. (4-6)
"The author explores man's changing ideas and growing knowledge of the nature of the universe from the earliest wonderings and beliefs to the present-day theory of some scientists that the universe may be expanding. The clear and accurate text and the graphic illustrations and diagrams give a surprising amount of information and take the child through the expanding universe from Ptolemy to Palomar."

FILMS

These films are available from the Central Audio-Visual Department. Contact your building A-V Coordinator to arrange for the use of these films.

All films should be previewed to determine suitability for use with your particular class.

Asteroids, Comets, and Meteorites 10 min. Col. Int.

Asteroids, Comets, and Meteorites are called the minor members of the solar system. This film shows how astronomers have learned about these objects traveling around the sun; what each group looks like; and the place of each in the solar system. The film illustrates the newest objects in the solar system: man-made, or artificial satellites.

Earth Satellites: Exploration of Outer Space 17 min. Col. Int.

Here is a film that explains how man-made satellites stay aloft, describes what we learn from satellites, and suggests some of the things that we may look forward to in the future. The concepts clearly expressed for pupils in the middle grades.

Earth in Motion, The 12 min. Col. Int.

The film describes how and why the earth travels around the sun. The student discovers the meaning of such terms as rotation, revolve, sphere, force, orbit, curvature, circumference, axis, gravity, stabilize, hemisphere, equator, galaxy, inertia, Milky Way, planet, and Solar System.

Exploring The Night Sky 10 min. B&W Int.

The story of constellations and how they got their names, nebulae and other star phenomena, the setting and rising of stars and how the stars helped in the making of the calendar, is told by means of animation and special cinema techniques.

How We Study The Sun 14½ min. Col. Int.

From the sun's light we can learn much about the sun. Sun gives off many forms of energy other than light. Today balloons, rockets, and orbiting astronomical observations are carrying instruments above the atmosphere to help us learn more about the sun.

How Man Travels Through Space   12 min.   Col.   Int.

For the first time in history, space travel has become a possibility for man. Film discusses space terms such as gravity, radiation, weightless, "G", zero gravity, thrust, space vehicle, rockets, booster, combustion chamber, escape velocity, life support system, lift off, meteors, and multi-stage rockets.

How We Explore Space   22 min.   Col.   Gr. 6

An introduction to the instruments the astronomers use and to the methods by which they obtain information about the objects in space. The telescope, camera, spectroscope, and photocell are demonstrated and explained. Over time-lapse telescopic motion pictures of the moon, Mars, Jupiter, Saturn, and the sun, we learn many of the facts astronomers have discovered in their exploration of space.

How We Know The Earth Moves   10 min.   Col.   Int

We have been told that the earth spins on its axis and that it travels around the sun. But how do we know these statements are true? This film demonstrates and explains the Foucault Pendulum by which the earth's rotation was first proved. The audience participates in an experiment that illustrates star shift, the method astronomers use to determine the earth's solar orbit.

Instruments of Astronomy   12 min.   Col.   Int.

The instruments man has used to look at the night sky--from an armillary sphere, quadrant and sextant to modern observatory telescopes--are the subjects of this introduction to astronomy.

Man in Space   35 min.   Col.   Int.

Walt Disney introduces topic of flight through space. History of rocketry and its future prospects presented by Dr. Heinz Haber. Animation is used to show problems man faces in region beyond earth's atmosphere, adjustments he must make, advances in space medicine. Dr. Wernher von Braun describes theoretical space ship flight with human passengers.

Milky Way and Beyond, The   13½ min.   Col.   Gr. 3 & 4

Presents the relationship of our solar system to the galaxy of which it is a part. Telescopic color photography and effective animation illustrate what stars are and how they are formed. An expanding picture of the universe is gained as other galaxies and their movements are portrayed.

Moon, The 12 min. Col. Int.

Uses animation to describe the structure, size, physical features, and gravitational field of the moon. Illustrates the apparent phases of the moon and discusses the effect of the moon on the tides of the earth.

Moon, The: Adventure in Space 15 min. Col. Int.

Presents an appraisal of the current U. S. programs for moon exploration. Basic moon concepts and leading scientific theories are covered. The need for unmanned and manned spacecrafts is explored.

Outer Space 12 min. Col. Int.

The film discusses the sky as it is seen through a telescope. It explains procedures for determining sizes of stars and their distances from us (light years) as well as from each other. Discussion of and photography of constellations, galaxies, comets and other cosmic formations.

Planets, The 11 min. Col. Int.

Movements of planets around the sun are shown by an orrery and the comparative sizes of planets, their distances from the sun, revolutions on their axes, and satellite systems are discussed. A planetarium is seen in use.

Planets Around Our Sun $13\frac{1}{2}$ min. Col. Gr. 3 & 4

This film affords a comprehensive and expanding view of our neighbors in space by means of the most modern astronomical instruments. We learn about gravity and centrifugal force and become better acquainted with the nine known planets in orbit around the sun; with natural satellites and with asteroids and comets.

Rockets and How They Work 16 min. Col. Int.

This film presents the basic principles of rocket flight in terms that can be understood by pupils in the middle grades of science. In addition, the material is interesting and the concepts are presented in such a way that the film will be useful at higher levels, including junior high and senior high as well as adults.

Satellites: Stepping Stones to Space 18 min. Col. Int.

Through animation, models, and live action photography the film shows the construction and instruments of Explorer I and explains how it was put in orbit. Demonstrates why satellites stay up, what determines their lifetimes, and how they record information.

Science of Orbiting 28 min. B&W Int.

Mr. Wizard takes a spin in a tumble tub by releasing CO_2 from a fire extinguisher, then launches an oil can into orbit. Film explains how the forces of gravity and inertia must be overcome and how a capsule falls toward center of earth. A balloon containing lead shot, a sandbag and scale help illustrate gravity and "weightlessness." The capsule's heat shield, re-entry effects communication, and how a capsule is slowed down by retro-rocket is demonstrated.

Space 10 min. Col. Int.

Demonstrates the most effective ways of representing space; size difference, vanishing points, color overlapping and exaggeration.

Stars, The 12 min. Col. Int.

Relative fixed positions and apparent circular movements of stars in the sky are explained; constellations identified; our sun and solar system are depicted; and galaxies and nebulae are illustrated and discussed. The film also points out the relation of astronomy to distant space travel.

Sun and How It Affects Us, The 11 min. B&W Int.

A comprehensive study of the sun is presented, including the sun's size, distance from the earth, physical nature, and its effect on life, weather, and tides on earth. A basic understanding of the probable origin and effects of the corona, prominences, flares, and sunspots is provided through telescopic motion pictures.

Sun and The Solar System, The 12 min. Col. Int.

As we review the planets beginning with Mercury, closest to the sun, we find they vary in size, in their number of moons, in their speed of rotation around the sun and in their atmosphere. Film also shows the planets Jupiter, Saturn, Pluto, Mars, Venus and Uranus.

Trip to The Moon 16 min. Col. Int.

An imaginary rocket takes off to the moon and explores its surface. During the trip we learn many facts about conditions met in navigation to the moon. Once above the moon surface, the film shows in detail the craters, valleys and mountains that can be seen from the earth.

What Is an Eclipse? 11 min. Col. Int.

Using animation and three-dimensional models, the film illustrates how the motion of the moon around the earth causes both solar and lunar eclipses. An eclipse of the sun occurs when the moon passes between the earth and the sun; an eclipse of the moon occurs when the moon passes into the shadow of the earth. But since the moon circles the earth once each month, why don't we have both a lunar and solar eclipse each month? The film explains why. Actual time-lapse telescopic motion pictures of both a lunar and solar eclipse are shown.

What Makes Day and Night 8 min. B&W Int.

Demonstrates that the alternation of day and night is due to the rotation of the earth and not to the apparent movement of the sun around the earth. Two children and their father discuss the cause of day and night.

What Is Space? 11 min. Col. Gr. 5 - 6

This film shows there is much space on earth and that there is more space around the earth. Explains space is not empty and how vast distance in outer space is measured in light years. Scientists believe that "solid materials" are mostly space.

Why The Sky Is Blue 13 min. Col. Int.

The phenomenon of color is explored, and basic concepts of light are illustrated in terms interesting to children and adults alike.

What Do We See in The Sky? 11 min. Col. Prim.

Freddie's curiosity about things he sees in the sky lead him to learn about the sun, moon, planets, stars and constellations--their relative sizes and distance from the earth, their light, and something of their composition.