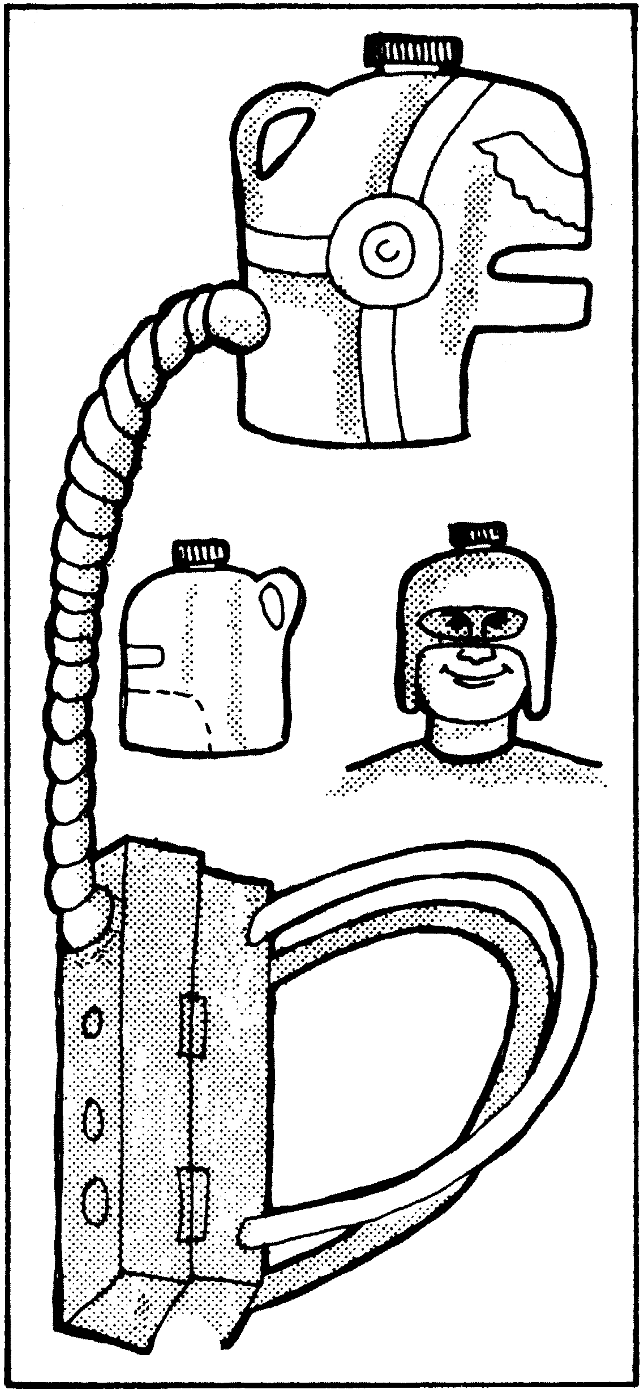
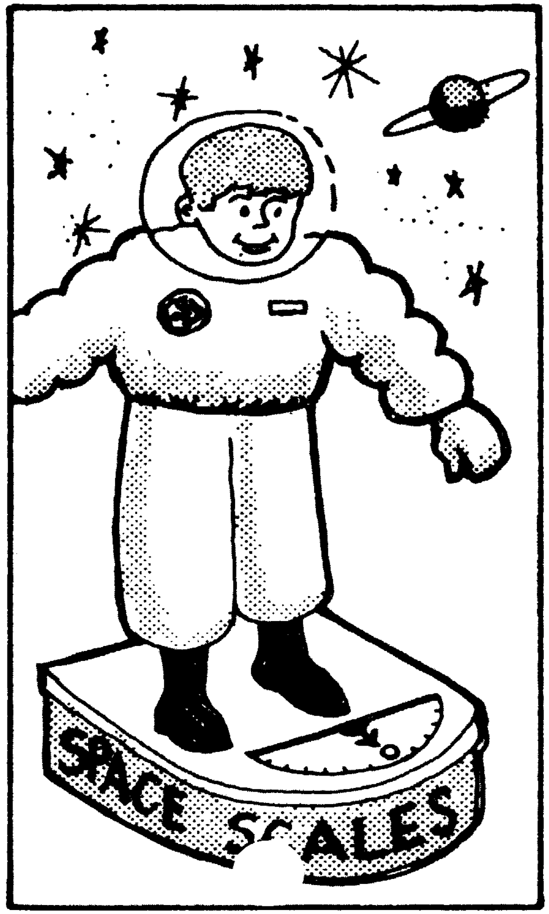


DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION



AVIATION
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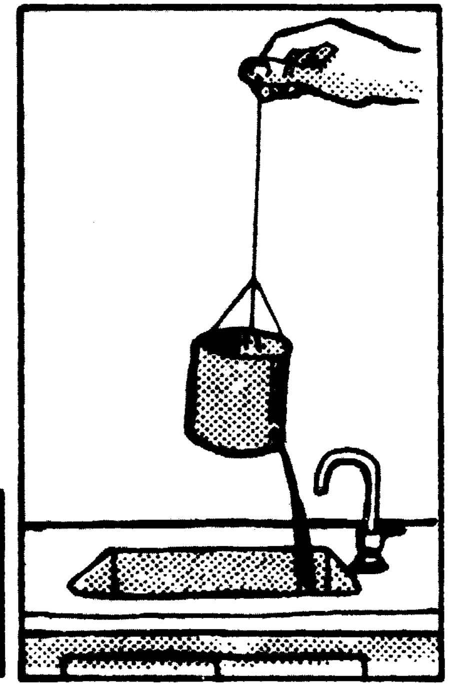
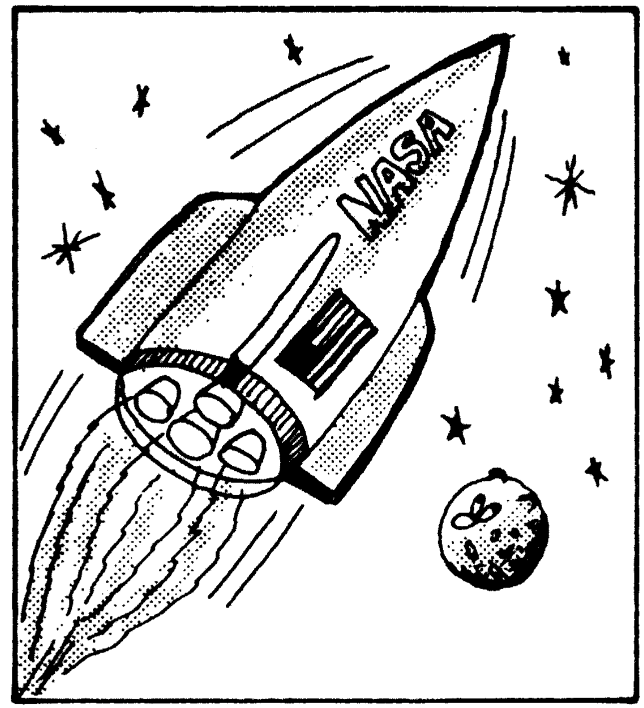




TEACHER'S INFORMATION

Demonstration Aids for Aviation Education-Volume II is a series of simple, concrete revealing experiments developed by the Civil Air Patrol Center for Aerospace Education Development for the Federal Aviation Administration specifically for upper elementary grades. These activities can be adapted to meet the needs of varied teaching situations and different grade levels.

These materials are primarily designed as pupil directed experiences. In some instances the teacher may want to further extend the investigations. This series is intended to be a springboard for your own ideas to demonstrate concepts of the Air Age to your students. Young children can learn scientific principles through simple learning activities; older students can benefit from a review using the same activities.

The purpose of this series is to illustrate certain principles related to various concepts of aviation and space. More important, it is an opportunity for you to directly involve students in investigations and in making discoveries on their own.

You needn't be an "expert" in science to use this material. In fact, you shouldn't be expected to have all the correct answers to the questions presented in the material. Moreover, many of the activities are designed to include interdisciplinary skills and need not be used in sequence.

Each packet in the series forms a coherent program of instruction on a single topic: Nonpowered Flight, Aerospace and the Environment, Space Exploration and Communications. Most of the tasks are introduced as a question. In order to answer the question, the students may want to first predict the solution. Then have them follow the activity instructions to arrive at an answer. This kind of student involvement may lead to other related questions generated by the teacher, other students, or suggested on the cards themselves.

Most of the activities utilize materials readily available from any given community and can be completed in the classroom. Others may require that you borrow some equipment from your science resource center or from a junior or senior high school in your district.

Please let us know your reactions to the materials and feel free to ask for more information related to aviation or space. We wish you success and many enjoyable experiences as you use these packets.

Written by Ms Debbie Williams and Ms Carol Hickson
Editorial Assistance by Mrs. Patricia Smithson
Illustrated by M r. Harley A. Samford

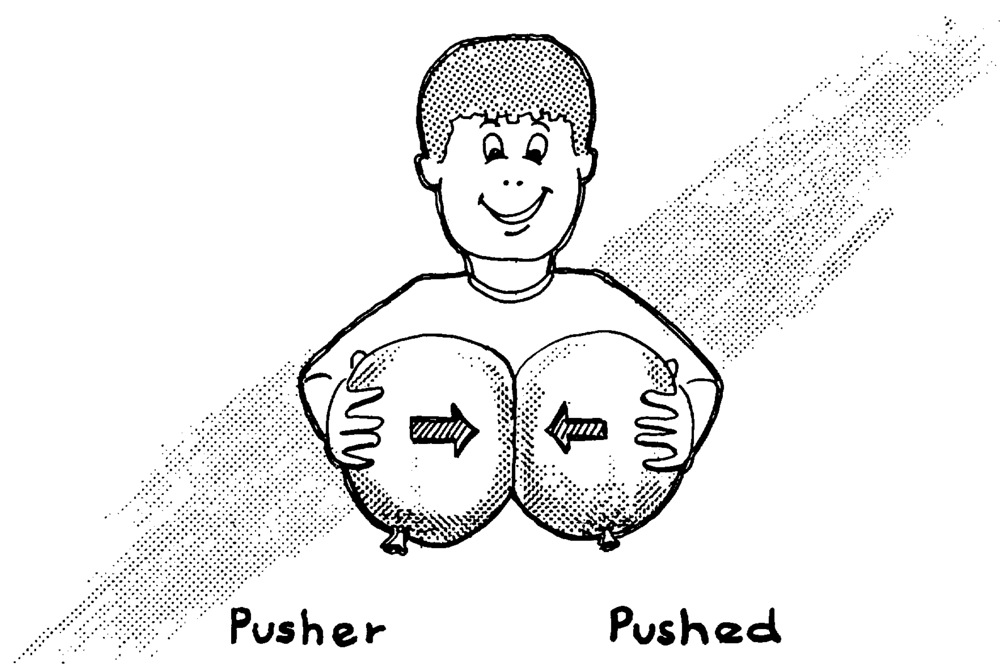
NL-1

NEWTON, THE FATHER OF EQUALITY OF FORCES

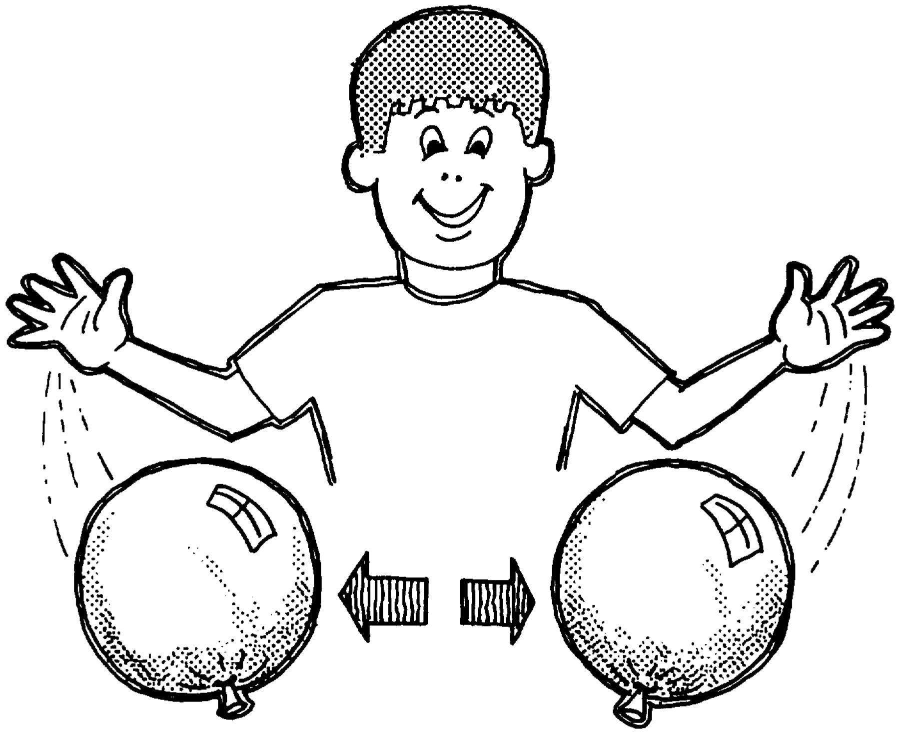
About 250 years ago Sir Isaac Newton discovered that "for every action there is an equal and opposite reaction." Test his law to see what happens.

MATERIALS:
2 balloons
inflated and tied

Squeeze the two balloons together, pushing with only one of them. The "pusher" is compressed by the force of the push. The " pushed" is also compressed from pushing back with equal force. Can someone else tell which is the "pusher" and which is "pushed"?



To prove further that they are pushing on each other equally, let go all at once. The balloons spring back into shape and push each other apart.



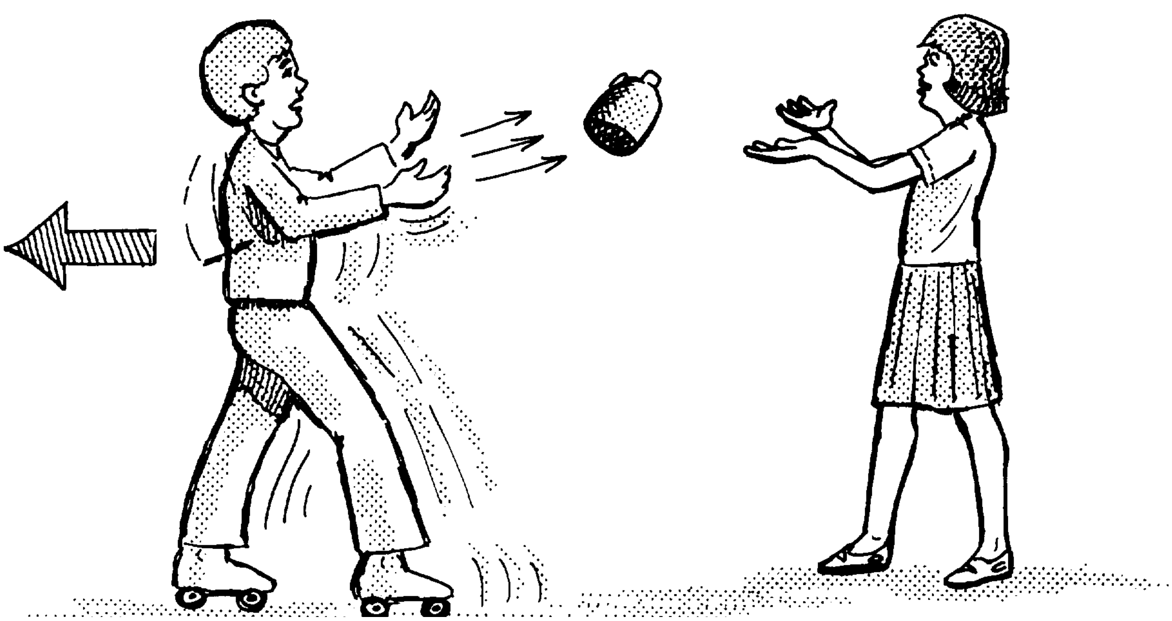
NEWTON'S LAW-EQUALITY OF FORCES

NL-2

You have seen how equal force applied to the 2 balloons resulted in an equal opposing force. Now let's give Newton's law "for every action there is an equal and opposite reaction" another test.

MATERIALS:
Roller skates
Plastic jug of water or sand

Wearing roller skates, feet parallel, throw a plastic jug of water or sand to a friend 10 feet away. You push forward, you roll backward . . . Newton's law at work again.



NEWTON IS RIGHT AGAIN!

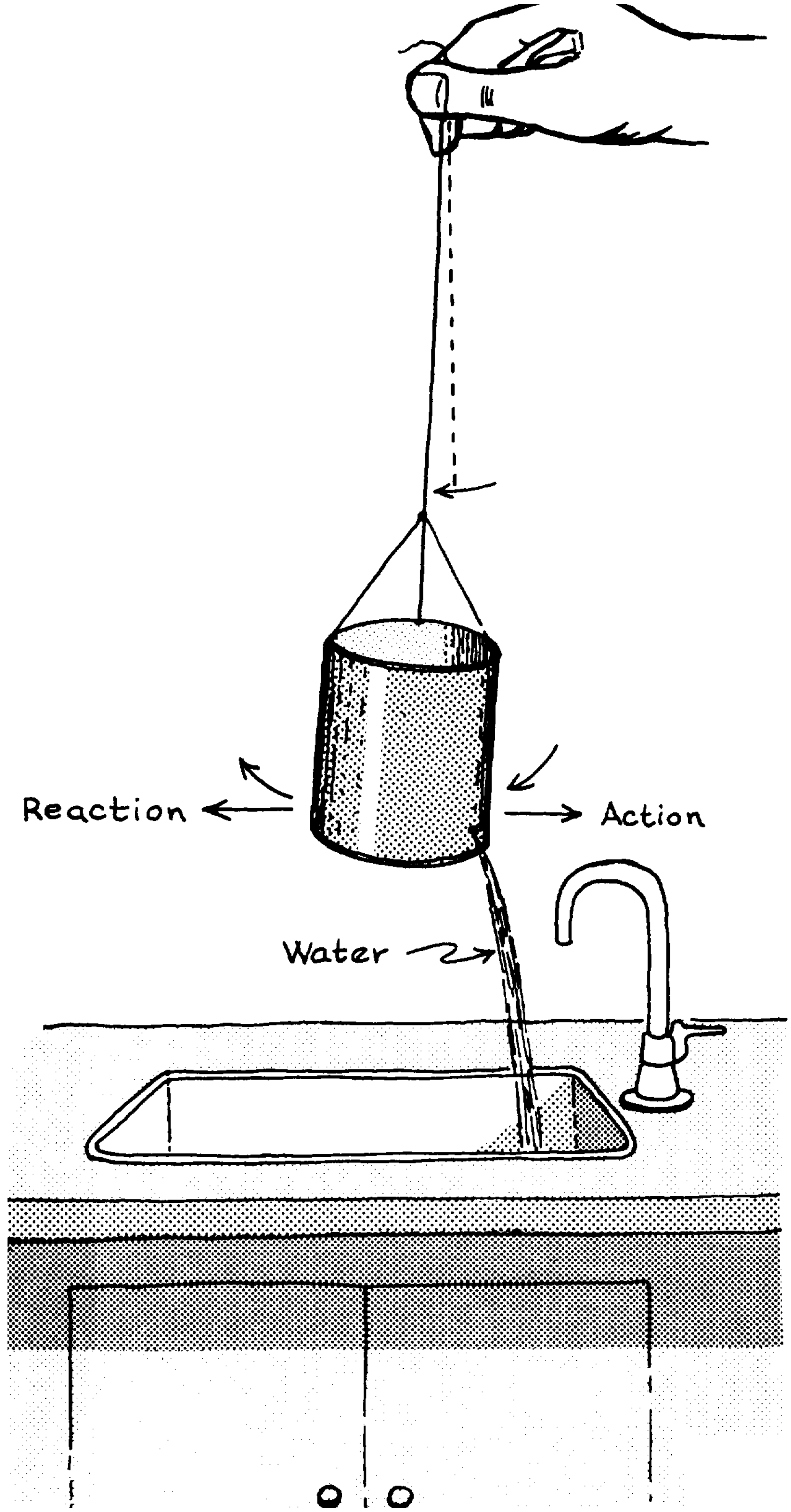
NL-3

Here is another way you can test Newton’s Third Law of Motion.

MATERIALS:

- Tin Can
- String
- Nail
- Water
- Sink

Punch a hole in the side of the can near the bottom. Suspend the can from a string and hold it over a sink. Pour water into the can. As the water rushes out the hole at the bottom of the can, the can moves in the opposite direction.

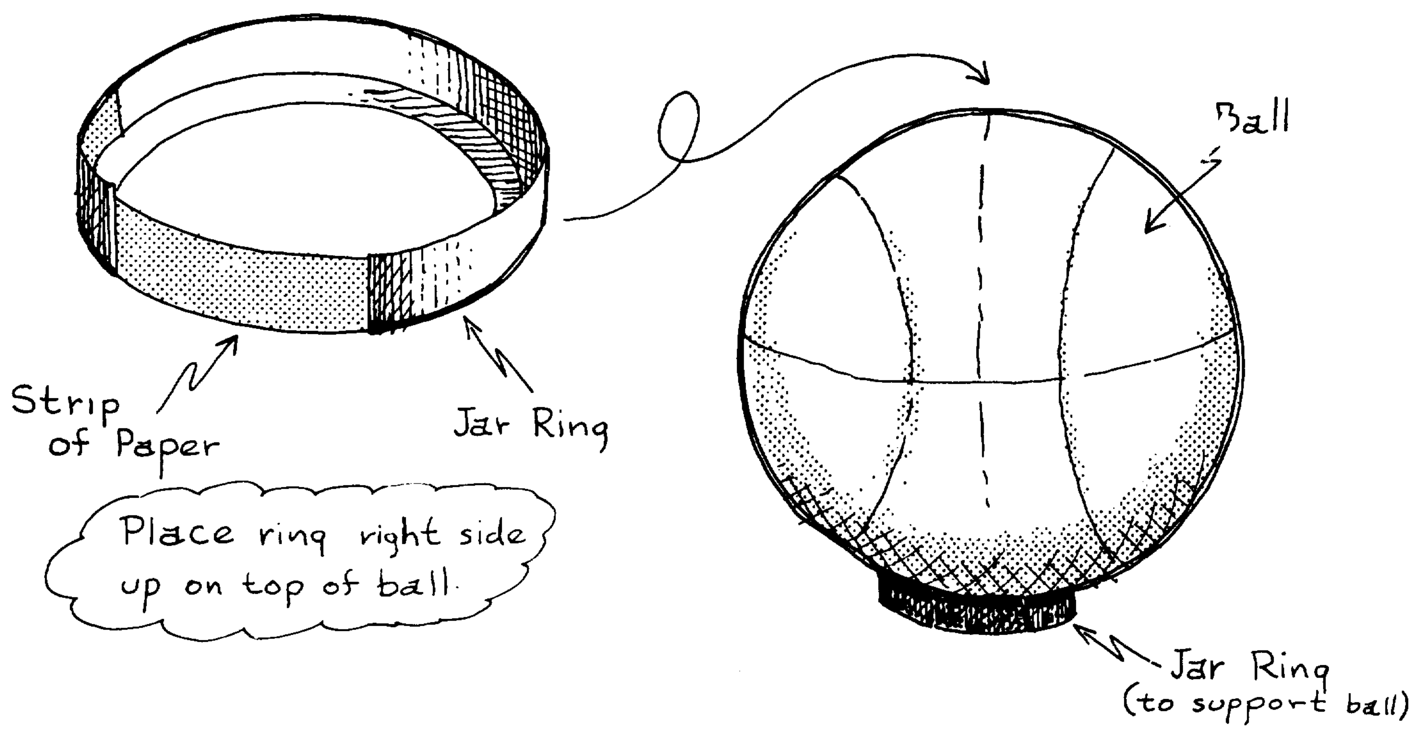

Reaction
Action
Water

HAS NEWTON LOST HIS MARBLES?

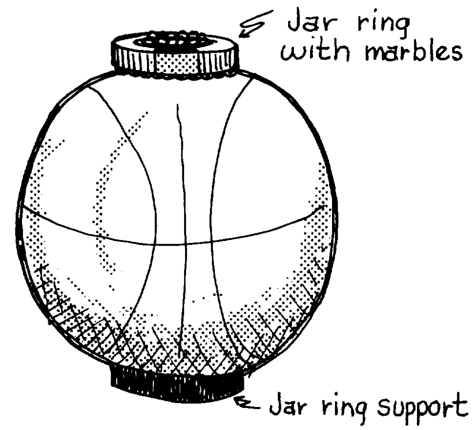
NL-4

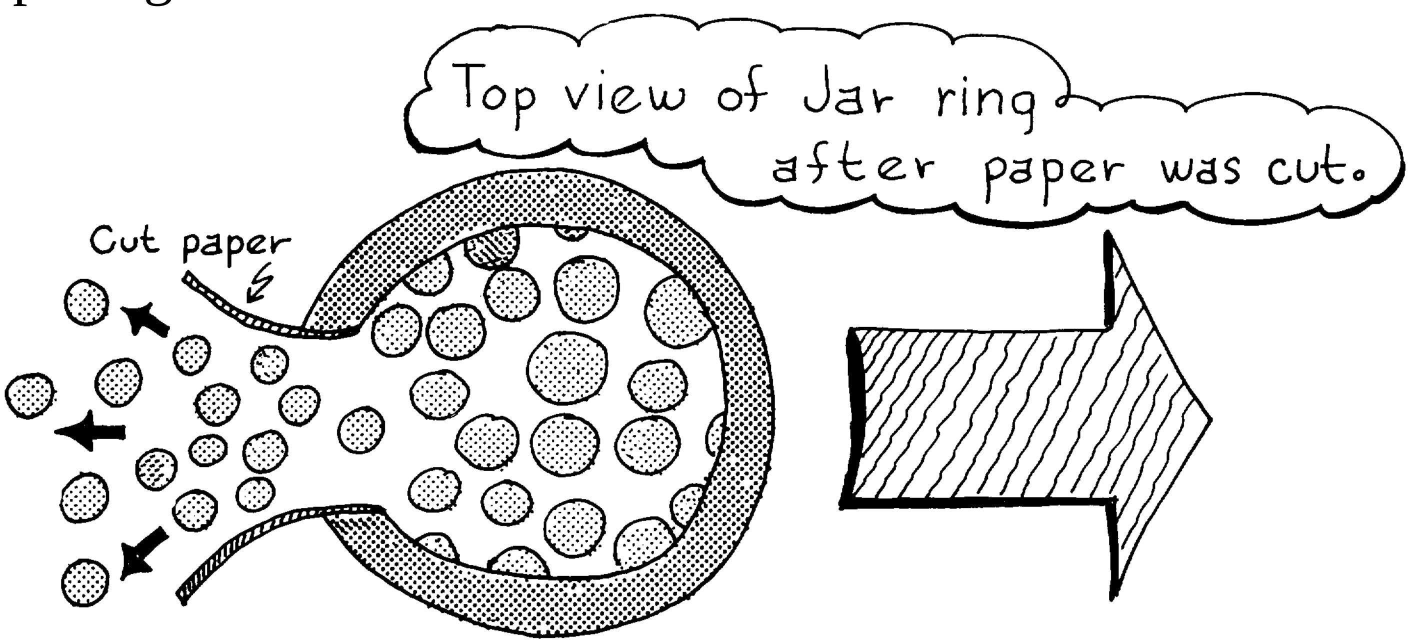
MATERIALS:
Large ball
Strip of paper
2 Mason jar rings
Marbles
Tin snips
Ring to support ball

Cut off about 1/3 of the rim of the mason jar ring. Replace it with a strip of paper. Secure the ball on a large ring to keep it from moving.



Place a ring on top and fill it with marbles. The marbles on the outside should fit under the edge of the lid so that the lid doesn't touch the ball. The ring does not roll because gravity is pulling each of the marbles down its own side of the ball, so the ring stays balanced. Carefully cut the paper. The marbles near the open end roll out reducing the force on that side. The ring then rolls away in the direction opposite the opening.

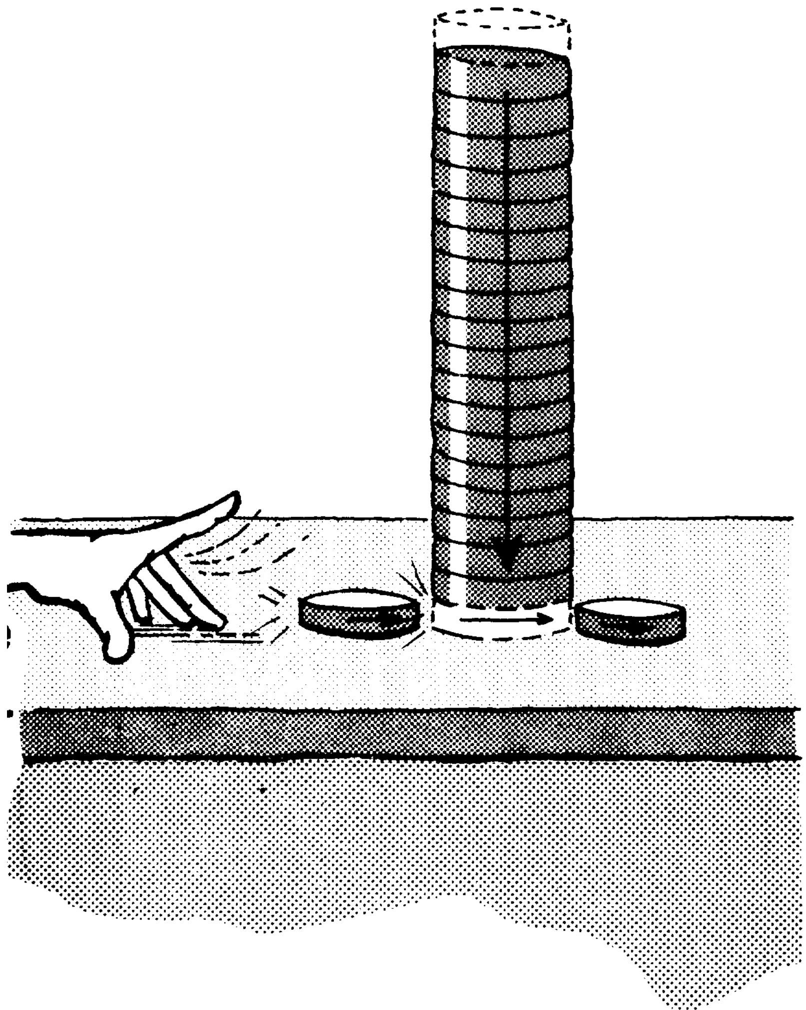




WHAT IS INERTIA? NL-6

Another of Newton’s laws says that an object at rest will remain at rest until acted upon by an outside force; and an object in motion will remain in motion, in a straight line at a steady speed until acted upon by an outside force. This is what he called inertia.

MATERIALS:
Stack of checkers or quarters



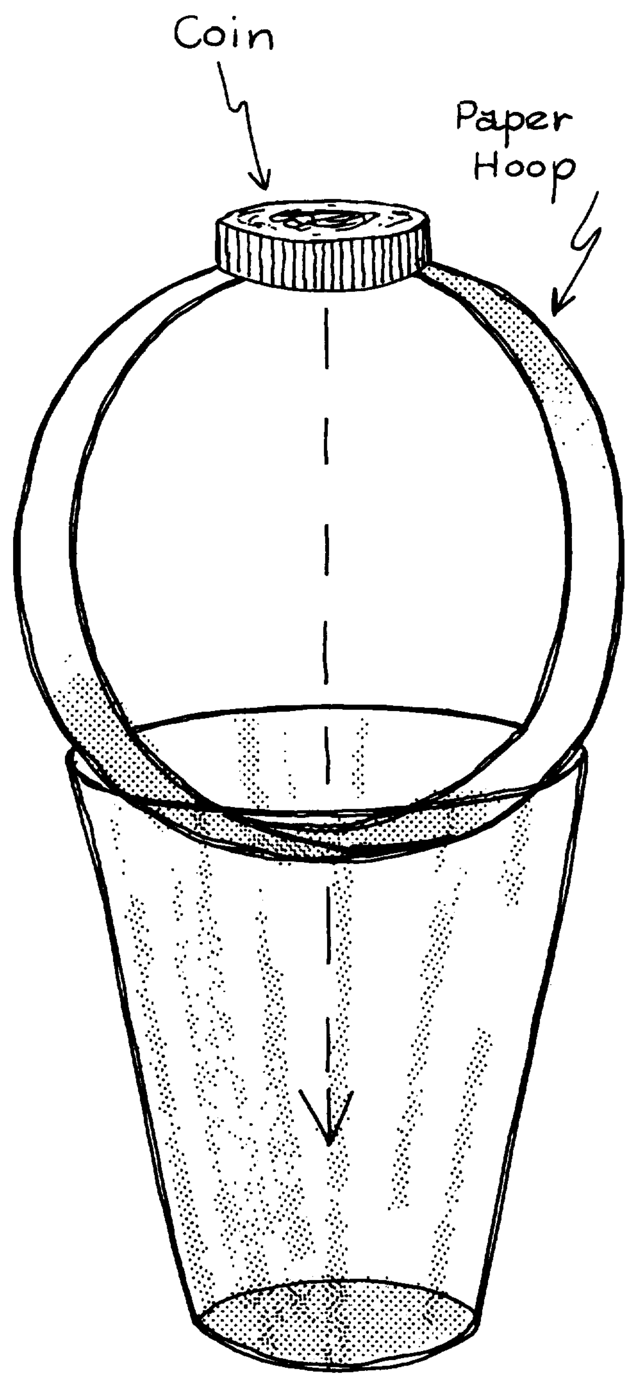
Stack the checkers. Shoot one so it hits the bottom checker. When you flip the checker, you give it inertia. When it hits the bottom checker its inertia is transferred and the bottom checker moves with almost the same speed and inertia. The other checkers fall down because of the force of gravity.

IS THE HAND REALLY QUICKER THAN[1] THE EYE?

NL-6

Put inertia to the test.

MATERIALS:
- Glass
- Paper hoop
- Coin



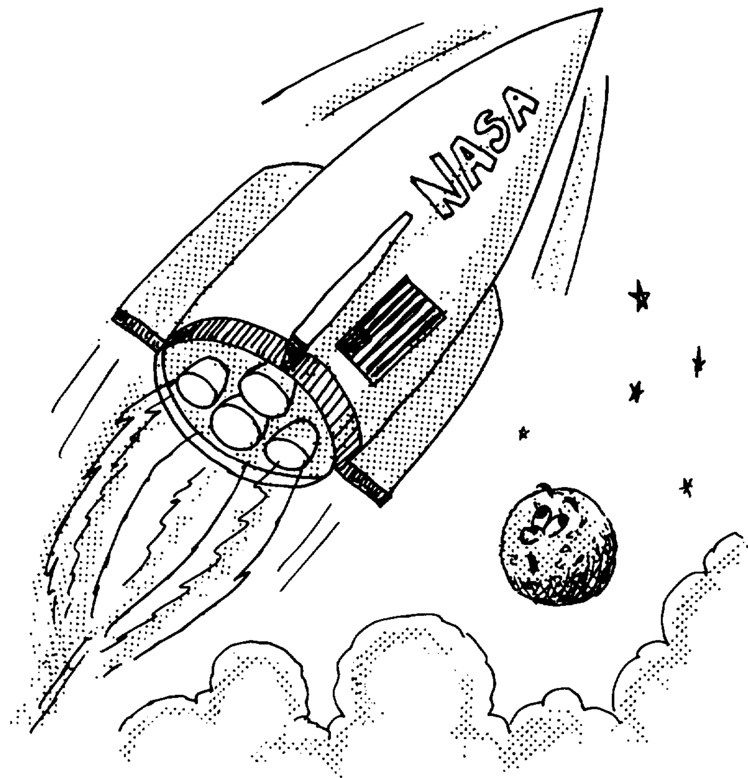
Place the coin on top of the paper hoop. Quickly pull the hoop away from the glass. The coin tends to remain at rest in mid air due to inertia. Then gravity takes over and causes the coin to fall into the cup.

WHY ARE ROCKETS SHAPED THE WAY THEY ARE?

R-1

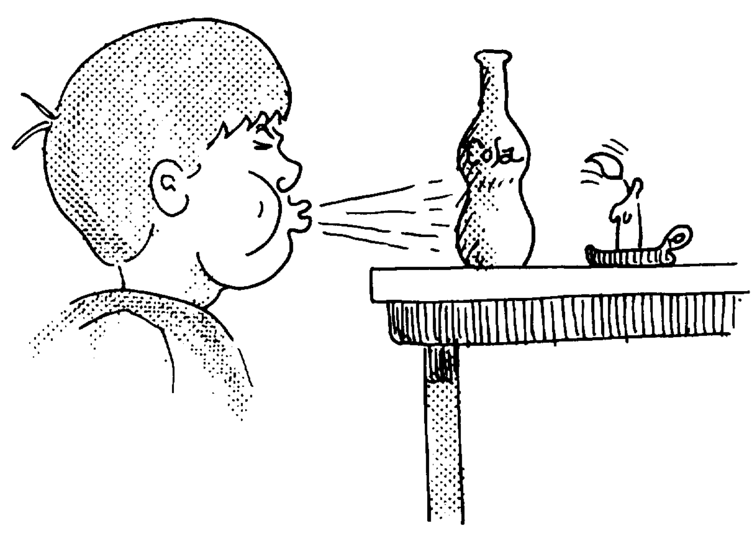
(This activity should be done only with supervision of the teacher or other designated adult.)

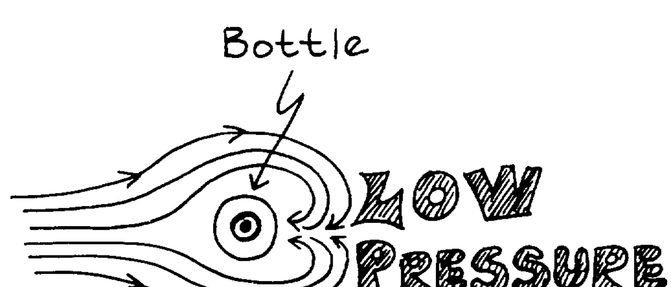
Rockets are streamlined to allow them to move through the air easily. Streamlining also cuts down on the amount of heat produced on the skin of the rocket as its speed increases.



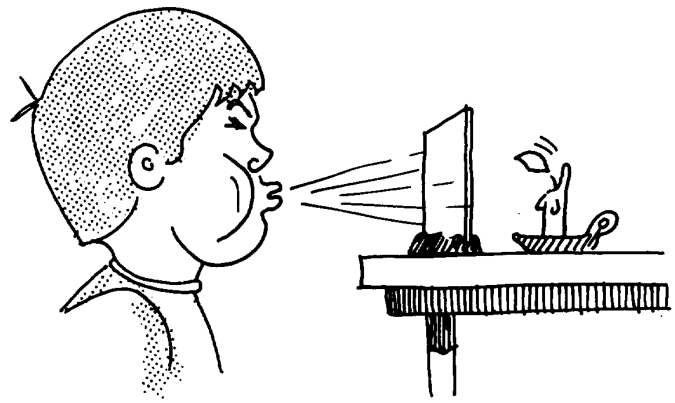
MATERIALS:
Round bottle, stiff paper, modeling clay, 3 inch candle, matches.

Place the bottle on a table. Place the lighted candle one inch behind the bottle. Blow on the front of the bottle. The flame moves toward the bottle.



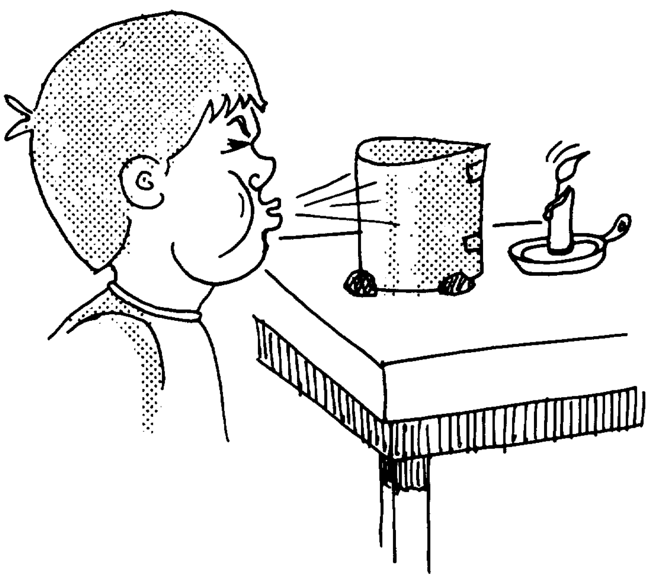


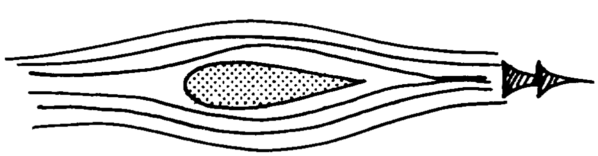
Cut the cardboard as wide as the bottle and half as high. Hold it in place on the table with modeling clay. Put the lighted candle behind the card and blow on the front of the card.



The flame moves toward the card.

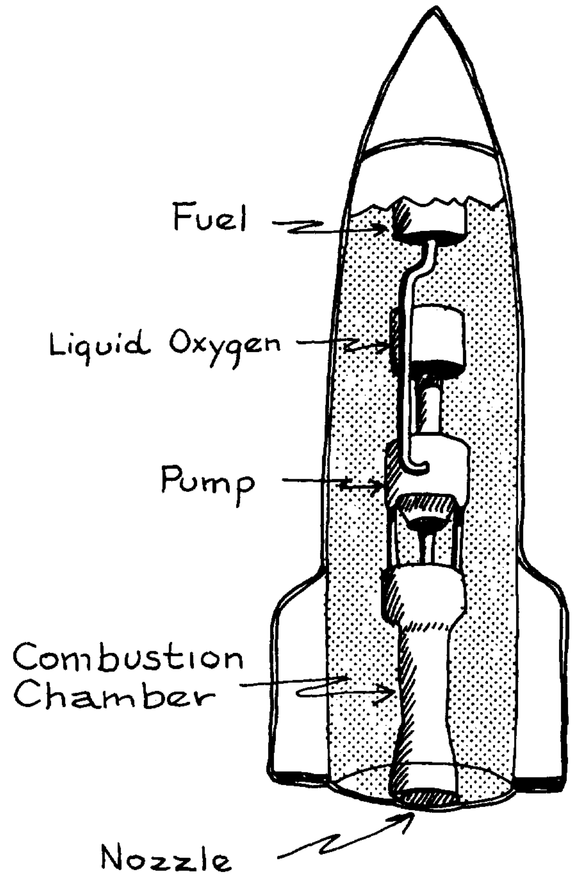
Now let's streamline! Wrap the stiff paper around the bottle. Cut it longer than the bottle is round. Tape the ends together so it looks like a teardrop. Place the candle behind the taped end and blow on the rounded end.





In which direction does the flame move? Why?

HOW DO ROCKETS WORK?

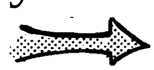
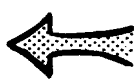


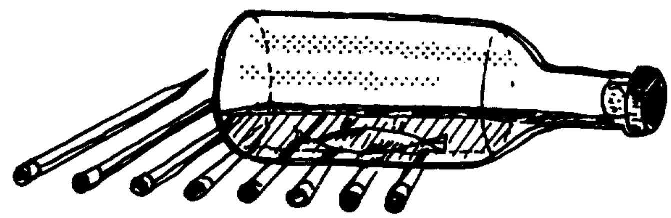
Rockets work like jets, but they do not need air. Therefore rockets work in outer space where jets cannot. Rockets carry their own supply of oxygen in the form of solid or liquid fuel. In a liquid fuel rocket, tanks of liquid fuel and liquid oxygen are pumped into the combustion chamber and ignited. This causes the liquids to expand, become gas, and build pressure rapidly. As the hot gases escape through the nozzle, the rocket shoots ahead.

MATERIALS:

- Bottle and cork
- Baking soda
- Tissue paper
- Vinegar
- Vaseline
- 6 (or more) round pencils

Proceed outdoors!

Lubricate the bottle top and cork with Vaseline. Fill bottle halfway with a mixture of 50% water and 50% vinegar (fuel). Put two teaspoons of baking soda (oxidizer) in tissue and twist the ends.  .Slip the baking soda into the bottle and put the cork in place. Place the bottle on its side on the pencils. When the baking soda mixes with the vinegar, a chemical reaction takes place releasing a large quantity of rapidly moving expanding gases. Then . . . The cork etc. - shoot  forward, the bottle rolls in the  opposite direction.



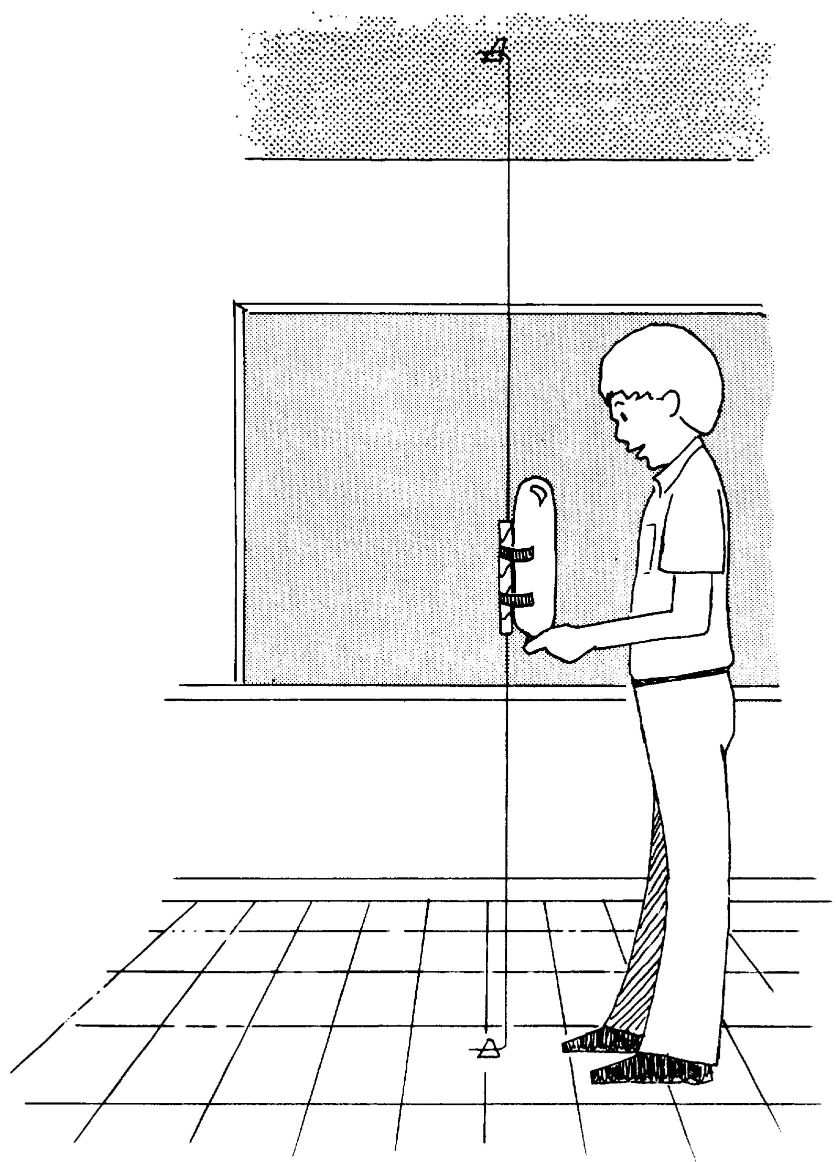
WHY DO ROCKETS FLY?

R-3

The amount of push that a rocket has is called thrust. The push of a balloon can be measured when the balloon is traveling on a string from floor to ceiling. Nuts, bolts, or washers can be used to measure the push of the balloon.

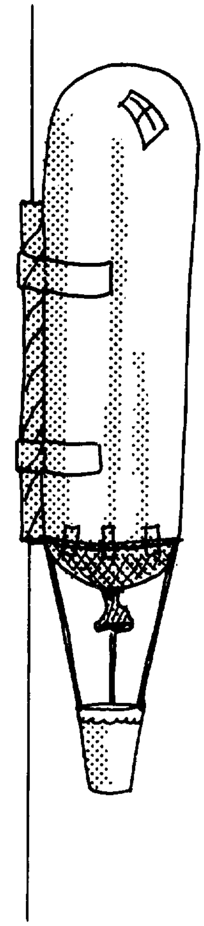
MATERIALS:

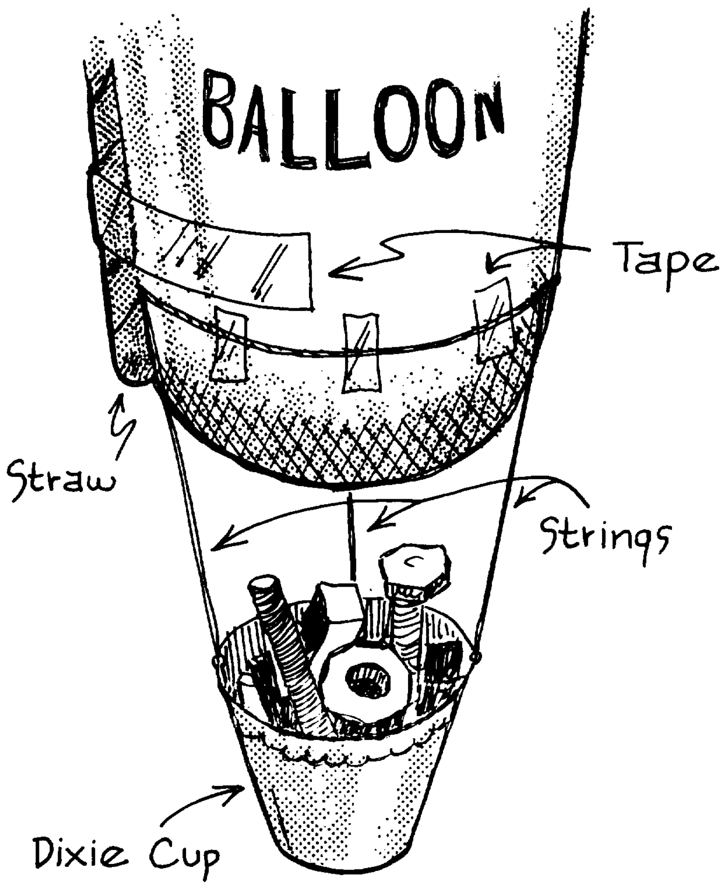
Balloon	Dixie cup
Straw	Nuts, bolts
String	Tape



Experiment 1: Thread a piece of string through a straw. Attach the ends of the string to the ceiling and the floor. Tape an inflated balloon to the straw. Release the neck of the balloon. How fast do the balloon and straw travel up the string?

Experiment 2:
Attach 3 strings to a Dixie cup. Tape the strings to the inflated balloon so that the cup is suspended like a gondola beneath it. Release the neck of the balloon. How fast did the balloon, cup and straw travel up the string?





Experiment 3:
Add some weights (nuts, bolts) to the cup and repeat the experiment. How fast did the balloon, cup and straw travel up the string?

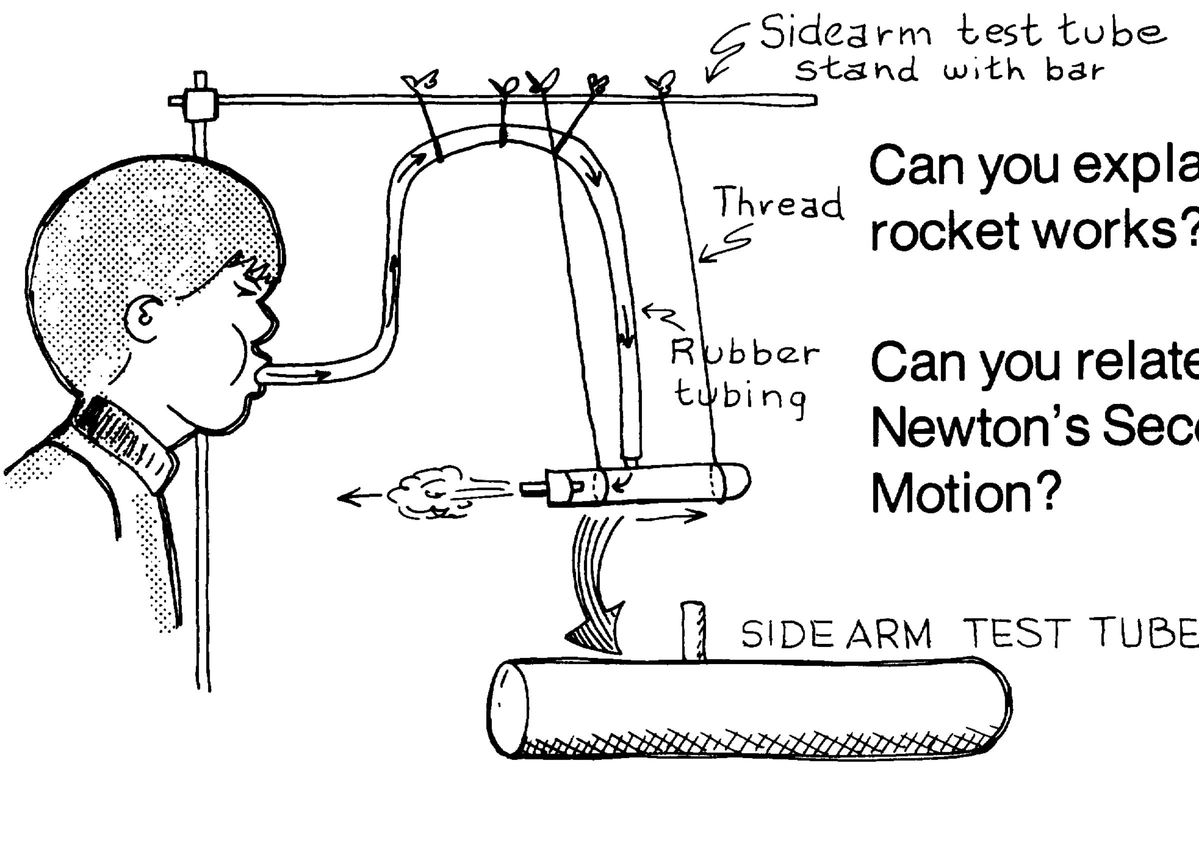
How much weight can the balloon lift?

TEST TUBE TAKEOFF!

The working model of a rocket shown here is most easily assembled if you have access to chemistry lab supplies. It can also be constructed from other readily available materials if you use your imagination.

MATERIALS:

A sidearm test tube stand with bar
A long piece of rubber tubing
A cork or stopper with glass tube in it
A sidearm test tube—Thread

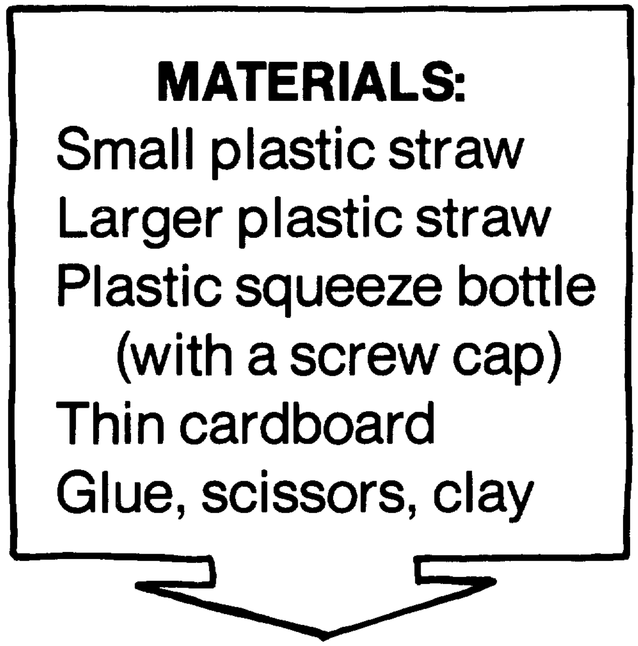


Can you explain how this rocket works?

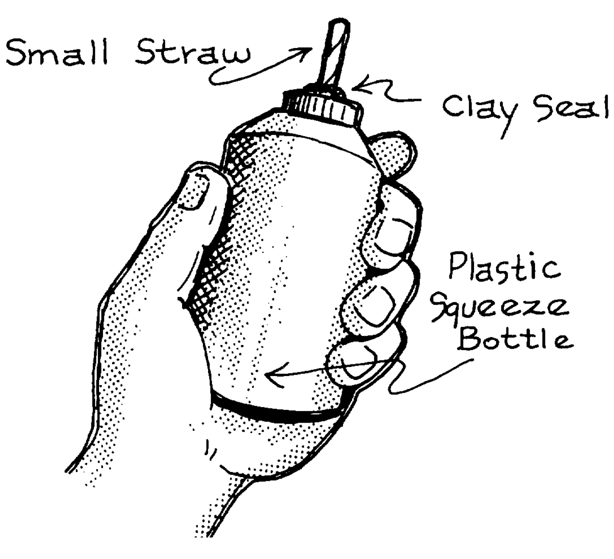
Can you relate this to Newton's Second Law of Motion?

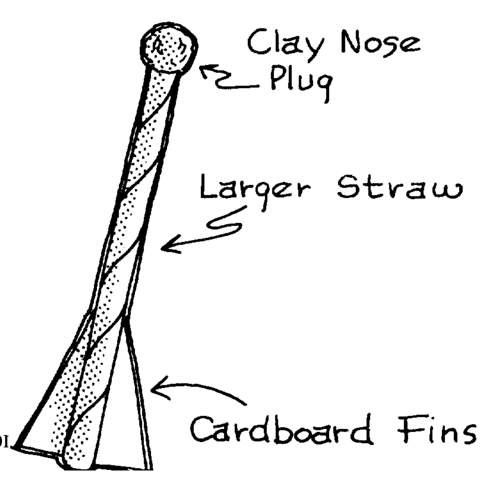
POP GOES THE ROCKET!

R-5



Make a hole in the bottle cap just wide enough to slide the small straw through. Leave about 4 inches sticking out of the cap. Seal with clay. Cut the larger straw to about 4 inches in length. Seal one end with a clay "nose cone." Use the cardboard to cut fins for your straw rocket. Glue them to the unplugged end.





Slide the straw rocket" over the smaller straw "launcher." Give the plastic bottle a quick, strong squeeze.

What happens? Why?

Can you compare this to suddenly letting go of an air filled balloon? Or, to pulling the trigger on a BB air rifle? What is meant by compressed air? Can you think of some industrial uses of compressed air?

THE FORCE!

The path of a speeding spaceship can be changed by the gravitational force of a planet. The gravitational pull of the planet can also cause the spaceship to speed up. You can make a working model to see how this happens.

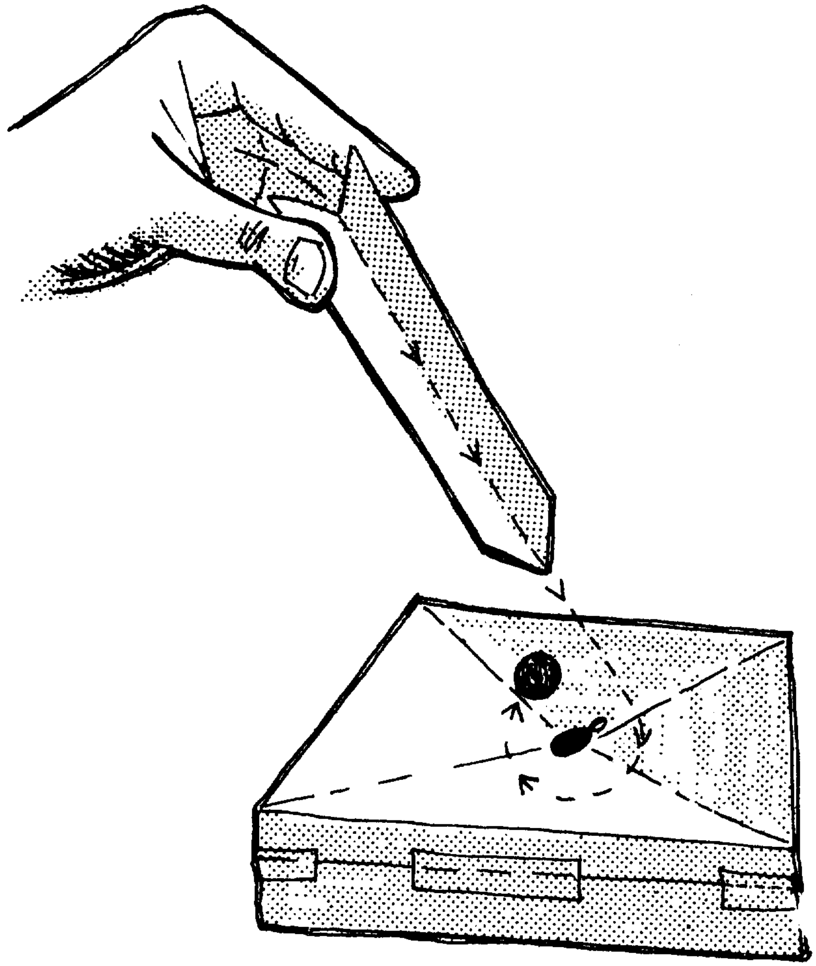
MATERIALS:
A square box
A piece of plastic
Lead sinker or weight
1″ x 12″ strip of heavy cardboard
Marbles
Tape

Fold cardboard along its length to make a launcher for the "spaceship" marble.

Stretch the plastic tightly over the opening of the box and tape in place.

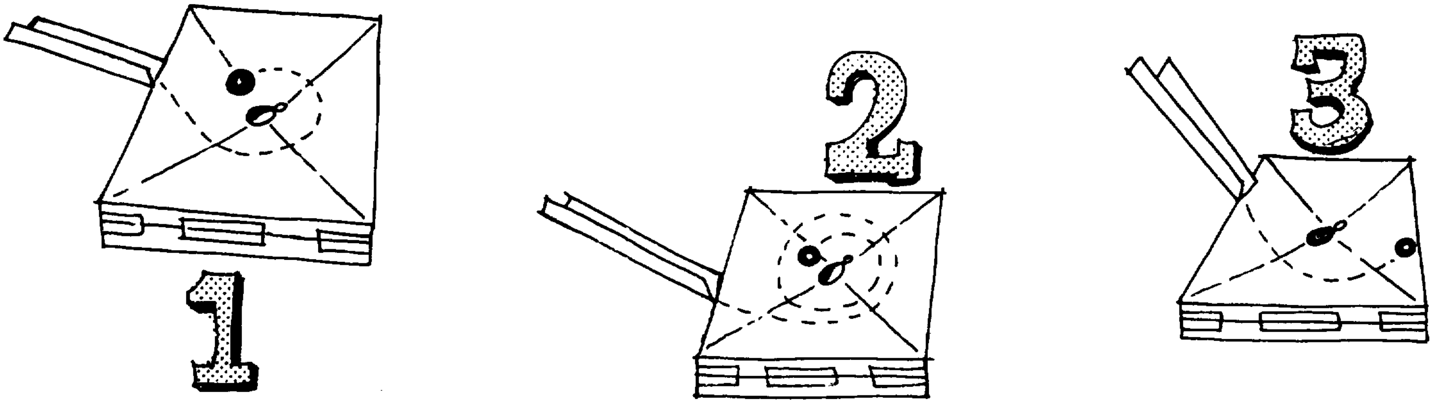
Put planet "sinker" in the middle of the sheet of plastic.

Launch a marble from any edge of the box. What happens?



Tape one end of the launcher to one side of the box. What happens to the speed of the marble as you raise or lower the launcher? What happens to the path or orbit of the marble as the speed increases or decreases?

Do you think scientists could use the gravitational pull of various planets to help guide a spaceship's journey?



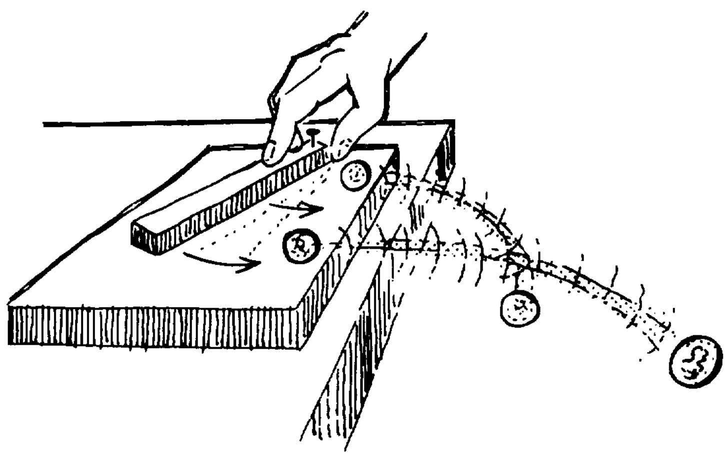
CAN GRAVITY BE SLOWED DOWN? G-2

What happens to the acceleration of gravity if you throw an object in a horizontal direction? Will the object take longer to reach the ground than an object merely dropped from the same height?

MATERIALS:
A stick — A smooth board
A small nail — 2 coins (similar)

Make a hole near one end of the stick and pivot the stick to the board by driving a slightly smaller nail through the hole. Place the board at the edge of a table. Position the stick and coins as shown, then swing the stick sharply to throw the coins off .

What happens? Were you surprised to learn that the rate an object falls toward Earth is not affected by its forward motion?



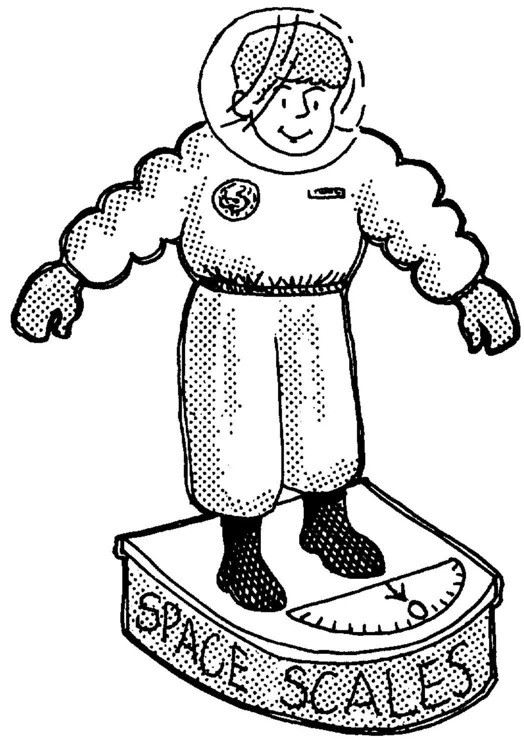
The faster an object moves in a horizontal direction, the farther it is able to go before gravity pulls it back to Earth’s surface.

Can you relate this to escape velocity of space vehicles or satellites?

WEIGHT A MINUTE! G-3

When a space traveler experiences "weightlessness," has gravity been suspended so that he really has no weight?

The pull of gravity is present throughout the universe, but during weightlessness, man and objects are falling freely at the same rate. They seem to have no weight because there is nothing in the way to oppose their fall. The following experiment will help you understand how free fall creates the illusion of "weightlessness."



MATERIALS:
Plastic cup
Loop of string
Wooden ball or a metal nut or washer

Suspend the plastic cup from a loop of string. Hang the wooden ball, metal nut, or washer from a shorter string held (but not tied) at the top of the loop.

First place the plastic cup on a table and release the ball from above the cup. Next, stand on a stool or chair, hold the cup and ball high, then drop them together. The ball will fall as fast as before but this time the cup is falling away from it with equal speed. As long as they are falling the ball will hang above the cup. The ball, with nothing to press against it, is temporarily weightless. This is the state of a space vehicle when it is coasting through space without power.

MAN MADE GRAVITY

G-4

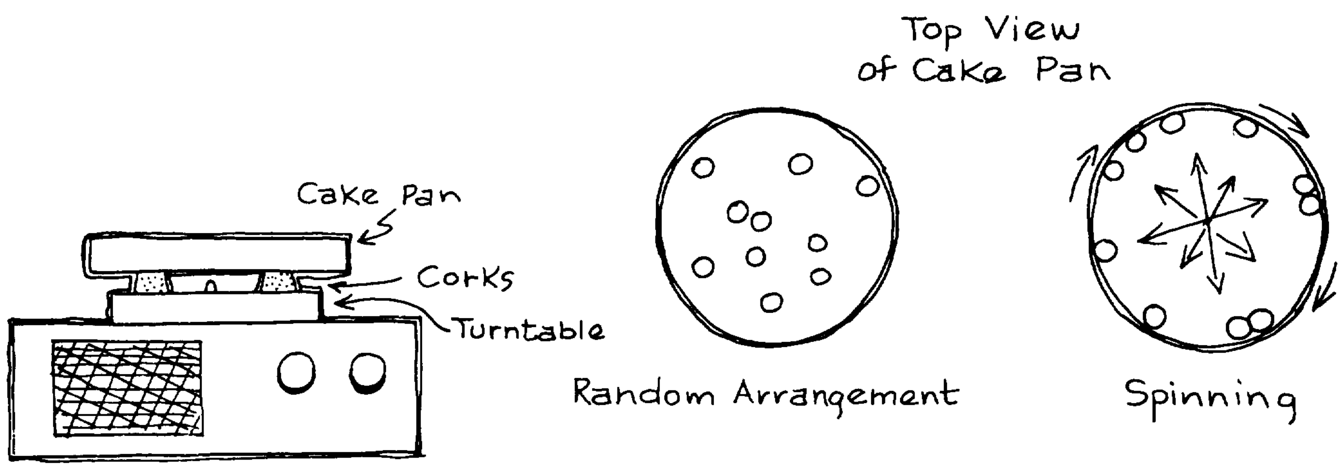
In a weightless space vehicle there would be no up or down. An astronaut could not walk because his feet would not press against anything. Loose objects would float around the cabin. A practical way to solve weightless problems would be to provide artificial gravity by giving the space vehicle or space station a spin.

Let's find out how rotation can produce artificial gravity.

MATERIALS:

Record player	Round cake pan
A few marbles	3 corks

Use the corks to raise the cake pan above the turntable spindle. Center the pan carefully. Arrange the marbles in the pan at random.



Start the turntable spinning. If the pan turns fast enough, the straight ahead effect of inertia will win and the marbles will continue in a forward motion until they are stopped by the side of the pan. Man, or unattached objects would be moved to the floor of a spinning space vehicle in this same manner.

Stop the spin, and like men under free fall, the marbles wander again. A strange property of artificial gravity is that it weakens as you move toward the center, finally becoming zero.

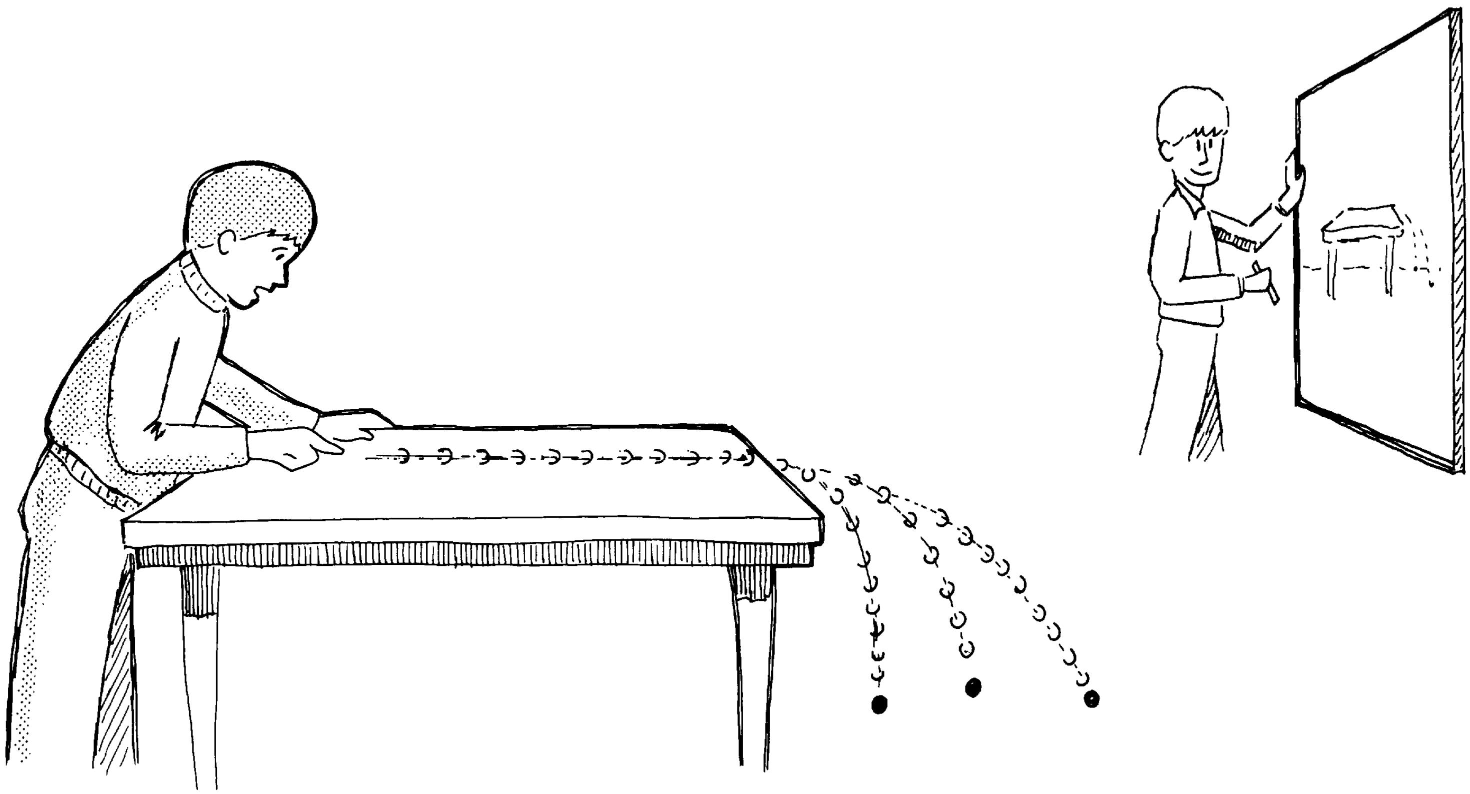
Experiment by placing the marbles at different distances from the center of the pan. Try experimenting with various speeds of the turntable also.

LAUNCH A MARBLE SATELLITE

S-1

MATERIALS:
Marble
Pencil
Paper

Roll the marble off a table.
Have someone draw the path or trajectory as it leaves the table.
Repeat the process using greater force each time.

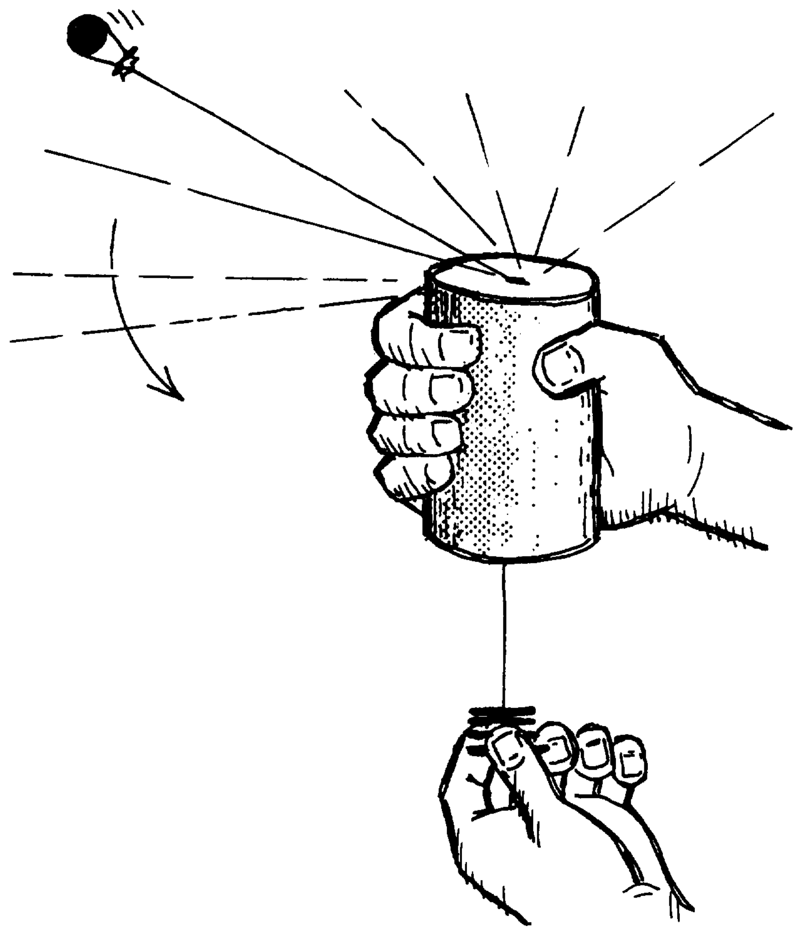


Compare the trajectories. What conclusion do you reach about speed (velocity) and the width of the trajectory? Write your conclusion underneath your trajectory drawings.

WHY DO SATELLITES STAY IN ORBIT? S-2

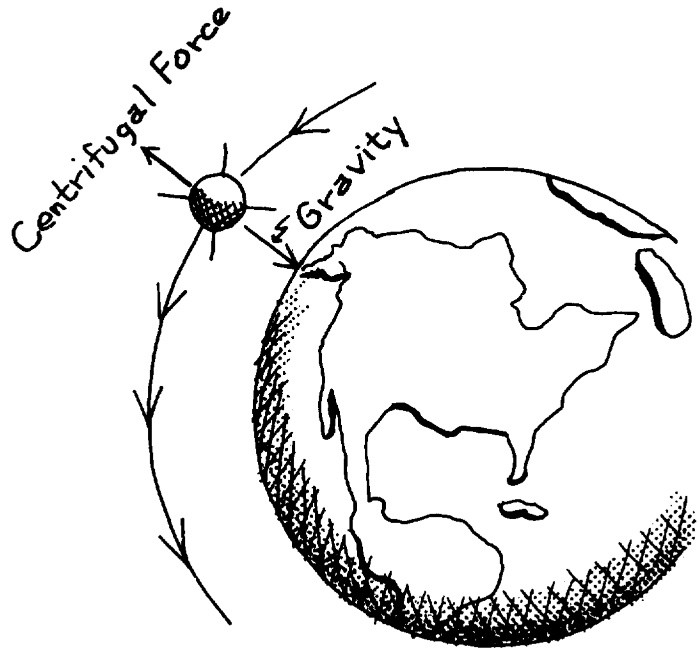
MATERIALS:
- Spool
- String
- Washers
- Nylon stocking
- Small rubber ball

Cut a piece of nylon to put around the rubber ball. Tie one end of a string around the nylon and put the other end through the spool and attach a



few washers to it. Hold the spool in one hand, the washers in the other. Begin to whirl the ball over your head. Gradually let go of the washers. As you increase the speed of the ball, the washers move closer to the spool. As you slow down, the washers begin to fall away from the spool. While the ball is whirling, have someone cut the string between the washers and the spool - The ball will fly away from the spool in a straight line due to its inertia.

The ball is held in orbit around the spool by the string. This corresponds to the force of gravity on a satellite, which causes an inward pull. The outward pull of the ball is called centrifugal force. When these forces are equal, the ball remains in an orbit, without falling into or flying away from the spool

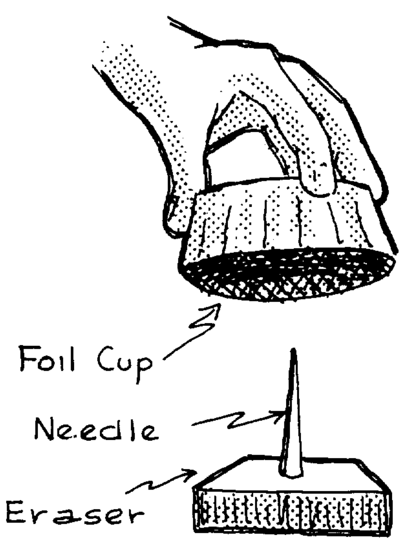


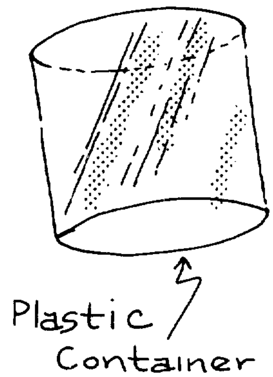
SPINNING SATELLITE!

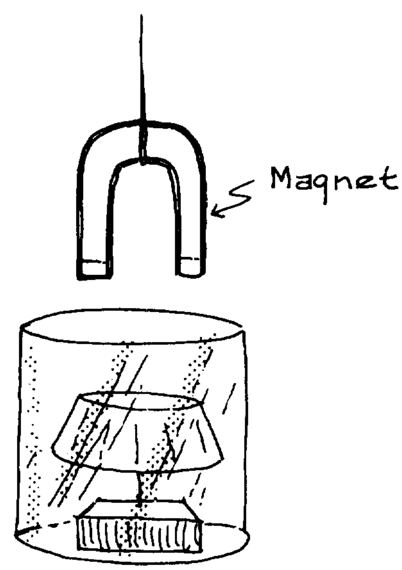
MATERIALS:
An aluminum foil cup
A needle—A cork or eraser
A clear plastic container
A horseshoe magnet
A piece of string (1 ft. long)

Satellites are sometimes given a spin to keep their axes pointing in the same direction.

Balance the aluminum foil cup on the point of the needle held upright in the cork or eraser. Then enclose it completely in the clear plastic container. Tie the horseshoe magnet to the string and suspend it above the container.







Twist the magnet several dozen times and let it go. The cup will spin in the direction of the whirling magnet. Spin the magnet in the other direction and the cup will also spin in that direction. Although the magnet will not attract aluminum, moving near the cup the spinning magnet generates stray electrical currents. The currents create magnetic fields which are attracted by the magnet and cause the cup to be dragged around as the magnet spins.

Earth's magnetism gradually slows down the spin of artificial satellites. Demonstrate this "holding-back" effect by spinning your cup and then resting the magnet on the container. What happens?

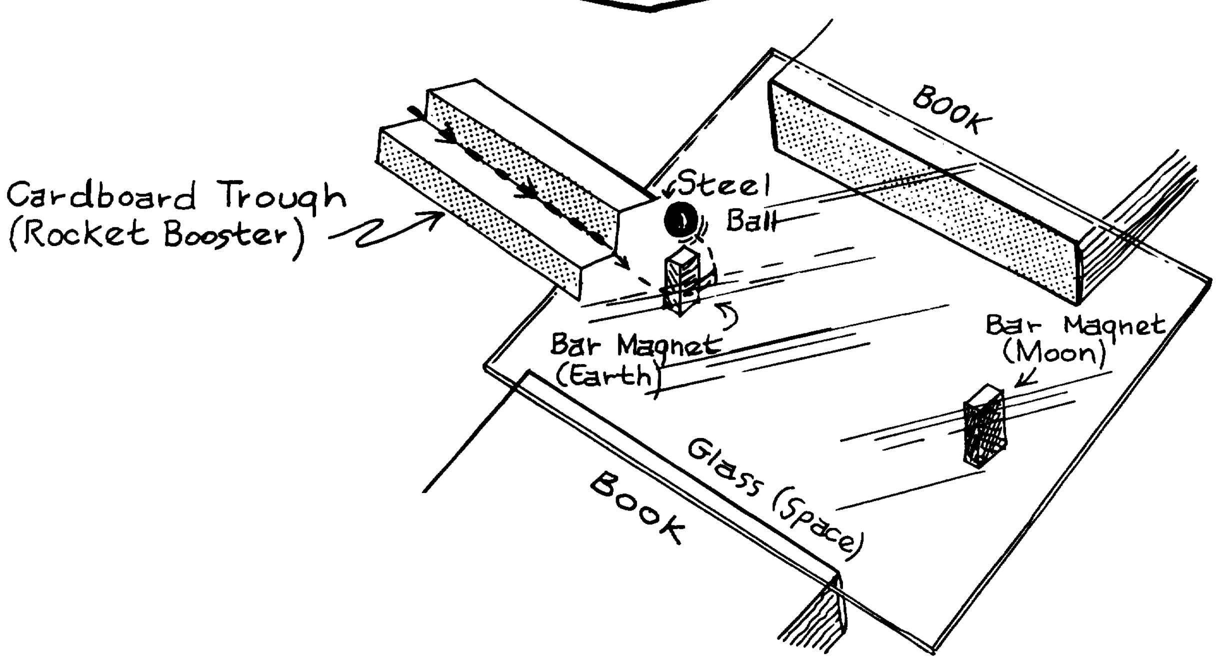
Investigate the mechanics of the speedometer on your family auto, or the kilowatt-hour meter in your home. How do they relate to your experiment?

THE GREAT ESCAPE!

Let's find out what space scientists mean by "escape velocity."

MATERIALS:

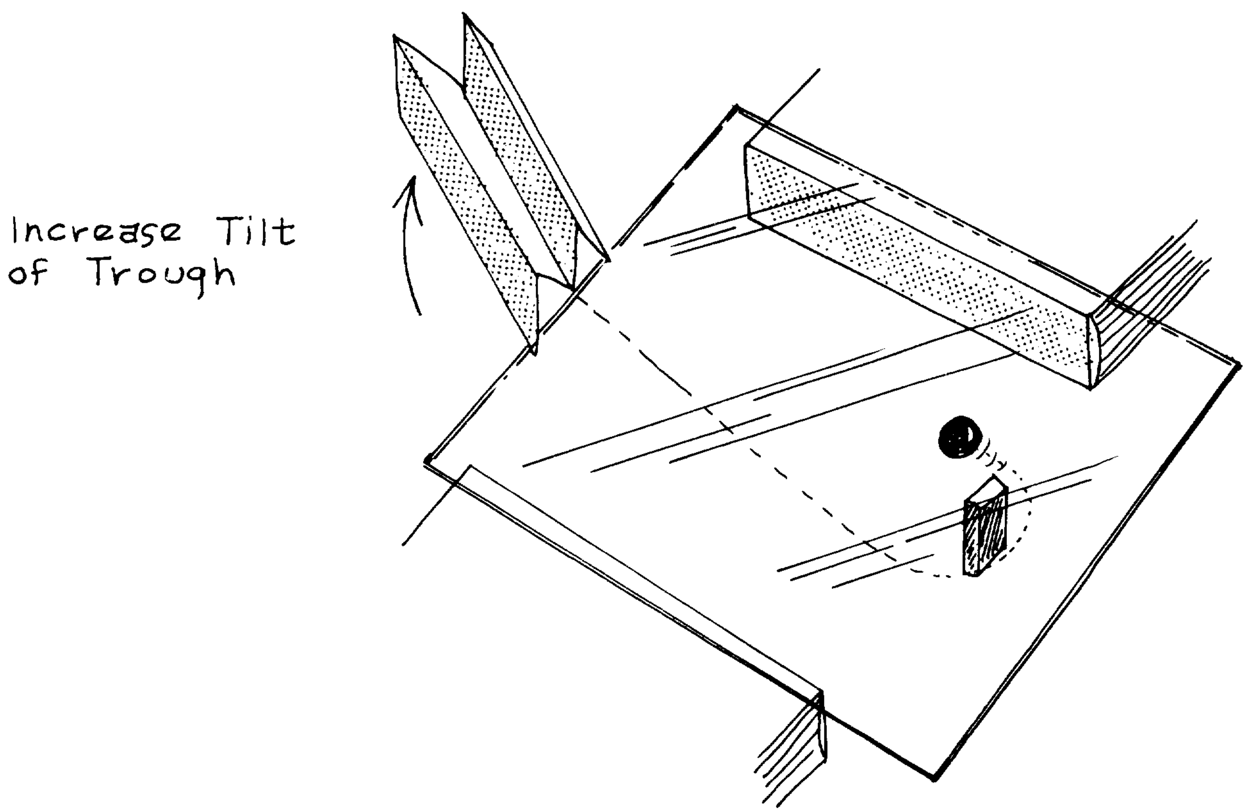
A cardboard trough shaped like a flattened M
Two supports of equal size (books, blocks, boxes)
A piece of glass (like a window pane)
A steel ball bearing
A strong bar magnet



Tilt the trough slightly and release the ball bearing near the end of the trough. What happens? Does the steel ball have enough escape velocity to pull free of the magnet?

To escape Earth's gravitational pull a space vehicle must be boosted to about 25,000 miles per hour. Once free it can coast through space indefinitely.

To increase the speed of the space vehicle (steel ball) increase the tilt of the trough and release the ball near the upper end. What happens as your space vehicle coasts through space (glass pane), and approaches the moon (bar magnet)? How can you change the orbit of your space vehicle?



What determines whether your space vehicle will circle, crash into, or race right past the moon?

SPACE CAN MAKE YOUR BLOOD BOIL! M-1

This activity should be done only with the supervision of the teacher or other designated adult.

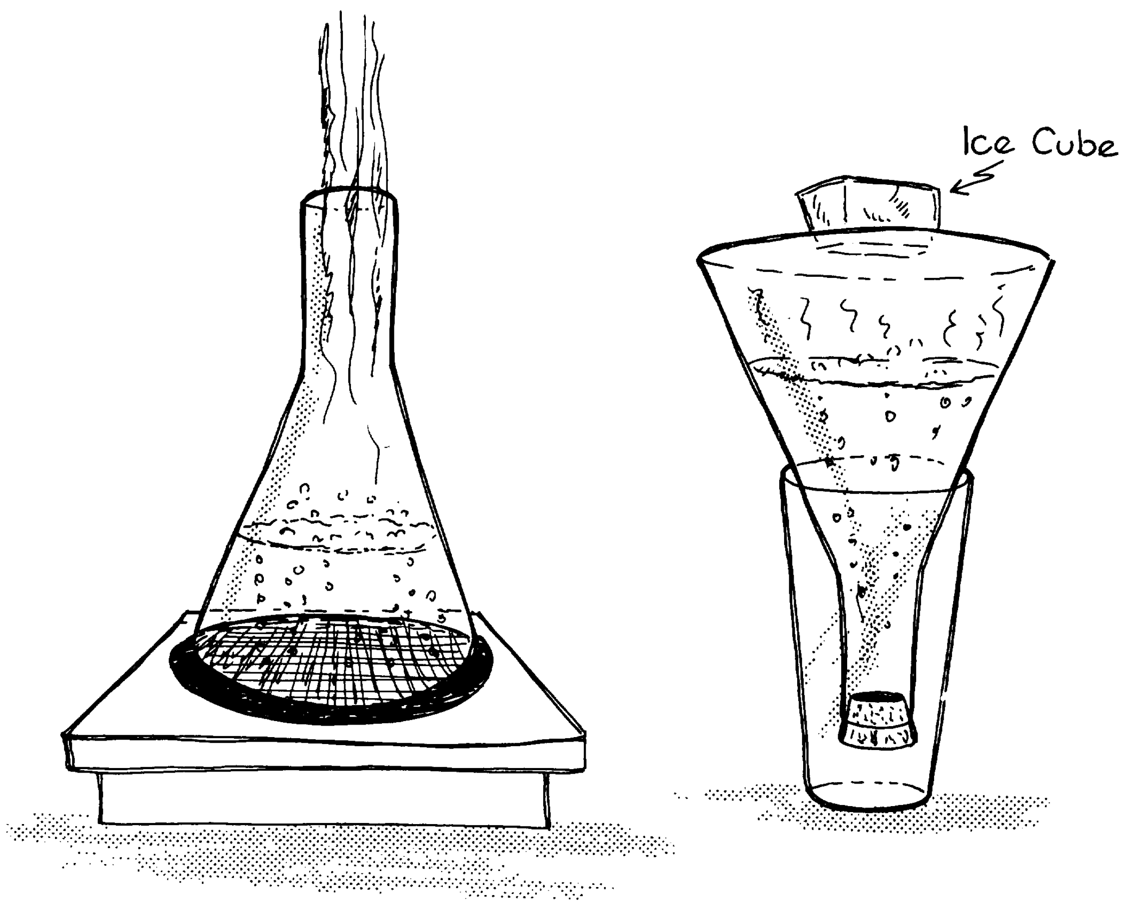
Have you ever wondered why pressurized cabins or suits are needed on high flying jets and spaceships? One reason is to supply oxygen to breathe. Another is to prevent water in your tissues - and even your blood -from boiling away! The pressure of the air or other vapor that bear down on a liquid determine its boiling point. At sea level, the boiling point of water is 212 degrees Fahrenheit. In the thin air at about 15,000 feet, water will boil at 98.6 degrees, the temperature of your body. At 63,000 feet, your blood will boil at this same relatively low temperature.

Use an ice cube to boil water!

MATERIALS:
500 ml lab flask (or smaller)
Glass tumbler — Stopper
Tongs or Pot holder
Water — Ice cube
Hot plate

Half fill the flask with water, and boil until steam drives out all the air. Use tongs or pot holder and remove flask from heat. Stopper it tightly! As soon as the visible boiling has stopped, turn the flask upside down in the tumbler and place an ice cube on the bottom.

As the ice changes the steam back into water-lowering the pressure in the flask-the water will start to boil again and continue boiling until it is barely lukewarm!



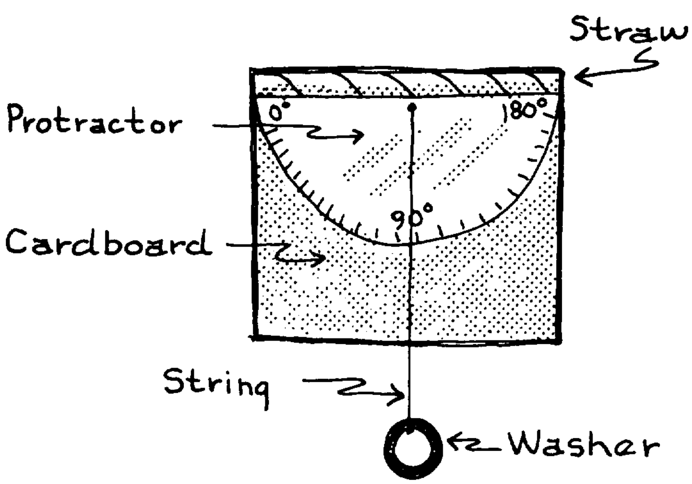
SKY HIGH!

Model building and flying is a way to learn more about aerospace. You might want to make a simple altitude finder to help you find out just how high your model flies.

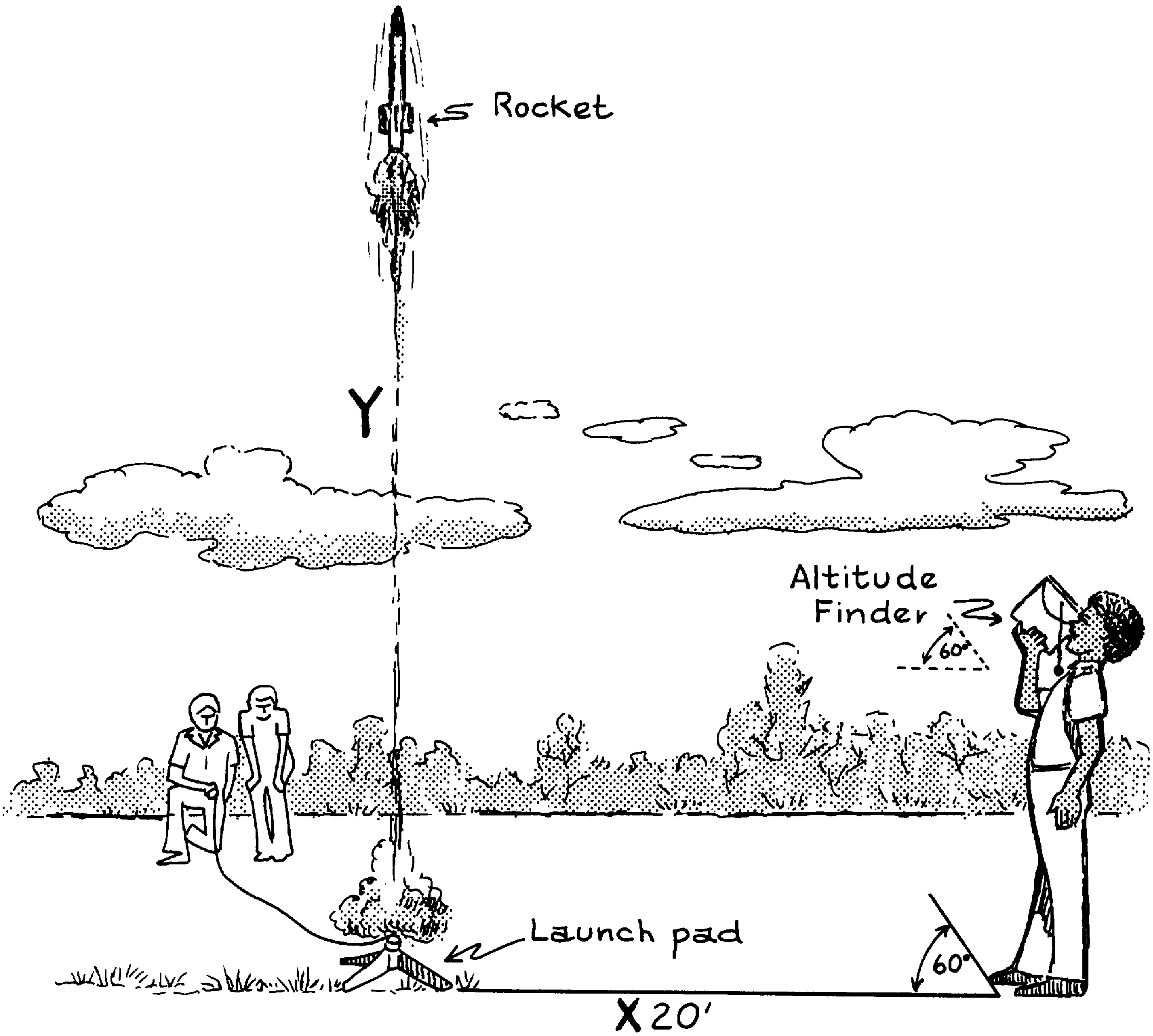
MATERIALS:

1 straw
1 protractor
1 piece cardboard
8″ string
Washer or weight

Glue or tape protractor to cardboard. Punch a hole near the top at the center of the protractor. Put the string through the hole and knot at the back to secure. Tie a washer to the other end of the string. Tape the straw to the top edge of the protractor.



To use the altitude finder, site through the straw and hold the string against the protractor to set the angle. To figure altitude multiply the base times the tangent of the angle.



Tangent L = y/x

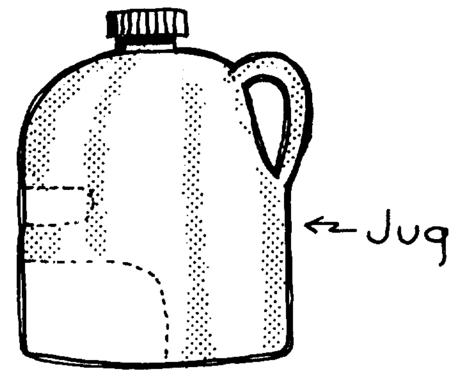
y = (x)(tan L) = (20 ft) (tan 60°)

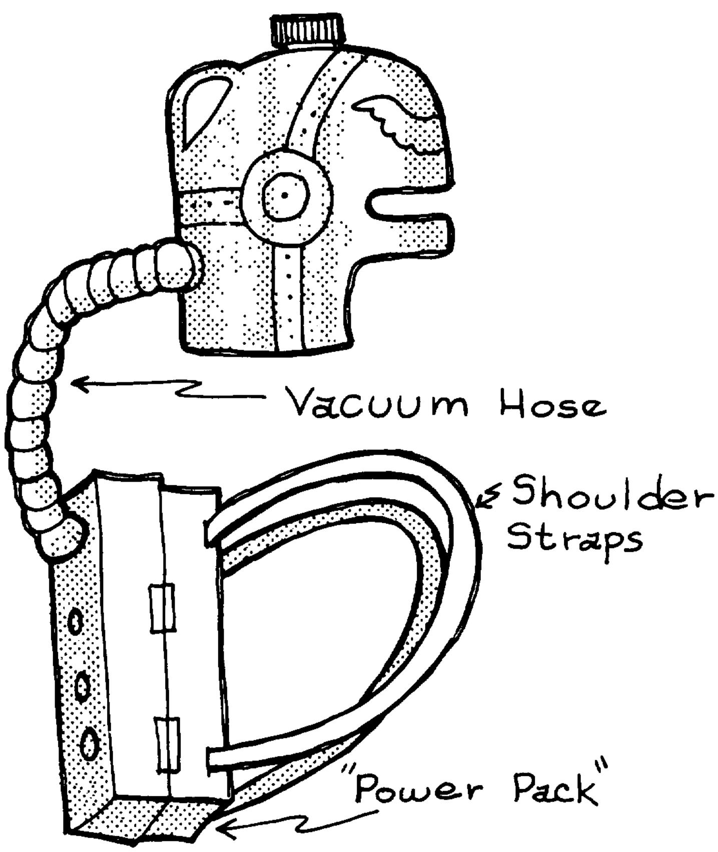
y = (20 ft.) (1.73)

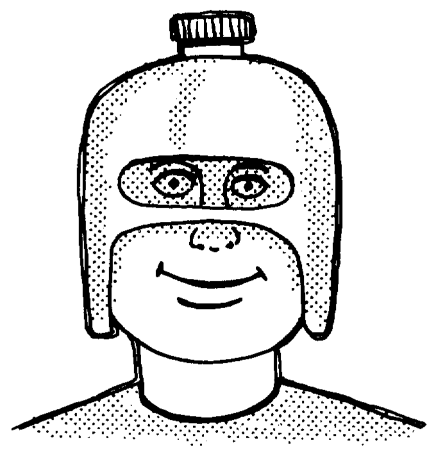
y = 34 ft.

SPACED OUT!

Let's dress ourselves for a space trip. Get a clean gallon milk jug, bleach bottle, or paper bag. Cut a helmet shape and smooth the edges. Decorate with paints, pens, crayons, pipe cleaners, coke tops, straws, paper, fabric or whatever you choose. You can use colored acetate or cellophane for the eye shield.

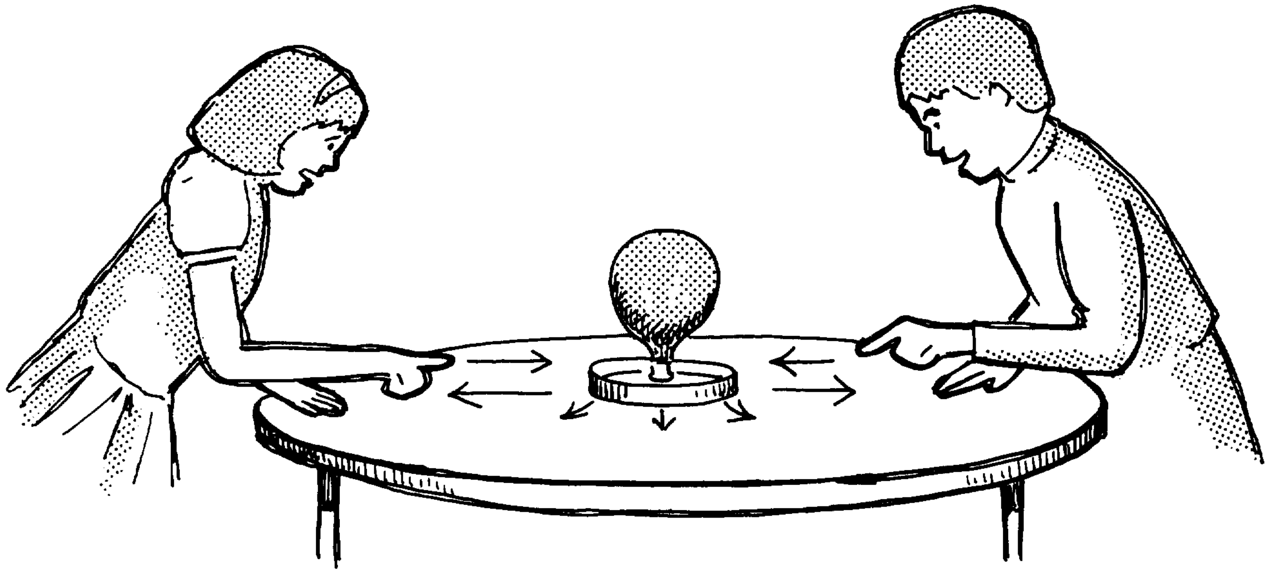






You might want to add a power pack to your space helmet by using a shoe box and a piece of garden, vacuum, or dryer hose. Decorate your power pack with controls and symbols. Attach some shoulder straps, and countdown for a funfilled space fantasy.

Hold your finger over the hole, then place the pan on a table or the floor and give it a slight push.



Can you explain what happens? What is the source of power? Can you relate this to the way a rocket works?

Design some experiments to see how far your craft will go, how fast it will go, and how much weight it can carry.

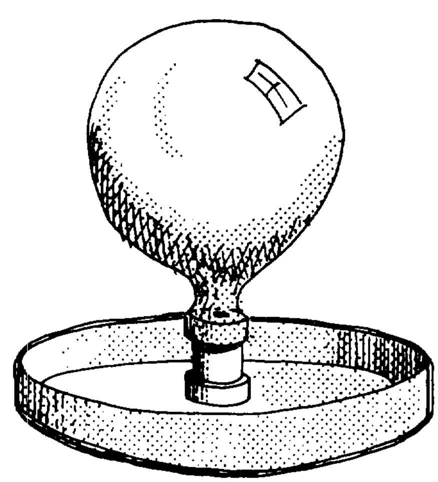
A REAL GEM!

Vehicles that skim over rough seas and rugged terrain on a cushion of air are called hover craft, hydroskimmers, or ground-effects machines (GEM). You can build a model that will show how these almost friction-free air supported vehicles work.

MATERIALS:

A metal pie pan with a smooth bottom
A spool
Glue
A balloon

Turn the pan over and punch a small hole in the center. Glue the spool to the inside of the pan, centering it over the hole. Stretch the neck of the balloon well down over the spool. Inflate the balloon by blowing through the hole in the bottom of the pan.



NOTES

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SPACE EXPLORATION

NL-1	NEWTON, THE FATHER OF EQUALITY OF FORCES
NL-2	NEWTON’S LAW -EQUALITY OF FORCES
NL-3	NEWTON IS RIGHT AGAIN!
NL-4	HAS NEWTON LOST HIS MARBLES?
NL-5	WHAT IS INERTIA?
NL-6	IS THE HAND REALLY QUICKER THAN THE EYE?
R-1	WHY ARE ROCKETS SHAPED THE WAY THEY ARE?
R-2	HOW DO ROCKETS WORK?
R-3	WHY DO ROCKETS FLY?
R-4	TEST TUBE TAKEOFF!
R-5	POP GOES THE ROCKET!
G-1	THE FORCE!
G-2	CAN GRAVITY BE SLOWED DOWN?
G-3	WEIGHT A MINUTE!
G-4	MAN MADE GRAVITY
S-1	LAUNCH A MARBLE SATELLITE I
S-2	WHY DO SATELLITES STAY IN ORBIT?
S-3	SPINNING SATELLITE!
S-4	THE GREAT ESCAPE!
M-1	SPACE CAN MAKE YOUR BLOOD BOIL!
M-2	SKY HIGH!
M-3	SPACED OUT!
M-4	A REAL GEM!

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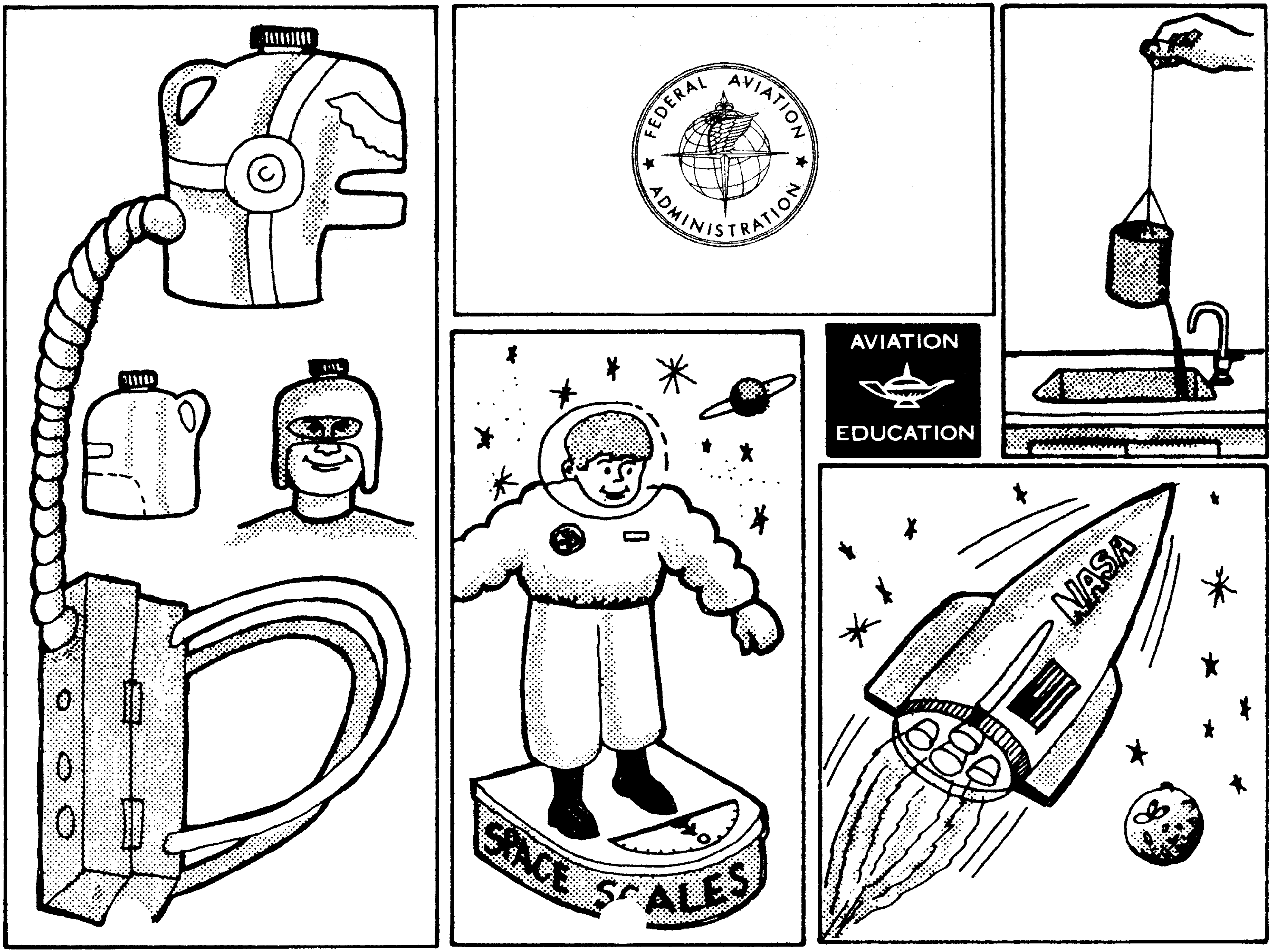

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