SOLAR POWER

150 EXPERIMENTS

By Avi Sochaczevski and Peretz Mahler

HEAT - LIGHT - COLORS - SOLAR ENERGY AND MORE ...

PARTS LIST

- Airplane cut-out sheet
- Balloons
- Candle
- Cellophane Sheets and Black Cardboard
- Crane Arm
- Cut-out Sheet
- Diode
- Electrodes
- Galvanometer Set
- Heat Absorber Bag
- Instruction booklet
- LED
- Magnifying Glass
- Mirror
- Motor
- Parabolic Reflector
- pH Paper
- Plastic Arm
- Plastic Jar and Lid
- Propeller
- Pulley
- Reflector Legs
- Reflector Pins
- Resistor
- Rubber Band
- Rubber Disks
- Solar Cell
- Steel Rod
- Sticker Sheet
- Styrofoam Base (for Solar Furnace)
- Support Reinforcer
- Test Tube
- Test Tube Holder - Metal
- Thermometer and Plastic Backing
- Thread
- Washers (cardboard)
- Wire

⚠ WARNING: CHOKING HAZARD -
Children under eight years can choke or suffocate on uninflated or broken balloons. Adult supervision required. Keep uninflated balloons from children. Discard broken balloons at once.

BE CAREFUL WHEN USING PARTS WITH SHARP POINTS OR EDGES.
KEEP AWAY FROM CHILDREN UNDER THREE YEARS OF AGE.
ALL EXPERIMENTS THAT ARE IN DIRECT SUNLIGHT SHOULD BE PERFORMED WHILE WEARING SUNGLASSES.
THERE ARE SOME EXPERIMENTS WHICH REQUIRE ADULT SUPERVISION, AND THESE ARE MARKED WITH THIS SIGN **.

Fifth English Endition, 1999

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SILICONE SOLAR CELLS

HOW TO CONSTRUCT YOUR GALVANOMETER

SOLAR ELECTROCHEMISTRY

NATURAL SOLAR ENERGY EXPLOITATION

** **These experiments require adult supervision.**

INTRODUCTION

This experiment kit has been assembled for young people who want to investigate and understand the problem, the proposed solutions and the meaning of solar energy; to personally experience it and not just to be told about it; to become familiar with the solar energy aspect of the energy problem.

It is a fascinating subject full of many intricacies. The sun provides us with unlimited amounts of free clean energy yet we live in an energy starved world. We often feel that our sun is hottest when least needed and cold and distant when most desired; and that it is most difficult to harness.

This experiment kit contains most of the apparatus required to perform the experiments described in this manual and much of what you will need for experiments you'll think up on your own. The experiments here range from the very basic to the very challenging. Some are straight forward, and others will require your ingenuity and resourcefulness. Follow the instructions carefully and patiently and you will succeed in in performing them all satisfactorily.

Certain experiments require adult supervision.
These experiments are marked with this sign.**

Think of the components of this kit as your laboratory and of this book as an idea source. Treat the explanations given with skepticism - verify each statement. After each experiment you will probably end up with many more questions than you answered. Some of these questions will be dealt with in later experiments; others you might want to look up in science texts. Try to reason them out on your own, verifying your conclusions through experiments you devise yourself.

You may think of other ways of proving the results of the experiments in your kit or you may be able to reach wider conclusions based on these experiments; well, that is our intention here. These experiments are meant to start you thinking and to demonstrate that experimental science is enjoyable and exciting.

IMPORTANT - BEFORE YOU START
Before starting your experimental work, become familiar with the components of the kit. Identify them according to the parts list. Read the instructions carefully and then go back and follow them step by step. Do not attempt to do any assembly from the illustrations without reading the related text. Most important....work in order. Start with EXPERIMENT NO.1 and continue on. Do not attempt to skip sections without at least reading them. The experiments are related to one another and skipping a section might mean that you will not have a clear understanding of what you are doing and will not be able to achieve proper results.

A NOTE OF CAUTION: The sun's intensity is great enough to damage the retina of your eyes when you look at the sun directly or at its image when concentrated by a lens. Avoid looking directly at the sun or at a concentrated image of the sun. Be very, very careful when working in bright sunlight. Wear sunglasses.

THE SUN
Though for centuries man has worshipped the sun as a god, we have started to think of our sun as only one medium sized star among billions and billions of stars in our universe. Yet to our planet, it is the sustenance of our existence. Certainly life on earth, or for that matter the earth itself, could not possibly exist were it not for our sun. The four million tons of mass that are converted into energy every second produce 380,000,000,000,000,000,000,000,000 watts of energy. The earth receives only one two-billionths of this amount. Research has proven that the energy that the sun radiates for 43 minutes is the amount of solar radiation that is consumed worldwide in a year! The most pessimistic estimates of the sun's remaining life is 10,000,000,000 (10 billion) years.

The sun's surface temperature is constantly increasing and it is estimated that in 1,000,000,000 years the increase in temperature on the sun's surface will cause the temperature on earth to reach 1,000° F. No life on earth as we know it would remain and unless some superhumans of the far future will find a way to protect earth from the sun, our oceans will boil away.

SOLAR ENERGY

At this time we only know of two main nonfossil sources of energy that have the potential to service the future needs of the human race: nuclear energy and solar energy. The energy we use today is usually taken from fossil fuels such as oil, gas, coal, or from hydroelectric power or nuclear power. Even electricity is a fossil fuel, because most of the electricity generated today is made by burning one of these kinds of raw materials.

Coal, gas and oil will not last forever. In a matter of one week, this amount of solar energy is greater than the natural coal resources that we know exist today. With the constant rise in price of these commodities throughout the world, solar energy is the hope of the future. It is vitally important to use the solar radiation in order to meet the increasing energy needs of our world. Solar energy holds the answer to these needs, however, there are still questions that have to be solved. Must we always have huge areas of land in order to attract and trap the solar energy, and what type of appropriate energy-storage systems need to be employed? How can we implement solar energy in remote areas of the world?

Experts say the world's oil supply will begin declining around 1990; and by 2050, we will have used up the two trillion barrels of crude oil accumulated since pre historic times. The conclusion is obvious. And urgent! We must develop other available energy sources...fast.

Is solar energy practical for the future? The answer is yes!

Solar energy is clean, safe, and found within our national boundaries. Best of all, it is plentiful. It has been estimated that enough sunlight falls on the roof of the average suburban home to supply three times as much energy as that home consumes. The potential is there. The challenge is ours.

In order to answer the needs of the future, new technologies need to be developed. Research is underway throughout the world and is constantly progressing. Some of the major studies today concern themselves with developing efficient solar high-temperature air heaters, converting solar energy to mechanical energy - which in turn will produce electricity, conversion of solar energy to non-electrical forms which will be able to be storaged, conversion of solar energy to chemical energy - which will later be transformed for daily use, and the possibility of converting solar radiation to laser light.

For more than two centuries man has endeavored to harness the energy of the sun for technological purposes. These early experiments included French solar furnaces, British irrigation pumping systems on the Nile, and in the early 1900's, solar water heaters in Arizona, California and Florida. The increased availability of inexpensive natural gas, oil and electricity, along with lower initial costs of conventional water heaters has all but put an end to this use of solar energy in the U.S. This kit is designed to let you experiment with the sun's rays. We hope that you will enjoy this adventure, and will understand the power of solar energy.

METRIC SYSTEM

The metric system is used in all scientific work - even in countries which have not as yet converted to it for non-scientific measurement.

The unit "meter" with the prefix "kilo" added, produces "kilometer" meaning "1000 meters." One kilogram is of course, 1000 grams. On the other hand, 1 cm = 1/100 of a meter, and 1 mm is 1/1000 of a meter.

WEIGHTS AND MEASURES

LENGTH

1 centimeter (cm) =10 millimeters = 0.3937 in.
1 meter (m) = 100 cm = 1.0936 yds
1 kilometer (km) = 1000 m = 0.6214 mile
1 inch = 2.5400 cm

1 foot = 12 in. = 0.3048 m
1 yard = 3 ft. = 0.9144 m
1 mile = 1760 yds = 1.6093 km

AREA

1 sq cm (cm^2) = 100 mm^2 = 0.1550 sq in
1 sq meter (m^2) = 10,000 cm^2 = 1.1960 sq yds
1 sq km (km^2) = 1100 hectares = 0.3861 sq mile

1 sq inch = 6.4516 cm2
1 sq yard = 9 sq ft = 0.8361 m^2

WEIGHT

1 gram (g) = 1000 mg = 0.0353 oz
1 kilogram (kg) = 1000 g = 2.2046 lb
1 tonne (t) = 1000 kg = 0.9842 ton

1 ounce = 437.5 grains = 28.350 g
1 pound (lb) = 16 oz = 0.4536 lg
1000 kg = 1 metric ton

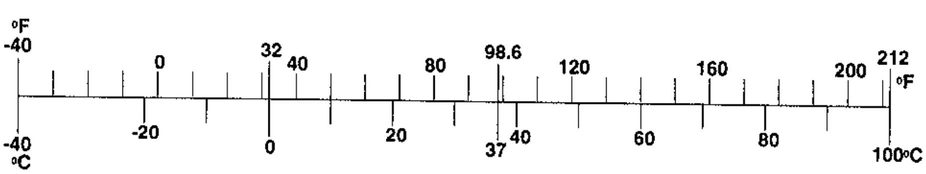
VOLUME

1 pint (pt) = 2 cups (c) = 473 ml
1 quart (qt) = 2 pts = 946 ml

1 gallon (gal) = 4 qts = 3.7853 l
1 liter (l) = 1000 ml = 1.06 qt

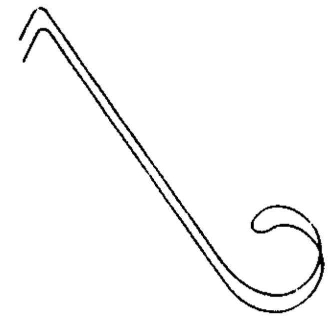
TEMPERATURE

Use this table for converting Fahrenheit to Celcius temperatures.



For your convenience, here is a ruler that you can use for measuring centimeters or inches.

HEATING AND COOLING TEST TUBES



Never heat a test tube while holding it in your hand. Always hold it in the test tube clamp. Do not put your face or hands over the open end of a heated test tube.

To prevent cracking, never heat an empty test tube.

Glass cools very slowly; do not touch a test tube for at least 15 minutes after it has been removed from a heat source.

Glassware must be allowed to cool slowly or it will crack. Never try to cool hot glassware by placing it in water.

Never put hot glassware on an unprotected table top - it will leave a scorch mark.

HEAT

Heat is our most important source of energy. Man has learned to regulate heat for his convenience. We heat our homes in winter and air condition them in summer. We cook and freeze our food. We clothe our bodies and insulate our homes. We use heat to control processing and to produce metals. Our use of heat is endless.

Enormous and ever increasing quantities of heat are required by modern man.
We have turned from burning wood to burning fossil fuels (coal, oil and natural gases) in our hunger for heat. Now, when we have finally realized that we can no longer keep burning fossil fuels without regard to the requirements of future generations, we have started our search for alternative sources of heat which are not finite. The sun provides unlimited quantities of pollution free heat.

The sun's surface temperature is over 10,000°C; its interior temperature 15,000,000°C. Even at a distance of 92,913,000 miles it can provide earth with all the heat man will require if we can learn to harness it effectively.

In our study of solar energy we must first understand what heat is, its effects and its characteristics.

TEMPERATURE - HEAT

All materials are composed of molecules, tiny particles of matter which are in constant motion. The more heat is applied to an object, the faster its molecules move. The more an object is cooled, the slower its molecular motion.

We should not confuse heat with temperature. The level of cold or heat is measured in degrees by a thermometer. The amount of heat gained or lost by an object is measured by calories.
Calories are a measure of heat. A SINGLE CALORIE IS THE AMOUNT OF HEAT REQUIRED TO RAISE THE TEMPERATURE OF ONE GRAM OF WATER ONE DEGREE CELSIUS. The same number of calories are needed to raise 15 grams of water 1°C as it takes to raise 1 gram of water 15°C.

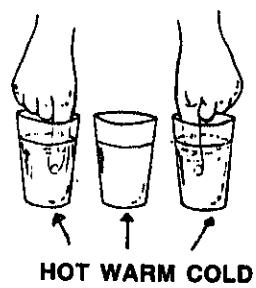
Cold is the absence of heat. Hotness and coldness are relative terms which mean little by themselves. We should not confuse heat with temperature. When compared to hot water, warm water feels cold, but, in comparison to cold water, it feels hot.

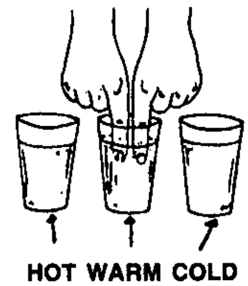
The human body is a very poor device for determining temperature; it can only sense a gain or loss of heat. Human skin is sensitive to both upward and downward changes in temperature, but not to a stable temperature level.

Temperature expresses the level of heat. It is measured in degrees by a thermometer. There are several popular scales for measuring temperature. The Celsius (Centigrade) scale, the Fahrenheit scale, and the Kelvin (absolute) scale.The most universally used scale is the Celsius scale. On this scale 0 is the freezing point of pure water and 100 is the boiling point of water. Each degree Celsius is 1/100 of the difference between the freezing and the boiling points of water.

EXPERIMENT NO. 1 HOT - WARM - COLD

Take three cups or glasses. Fill the first with water as hot as you can comfortably bear, the second with warm water, and the third with cold water. For about three minutes, immerse your right index finger in the cold water and your left index finger in the hot water. Remove both fingers and put them in the warm water. While your right index finger will feel that the water is warm, your left index finger will feel cold water.





Your right index finger was cooled when immersed in the cold water. When placed in the middle cup, it was heated up by the warm water and you sensed warmth. Your left index finger was heated by the hot water and was thus warmer than the water in the middle cup. Heat travelled from your hand to the water and thus, your hand felt cold.

Our senses react not only to the degree of temperature - whether 10°C, 100°C, or 1000°C, but also to the total amount of heat. Sparks have a high temperature, but they are so small that there is very little total heat. The same with snowflakes. They are very cold, but they are so very light. A glass of water on the other hand may be less cold, but if you pour cold water onto your arm, it feels colder than a snowflake.

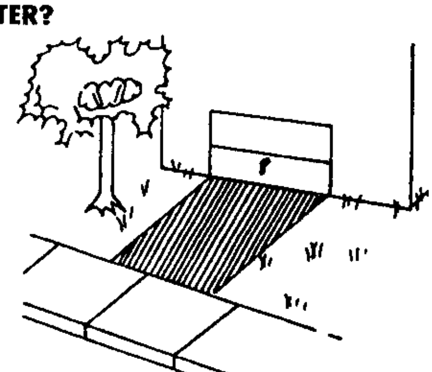
EXPERIMENT NO. 2 IT ONLY SEEMS COLDER

On a cold morning stand in bare feet, one foot on a rug and the other on a tiled floor. The tiled floor will feel cooler.

Both the rug and the tiles are at room temperature. The tiles seem cooler because they conduct heat away from your body faster than the rug.

EXPERIMENT NO. 3 WHY IS THE DRIVEWAY HOTTER?

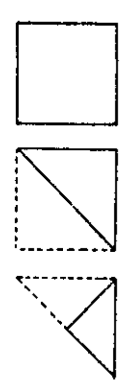
Touch an asphalt driveway on a hot, sunny day. Next, touch a concrete sidewalk. The asphalt is much hotter than the concrete.

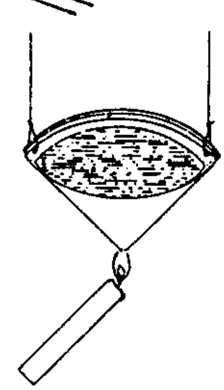


Both the driveway and the sidewalk have been under the same sun for the same amount of time. Why is the driveway warmer? Dark colors absorb solar energy more readily than light colors. Hence, the dark asphalt driveway is hotter than the lighter colored concrete.

EXPERIMENT NO. 4 A PAPER POT **

Take a sheet of good quality paper approximately 20 cm square, and fold it in four as shown in the diagram. Open the folded sheet into a cone so that there are three layers of paper on one side and one on the other. At the top, at opposite ends of the cone, punch two small holes through the three layers of paper and tie two strings through them.



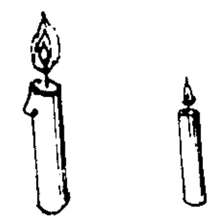


Fill the cone with water and position it over a small candle, holding it by the strings, you will be surprised that the paper cone does not burn. You can actually boil the water in it. BE CAREFUL that the flame touches only the paper at the bottom of the cone and that there is always water in the cone while it is being heated.

The heat of the flame is absorbed by the water through the paper. Since water cannot be heated to a higher temperature than 100°C and since paper will not ignite until it reaches a higher temperature, the paper will not burn until all the water has evaporated.

EXPERIMENT NO. 5 QUANTITY OF HEAT **

Observe the difference in the the time it takes to boil water with a small flame and with a large flame.



The large flame will boil water faster,even though the temperature of the small and larger flame is the same, since more heat is available. The larger size of the flame is a definite advantage.

EXPERIMENT NO. 6 ICE GLUE

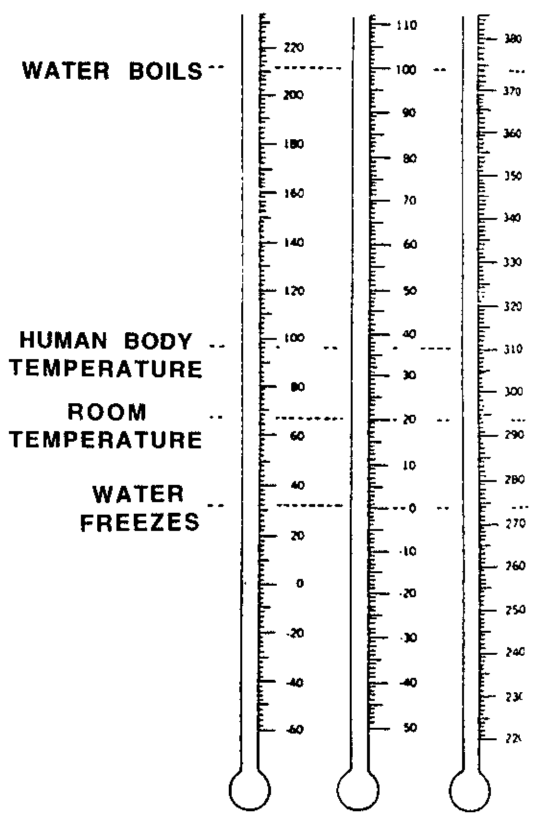
Press two ice cubes tightly together for several minutes. Release the ice cubes. You find that they have joined together.

While under the pressure of your hands the melting point of the ice was lowered and the surface ice melted. When you released the pressure, the freezing point went back up to its former level and the two pieces of ice froze together.

EXPERIMENT NO. 7 THE THERMOMETER

There are many types of thermometers; the one enclosed in your kit is the most common kind. It contains a bulb of liquid at one end and a long thin bore which runs up the center of the glass rod. When the liquid in the bulb is heated, it expands and moves up the bore; when it is cooled, it moves down.

TEMPERATURE SCALE CONVERSION



To determine the temperature we see how far the liquid has moved up or down the bore and read off the temperature from the scale.

Examine your thermometer tube carefully. You will notice a small mark (like a horizontal scratch) about 2/3 up the glass rod. Your thermometer has been carefully calibrated so that the liquid inside the bulb will reach that particular mark at exactly 20°C.

The scale card of your thermometer is calibrated in both the Fahrenheit and Centigrade scales.
The centigrade (sometimes referred to as Celsius) scale is the one most commonly used in scientific work. On the Centigrade scale 0° is the freezing point of water and 100° is the boiling point of water. The range between the

freezing and boiling point of water is divided into 100 equal parts of degrees. Degrees centigrade are written as °C.

The United States still uses the Fahrenheit scale of temperature, you will very often come across this unit of temperature measurement. In the Fahrenheit scale water freezes at 32° and boils at 212°. The temperature range between the freezing and boiling point of water is divided into 180 equal parts of degrees. The common abbreviation for a degree Fahrenheit is oF.

There is one other temperature scale which is in common use in more advanced scientific work; it is the Kelvin scale. Knowing that a gas when cooled one degree centigrade loses 1/273 of its pressure, Lord Kelvin reasoned that at 273°C below zero -absolute zero - a gas would not have any pressure. He devised a scale where 0°K is that theoretical point where gases do not exert any pressure and each degree is identical to a degree centigrade.

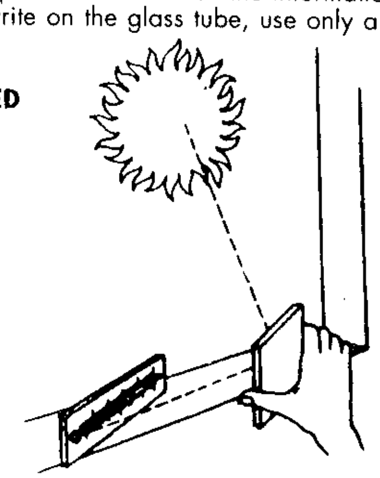
Included here you will find a comparative chart of all these temperatures.

When taking temperature readings with your thermometer make sure that the indicator mark on the glass rod is aligned exactly with the 20°C marked on your scale. You will sometimes find it more convenient to remove the thermometer from the scale, measure the temperature and then quickly insert the thermometer into its plastic backing, align it and take the temperature reading. Be careful not to break the thermometer.

The distance the column has fallen from 20°C to 0°C, divided by 20, is the amount the thermometer will rise or fall for every 1°C change in temperature. This is all the information you require to graduate your thermometer. If you want to write on the glass tube, use only a felt-tip pen!

EXPERIMENT NO. 8 SOLAR HEAT CAN BE REFLECTED

Place the thermometer on the window sill so that it is shielded from the sun by the card. Record the temperature reading.



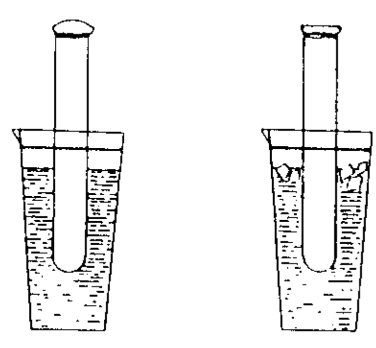
Now hold your mirror in such a way that the sun's rays are reflected from the mirror onto the thermometer tube. Take a new reading after several minutes. The temperature should now read practically the same temperature as it would read if it were facing the sun directly.

EXPERIMENT NO. 9 TEST TUBE THERMOMETER

Stretch a rubber sheet (piece of your balloon) tightly over the mouth of the test tube. If it does not stay in place on its own, hold it in place with the rubber band. Be sure that the seal between the rubber sheet and the test tube lip is airtight.

WARNING: When heating the test tube, keep it away from your face!

Gently heat the test tube by placing it in warm water; as the air in the test tube warms up, it expands and the rubber sheet bulges a bit. Cool the air in the test tube by placing the test tube in ice water for several minutes, the rubber sheet caves in under air pressure, since the air in the test tube has contracted. Repeat this experiment once more for greater success.This experiment is very indicative of what happens in our thermometer.



WARM WATER ICE WATER

EXPANSION - CONTRACTION

Most substances, whether in solid, liquid or gaseous form, tend to expand when heated and to contract when cooled. Here are a few interesting experiments which demonstrate this property.

EXPERIMENT NO. 10 GASES EXPAND WITH HEAT **
Put enough drops of water in the test tube so that it covers the bottom, and stretch your balloon over it. Gently heat the test tube. As the air in the test tube is heated it expands and inflates the balloon.

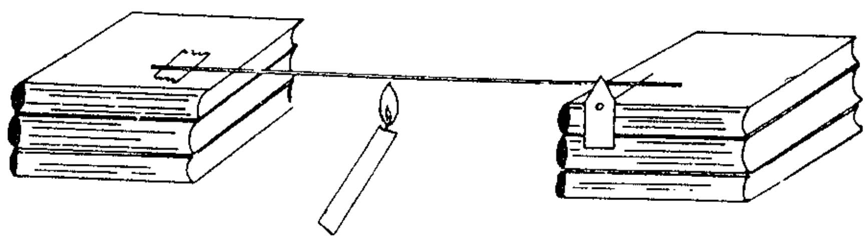
EXPERIMENT NO. 11 GASES CONTRACT WHEN COOLED **
When the air cools again, the balloon deflates.

Do not continue to heat the test tube without a few drops of water in it, otherwise the test tube would crack.

EXPERIMENT NO. 12 SOLIDS EXPAND WHEN HEATED **
The phenomenon of solids expanding or contracting with temperature change can be seen almost everywhere. Watch telephone or hydro lines: in the summer, the wires tend to hang quite loosely from pole to pole, while in the winter they are taut, as they have contracted with the cold. In construction, provision is almost always made for the expansion and contraction of materials.

In this experiment, we will build a gauge which is basically the same as the sophisticated expansion gauges marketed commercially and very similar to dial thermometers.

Set up two even piles of books about 15 cm (6 in) apart. Cut off 20 cm (almost 8 inches) of the copper wire that is included with your galvanometer. Straighten it, lay it across the two piles and tape it to the top book in the left pile. Be sure that the wire is very straight and that it lies on the pin without touching the books on the right. Remove the dial K from the cut-out sheet and insert a pin completely into it, so that the head of the pin touches the dial. Place the pin under the other end of the wire, with the dial pointing upward.



Slowly and carefully, heat the wire with your candle. As the wire expands with the heat, it rolls the pin, and thus moves the indicator dial.) The indicator arrow should slowly move to the right! This shows that the copper wire is growing. It lengthens towards the direction where it is not held down. As the wire expands it rolls the pin and moves the indicator dial with it.

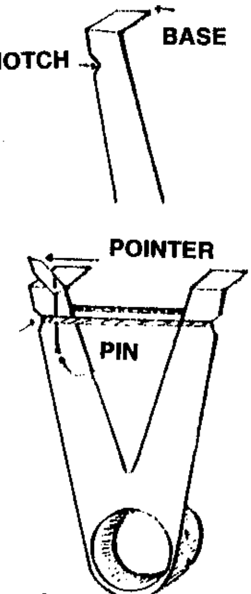
EXPERIMENT NO.13 COEFFICIENT OF EXPANSION **
In the assembly for the previous experiment, replace the copper wire with an aluminum knitting needle. Heat the knitting needle. Notice that this expands less and much slower than the copper wire.

Materials differ very widely in how fast and how much they expand for a given level of heat. The measurement of this property is known as the coefficient of expansion. Metals have a very high coefficient of expansion, while those for wood are very low. Other materials range in between.

EXPERIMENT NO. 14 RUBBER CONTRACTS WHEN HEATED **
Take one of the reflector legs and stretch a rubber band between its arms so that it is placed between the two notches. See drawing.

Insert the pin and pointer from the previous experiment between one of the legs and the rubber band, so that the pointer is just above the surface of the base but not resting on it. Very gently heat the rubber band with your candle. With the heat, the band will contract, moving the pointer at its center, counter clockwise.

Although most materials expand when they are heated, there are some exceptions. This is one of them.



EXPERIMENT NO. 15 AIR CONVECTION
Warm air is less dense than cold air and therefore tends to rise. We refer to this movement of air as air convection.

EXPERIMENT NO. 16 HEAT TRANSFER
Heat is continuously transferred from a warmer to a colder object until they are both at the same temperature. Heat can be transferred by radiation, by convection, or by conduction.

EXPERIMENT NO. 17 WARM AIR RISES **
Use a burning twig as a source of smoke.
Carefully bring the source of smoke close to one side of the flame. The smoke will be drawn towards the flame and sent up.

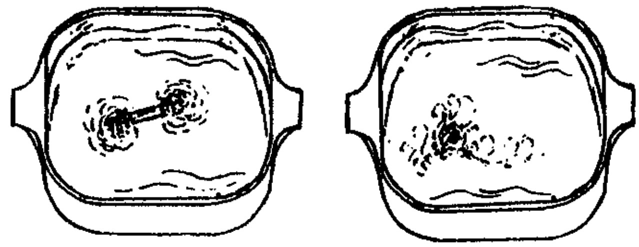
The air, warmed by the flame, rises and pulls the smoke with it.

EXPERIMENT NO. 18 CONVECTION **
Hold your hand carefully about 30 cm above a candle flame for **a very short time**. You feel considerably more heat than if your hand was the same short time and distance from the side of the flame. Most of the heat reaching your hand is transferred from the flame by convection.

Since hot water is less dense, and hence lighter than cold air, it rises to your hand, bringing heat with it.

EXPERIMENT NO. 19 COLD AIR DROPS
Hold your hand over, and then just under an ice cube. Notice that your hand feels colder when it is beneath the cube. Cold air from the ice cube tends to move downwards, since it is heavier than the surrounding air.

EXPERIMENT NO. 20 THE WEATHER IN A CASSEROLE **
When talking about solar energy, it is important to remember how the sun influences the air around us. The sun heats the air and thus, causes it to rise; the air descends as it cools, and this is what is responsible for the weather. Here is an experiment where you should be able to see how this happens. If you can find a white ceramic casserole or a pyrex dish that is made to be heated on a gas ring or hot plate, you can make a visible model of the weather.



Take a dried up felt-tipped pen. Open it by breaking it or by cutting it, and you will notice the cartridge inside. Using a pair of scissors, cut off a few pieces of this cartridge. See whether they float on water. If they do not, hold them under water. After a short time, they will sink.

Now take the casserole dish and fill it with water. Place it on top of an unlit stove. Take one segment from the ink cartridge and place this onto the middle of the casserole. Wait a few minutes and you will see that the ink emerges from the cartridge segment. As yet, the ink does not mix with the water. It makes at first two colored pools below the water's surface.

Now, heat the casserole carefully at "low heat" and see what happens. The colored bands demonstrate how hot air rises in the atmosphere and cool air sinks. It shows how winds and cyclones are produced.

The windiest place in the world is Antarctica, but it can get quite windy in other places as well. Winds with a speed of over 220 miles per hour (350 km per hour) have been recorded. Winds can cause a lot of damage, but they can be useful. In Holland and other countries, the wind is used to drive windmills. Research is underway to use the wind to make electricity. This would be a much cleaner method for electricity production, and would avoid the pollution produced by usual power stations. In California, there are extensive experiments in wind generation. You use a fan to make "artificial" wind to cool you when you are hot.

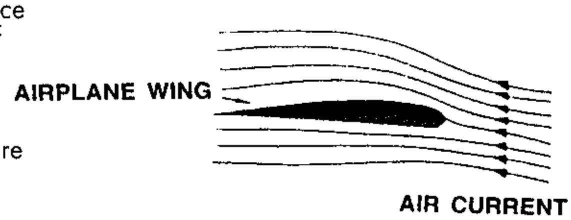
EXPERIMENT NO. 21 CONVECTION IN OUR HOME

In homes, as everywhere else, hot air rises. Examine the temperature of a house with several stories on a hot day. Notice the striking difference between the warmth of an attic or upper floor and the relative coolness of a basement.

EXPERIMENT NO. 22 BERNOULLI'S PRINCIPLE

The Swiss mathematician Daniel Bernoulli developed the idea that when a fluid (gas or liquid) is moving, it exerts a lower pressure as it moves faster.

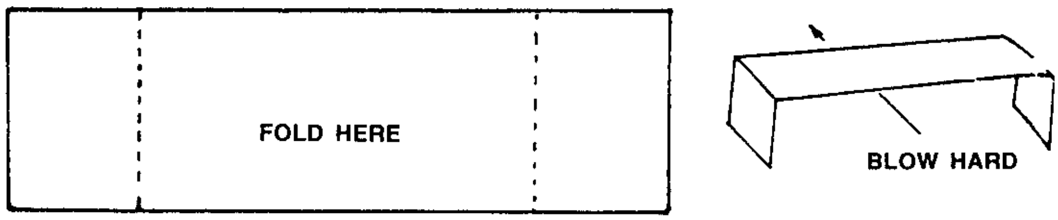
An airplane wing is designed to take advantage of this phenomenon. The shape of the wing is such that air traveling over the top of the wing must travel a longer distance than the air travelling across the bottom of the wing. Since the air must travel faster over the top of the wing, it exerts a lower pressure on the top of the wing than the slower air at the bottom. The higher pressure on the bottom of the wing gives the plane the "lift" it requires for flight.



Take a small sheet of tissue paper. Hold it to your lips and blow hard across the top surface of the paper. The air moving across the top surface creates an area of lower pressure, so the air pressing from below pushes the sheet upwards.

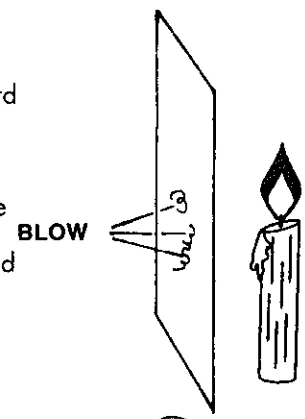
EXPERIMENT NO. 23 WHAT HOLDS IT DOWN?

Copy this illustration onto a piece of thin cardboard. Fold it as shown in the diagram along the dotted lines. You have constructed a "bridge." Blow hard underneath the "bridge." Try to overturn it with your breath. The harder you blow, the more it is pulled to the table! Why is this?



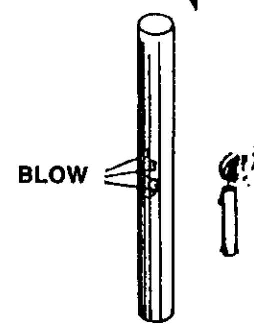
EXPERIMENT NO. 24 HOW CAN THAT BE? **
Place a lit candle behind a flat strip of cardboard or a ruler. Blow hard against the card in the direction of the flame. The flame moves <u>towards</u> the card!

Air turbulence caused by the flat surface of the card will pull the flame towards the card. Take care not to set the card on fire! (You could perform this experiment using a bit of glass or metal instead of the cardboard.)



EXPERIMENT NO. 25 STREAMLINED BROOM HANDLE **
Repeat the previous experiment, but this time use a round object such as a broom handle or round cardboard tube. Blow hard against this in the direction of the flame.

This time the streamlined shape offers little resistance to the airflow. The flame moves away from the broomstick in the direction of your breath.

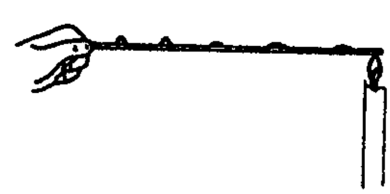


EXPERIMENT NO. 26 RATE OF CONDUCTION
Take a small pan with hot, but not boiling water, put spoons made of various materials. You will probably be able to locate spoons of stainless steel, silver, plastic and possibly wood.

Leave the spoons in the pan for about one minute and then touch each of the spoons; the silver spoon will be the hottest and the wood the coolest. The spoon made of the best conducting material will heat up fastest.

EXPERIMENT NO. 27 COPPER IS A GOOD CONDUCTOR **
Hold the copper wire that you used earlier at one end, and place the other end in a flame. You will find, in a matter of seconds, that the heat of the flame is transferred throughout the wire to your hand. This form of heat transfer is called **CONDUCTION**. The copper wire conducted the heat to your hand. Be careful not to burn your fingers!!!

EXPERIMENT NO. 28 WE "SEE" HEAT TRANSFER **
Put drops of candle wax several centimeters apart along the copper wire. Hold one end of the wire in the flame of your candle. As the wire slowly heats up, you can "see" the heat moving along the copper wire from one drop of wax to the next.



EXPERIMENT NO. 29 CONDUCTION RATE **
Repeat the previous experiment with the length of a knitting needle or a long nail. Try this again using your test tube instead of the wire. Note how poor glass is as a conductor of heat - so poor that it is classified as an insulator.

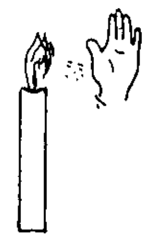
EXPERIMENT NO. 30 RADIATION OF HEAT

The average distance between the earth and the sun is approximately 150,000,000 kilometers and the temperature in this vast, empty space is extremely cold. Being dependent as we are on the sun, how do we manage to survive? Obviously, the sun's heat does not reach us either by conduction or by convection.

Heat can move through the vacuum which exists between the earth and the sun by a third process of heat transfer called radiation. Heat radiation travels in rays, through space, in the same way light does.

Heat radiation is also known as infra-red light. All sorts of electromagnetic radiation travel through space; these include radio waves, X-rays, light waves and the infra-red.

EXPERIMENT NO. 31 RADIATION **



Hold your hand near the flame of a candle and feel the heat. This heat is transferred from the flame to your hand in waves very similar to light waves, which disperse in all directions. The transfer of heat by the dispersion of waves is called radiation. Your home may have radiators which warm the room by radiating their heat.

EXPERIMENT NO. 32 RIGHT THROUGH SOLID GLASS

You have no doubt sat behind a glass window, on a sunny, cold, clear, winter day and felt the heat of the sun. The sun's rays can radiate through any clear medium, be it the extreme vacuum of outer space, the glass of your window, or a clear ice cube.

On the next opportune day, when the above conditions occur, record the temperature on both sides of the glass. The glass transmits practically all of the solar radiation, reflects some back, but absorbs very, very little. On the other hand, the glass effectively blocks in most of the longer "infra-red" radiation that the interior of the room radiates.

This principle of heat transfer is very important in designing various solar energy devices. It allows us to use sunshine, on bitter cold days, to produce and store heat.

EXPERIMENT NO. 33 A HOT CAR

Try to get help from cooperative adults for this next experiment. Let the owners of two similar cars, one dark and one light colored, park their cars in the sun at the same time. Close all the windows and doors in the car and measure the temperature in each. They should be practically identical. Take a temperature reading in each car every 10 minutes. Record your findings. When the sun's rays strike the cars a lot of heat is absorbed by the metal exterior. The amount of heat is dependent, to a great extent, on the color and texture of the surface of the car. Rough black surfaces such as cars with a matt, vinyl, black roof will absorb considerably more than shiny, white ones.

The rays passing through the glass windows (radiation) are absorbed by the interior parts of the car. The parts of the cars that are not in the direct path of the sun's rays are heated by conduction, convection and re-radiation of the car parts heated directly by radiation. As the car absorbs heat, its temperature increases. As the temperature of the car increases it begins to increase the amount of heat that it radiates outward until a balance is reached when the rate of heat absorbed by the car equals the rate radiated from the car.

EXPERIMENT NO. 34 WHITE IN THE SUN

Place two glasses filled with cold water in sunlight or near an electric space heater. Wrap one glass with a white sheet of paper and the other with a black sheet of paper. Measure the starting temperature of the water in each glass and then after half an hour.

The water in the glass covered with black paper will absorb heat radiation and be warmer than the one covered with white paper. Perhaps it will be easier for you to understand now why people wear light colored clothing in summer and why heat absorbers are matt black.

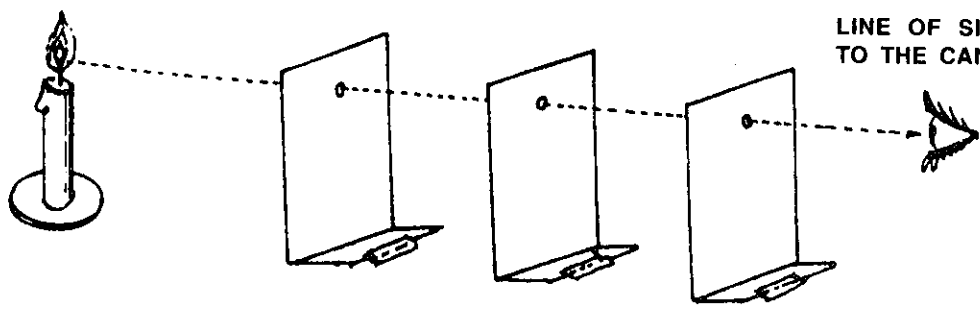
LIGHT RAYS

Light is created when a substance is heated to a temperature at which its atomic activity generates bundles of energy called photons. A light ray is a stream of photons. A group of light rays form a beam of light. The entire beam of light is not visible to the human eye. We can see the "visible" portion of the ray from the red to the violet but the ray extends beyond the violet to the ultraviolet and beyond the red, at the other end, to the infra-red. Sunlight, or solar energy reaches us via light rays. In a vacuum, light rays travel at the remarkable speed of 299,729,500 meters per second.

EXPERIMENT NO. 35 BULL'S EYE **

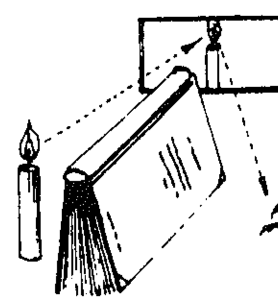
Remove the three cards from the cut-out sheet marked A I, A II, and A III. With a pin, pierce through the card at the dot in the middle of each card. Fold the cards along the dotted lines. The cards will stand upright if you place small weights on the folded flaps.

Align the three cards as shown in the diagram. You should be able to see the candle flame when you look through the holes of all three cards. If you move any one of the cards even slightly in any direction, you will no longer see the flame because the straight line of sight will have been broken. Light rays travel in straight lines only.



EXPERIMENT NO. 36 REFLECTED LIGHT **

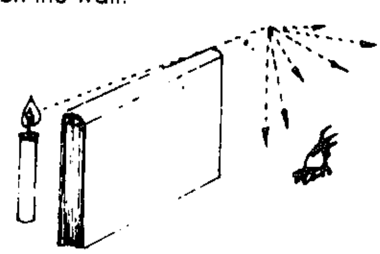
Set up the candle and a mirror on a table so that they stand about 30 cm (12 in) apart. Now hold a book so that it blocks your view of the candle. Look in the mirror. You can see the candle!



The light produced by the flame of the candle is not traveling directly to your eyes. It is being reflected off the mirror. The path of the light beams from the flame to the mirror, and from the mirror to your eyes is still in straight lines.

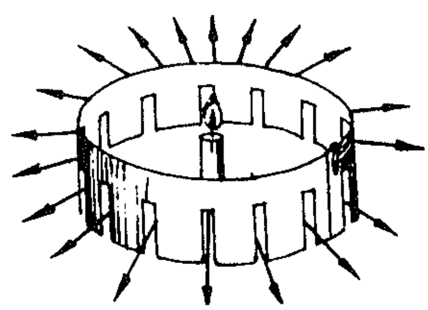
EXPERIMENT NO. 37 LIGHT DIFFUSION **

Light a candle in a darkened room. Stand it near a wall and hold a book between the flame and your eyes. You will see a small illuminated area on the wall.



The surface of a wall is quite rough compared to the extremely smooth surface of a mirror. The roughness causes the light striking the wall to be reflected in all directions. This type of reflection is called diffusion. Diffusion of light is essential to vision. We can see things because they reflect and diffuse light. If a surface did not diffuse light we would have a hard time defining that surface; all we would see is a reflection of the light source. If the surface were to absorb all the light, it would appear to be black.

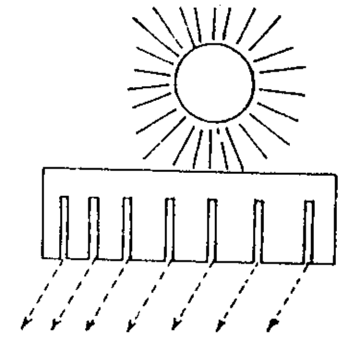
EXPERIMENT NO. 38 DISPERSION OF LIGHT **



Remove strip "B" from the cut-out sheet. Connect the two ends of the strip with a paper clip to form a ring. Place this ring, with the slits at the bottom, on a table. Place a short, lighted candle in the center of the ring. Take care that the paper does not come too close to the candle. You will notice light rays coming through each of the slits in the ring. Each light ray extends in a straight line from the candle flame through and beyond each slit.

Light rays disperse uniformly in all directions. The rays of light diverge, that is, they get further and further away from each other the farther they are from their source.

EXPERIMENT NO. 39 SUN'S RAYS APPEAR PARALLEL

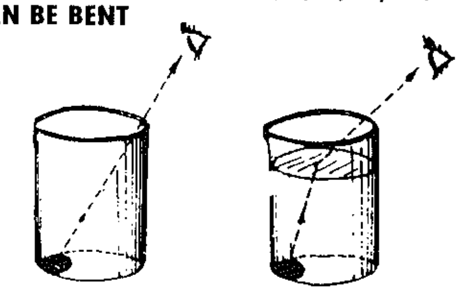


Cut out the shaded area of the strip used in the previous experiment. Hold it flat and let a ray of sunlight shine through the slits. Notice that the rays are parallel to each other. They do not seem to diverge.

Due to the immense size of the sun and its enormous distance from us, the sun's rays reaching the earth are, in effect, parallel. Their divergence becomes a factor only when they are considered on the scale of the entire universe.

EXPERIMENT NO. 40 LIGHT RAYS CAN BE BENT

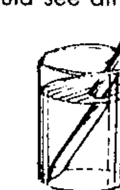
Place a coin at the bottom of an empty glass. Continue looking at the coin while you move your head away. Move away until you can see only a small part of the coin. S-l-o-w-l-y, and without moving your head, pour water into the glass. As the glass fills with water the rest of the coin will gradually appear! Why?



EMPTY GLASS FULL GLASS

Light is "bent" when it passes from one medium, such as air, to another, such as water. Scientists call this "bending" effect refraction of light. When you looked at the coin in the empty glass you could see only a part of it, but once the light rays were bent by the water, you could see all of it.

EXPERIMENT NO. 41 LIGHT REFRACTION

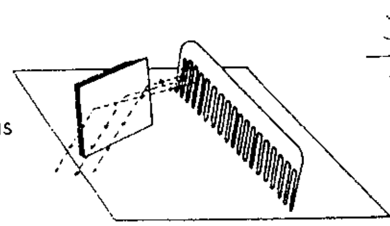


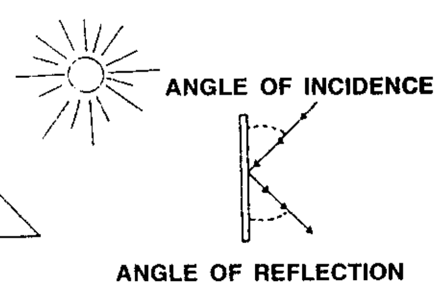
Place a pen in a glass half filled with water. Observe the pen from the side. It appears to be "broken" at the water line. This "break" is caused by the refraction or bending of the light rays as they pass from the water to the air.

EXPERIMENT NO. 42 ANGLE OF REFLECTION EQUALS ANGLE OF INCIDENCE

Hold a comb on a piece of white paper so that its teeth cast a long shadow in the sunlight. Place your mirror diagonally in the path of the light rays passing between the teeth. The beams of light reaching the mirror are reflected at exactly the same angle as that at which they reach the mirror.

Turn the mirror gradually to vary the angle. Note that the angle between the mirror and the reflected light ray (angle of reflection) is always the same as the angle between the mirror and the original light ray (angle of incidence).





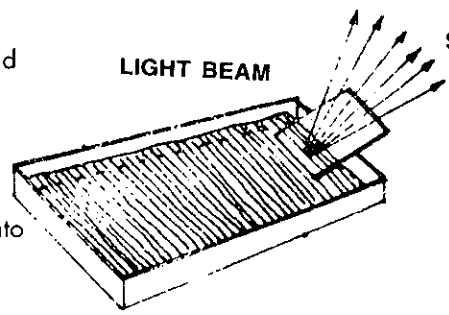
THE COLOR OF LIGHT

EXPERIMENT NO. 43 MAKE A PRISM

Ordinary white light is a mixture of many colors. It is possible to break up white light into its various color components. To separate the colors of white light you can use a homemade prism.

Lean a mirror against the edge of a tray or deep saucer filled with water. The area of water enclosed between the mirror and the surface of the water has a triangular shape. This shape is one of the characteristics of a prism.

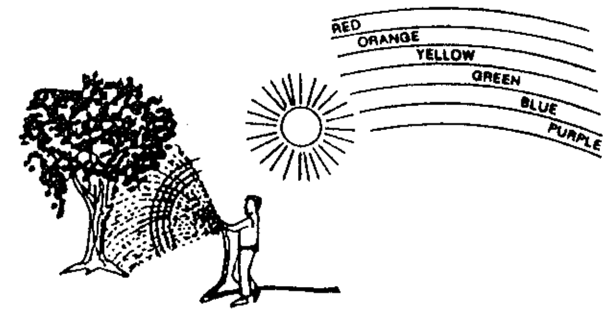
To try out your homemade prism first adjust a window blind so that it lets in only a narrow band of light. (A narrow band of light is the best kind of light source for a prism. Obviously you must do this on a sunny day!) Next, adjust the prism so that the band of light reflects off the mirror. Look at the ceiling. You should see a color spectrum. The prism separated the white light into its color components. A flashlight shining on the mirror will produce a weaker spectrum.



EXPERIMENT NO. 44 A RAINBOW

Water droplets in the atmosphere act like prisms to form a natural rainbow. You can also produce a rainbow.

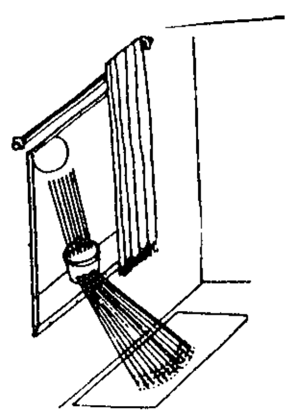
In early morning or late evening, stand with your back to the sun and spray water from a garden hose against a dark background such as a row of trees.



EXPERIMENT NO. 45 THE SPECTRUM

There is a very simple way of producing a spectrum. Fill a glass full of water and place it on a brightly lit window sill on a sunny day. Place the glass so part of it projects a bit over the inside edge of the sill. Now place a large piece of white paper on the floor directly under the glass. Observe the spectrum which appears!

NOTE: The success of this experiment depends on certain specific conditions of the sun. So try this at various times of the day in order to catch the sun at different heights in the sky.



EXPERIMENT NO. 46 LIGHT RAYS HAVE NO COLOR

Observe the path of the white light striking your prism. Then, observe the path of light emerging from the prism which forms the spectrum. Notice that you cannot see color in the light as it comes from the prism. Light rays themselves have no color; the color becomes visible only after they have been reflected to the eyes. Place a sheet of white paper in the path of the rays from the prism and observe the spectrum on it.

EXPERIMENT NO. 47 JUST BEYOND RED

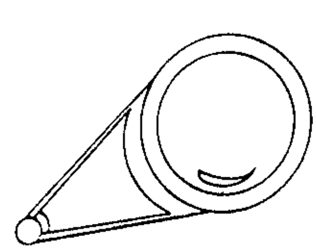
In the section on light we learned how to make various prisms. Build the prism with which you were most successful in obtaining a good spectrum. Take a careful temperature reading in the light spectrum and then place the thermometer just beyond its red end - where the invisible infra-reds are thrown by the prism. Your temperature reading will increase.

CONCENTRATED INFRA-RED

The infra-red radiation behaves like light rays and like them can be concentrated by our lens. Place your lens in the infra-red region of your spectrum and concentrate them on your thermometer bulb. Even though you do not see the bright spot that you see when concentrating light rays, the concentrated infra-reds produce more heat.

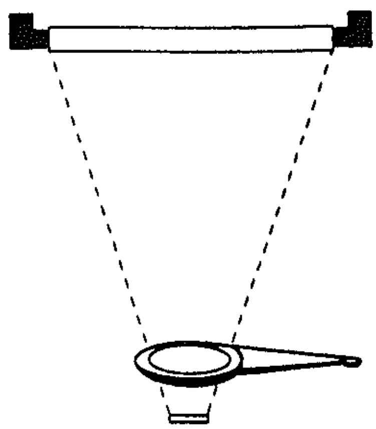
EXPERIMENT NO. 48 A SCIENTIFIC EXAMINATION OF A MAGNIFYING GLASS

The lens enclosed in your kit is a 20.0 mm diameter double convex converging lens with a focal point of 50 mm. Hold your lens over any letter E in this manual. As you increase the height of the lens over the letter E, the letter grows and grows until a point is reached where the image seems to become blurred. You have passed the focal point. Try to find the F.P. Is it really 50 mm? All parallel light rays striking our lens on one side will meet at a single point exactly 50 mm on the other side of the lens. Try it by focusing the light of a table lamp through the lens onto a sheet of paper. You see the light as a single point. The distance between the lens and the point of light (F.P.) is the focal length of your lens.



EXPERIMENT NO. 49 CONCENTRATED ENERGY

A converging lens focuses all the energy received on its surface to a considerably smaller area than the area of the light source. You can visualize this relationship with a simple experiment. Reflect the light from a florescent light through your lens onto a piece of paper. A clear and reduced image of the florescent light appears at the focal point. This reduction shows how the energy is concentrated on a smaller area.



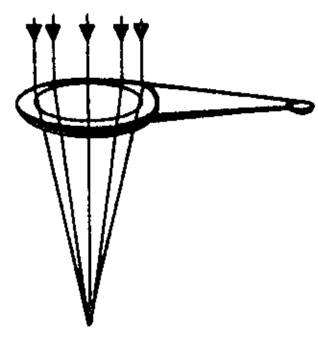
Our lens has a surface area of approximately 300 square millimeters. If we focus our lens on an area of 1mm square, that area receives 300 times the energy per mm that reaches the lens. If our lens receives 1 calorie of radiant energy per mm, then the focal point of our lens would receive 300 calories per mm. This concentration of energy increases the temperature of the object placed at the focal point. While the total energy involved has not increased, the effect of the energy is localized, resulting in higher temperatures at the focal point.

EXPERIMENT NO. 50 CONCENTRATED HEAT

In a normally lit room, place the bulb of your thermometer at the focal point of your converging lens. Record the temperature at the start and after 5 minutes. Was there any noticeable change? Now take your lens and thermometer outdoors and in sunlight. Place the bulb of the thermometer again at the focal point of your lens. Record the temperature at the start and see how long it takes your thermometer to reach 125°F. Be sure to remove your thermometer at that temperature.

EXPERIMENT NO. 51 MAXIMUM TEMPERATURE

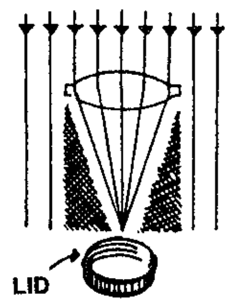
We will try to determine the highest temperature we can achieve with our lens. Put your lens and holder in bright sunlight and place various objects at the focal point of the lens to determine the highest temperature we can achieve.



Start with wax. We know if we melt wax, the wax reached a temperature of 54°C or more. If we can boil a drop of water, and we know that the boiling point of water is 100°C, then our temperature must be more than that. You can look up in a chemistry handbook the melting points of various common items around your house to help you.

EXPERIMENT NO. 52 A LENSES' SHADOW
Try to locate a small bottle cap the same size as your lens. Fill the cap with water. Place it in direct sunlight for 10 minutes. Measure and record the water temperature at the beginning and end of the time period.

Now start again. Place an equal amount of water in your bottle cap. Make sure the water is at the same starting temperature as before. This time place the water in sunlight with the lens in front of the cap and the water at the F.P. of the lens. Compare the temperature of the water after 10 minutes with the results of your previous try - they should be very similar. When the lens is placed in front of the water in the bottle cap the concentrated rays converge on a small area of the water. The surrounding area will be in the shadow of the lens, so it does not receive the energy that is being gathered by the lens. The total amount of heat received remains the same.



If the area of the body of water is smaller than that of the lens, then the water will receive more energy and the lens can be thought of as a collector.

EXPERIMENT NO. 53 CHARRING PAPER
Place your lens in bright sunlight with a white piece of paper at its focal point. Can you char the paper?

If the sun is bright enough, you may be able to char it. It will char best right at the edge of the paper. The white paper reflects most of the sunlight and solar heat. Even though the solar heat is concentrated at a small point the paper barely, if at all, reaches its kindling point.

EXPERIMENT NO. 54 DARK COLORED PAPER CHARS EASIER
Replace the white piece of paper in the previous experiment with a dark colored, matt paper. Now it chars much better! The dark colored paper absorbs most of the concentrated sunlight and heat so the paper reaches its kindling point more easily.

MIRRORS

One of the major problems encountered in trying to harness solar energy is that the sun does not stand still. We must constantly redirect sunlight. The most effective way to redirect it is by using mirrors; in fact, mirrors are used extensively in practically all solar projects.

EXPERIMENT NO. 55 LEFT - RIGHT
Stand in front of a mirror and scratch your right ear with your right hand. Notice that in the mirror you appear to be scratching your left ear with your left hand.

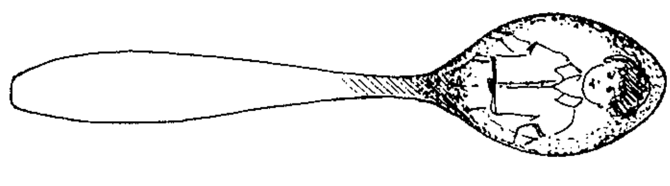
Mirror images are laterally inverted, they transpose right with left and left with right.

EXPERIMENT NO. 56 WHITE DIFFUSES BEST **
Affix the candle to a table. Cover the back of a piece of glass with a sheet of white paper. (You can use a window pane, a glass plate, or a glass shelf.) Make sure that the distance between the glass and the candle is about 30 cm (12 in). Put a pen between the glass and the lighted candle. The image of the pen in thé glass appears very unclear.

Now repeat the experiment, but this time use a black piece of paper to back the glass. Now the image of the pen is much clearer. The black paper diffuses much less light than the white paper does, so the image is clearer. This may remind you of the times you have walked past a store window and noticed your reflection in the glass.

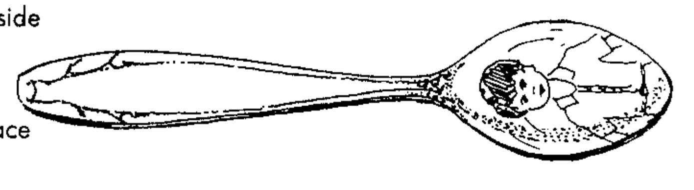
EXPERIMENT NO. 57 CONVEX MIRROR

Examine the outward curving, back surface, of a shiny soup spoon. An outward-bulging reflecting surface is called a convex mirror. Notice that when you look at your reflection on this surface your image is reduced in size. A convex surface reduces the size of a reflected image.



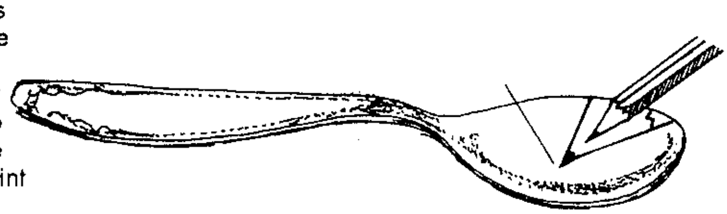
EXPERIMENT NO. 58 CONCAVE MIRROR

Now examine the inward-bulging, inside surface of the spoon. This is a concave mirror. Notice that your reflected image is reduced and inverted. A concave reflecting surface reduces and inverts an image of an object not close to its surface.

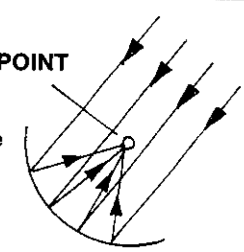


EXPERIMENT NO. 59 MAGNIFYING MIRROR

Hold the point of a pencil very close to the concave surface of a spoon. This time the spoon will reflect and enlarge the image of the pencil point. The image will be right side up. An object closer to the concave surface than to the focal point of that surface will be enlarged by the mirror. The focal point of a concave surface is the point in midair where all parallel rays reflected off the surface will converge.



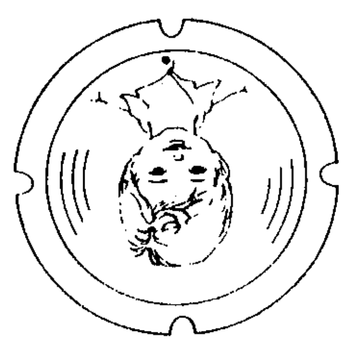
FOCAL POINT



Take a look around the house. Do you have a shaving or make-up mirror? Is this mirror concave or convex? Can you figure out where the focal point is?

EXPERIMENT NO. 60 BEAUTY IS IN THE EYES OF THE BEHOLDER

Look at your face in the solar reflector. Move your face close to the reflector, and then move it further away. Aren't you beautiful? When will the next beauty contest be held?

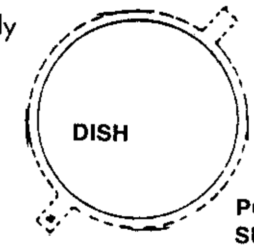


SOLAR FURNACE

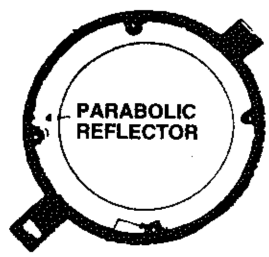
The purpose of our solar furnace is to concentrate the sun's rays into a small area and so increase its heat output to a level where it becomes useful to us.

EXPERIMENT NO. 61 BUILDING OUR SOLAR FURNACE **
ADULT SUPERVISION IS NECESSARY FOR THIS EXPERIMENT!

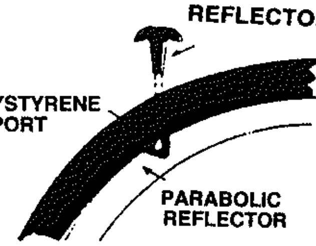
To build your furnace, carefully use a craft knife to slowly separate the part of the polystyrene tray where the test tube and other parts were stored. The dotted line in the following diagram indicates where to cut. The parabolic base is ready for use.



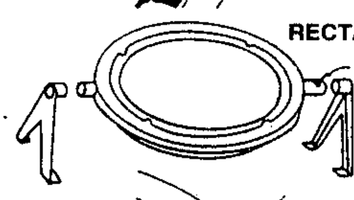
Using the tip of your pencil, make four small holes in the polystyrene cavity. Look at the drawing so that you will know exactly where to make the holes. Lay your parabolic reflector in the dish and align it so that the four cutouts at the edge of the dish are over the four small holes in the polystyrene support.



Push a reflector pin into each of the small holes so that the pin head presses and holds the parabolic reflector in place.



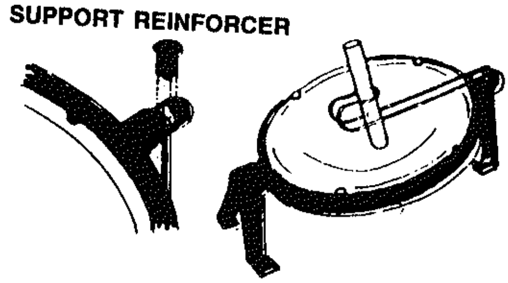
Slide the reflector legs onto the protrusions in the polystyrene support as shown in the following diagram.



Be sure to push both legs in as far as they can go.
One of the protrusions in the polystyrene support has a rectangular hole in it. Be sure that this is completely on the outside of the reflector leg.

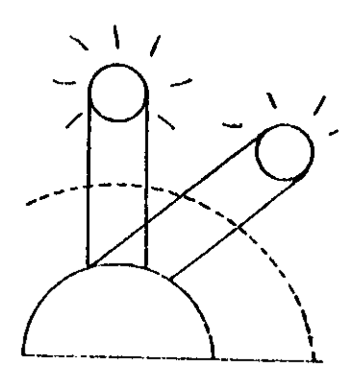
Push the support reinforcer until its "half circle" head is laying on the polystyrene protrusion. Insert each of the two wire ends of the test tube holder into each of the holes in the support reinforcer.

Place the test tube into the test tube holder as shown in the diagram. If the supports become loose at the edges after use, you can add some cellotape to keep the apparatus sturdy. Save the rectangular tray for later experiments.



EXPERIMENT NO. 62 USING OUR SOLAR FURNACE

To concentrate heat, your solar furnace must face the sun. It is constructed in such a way that the parabolic reflector and its styrofoam support can be tilted so that you can point the reflector directly at the sun.



You'will achieve the best results in your experiments with the solar furnace if you try them when the sun is directly overhead. This is due to the fact that the sun's rays are strongest when they strike the earth at an angle of 90°.

When the sun is directly overhead, its rays travel the shortest possible distance before they reach you. Rays that strike your reflector at a greater angle (when the sun is not directly overhead) are weaker since they travel a longer distance through the earth's atmosphere.

As the rays travel from the sun, the atmosphere of the earth absorbs some of their heat. If the rays travel a longer distance, they lose more heat. In addition to that, when the sun's rays strike the ground at an angle, they cover a greater area and less heat is available than when the sun is overhead.

<u>Remember:</u> A breeze will effect your experiments, too. Any wind will cool the items while you are trying to heat them. Needless to say, on a cloudy day you will be unable to perform these experiments.

EXPERIMENT NO. 63 DETERMINING THE FOCAL POINT

<u>USE SUNGLASSES WHILE PERFORMING THIS EXPERIMENT!!</u>

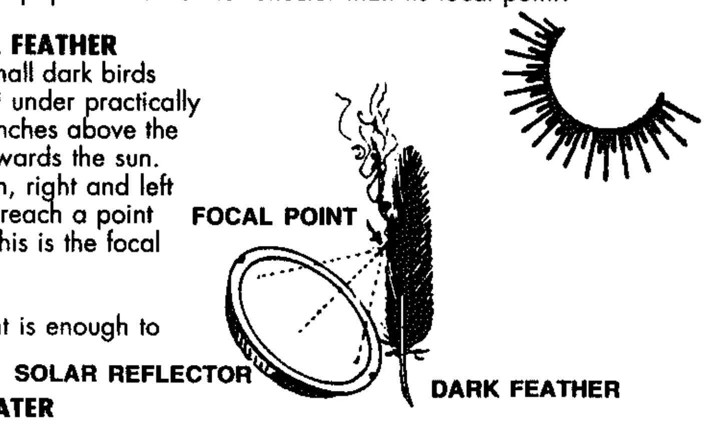
The focal point of our parabolic reflector is located 6 cm above its deepest place.
Place your solar furnace in sunlight. Take a white sheet of paper and slowly move it towards the reflector. As the sheet approaches the focal point of the reflector you will begin to see a circular bright spot. The closer you get, the smaller the spot becomes. At the focal point it is quite small. At this point our solar furnace will be the most effective.

The focal point is the point in mid-air where all the light hitting our parabolic reflector is reflected upon. What happens as you move the paper closer to the reflector than its focal point?

EXPERIMENT NO. 64 BURNING A FEATHER

For this experiment, you will need a small dark birds feather which you can most likely find under practically any tall tree. Hold this feather 2 - 3 inches above the reflector with the reflector pointing towards the sun. Move the feather a little up and down, right and left (horizontally and vertically), until you reach a point where the feather begins to smoke. This is the focal point.

At this point, the concentrated sunlight is enough to singe the feather.



EXPERIMENT NO. 65 BOILING WATER

Place a drop of clean water in the test tube and put the test tube into its holder in the solar furnace. Place the furnace in sunlight and determine how long it takes for the water to boil. Be sure that the focal point of the reflector is in line with the water.

Repeat the experiment with an equal amount of water but this time add some dark food coloring, water color or plain ink to the water. Does it boil faster? Can you explain why?

EXPERIMENT NO. 66 BREWING TEA
Place a few tea leaves (less than 1/4 teaspoonful) into a test tube and add enough water to half fill it. Fit this into the solar heater. See how long it takes to brew yourself a "cup of tea". Never drink directly from a test tube.

EXPERIMENT NO. 67 MELT A CANDLE
Insert a small candle into the test tube and bring it into the F.P. of the reflector. The candle will melt.
NOTE: In this experiment you will dirty the test tube with molten wax and it will be difficult to clean. To do so you need soap, hot water and a test tube cleaner. You can make one by wrapping a little steel wool around a pencil or suitable stick.
CAUTION: The test tube is fragile. Clean it carefully.

EXPERIMENT NO. 68 CAN YOU COOK AN EGG? (THE EGG WHITE)**
Take an uncooked egg and separate the white from the yolk. Keep the yolk for the next experiment. Pour some of the egg white into the test tube. Bring this into the F.P. of the solar heater. Can you cook the egg white? How long does it take to make it hard?

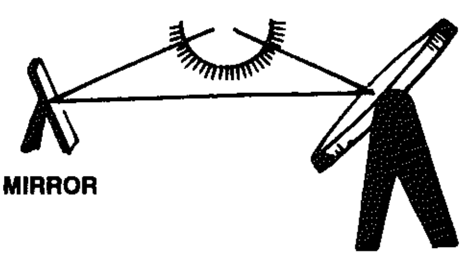
EXPERIMENT NO. 69 CAN YOU COOK AN EGG? (THE YOLK)**
Now comes the turn of the yolk to be heated. Does it take a longer or a shorter time to cook?

EXPERIMENT NO. 70 FRYING AN EGG**
Form a small plate out of a piece of aluminum foil and place it on your test tube support in the solar furnace. Break an egg into the aluminum foil plate and place the furnace in the sun. Be sure that the focal point of the reflector falls just above the plate. Try to fry the egg. If the sun is sufficiently bright and you are sufficiently patient you might succeed. If you are less patient, using your candle, blacken the outside of the aluminum foil and try again.

Try roasting a marshmallow. Its clean white color will reflect practically all the rays hitting it and it will hardly warm up. Solar energy is used in remote areas of the world for cooking. While no great hope in energy savings is being held for solar ovens, it is important for us to understand this principle.

When ideal conditions exist you will be able to cause a piece of black cloth material to smolder with your solar oven by simply placing the the material in the test tube holder so that the focal point of the parabolic reflector falls on it.

EXPERIMENT NO. 71 A LITTLE OUTSIDE HELP
The solar reflector faces the sun. It collects all the sunlight that falls on it and concentrates it at the F.P. What would happen if you reflected some additional sunlight by means of an ordinary mirror or even several mirrors? Can you increase the heat at the F.P. significantly?



EXPERIMENT NO. 72 WONDER IN A TEA GLASS
The lens enclosed in your kit is a 20.0 mm diameter double convex converging lens with a F.P. of 50 mm. The distance between the lens and the point of the light (F.P.) is the focal length of your lens.

All we have written here is true and very important, but why take our word for it? You can actually see this by the following fascinating experiment. Take a tea glass and fill it with water, then add three drops of milk. After stirring, the water should be "milky," but still perfectly transparent.
Take the glass to a sunlit spot indoors or outdoors. Place the magnifying glass near the top of the glass as shown in the illustration. Look through the side of the glass. Interesting, isn't it?

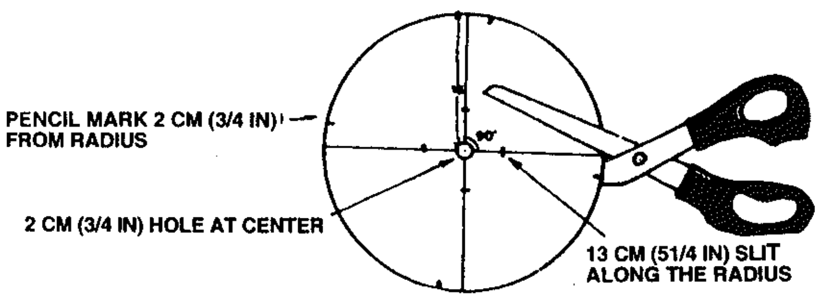
EXPERIMENT NO. 73 CHINESE HAT TRICK

Cut out a circle with a diameter of 30 cm (12 in) on another piece of carton or stiff paper.

Stick some aluminum foil onto this disc just as you did when making the first solar trap.

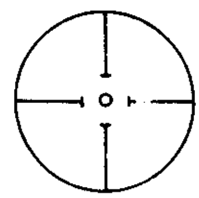
Step 1: Bisect the circle by drawing a line through its middle.

Step 2: Bisect this line by drawing another line through the middle at right angles to the first.



Step 3: Cut along the four lines from the outside of the circle towards the center, but stop cutting 2 cm (3/4 in) before you reach the center.

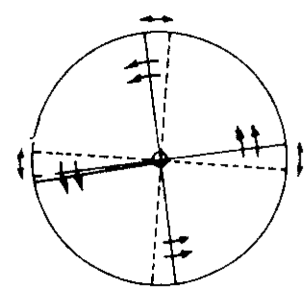
Your disc should now look like this:



Now punch a 2 mm hole at the center of the disc.

Measure and mark a point 2 cm (slightly less than 1 inch) to the right of each slit and overlap the two sides of the slit so that the one side comes to lie on the other, at the point you mark.

Do this with every slit and fasten it with glue, tape or staples.

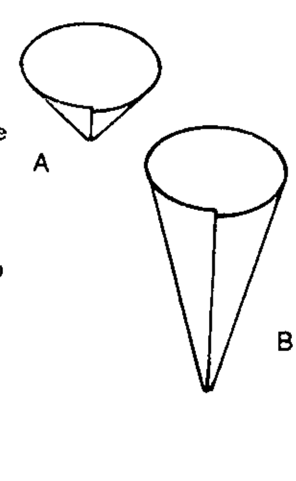


You have made something that looks like a Chinese hat. This is your solar reflector. Of course, the silver paper must be inside! Go out into the sunlight and try it out.
Compare it with the solar reflector that comes with this kit.

EXPERIMENT NOS. 74 - 76 ALTERATIONS AND VARIATIONS

This experiment is not one, but many experiments.
It all depends on how interested you are in learning more about solar energy. You could make two more solar traps: One half the size described here, the other twice the size.

Similarly, you could mqke a bigger and smaller solar reflector (Chinese hat) and compare them. Of course, the larger the reflecting surface, the more energy can be collected and concentrated.



However, it is not only the amount of surface area that matters. What would happen if you changed the angle of the solar trap? You could change the angle of the solar trap as illustrated in A or as in B. At what point within the conus is the heat at its greatest? What would happen if you overlapped the lips of your slit in the solar collector more than 3cm or less?

EXPERIMENT NO. 77 SOLAR HEAT CAN BE CONCENTRATED

Here again you MUST wear sunglasses. Leave your thermometer in direct sunlight and record its temperature reading. Now place it with its bulb at the focal point of your parabolic reflector and watch the temperature reading climb. Be sure to remove the thermometer tube before the reading reaches 125°F(55°C).

In this experiment all the solar heat striking the entire surface of the reflector is concentrated on the thermometer bulb and the heat at that point is intense.

Around 200 B.C., Archimedes devised a system of mirrors that concentrated the sun's rays on the sails of enemy ships at Syracuse and succeeded in burning the entire fleet.

EVAPORATION - CONDENSATION

EXPERIMENT NO. 78 CHANGING A LIQUID TO A GAS **

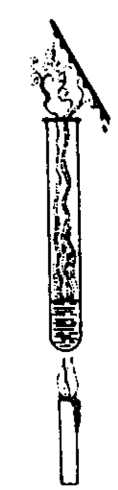
The sun provides the earth with 30,000 times more energy than we are presently using from fossil fuels and 23% of that enormous amount of solar energy, thousands of trillions of kilowatt hours of energy, are used in the evaporation and condensation of our oceans and lakes to provide us with rain, dew, snow, etc.

Let's try this out in our laboratory and see how it works. Boil some water in a test tube. As you heat the water in the test tube it changes from a liquid to a gas. You can see water vapor (water in gas form) escaping from the top of the test tube. The level of water in the test tube drops as more and more of the water turns into water vapor.

The changing of a material from its liquid state into the gaseous state is called evaporation.

EXPERIMENT NO. 79 CHANGING A GAS TO A LIQUID **

As the water in the previous experiment boils, hold a sheet of glass over the top of the test tube. Be careful not to scald your fingers. The water vapor hits the glass as it escapes from the test tube. Since the glass is relatively cold, it cools some of the water vapor sufficiently to change it back into the liquid state and water droplets form on the glass.



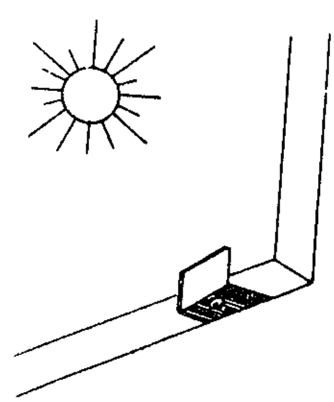
The changing of a material from the gaseous to the liquid state is called condensation.

EXPERIMENT NO. 80 THE GREAT VAPORIZER

Put two identical drops of water on a sunny window sill, about 10 cm apart. Shade one drop of water by putting your mirror between the drop of water and the sun. Observe the two drops of water: the one in the sun will evaporate considerably faster.

The rate of evaporation is directly related to the amount of heat that the liquid is receiving.

The sun, heating the surface of the oceans and lakes, evaporates enormous quantities of water which rise in the form of water vapor and forms into clouds. Condensation of the clouds produce rain. Throughout the ages we have used solar energy to preserve our food by drying it, to produce salts and other chemicals by evaporation, and to dry our laundry. We also need sunlight to grow our food.



EXPERIMENT NO. 81 EFFECT OF SURFACE AREA ON RATE OF EVAPORATION
Cover the bottom of a test tube with water and pour the same amount into a drinking glass. Leave them overnight and in the morning, measure the amount of water left in each.

Since a liquid evaporates only at its surface, the water in the beaker will evaporate faster than that in the test tube. The larger the exposed surface of the liquid, the faster it will evaporate.

SOLAR MOTION

EXPERIMENT NO. 82 APPARENT MOTION OF THE SUN
This next experiment should keep you busy all day long. Starting at sunrise, every half hour, mark off on the ground the shadow position of the tip of a convenient telephone pole. At sunset, line up the marks you made on the ground with the tip of the pole and extend them into space to determine the apparent motion of the sun around the earth.

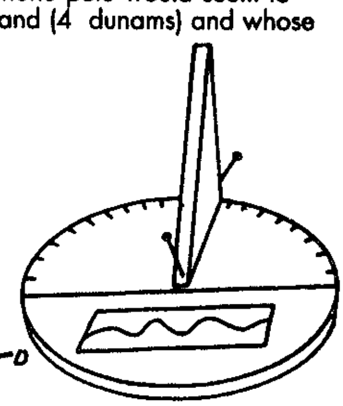
Not too long ago man believed that the sun revolved around the earth; to the human eye this appears to be true. In many solar energy experiments and for nearly all practical applications of solar energy we only concerned with the apparent motion of the sun in the sky.

SUNDIALS

Practically four thousand years ago people started using the apparent motion of the sun in the sky to tell time. They built instruments called sundials which cast a shadow on the ground. They indicated on the ground the time of the day in such a way that the shadow of the sundial's pointer pointed to the time of day at the correct time.

In the previous experiment, if you had marked the time that you had made each of the shadow markings on the ground. They indicated on the ground the time of the day in such a way that the shadow markings on the ground beside the mark itself, and if you would then return the following day at an unknown time you would be able to very closely approximate the time of day from the location of the shadow.

Don't be astounded by the apparent large size of sundial that your telephone pole would seem to be. In India, in 1724, a sundial was built that occupied over an acre of land (4 dunams) and whose pointer was over 100 ft. (30 meters) in height.

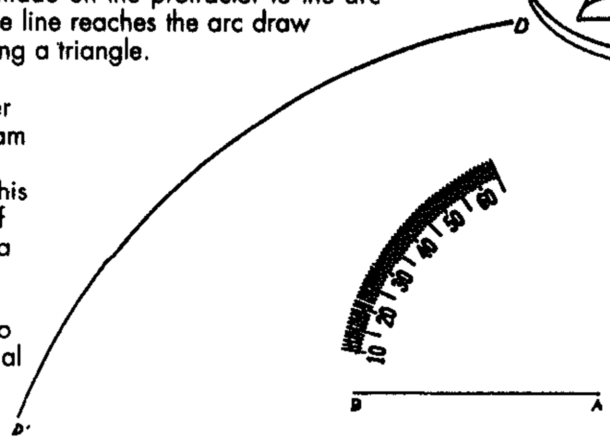


EXPERIMENT NO. 83 MAKING OUR SUNDIAL
Carefully cut out the circular dial from your cut out sheet and adhere it to a board or heavy piece of cardboard. Determine the latitude of the city you live by referring to the following table or to an atlas.

Mark on the protractor in the following diagram the latitude you determined for your city. Extend a line from point A through the mark you have made on the protractor to the arc D-D1. From the point that the line reaches the arc draw another line to point B, making a triangle.

Copy this triangle to a corner of cavity D of your styrofoam tray and cut it out carefully with a sharp hobby knife. This triangle will be the pointer of *our sundial* and is known as a "gnomon'.

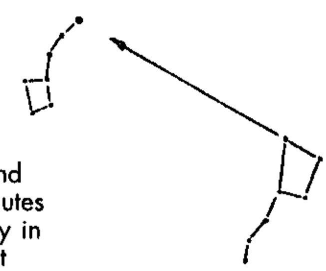
Carefully pin your gnomon to the shaded area of the sundial base.



LATITUDES

Amsterdam, Netherlands	52°22'N	Munich, Germany	48°08'N
Atlantic City, New Jersey, U.S.A.	39°22'N	New Mexico, New Mexico	34°30'N
Boston, Mass., U.S.A.	42°22'N	New Orleans, Louisianna	29°58'N
Chicago, Ill., U.S.A.	41°21'N	New York, N. Y., U.S.A.	40°43'N
Cincinatti, Ohio, U.S.A.	39°06'N	Oslo, Norway	59°55'N
Dallas, Texas, U.S.A.	32°47'N	Paris, France	48°52'N
Detroit, Michigan, U.S.A.	39°37'N	Pittsburgh, Pa., U.S.A.	40°26'N
Houston, Texas, U.S.A.	29°46'N	Rome, Italy	41°54'N
London, England	51°30'N	San Fransisco, Calif., U.S.A.	37°48'N
Los Angeles, Calif., U.S.A.	34°03'N	St. Louis, Mo., U.S.A.	38°38'N
Las Vegas, Nevada, U.S.A.	36°11'N	Tel Aviv, Israel	32°07'N
Memphis, Tenn., U.S.A.	35°08'N	Tokyo, Japan	35°42'N
Miami, Florida, U.S.A.	25°46'N	Toronto, Ont., Cañada	43°39'N
Milwaukee, Ill., U.S.A.	43°02'N	Washington, D.C.	38°54'N
Montreal, Que., Canada	45°30'N	Zurich, Switzerland	47°23'N

EXPERIMENT NO. 84 LOCATING THE NORTH STAR



To set up our sundial we will have to first locate the North Star - here is how it is done:

On a cloudless night, preferably when the moon is not too bright, find a darkened area from which you can view the sky. Wait a few minutes for your eyes to get accustomed to the darkness and look at the sky in the general "North" direction. Locate a grouping of seven stars that look like points along a "dipper" with a curved handle.

When you have located one such grouping, look around in the same general direction for another grouping of seven stars, again in the shape of a dipper with a curved handle. This time, the handle is curved in the opposite direction. The larger of these two groupings is the Big Dipper and the other is the Little Dipper.

Imagine a straight line connecting the two front stars of the Big Dipper (the stars that are the farthest away from the handle); extend this imaginary line towards the Little Dipper until it reaches the farthest star along the handle of the Little Dipper. That is the North Star.

Due to the seasonal changes in the location of the earth, the Dippers' apparent position seems to change constantly but the imaginary line from the two front stars of the Big Dipper will always point to the North Star. The North Star is the brightest star, and the only seemingly bright star in that general area. With a little effort you should not have any trouble locating it.

EXPERIMENT NO. 85 SETTING UP OUR SUNDIAL

Strange as it may seem, the best time to set up our sundial is during the night.
The gnomon must point North; and what better way is there of setting it up than by pointing it at the North Star. You could, of course, also use a compass to show you which direction is north.

Put the sundial where it would not be disturbed by passing people, but in a place sufficiently convenient that you can get to it easily enough when you want to tell the time. Of course, it should be a place where the sun shines from sunup to sundown.

Sight along the slanted side of the gnomon and line it up with the North Star. Find a way to fix the sundial in place so it does not move easily.

EXPERIMENT NO. 86 TELLING TIME

To tell time on our sundial simply note the number to which the shadow of the gnomon points. Take careful readings throughout the day and record them and the equivalent time on your watch. The accuracy of your sundial now, strangely enough, will be dependent on the particular date that you performed this experiment.

If, for instance, you performed this experiment around April 20th, June 15th, September 5th, or December 27th, you should be quite accurate. On the other hand, mid-February or early November are bad times.

EXPERIMENT NO. 87 SEASONAL ADJUSTMENT TO OUR SUNDIAL

To make our sundial useful to us all year round we will use the diagram on the bottom half of our sundial face.

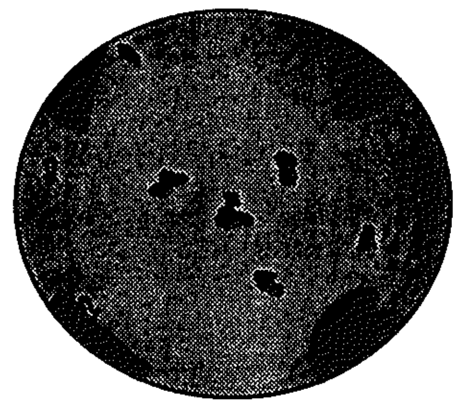
The sundial is simple to use; suppose it is March 15th. Draw an imaginary line at the middle of the March column. The point where the imaginary line meets the curved line is at +10 on the scale on the left. In order to get a correct reading we must add 10 minutes to the time recorded on your sundial. For readings above the '0' line we must add minutes to our sundial time and for the readings below the '0' line, we must subtract minutes.

EXPERIMENT NO. 88 YOUR WATCH IS WRONG

You built your sundial very carefully and followed all the instructions diligently and your sundial is still off... don't fret, the worlds watches are wrong. About a hundred years ago each town had its own time zone and our sundial would have been accurate in any of these towns. But since having each town on a different time zone causes great confusion the world was arbitrarily divided into huge time zones that are (practically everywhere) one hour apart from their adjacent time zones. Time in all the places within a time zone was artificially adjusted to be the same.

EXPERIMENT NO. 89 SUNSPOTS **

When seen through a telescope, sunspots appear like huge, jagged, black pits. Scientists to this day are not certain exactly what sunspots are or what causes them. They appear to be surface indications of the enormous electrical currents that flow within the sun and generate great magnetic fields. They range in size from only a few thousand miles in diameter to over 15,000 miles across. They usually appear in groups, last a few days and disappear. Most sunspots are in the middle regions of the Northern and Southern Hemispheres of the sun.



Each sunspot has a nucleus, called umbra, which is only about 8400oF. Since it is about 1600oF cooler than the sun's surface temperature it appears darker in color. A lighter, hotter penumbra edges the umbra.

Do not look directly at the sun; it can cause permanent eye injury. Even if you use sunglasses, shaded field glasses or smoked glass - they do not cut out enough light. Nature, however, does provide us with a suitable filter at sunrise and sunset, when the color of the sun is red.

If you are making your observations at sunrise, <u>stop as soon as the sun's color becomes orange</u> - it is then no longer safe for watching.

If you are making your observations at sunset, <u>do not start until the sun's color is red.</u> Large sunspots can be seen with the naked eye. Small ones can be spotted with the aid of a pair of field glasses (binoculars).

Once you have spotted a sunspot indicate its location on a diagram of the sun. Keep marking its location on successive days and you will be able to prove that the sun rotates.

SOLAR FLARES

Solar flares are great eruptions on the sun, each one representing the release of enough energy to fill the United States' needs for many centuries. The first solar flare was discovered in 1859 by an Englishman while he viewed a "white light" or visible-wavelength image of a large group of sunspots. Even from that initial observation, which was accompanied by a magnetic disturbance on earth, it appeared possible that flares might have terrestial effects. Today we know that they do indeed cause profound changes in the ionosphere and higher layers of the earth's atmosphere, thereby affecting broadcast communications. In addition, scientists are investigating the possible effects of flares and other transient solar phenomena on the weather.

As astronomers progressed in the study of flares, they found that the basic visible eruption occurs in the chromosphere, a thin layer just above the visible surface of the Sun. From theoretical studies, it became clear that the only likely source of energy for flares is the solar magnetic field. However, very comprehensive measurements with ground-based telescopes have demonstrated that there is no constant detectable change in the magnetic field at the solar surface ("photosphere") during a flare. On the other hand, profound changes in the structure of the corona (the hottest and outermost region of the solar atmosphere) have been observed during flares.

The changing coronal structures are thought to represent varying magnetic field configurations, thereby suggesting that the in situ source of solar flare energy may lie above the photosphere, in solar regions where the magnetic field has not yet been measured.

Solar flares are of special interest because of their great energy, their effects on earth, and the remarkable plasma phenomenons that occur in them.

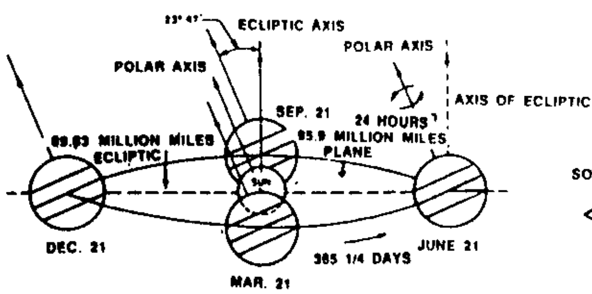
EXPERIMENT NO. 90 ANGLE OF SUN'S RAYS

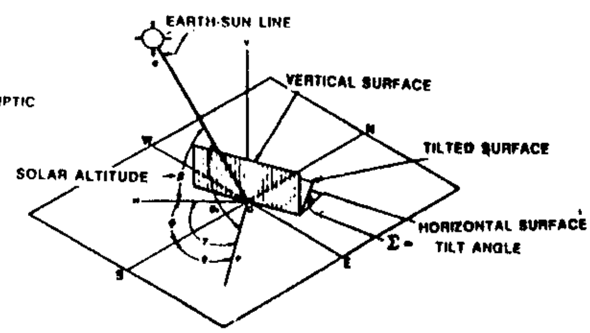
Cut a round hole, about 1/2 inch diameter, in a piece of white paper. Tape this paper on a sunny south facing window. Place a large sheet of white paper on the floor so that the sun shining through the hole makes a circular spot on the paper. Tape this paper to the floor.

Draw an outline of the spot where the beam of light strikes the paper. Record the date and hour inside the outline.

Repeat this experiment for several days at exactly the same hour.

The angle of the sun's rays change from day to day and the location of the spot will change. This would make a good project for school.



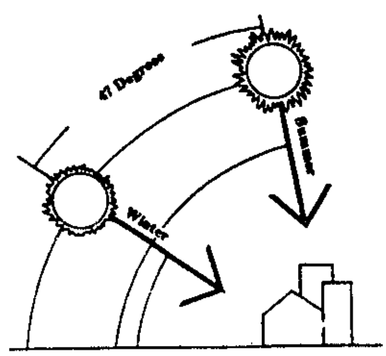


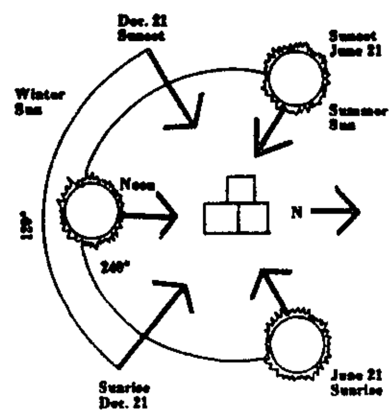
The intensity of solar radiation at the earth's surface exhibits major variations due to the elliptic shape of the earth's orbit around the sun and the tilt of its axis with respect to the orbital plane.

The earth's tilted axis results in a continuous, day-by-day variation in the angle between the earth-sun line and the earth's equatorial plane as the earth orbits the sun. This daily change is the primary reason for variations in distribution of solar radiation over the earth's surface. The latitude of a given location determines its yearly high and low values of solar radiation available on a day by day basis. Another important consideration in determining the variations in solar energy available for use is the angle between the direct solar rays and a line normal to the irradiated surface. This angle is important because it determines the intensity of the direct radiation component striking the surface and the ability of the surface to reflect, transmit or absorb the sun's rays.

More familiar variations in solar energy availability are due to atmospheric conditions. The annual and monthly percentage of cloud cover, total hours of sunshine and wind conditions are all factors affecting the total energy or insulation that may be expected in any location. Extensive publications of the U.S. Weather Bureau and other literature are available to help determine the solar energy availability that is necessary in designing a solar energy system.

Typical positions of the Sun for 40° North latitude.

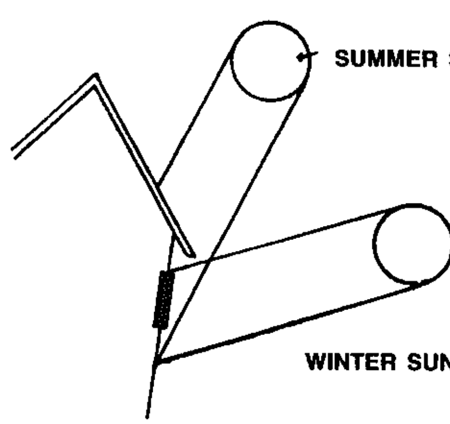




EXPERIMENT NO. 91 ROOF OVERHANG

Probably the single, simplest and most effective way to reduce home energy consumption is by the use of a properly designed roof and/or window overhangs. Since the sun is much higher in the sky in summer than in winter, a properly designed overhang can shield our windows from most of the summer sun in summer and allow in most of the sun in winter.

Take a typical window in your house and calculate what percentage of your window is exposed to winter sun and what percentage to summer sun. Can you redesign the overhang to give you a better balance?

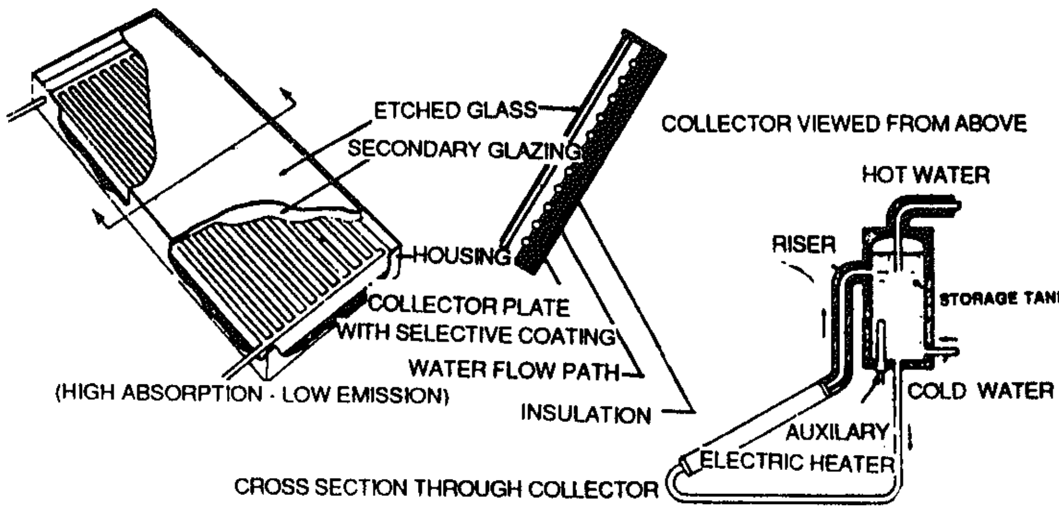


WATER HEATERS

RESIDENTIAL HOT WATER HEATERS

There are many installations of solar water heaters in use today in Israel, Australia, and Japan. The "Thermo-Siphon" heater is by far, the most common one in use.

An insulated storage tank is mounted above a solar collector and piped so that cold water flows in the bottom of the solar collector. The collector heats the water, which flows into the storage tank as long as the sun heats the collector.



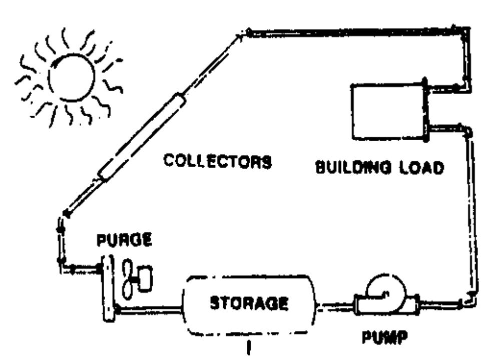
COMMERCIAL HOT WATER HEATERS

The basic solar system generally used in commercial buildings consists of the following basic components:

1. flat plate solar collectors (non-focusing)
2. storage reservoir (normally an insulated tank)
3. purge unit

There are two types of systems; the single fluid and two fluid systems. As the name implies, the single fluid system uses the same fluid in the collectors, storage tank and heating units. In most climates (wherever it gets below freezing) this fluid is an ethylene glycol/water solution to prevent freezing of the collectors. In systems using large storage tanks, the two fluid system is commonly employed to minimze the amount of Ethylene Glycol/Water solutiion required. This is done by adding a heat exchanger between the collectors and the storage tank.

SINGLE FLUID SYSTEM



CONSERVING ENERGY - SOLAR HEATERS

FLAT PLATE COLLECTORS

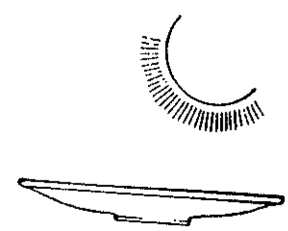
The method of heating water by solar energy is becoming more popular as the conservation of energy through solar power is proving itself. Solar systems heat water up to aproximately 55oC. Special coatings on the collectors allow the water to heat to even higher temperatures. The flat "collectors" are generally installed on roofs. They have been proven to successfully heat privatel homes, apartment houses, hotels, hospitals, universities and swimming pools, as well as other uses. They are noted for saving 8% of electricity consumption in a normal household.

CONCENTRATING COLLECTORS

Concentrating collectors are used to generate steam and electricity, and to heat fluid to higher temperatures. They focus the sun's rays onto a central heat collecting element.

EXPERIMENT NO. 92 THE SUN HEATS WATER

Take two glass saucers and place them in the sunlight. Pour the same amount of cold water into each saucer. Measure the temperature of the water, and make a note of it.



Cover one of the saucers with another saucer. Wait about an hour and measure the temperature in both saucers. You will find that there was a rise in temperature in both cases. The water in both saucers is now warmer than it was before, but in the saucer that was covered, the water is even warmer. This is what is known as "the greenhouse effect."

EXPERIMENT NO. 93 HEAT ABSORPTION OF BACKGROUND

Take the same saucers and once again fill them with the same amount of cold water. Again put them in the sunlight. This time you may either keep them both uncovered, or, if you like, cover them both with a transparent saucer. The variation in this experiment is that you place one saucer on white paper, and the other saucer on dark paper. After about an hour, measure the temperature and note that there is a difference. A dark background absorbs more heat than the white background . The water over the dark background should be warmer.

EXPERIMENT NO. 94 OVER A MIRROR

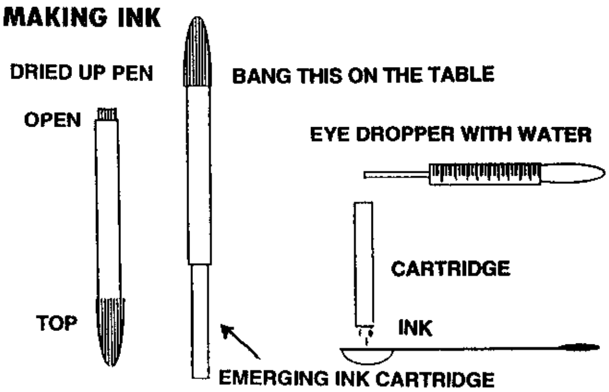
Place a saucer with water over a mirror.What happens? Note that the mirror reflects heat and light.

EXPERIMENT NO. 95 WHICH IS IT TO BE?

Repeat Experiment No. 92, but this time perform it on a table in a sunny room with the window closed. In other words, you will test sunlight which has passed through glass windows. Before you start, can you guess what the result should be? Even the scientist who developed these experiments was not sure until he tried it. There is no doubt that the window glass absorbs some of the heat so you would expect the water to remain cooler. On the other hand, we spoke about "the greenhouse effect." Obviously, the water should be warmer. Which is it??

EXPERIMENT NO. 96 COLORED WATER, MAKING INK

Supposing you were to dye the water you place in the saucers or glasses black - would you expect to obtain a higher temperature? Could this idea be put to practical use? Perhaps you could design an experiment to test this hypothesis. For this procedure, you will need ink. Here is a way of making homemade ink. Certainly you have some old colored felt tipped pens around your house - red, green, black, blue, etc... Some still write, but many have probably dried up. Take one of the pens, even if it is dried up.



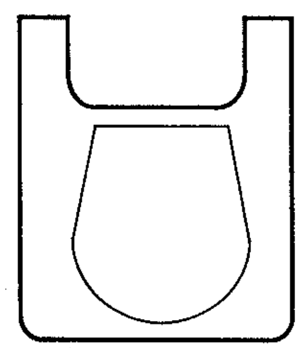
Open the top, as shown in the drawing. Turn it upside down. Hold it in your fist and bang the fist on a table in such a way that the pen itself does not touch the table. Bang the table with your fist. Soon the ink cartridge emerges from the pen. If it won't, fish it out with a bent paper clip. With an eye dropper, drip water, drop by drop, into the cartridge which should be held over a spoon in order to collect the drops of ink which soon appear. Look at the drawing. There are some pens with the top glued down, others where the top cartridge will not budge. If you have such a pen, just break it in half. A dried up pen has no other use in any case. When you have collected as much ink as you want, return the ink cartridge to the pen (unless you broke it). Wonder of wonders, it writes again!

EXPERIMENT NO. 97 THE COOLING EFFECT OF EVAPORATION
When water, or other liquids evaporate, they require energy to do so. They take this energy from wherever they can get it. Moisten your arm and blow on it. Your arm feels cool. The moisture on your arm evaporates and it takes the energy it needs from your arm. That is why it feels cool. People perspire when they are hot. The perspiration evaporates and this is nature's way to cool the body which may otherwise get too hot on a sweltering day.

How hot and uncomfortable you feel in summer, depends on how quickly your perspiration evaporates. That depends on the following: the air temperature, the strength of the wind, and the amount of moisture in the air. Evaporation is speeded up: on a hot day, on a dry day, and on a windy day.

EXPERIMENT NO. 98 THE SWIMMING POOL
On a hot, dry, windy day, the swimming pool cools down! It should be cooler on such a day than on a damp, slightly cooler windless day. You too feel hotter, and perspire more on such a day. Why not use your thermometer and find out for yourself?

EXPERIMENT NO. 99 HOT WATER HEATER **
Lean the heat absorber bag against any cardboard box or the remainder of the polystyrene tray. Take the bag and fill it with cold water. You may find this difficult as there is very little room between the transparent cover and the black backing. Use a pen or pencil to help you open the bag. It is necessary to prepare the heat absorber bag so that you can use it.



Heat some water until it is very hot, but <u>not</u> boiling.

Hold the bag at A and B and dip it into the water without immersing your fingers. Keep the bag in the hot water for about half a minute. Withdraw it and blow into A as if it was a balloon which you want to inflate. Hold B with your finger to prevent the air from escaping and keep it like that for about a minute. The bag cools and stays inflated, ready for use. Fill it right up to the top with cold water. Place the heat absorber bag with water, in thepolystyrene tray or cardboard box, with the clear side facing front and the back black side of the bag towards the tray. Place the heat absorber bag facing towards the sun. As the sun heats the water in the bag, the density of the hot water lowers and it rises to the top of the heat absorber bag and the colder water drops down.

A commercial hot water tank is very similar to our bag. A water tank is placed above the heater and a pipe from the bottom of the tank is connected to inlet A and another from the top of the tank to outlet B. As the water is heated, it rises and goes to the top of the tank. As water rises to the tank, it pulls in colder water from the bottom of the tank to be heated. Insert your thermometer into the heat absorber bag to verify the water temperature. You will have to carefully remove the thermometer from the scale backing.

EXPERIMENT NO. 100 GLASS COVERED HEAT ABSORBER
Commercial hot water heat absorbers are covered by glass. The purpose of the glass is to trap the sun's heat by means of the greenhouse effect. The sunlight goes through the glass and heats the black heat absorber. The glass cuts down considerably on the heat loss by radiation from the heat absorber itself.

Tape your tray or cardboard box lid, with the heat absorber bag full of water inside of it, to a window pane that faces the sun. Check to see how much faster the water heats up.

EXPERIMENT NO. 101 ENERGY CONSUMED BY A HOT BATH
To date, the only practical use to which solar energy has been applied to in any great degree has been in residential hot water heating. To get an indication of how much energy is saved by this, let's try to calculate the amount of energy required to heat the water for one bath.

To calculate the amount of water in your bath, take careful measurements of the inside dimensions of your bathtub and calculate the volume of water or, time how long it takes to fill a liter (1.06 quarts) bottle and then note how long it takes to fill the bathtub. If it takes 3 seconds to fill a one liter bottle and 900 seconds to fill our tub, the tub must contain 900:3 or 300 liters.

Knowing that one calorie is equal to the amount of heat required to heat one cc of water one degree Centigrade, we can now calculate the amount of heat required for our bath. If our bath contained 300 liters of water and the temperature difference between the cold water and bath water was 35°C our calculation would be as follows:

300 liters x 1000 cc/liter x 35°C= 10,500,000 calories.

Now we must add the heat loss in the pipes and walls, the heat required to keep the water in the tank hot between baths, and the energy lost in the heating coil of the hot water tank itself.
In generating electricity from fossil fuels at the power station, only about 33% efficiency is achieved: for every calorie of hot water used in your bath three calories of fuel had to be burned.

EXPERIMENT NO. 102 COST OF OUR BATH
Assuming 30% loss of heat in your pipes, tank, etc., assuming that one calorie equals 1.2 x 106 kwh of electricity and assuming that electricity is charged at 10 cents per kwh; how much did it cost to heat our bath?

DEGREE DAYS

EXPERIMENT NO. 103 CALCULATING HEATING DEGREE DAYS
You have no doubt heard 'degree-days" being discussed or seen reference to it in your local paper, but what exactly is a Degree-day? Degree days, for a certain date, are arrived at by adding the maximum temperature for the day to the minimum temperature for the day, dividing the sum by two to get the daily mean temperature: the daily mean temperature is subtracted from 65°F and the result is the Degree Days for that particular date.

Suppose on Jan. 5th the maximum temperature was 45°F, and the minimum was 15°F. The daily mean temperature was 30°F and there were 35 heating degree days on that date. Look at your local newspaper and calculate today's degree day.

EXPERIMENT NO. 104 COOLING DEGREE DAYS
What happens if the result of our calculation gives a negative figure?
Suppose our daily mean temperature is 70°F; when we deduct it from 65°F our result is -5°F. Negative figures are referred to as Cooling Degree Days and these figures are very important to the air conditioning industry.

EXPERIMENT NO. 105 CHARTING DEGREE DAYS
Prepare a graph with the dates along the X axis and the heating degree days on the Y axis. Keep a running record and notice the long and short term fluctuations in degree days.

Heating degree days are very important to home owners, fuel oil suppliers, etc. They are used to calculate the estimated amount of fuel that will be consumed and in comparisons of types of fuel, insulators, type of heating, etc. Very careful charts are kept by the weather bureaus, energy boards, etc.

RELATIONSHIP BETWEEN DEGREE DAYS AND FUEL REQUIREMENT

Suppose you live in a desert where the maximum temperature at noon is 115°F and at night the temperature drops to 15°F. Your daily mean temperature is 65°F and your degree day is 0. Does that mean that you did not require any fuel to heat at night or power to air condition during the day? Your local heating fuel contractors know your region and how to interpret the figures. Obviously degree days mean different things in different regions.

SOME SOLAR CELL APPLICATIONS

A wide range of additional applications are taking advantage of the unique characterisitics of solar energy systems.

* Obstruction lights for airports
* Water pumping for drinking and irrigation
* Facilities power for firetowers and second homes
* Emergency location and alarm transmitters
* Electric fences and intrusion alarms
* Battery float charge systems
* Highway signs and Bus Station Signs
* Portable backpack radios
* Ranger stations in forests
* Electronic calculators
* Chargers for boat batteries
* Traffic Lights
* Space Satellites

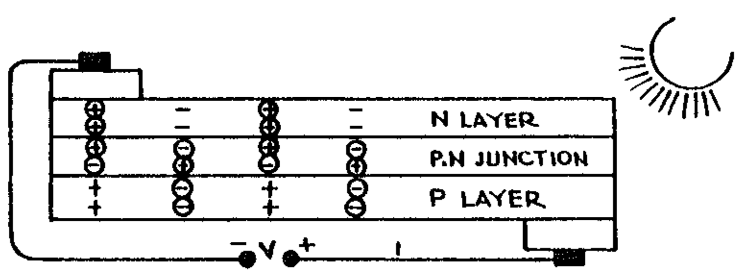
SILICONE SOLAR CELLS

In the year 1839, a scientist named Bacquerel was the first to explain in theory how photovoltaic cells work. This led to the development of the solar cells used today. The first cells had an efficiency of only 1%. This means that only 1% of the sun's energy that reached the cell was turned into electricity. Even today, less than 20% of the sunshine can be utilized by such cells. Nevertheless, they can be used for many things as you will see. A light airplane has been fitted with solar cells and actually flown!

Solar cells are very reliable, clean and safe - and what is most important - unlike oil and coal, these cells produce energy from sunlight which will never be used up. Another advantage of solar cells is that they are quiet, have no moving parts that can break and therfore need little looking after. This makes them ideal for places far removed from towns, such as an isolated telephone booth or even lightning houses, and powering T.V. sets in areas where electricity is not available.

HOW SOLAR CELLS WORK

The basic principle of the solar cell is not very difficult to understand. Sunlight contains energy particles called photons. When these photons strike any semiconductor surface such as our solar cell, the photons cause electrons in the semiconductor material to move about. Since electric current is simply a flow of electrons if we can get the electrons to flow instead of move around we will have a usable electric current. A solar cell does exactly that; it causes the moving electrons to flow in a specific direction.



The solar cell is constructed of three different layers: the P layer, the N layer and a barrier layer called the P-N junction. The P layer is composed of fixed electrons and free protons and is positively charged. The N layer is composed of the exact opposite; fixed protons and free electrons and is negatively charged. The P-N junction prevents the free particles of opposite charges from uniting. When the photons strike the top layer of the cell, they penetrate through the ultra thin N layer (only about 1/200000 of a meter) far enough to cause some of the free partidles of each layer to move. Since the P-N junction prevents them from uniting, they are forced to flow through the wires. This flow is electricity.

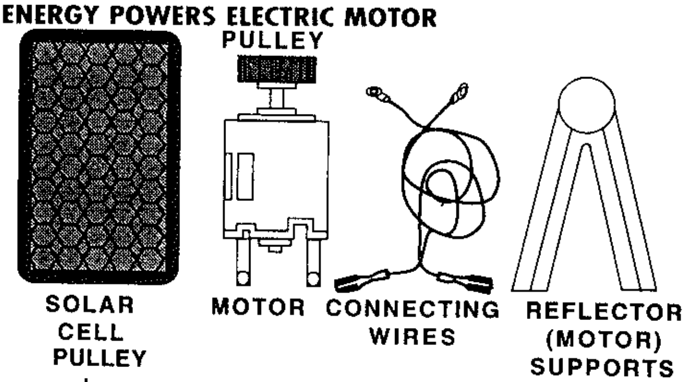
PHOTOVOLTAIC TECHNOLOGIES

Photovoltaic systems allow the generation of electricity directly from sunlight. This is practical especially in remote areas, far away from electric grids. There, power can be provided by photovoltaic panels. Batteries are used to store the power. This system is in use in a remote village. The electricity that is supplied to the entire village is provided by these photovoltaic power cells. Further research is underway on large scale to provide photovoltaic power at a reduced cost.

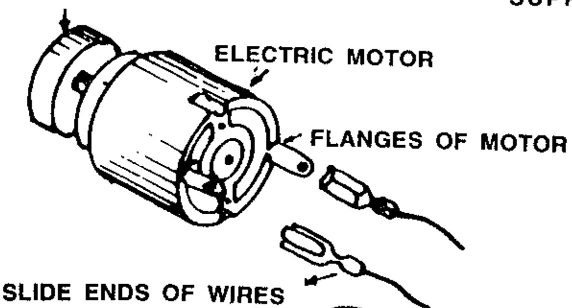
EXPERIMENT NO. 106 SOLAR ENERGY POWERS ELECTRIC MOTOR

We can use the electricity produced by the Solar Cell to turn an electric motor. You will need the solar cell, the electric motor, the connecting wires and the reflector supports. This is how you do it:

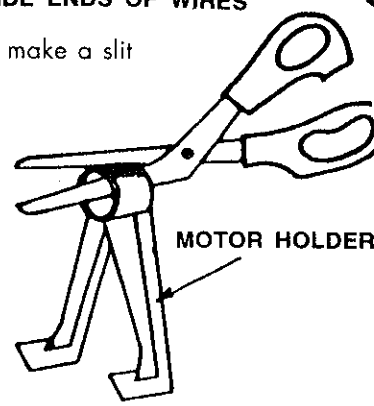
You will need the solar cell, the electric motor, the connecting wires and the reflector supports.



Attach the slide ends at the other end of the wires to the flanges of the electric motor. Push the pulley gently onto the motor's shaft. Be careful that the pulley does not touch the motor's body.

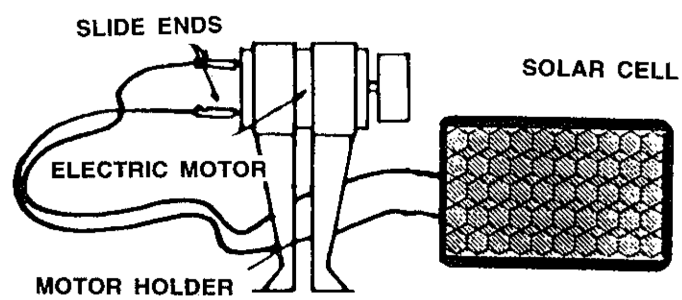


Next, take the two reflector supports and make a slit in the top of both supports.

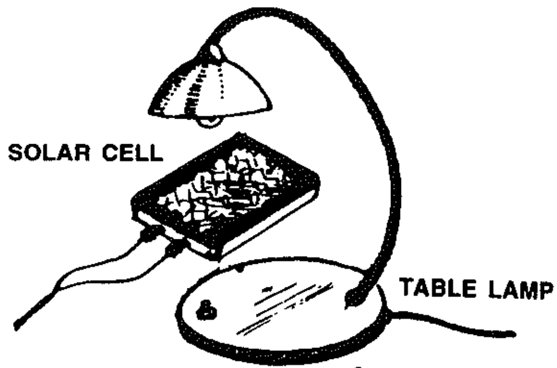


Lastly, slide the motor into the two supports. The finished assembly should look like this:

When you turn the solar cells towards the sun, the pulley on the electric motor will begin to revolve. You may help start it by revolving the pulley with your fingers.

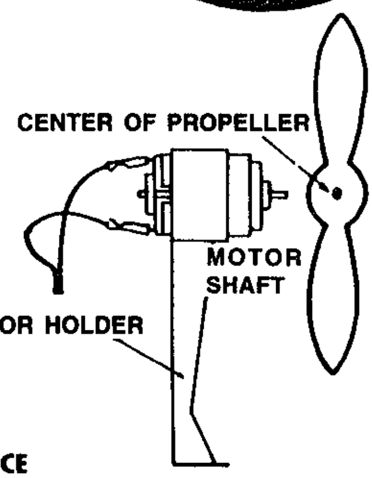


EXPERIMENT NO. 107 A SUNLESS DAY
Can you make the motor revolve even on a rainy day? Hold the solar cell near a lit electric light bulb. The motor will revolve as before.



EXPERIMENT NO. 108 FLORESCENT LIGHT
Bring the solar cell near a source of florescent light. This time the electricity produced by the solar cell will scarcely be enough to turn the motor, even though the florescent light seems brighter than the bulb.

EXPERIMENT NO. 109 THE PROPELLER
Remove the pulley from the motor by gently pulling until it slides off the motor shaft. Attach the propeller by simply placing the hole at the center of the propeller over the motor shaft and gently pushing. Make sure that the propeller is not touching the side of the motor. It must be able to revolve freely.



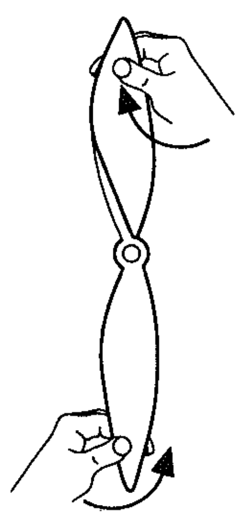
EXPERIMENT NO. 110 TESTING THE LIGHT SOURCE
See if you can rotate the propeller by exposing the solar cell to sunlight, an electric bulb or a florescent light tube. In sunlight the motor will work immediately. In electric light, it may be necessary to give the propeller a gentle tap in order to start it off. Observe the direction in which the motor revolves.

EXPERIMENT NO. 111 REVERSING POLARITY
Remove the wires which bring the electricity from the solar cell to the motor, by sliding the "slide ends" off the flanges of the motor and reattaching them, by placing the "slide end" which was on the right flange, onto the left flange. The "slide end" which was on the left flange goes onto the right one.

You have "crossed over" the wires and the motor will now revolve in the opposite direction. This is called "reversing the polarity."

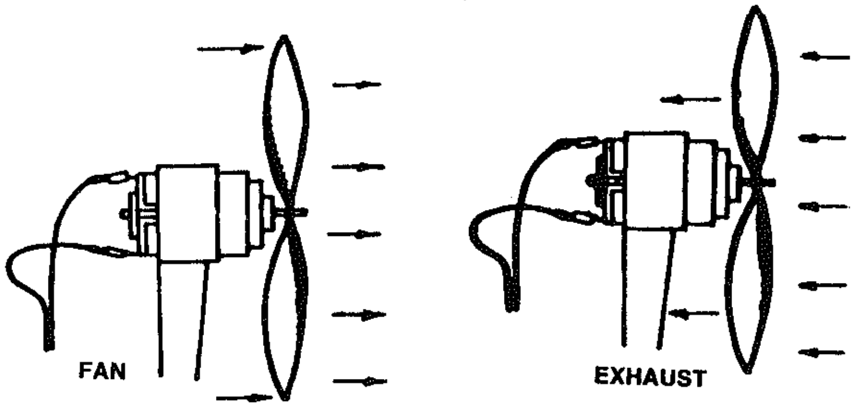
EXPERIMENT NO. 112 SHAPING THE PROPELLER
The propeller you have used up to now is pretty useless! If you want it to "do some work" you must modify it, by giving it the form of a screw.

Carefully pour some hot water into a cup and dip the propeller into the water. The heat will soften the plastic. After a few seconds remove the propeller from the cup and while the plastic is still hot, give it a slight twist as shown in the illustration. Be careful not to burn your fingers! Cool the propeller by holding it under running cold water.



EXPERIMENT NO. 113 THE VENTILATOR (FAN)

Reattach the modified propeller to the motor, place the solar cell under a suitable light source so that the propeller revolves. It is now able to move air. The direction in which the propeller moves the air, whether away from the motor or towards it, depends in which direction the motor revolves.If the air moves away from the motor, you have made a fan or ventilator.



EXPERIMENT NO. 114 THE EXHAUST

Change the direction in which the motor turns, by crossing over the wires (either at the flanges of the motor or at the screws of the solar cell). The propeller will now move the air in the opposite direction. Let us say that in the previous experiment the air moved away from the motor and you had made a ventilator. Now, the air will move towards the motor. You now have an exhaust.

Exhausts are commonly used in factories, mines, or laboratories and kitchens where we are interested to remove bad fumes and replace them with fresh air.

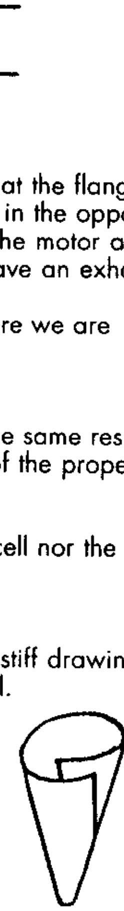
EXPERIMENT NO. 115 WORKING ON THE PROPELLER

By removing the propeller, turning it around and reinserting it, you can achieve the same result as in the previous experiment. If necessary, you can also change the twist (or pitch) of the propeller by reheating it in hot water, retwisting and cooling it.

Let us pause at this stage and try an experiment which requires neither the solar cell nor the electric motor. It does require sunshine.

EXPERIMENT NO. 116 THE SUN TRAP

For this and the next two experiments, you need fairly large pieces of carton or stiff drawing paper (Bristol paper). You also need some bought or homemade glue and aluminum foil.



Find a piece of thin carton or stiff drawing paper about 50 cm x 30 cm (20 in x 12 in). Cover a table with a piece of old newspaper to protect it. Place the carton on the newspaper. With a paint brush, or cotton ball, spread the glue evenly over the carton. Take a piece of aluminum foil the same size as the carton. Stick it down smoothly and firmly. You have made a crude cardboard mirror! Let the glue dry for at least half an hour.

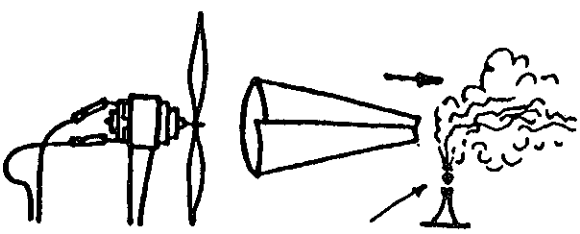
In the meantime take it outdoors and try, by means of this mirror, to reflect sunlight onto the wall of a house. See what happens when you bend the cardboard mirror slightly. After half an hour, roll the carton into a conus (funnel) as illustrated. The side with the aluminum foil must be inside. The top opening should be approximately 20 cm across, the bottom about 2 1/2 cm (8 1/2 in and 1 in). Fix together with tape, glue or staples. Your solar trap is ready.
Now, go outside into the sunlight. If anybody asks you what you are doing, answer innocently, "I'm trapping some sunlight!" People will think that you are stark raving mad, but in fact you are very scientific. This is exactly what you are about to do! Insert your index finger into the small hole of the conus. Stand in sunlight and slowly turn round, revolving in a complete circle. You will find there is a point where your finger feels much hotter. At that point, of course, you are facing the sun.

Now, still keeping your finger in the hole, lower and elevate your arm. There comes a point where you will take your finger out quickly! There is no danger that you will burn your finger, but it will get uncomfortably hot.

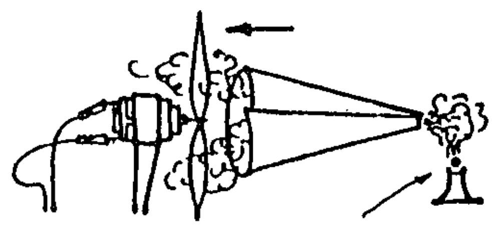
If you insert a candle into the opening, instead of your finger, it will melt like butter! A bit of rubber will start to smoke and smell!!! The conus (cone) you have made is necessary for the next experiment.

EXPERIMENT NO. 117 THE WIND TUNNEL

We will use the conus from the last experiment as a wind tunnel. Set up your motor as a ventilator and hold the large end of the conus near the revolving ventilator. The conus will strongly reinforce the air current and this can best be shown, by placing a source of smoke or steam near the smaller end of the conus. Look at the drawing.



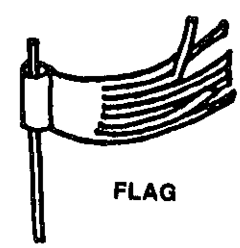
SOURCE OF SMOKE OR STEAM



SOURCE OF SMOKE OR STEAM

EXPERIMENT NO. 118 FLAG IN THE WIND

Now reverse the polarity of the motor to make the exhaust. A source of smoke or steam will again indicate the direction of flow of the air. Try making a "flag" from thin tissue paper cutting the free end into thin strips with a pair of scissors. See the drawing.



FLAG

Up to now, we have used the Solar Cell to power an electric motor. Surely there are other things we can do with such a cell. There are indeed. Already at the beginning of this chapter we explained in reasonable detail what a solar cell is and how it works. The time has come to investigate some more of its properties.

For this you need a tool to measure electricity. One such tool is called a **GALVANOMETER.**

HOW TO CONSTRUCT YOUR GALVANOMETER

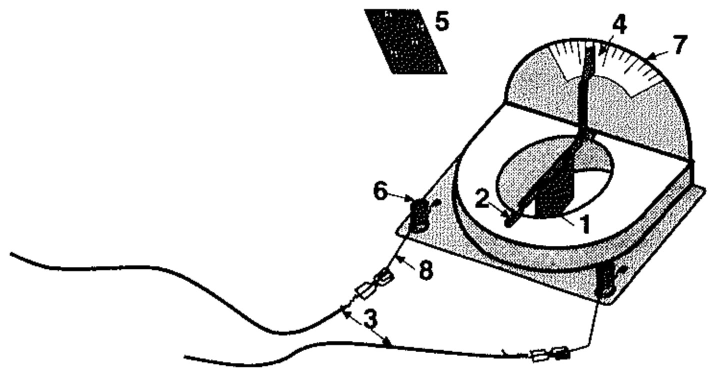
In 1830 Michael Faraday made several experiments with magnets and coils, in order to find a way to measure electric current. He found that if you pass electric current through a coil, you create a magnetic field. When you put a magnet attached to a pointer into the coil and you connect the coil to a source of electricity **(NOT MAINS - ONLY BATTERY)**, the pointer will deflect in relation to the current flowing through the coil. In this kit, you will build your own galvanometer which you will use with the solar cell. You can also use it with a battery to test resistance, or to test a battery.

Never connect to mains or more than a 9V battery.

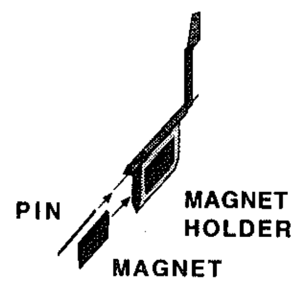
ASSEMBLY

Take the small bag with the parts and identify each component.

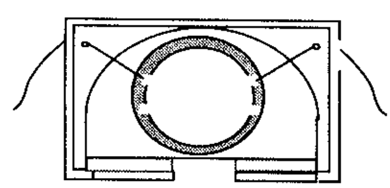
1. magnet
2. pin
3. wires
4. pointer
5. sandpaper
6. caps for connections
7. scale
8. enamelled wire



Take the magnet, be careful not to drop it, as it is breakable. Slip the magnet into the magnet holder of the pointer. Take the pin and push it through the holder so that it rests on top of the magnet - and protrudes equally on both sides of the holder. Your pointer is now ready. Put it aside until you are ready to use it.

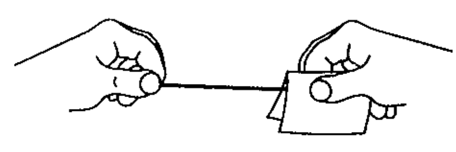


Turn the base over. You will see the core of the coil. It has two short slits on both sides of the core. Unwind from the coil 6 in (15 cm) of wire. Wrap it twice around the slit. Push that end of the wire out of the way, into the middle of the coil. Slowly start wrapping the wire around the core. It does not make a difference if one wire is on top of the other. However, make sure it does not go over the 6 stops on the bottom of the core. Keep winding until you finish all the wire, except 6 in. (15 cm), and wrap it around the remaining two slits tightly. You should now have 2 ends of wire free. Pass one on each side, through the holes in the base.



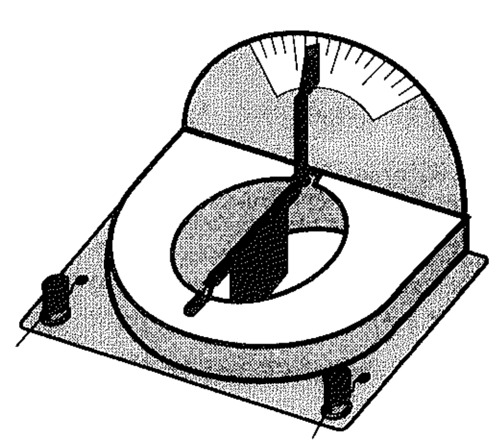
BASE FROM UNDERNEATH

Take your sandpaper and clean the enamel insulation at the end of the wires. Take the 2 connecting wires and wrap the bare end of the wire around the bare end of the coil wire. Push the two wires into the slit on the protruding pins of the base. Push the small black cap hard onto the pin, this will keep your wires firm and connected.

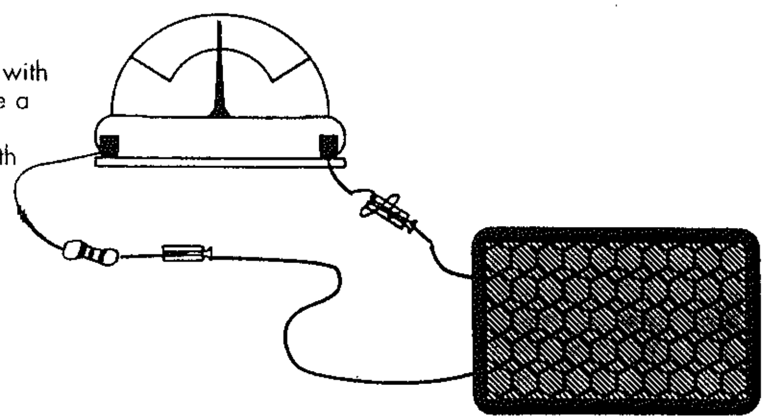


You are nearly finished. Make sure that the wire on the core does not disturb the needle from functioning. If it does, press the wire slightly with a pencil. Peel the scale off the prepared label and stick it onto the base. Take your pointer with the magnet and place it into the base.

Make sure that the magnet holder does not touch any of the sides of the base. To check this - give a slight push to the pointer with your finger and see that it returns to the upright position, pointing to the 0. The scale has the 0 in the middle. Depending which way you connect the current, the pointer will point either to the left or to the right - indicating the flow of electricity, either to "+" or to" -". You can try this with a 1 1/2 Volt battery to see if it works properly.



Your solar cell produces 0.38 Volt with maximum artificial light. You have a chart indicating the voltages and amperage of various distances with resistor in series and without.



	DISTANCE	APP. VOL	1Ω	CURRENT	1Ω
SCALE	75 W FROM CELL	WITHOUT RESISTOR	WITH RESISTOR	WITH MA RESISTOR	WITH RESISTOR
FULL	5 cm 10 cm	0.38 0.25	0.30 0.20	+ 1mA 0.95	1 mA 0.94
HALF	15 cm 20 cm 20 cm 28 cm 35 cm 50 cm	0.15 0.10 0.10 0.06 0.05 0.025	0.12 0.08 0.08 0.05 0.04 0.018	0.87 0.80 0.80 0.75 0.70 0.64	0.84 0.78 0.78 0.73 0.69 0.63

NOTE: These are all approximate values.

EXPERIMENT NO. 119 QUANTITATIVE EXPERIMENTS
Turn the Solar Cell to face the light source so as to get the maximum (greatest possible) deflection of the meter-needle. What is the reading?

In a bag you will find several large (7 x 10 cm) pieces of colored cellophane and a piece of rubber of the same size. Take this piece of rubber and cover the Solar Cell (S.C.). The needle of the meter should return to 0. Move the rubber to cover exactly 1/2 of the S.C. What is the reading now? Is it exactly 1/2 the reading of the uncovered S.C.?

EXPERIMENT NO. 120 THE FUNCTION OF DISTANCE
You will probably have found out that if you use a table lamp, instead of sunlight, the amount of electricity which the S.C. produces, depends on the distance of the S.C. from the lamp.
You can test this scientifically with your meter. Place the S.C. connected to the meter on a table near a table lamp. Note, this experiment is best done in the evening when the table lamp is the only source of light in the room.

By slowly moving the S.C. nearer or further away from the lamp, find a position where the meter reads 3. Measure the distance of the S.C. from the light bulb.

Move the S.C. further away until the meter reads exactly 2. Measure the new distance.

Do the same again and make the meter read 4 and later 1. Measure these distances.

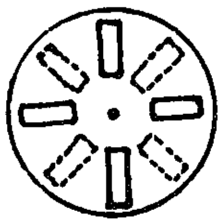
Can you find a relationship between the distance of the S.C. from the light bulb and the amount of electricity produced?

EXPERIMENT NO. 121 DRAWING A GRAPH
Do you know how to draw a graph? If you do and feel like it, you could try to draw one, placing the distance of the S.C. from the light bulb, expressed in cm, on the x'x axis of the graph and the amount of electricity, 4,3,2,1 on the y'y axis.

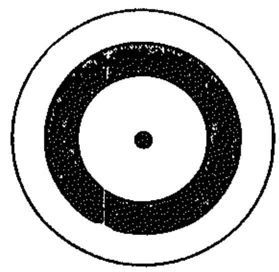
EXPERIMENT NO. 122 WOULD ADDITIONAL LIGHT EFFECT YOUR RESULT?
If you are scientific enough to draw a graph, you might be interested to repeat the experiment in daylight, when you have a certain amount of sunlight in the room in addition to the light coming from the table lamp. Notice how this effects your graph!!

EXPERIMENT NO. 123 REVOLVING THE DISCS
Let us return now to our experiments with the MOTOR.

Remove the propeller from the motor and replace it by one of the carton discs. When the electric motor starts revolving the disc, you will see, that the part of the disc where the 'windows' are, becomes transparent.

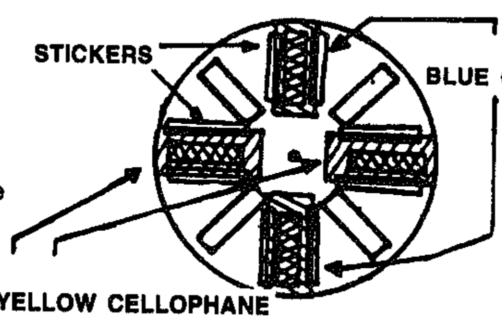


DISC AT REST



REVOLVING DISC

EXPERIMENT NO. 124 YELLOW AND BLUE ETC.
Remove the disc from the motor. Cover two of the windows of the disc with blue cellophane and the other two windows with yellow cellophane. To fasten the cellophane to the disc, use some of the stickers provided in this kit. Use as few of the stickers as you can, since you will need this for many experiments. See diagram.



IMPORTANT: Should the disc fit too loosely on the motor shaft, affix rubber disc as will be explained later on. See "The Rubber Washer."

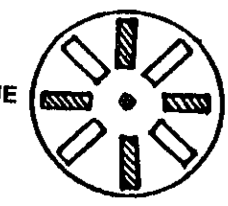
Spin your disc on the motor. What color did you expect to see when looking through the revolving windows? What color did you in fact see?

EXPERIMENT NO. 125 BLUE AND RED
Prepare another disc in the same way as you did the previous one, only this time, cover the windows with blue and red cellophane.

Take a pin and put it through the hole in the center of the disc which you have just prepared. Revolve the disc by hand, gently pushing it with the finger of one hand while holding the nail with the other. Revolve the disc as fast as you can and look through it while it is revolving. Do you see the color you had expected to see? When you look through the revolving disc from the side, do you see the same color as you saw, looking through it?

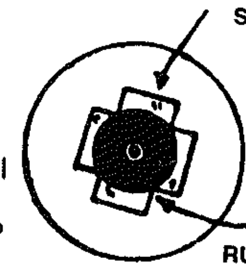
EXPERIMENT NO. 126 WHITE LIGHT
Take yet another disc. This time, you must affix it with 4 colors: red, green, yellow and blue, to the four windows. What color would you expect to see when you spin this disc?

NOTE: When you mix yellow and blue you get green. By mixing yellow and red, orange is obtained. When you split up ordinary (white) light by means of a prism, you obtain the colors of the spectrum: Violet, Indigo, blue, green, yellow, orange, red. (A rainbow is a good example, where white light is split up by rain drops). When you mix the colors of the rainbow, you get white or ordinary light. Red, yellow, green and blue are not all the colors of the spectrum, but even so, when looking at the spinning disc, the four colors should blend to a fairly light gray.



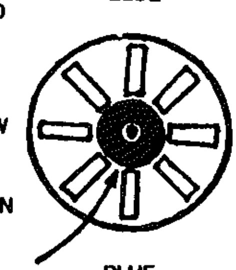
When looking through the spinning disc, the effect should be even more striking.

EXPERIMENT NO. 127 THE RUBBER WASHER
When you affix one of the discs onto the motor, it spins round as the shaft of the motor turns, because the hole in the middle of the cardboard disc, exactly fits the shaft of the motor. However, after some time, the hole becomes enlarged through wear and tear. The disc begins to slip and no longer revolves properly. We must reinforce the hole. You can do so by sticking one of the small rubber circles over the worn hole of the cardboard disc. If you have some plastic glue or rubber solution at home, use it. If you do not have either, use some of the stickers as shown in the diagram.

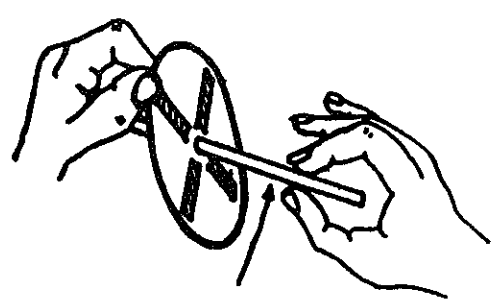


Make a hole in the center of the rubber disc by means of the nail or pin.

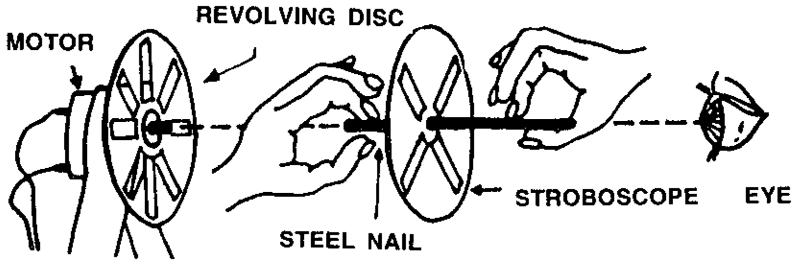
EXPERIMENT NO. 128 IMPROVING THE DISC
Take the disc on which you affixed the red, green, yellow and blue cellophane. Reinforce the center with a rubber disc. All the cardboard discs have 4 slits already punched out and ready to use. Another 4 slits are still covered with cardboard. This is easily removed by pressing on it with your finger. Do so now and prepare this disc by adding an additional set of colors as illustrated. Spin this disc of 8 color strips on your electric motor and see if it is an improvement over the experiment with 4 colors.



While the disc from the previous experiment is still spinning on the motor, take the final disc from the kit, affix a rubber disc to its center, and use it just as it is. Put a steel nail through the center and spin this disc. Look through the spinning disc at the one that is still revolving on the electric motor. What do you see?



EXPERIMENT NO. 129 THE STROBOSCOPE
A stroboscope is an instrument by which the speed of a revolving or occilating object can be measured. In its simplest form, it is a disc with one slit in it. If we look through such a revolving disc, at another, which revolves at exactly the same speed, this, will seem to be standing still. If you were to slow down Disc No. 1, Disc No. 2 will seem to be moving forward; if you increase the speed of Disc No. 1, Disc No. 2 will seem to be moving backwards. If Disc No. 1 has four slits, you can achieve the same effect by revolving it at 1/4 the speed of Disc No. 2. Of course, if Disc No. 1 has 8 slits, then only 1/8 of the speed of Disc No. 2 is required in order to "stop" it. We use stroboscopes to measure speeds of quickly revolving objects.



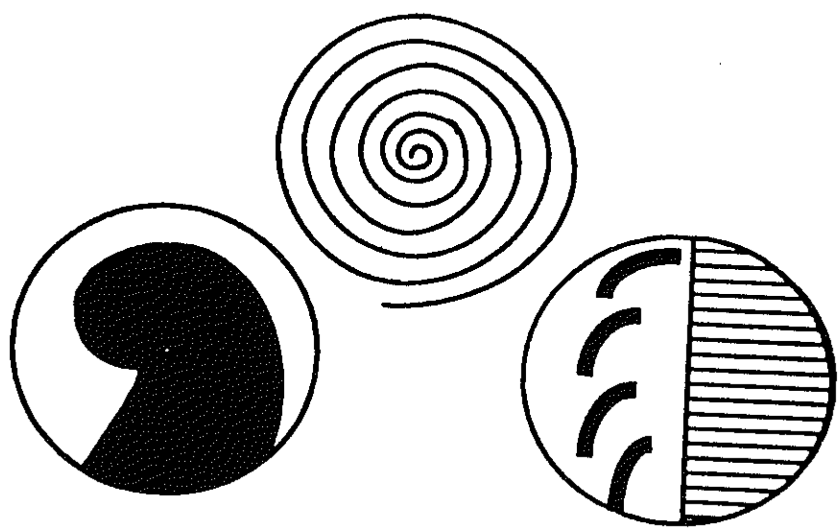
You can use the stroboscope to look at a revolving gramophone record, a bicycle wheel while in motion, water dripping from a tap or a lit, single florescent light tube. Stick a nail or a knitting needle through the hole in the middle of the stroboscope. Hold this with one hand and with the other, rotate the disc.

EXPERIMENT 130 STROBOSCOPE AND YOUR T.V.
Use your stroboscope to look at the lit up screen of a television set.

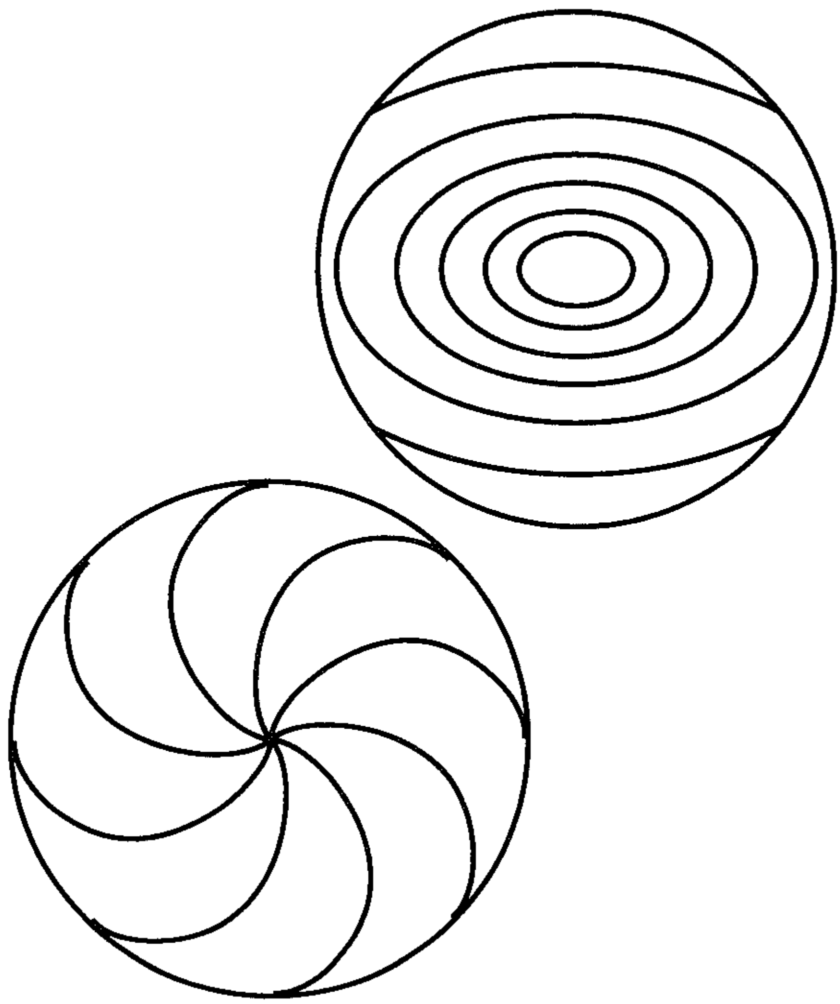
Experiments with a stroboscope are many and interesting but beyond the scope of a Solar Energy Kit. However, if you are interested, it is well worth your while to look up in any textbook on Optics or Physics to find many, many experiments which you can perform with the electric motor and stroboscope in this kit. Such a book can be borrowed from your school library.

EXPERIMENT NO. 131 THE MOVING PATTERN
Among the discs in this kit, you will find a blank one. Transfer the two patterns illustrated here onto the two sides of this disc. The best way to do this is to place a sheet of carbon (copy) paper underneath the patterns and trace over them with a knitting needle, thus transferring the patterns onto the two sides of the blank disc.

Now fit the disc with the new pattern to the electric motor. What do you see as the motor revolves? Turn the disc around and look at the other side.



STROBOSCOPES



EXPERIMENT NO. 132 MORE PATTERNS
See if you can find some transparent plastic material. Make two discs from this. The discs should be the same size as the cardboard discs from your kit. Trace out and transfer the above pattern onto the transparent plastic discs just as you did in the last experiment.

Place one disc on top of the other and revolve the top disc slowly. Change over the discs so that the bottom disc now lies on top.

EXPERIMENT NO. 133 MOIRE PATTERN
If you can get hold of some stiff transparent material, cut out a disc similar to the blank disc and transfer the pattern of the above illustrations to this transparent disc. Place the transparent disc over the blank disc so that one diagram covers the other, then start revolving one of them. What you see is called a Moiré pattern.

EXPERIMENT NO. 134 MORE MOIRE PATTERNS
Having made two sets of Moire patterns by transferring the patterns from this booklet, you could easily cut out some more discs, both blank and transparent and make more patterns of your own design.

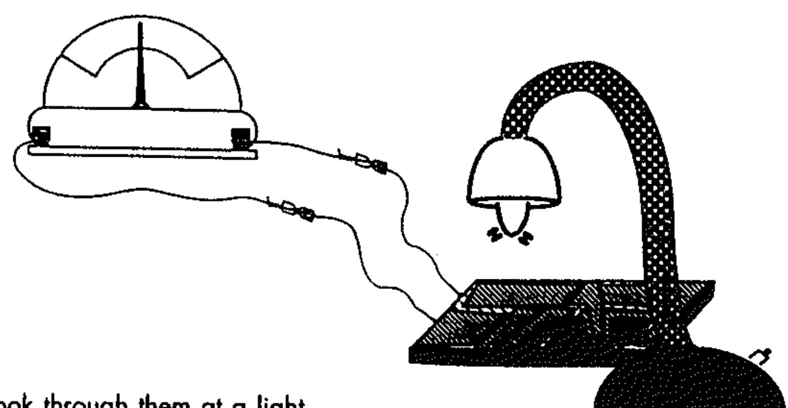
EXPERIMENT NO. 135 ADDITIONAL QUANTITATIVE EXPERIMENTS
We have seen that light striking the Solar Cell (S.C.) produces electricity and deflects the needle of the galvanometer. Let's look and see what colored light can do. This experiment is best performed in a room with electric light.

Place the S.C. connected to the galvanometer on a table near a table lamp. When you light the table lamp, the needle of the meter will probably reach the end of the scale. Cover the S.C. with the piece of rubber. Expose the S.C. to light, just enough that the needle of the meter shows exactly 2 1/2. Take a piece of yellow cellophane and without displacing (moving) the rubber sheet, cover the S.C. What is the new reading? How much less electricity is being produced? The difference may be very slight, so look carefully.

What happens if you cover the S.C. with two pieces of yellow cellophane?
We can call these pieces of cellophane filters since they filter the light which reaches the S.C. Next, try every one of the color filters in turn and note the deflection of the meter needle.

Take a piece of yellow and a piece of blue cellophane together. Looking through them at a light source, you will see that the light reaching your eye is green. Place both over the S.C. and note the deflection of the meter. How does this compare with the deflection obtained by the green filter? Again, take a red and a blue filter and look through these as you hold them together towards a light source. The color reaching your eye is purple.

Take a piece of yellow and a piece of red cellophane, placing the yellow filter above the red filter. Look through these. You should expect to see orange light and you will if you look through these at a white sheet of paper. However, if you look through both filters at your light source, you may be surprised to see that the light reaching your eyes is red and not orange!



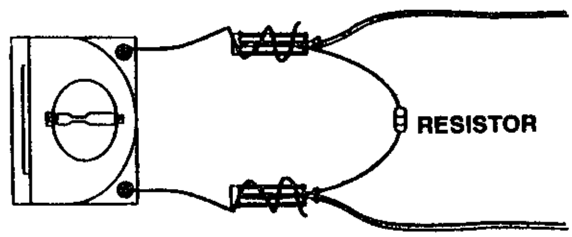
Lastly, take all four colors and look through them at a light source. Very little light reaches your eye now. (Check with the S.C. and meter). The light that does reach your eye is red, no matter which filter you place uppermost.

Remember, when we spun the four colors on a disc and found that they "added up" to white? The results we have now obtained seem like a contradiction! The explanation for that lies in the difference between REFLECTED, REFRACTED and TRANSMITTED light. As with the stroboscope, a little research of your own will vastly enhance the benefit obtained from this kit. Learning is a tool; just like a hammer, a screwdriver or an electric drill. There to be used. Knowledge is a tool that can be given away, lent, even sold and it will still remain yours!

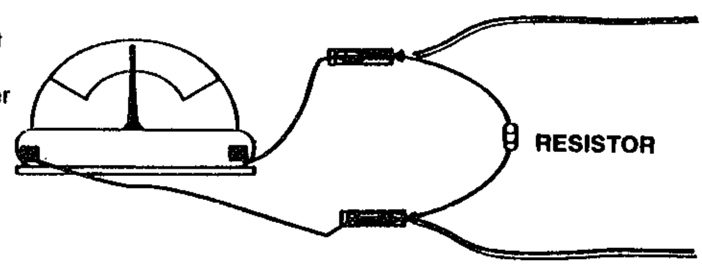
EXPERIMENT NO. 136 THE BYPASS OR "JUNT"

Our galvanometer is sensitive.
If we have performed most of the experiments with the S.C. in sunlight, and if the needle of the meter moved beyond 5, then we would have a problem.

We will now make our meter less sensitive so that we can use it in sunlight.



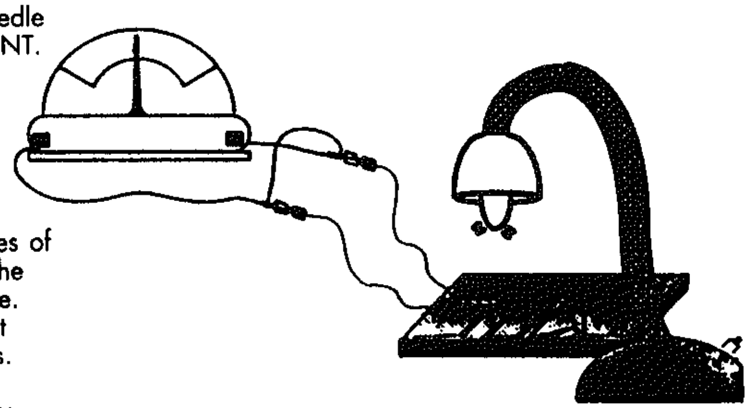
If we connect a wire between the 2 galvanometer connections and short circuit the coil, all the electricity will flow through that wire and the meter will not function.



By putting different conductors or resistors between the connections, the meter will function although the needle will deflect less. This is called a JUNT. This is used when a meter is too sensitive to measure a fairly large current.

By placing various resistors (conductors) between the two wires of the galvanometer you can make the galvanometer less or more sensitive. The enclosed resistor should be just right for the following experiments.

The diagram will show you exactly how to do it.



You can now use the meter even in bright sunshine. You could, for example, measure how much light is needed to turn the motor, with or without one of the discs.

Repeat using some or all of the color filter experiments but this time, do so in sunlight with the meter fitted with the junt.

EXPERIMENT NO. 137 ADDITIONAL REFLECTED SUNLIGHT

Measure the electricity produced by S.C. in sunlight with the modified meter (fitted with junt). If the sunlight is too strong even for the modified meter, hold the S.C. at an angle, so that part of the S.C. is in shadow. The meter should read between 1 and 2.
Take a mirror and reflect some additional sunlight onto the S.C. What happens?

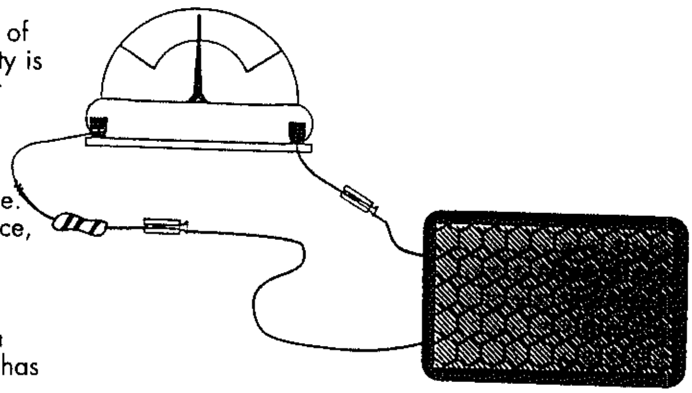
EXPERIMENT NO. 138 MEASURING ROOM LIGHT

Repeat the last experiment in your room using electric light. You may or may not need the junt depending on how much light your lamp gives. Use one mirror and even two. If you have a convenient source of florescent light, try that as well. Is there a limit to the amount of electricity your Solar Cell can produce or is this only limited by the amount of light you manage to shine on to the Solar Cell? Yes, there is a limit. Can you determine what it is?

EXPERIMENT NO. 139 THE ELECTRONIC THERMOMETER

You have in your kit a part which looks like a resistor, (it is made of glass) but it has no colored bands on it. This is a **SILICONE DIODE**. A diode is a special kind of resistor. It will let an electric current pass through it in one direction only. It is a kind of electronic traffic policeman.

The Silicone Diode has many uses in the field of electronics where a one-way flow of electricity is important. Our diode has another important function.



Its resistance, in other words, its ability to transmit electricity depends on its temperature. The warmer it becomes, the lower its resistance, the more electricity passes through it.

We can use a diode as a solar, electronic thermometer! An electronic thermometer is a very sensitive, highly accurate instrument. It has a (negative) value of 2.3 milli-volt for every degree Celsius change of temperature depending on the Diode used.

If you want to make your instrument accurate, you would have to ensure a constant light source and solder every connection. Moreover, you would have to calibrate the meter in degrees. Nevertheless, even as it is, your thermometer will work.

Construct the thermometer as shown in the diagram. Since electricity flows through the diode in one direction only, make sure the diode is in the right position. If not, turn it around. If you do not get good results, recheck all of the connections.

Your thermometer is ready and when the S.C. is exposed to sunlight, the meter should give a reading of about 1.

Hold the diode between your fingers and the heat of your body will be shown by the meter needle moving to the right as a rise in temperature. Take away your fingers and the needle returns to its original position. If it does not register, you can heat the diode with a candle, but just the glass of the diode. To make it more convenient, place the diode on a glass saucer, and heat from below.

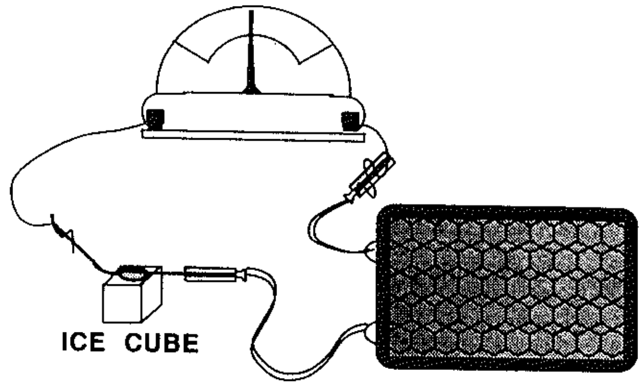
EXPERIMENT NO. 140 COOLING AND HEATING THE DIODE**

Do you have you any ice cubes in the kitchen refrigerator? Take one and place it under the diode.

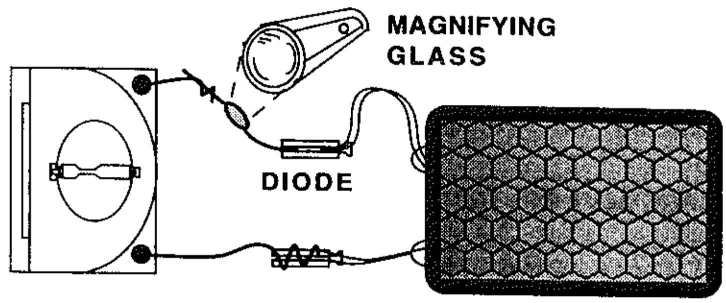
The needle will move towards the left, indicating a fall of temperature. Since melting ice has temperature of 0° C, you know where the needle comes to rest indicates 0°C.

Slowly pour some hot water over the diode. The needle moves to the right to indicate a temperature less than 100^{o}C (the temperature of boiling water). This is not very accurate since the water loses heat as it falls on the diode.

CAUTION: Hot water can be very dangerous. Take care not to scald your fingers. Also, hold the diode over a bucket so as not to make a mess or damage furniture.



Take the magnifying glass and focus the sun's rays onto the diode. Is the heat produced more than 100^{o} Centigrade? The magnifying glass from this kit is ideal for this experiment. It is big enough to give good results, and not big enough to burn the diode.



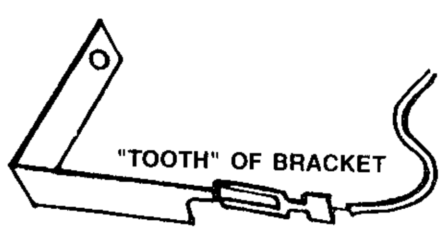
SOLAR ELECTROCHEMISTRY

When salt is dissolved in water, the salt does not vanish even though it can no longer be seen.

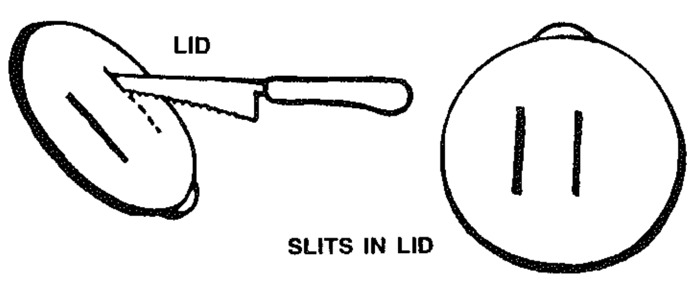
The chemical name for table salt is Sodium Chloride. Chemists write this NaCl which means that an atom of Sodium is attached to an atom of chlorine by a chemical bond. When you dissolve table salt in water, this bond is loosened and you get IONS of sodium and IONS of Chlorine dispersed in the water. These cannot be seen. If you insert two electrodes into a glass of salt solution and pass an electric current through it, the Sodium ions will migrate towards the negative electrode, while the chlorine ions migrate towards the positive electrode. You will see this in the following experiments. Gas bubbles form on one or both electrodes.

EXPERIMENT NO. 141 ELECTROLYTES

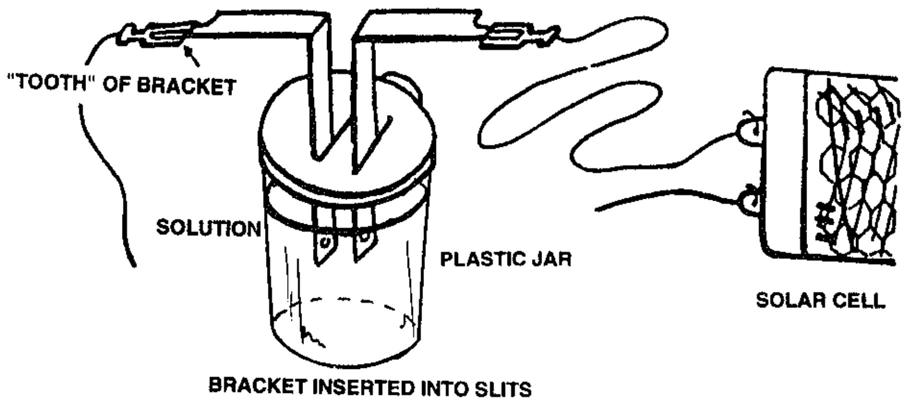
Take the enclosed plastic jar. Fill it with water, add a teaspoonful of table salt and dissolve it by stirring. Take the two brass electrodes. Note that each electrode has a "tooth" on one end. This fits the slide end of the Solar Cell.



The plastic jar has a lid. Take this lid and with a sharp knife, carefully make two slits in the form of windows. Look at the drawing before you start. Cover the jar with this lid and dip both electrodes through the slits into the salt water solution, (one electrode through each slit) making sure that they do not touch one another.



Connect them to the solar cell as shown in the diagram and let this apparatus stand in sunshine for about half an hour. Do you see any gas bubbles on the electrodes? Smell them carefully. Do you notice anything? The smell comes from the gas (chlorine).



EXPERIMENT NO. 142 pH INDICATOR PAPER
You have a piece of orange indicator paper in your kit. This paper turns blue in a basic solution. It turns red in an acid solution and green in a neutral solution, e.g. water. Take a bit of this paper and touch it with both the electrodes which were in the salt water. What happened? You only need a very small piece of the pH paper. A piece this size is all you need for each experiment: ☐

Look at the paper again after few hours.

NOTE: Chlorine is a bleaching agent!

The use of Solar Energy for electrochemistry is of increasing importance these days. Here are some experiments in this field. You have probably read about them. Now you can try them out!

EXPERIMENT NO. 143 COPPER PLATING
NOTE: In order to perform this experiment you will need to use the chemical Copper Sulfate. Due to safety regulations, this chemical cannot be included in this kit. We suggest that you perform this experiment at school under the supervision of your science teacher.

Copper Sulfate ($CuSO_4$) dissolves in water, just like table salt. Place solution of Copper Sulfate into a plastic jar, cover with lid and insert two electrodes. Connect the electrodes to the Solar Cell and stand in sunlight.

When Copper Sulfate is dissolved in water, it breaks up into copper and sulfate ions. The Copper (Cu) ions have a positive electrical charge while the Sulfate ions have a negative charge.

As soon as you expose the Solar Cell to light you produce electricity. This gives one of the brackets a positive and the other bracket a negative, electrical charge. Like a magnet, the negatively charged bracket attracts the positive ions of copper and after about half an hour it will be covered with the red metal. This is called electroplating. The brass bracket has been copper-plated.

IMPORTANT: If you perform this experiment at school, your teacher will tell you what to do with any remaining solution.

EXPERIMENT NO. 144 SILVER PLATING

If you were to use a solution of silver nitrate ($AgNO_3$), you could silver plate objects in a similar manner. Silver nitrate is not included in this kit but you need only a small quantity of a 2% solution. Once again, your science teacher may help you.

NATURAL SOLAR ENERGY EXPLOITATION

The sun has been generating energy for millions of years, long before the first man was born; long before the first plants came into being. In nature, it evaporates water. Water evaporates from the seas, condenses in the clouds and falls down to earth as rain, hail or snow. This is by far the most important use of solar energy, and it was not invented by man!

Another very important use of solar energy is photosynthesis. This too is a process that has been going on for hundreds of millions of years, and was not invented by man.

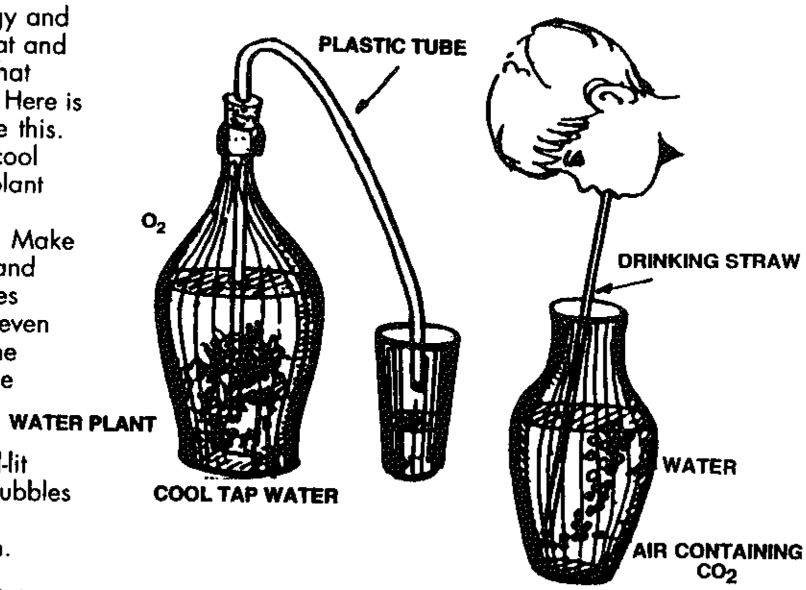
EXPERIMENT NO. 145 PHOTOSYNTHESIS

For this experiment you need several things not included in this kit, but you will find most of these at home. You need a bottle with a proper fitting cork, a piece of rubber or plastic tubing and a measuring jar as used in the kitchen. You should also use a water plant such as ELODEA which is used in most fish tanks (aquarium). If you cannot find any aquarium plants, many other plants which grow in the garden will do, but you would have to experiment as some plants work better than others. Plants "breathe" in carbon dioxide (CO_2)from the air, and use it together with water (H_2O) to produce carbohydrates ($C.H_2O$) such as sugars, starches and cellulose, the main constituents of all plants. As you can see from our very simplified formula

$$CO_2 + H_2O = C.H_2O + O_2$$

Oxygen (O_2) is left behind and this is exactly what does happen, but only in sunshine or artificial light. Light is needed for this chemical reaction. That is why it is called photosynthesis.
Photo = light : synthesis = putting together.

Nature transforms solar energy and stores it in plants which we eat and digest. This gives us energy that originally came from the sun. Here is an experiment to demonstrate this. Completely fill a bottle with cool tap water. Insert a suitable plant into the water, then set up an apparatus as illustrated here. Make sure that the cork fits tightly and also that the tube which passes through a hole in the cork, or even directly through the neck of the bottle (without a cork) must be <u>absolutely air-tight</u>.



Place this apparatus on a well-lit table, and soon you will see bubbles rising from the plant.
These bubbles contain oxygen.

This oxygen rises to the top of the bottle, but since the bottle is full and is hermetically sealed, the oxygen has to make room for itself and it does so by pushing out the water. This water enters the plastic tube at the bottom of the bottle, rises slowly within the tube and soon comes out on the other end of the tube. Collect this water and measure its quantity. The quantity of water you collect is equal to the quantity of oxygen containing gas which the plants produce.

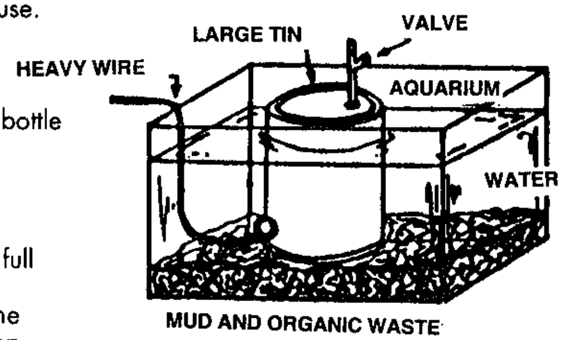
Perform the same experiment a second time, replacing the stale water with fresh water. Place the apparatus on a table in a dimly lit room. See how much water is displaced in a period of half an hour. Take the apparatus into sunlight and see how much water is now displaced in half an hour.

Using your solar cell and galvanometer as a light meter (just as in a camera), measure the light in several places and see whether there is any numerical relationship between the amount of water displaced.

EXPERIMENT NO. 146 MARSH-GAS PROJECT

Did you ever go on a picnic where you bathed in a stagnant pool? You may have noticed that bubbles from the mud rise through the water to the surface. If you took a drinking glass, filled it with water and held it upside down beneath the surface of the pool, as you walked in the mud, you could have collected these bubbles, which would displace the water in the glass until the glass seemed empty but was, in fact, full of gas, called methane or marsh gas. If you would light this gas, you would see that it burns.

Experiments are now under way to produce marsh gas on a large scale, for industrial use. The raw material for these experiments is municipal garbage, water and sunlight. Join us in these experiments as a special project. You will need a very large glass bottle or an aquarium, a large tin and a small aquarium tap. You also need some stout copper or aluminum wire.



Fill a large container or an aquarium 1/4 full with earth, to which you add some food remains, grass cuttings, or, better still, some animal manure. Fill the container to the top with water and place it in the garden, both in order to ensure maximum sunlight and also because very soon it will smell very strongly.

Take a large tin with one end open. Drill a hole in the bottom and insert a small aquarium tap. Cement this in place with some epoxy resin or other suitable adhesive. You may need some help here from an older friend or parent. They could also help you to find a stout copper or aluminum wire, which should be bent as shown in the illustration. Place both the wire and the tin in the aquarium and wait until gas bubbles start to form.

The wire loop which you had made, enables you to release the gas bubbles formed in the soil/ manure substrate and these are collected in the water-filled tin, in the same way as you could have gathered the marsh gas in the pond. When you have collected a quantity inside the tin, hold a test tube over the tap and open this tap. Since marsh gas is slightly lighter than air, it will fill the test tube. **LIGHT THE GAS IN THE TEST TUBE ONLY AND NEVER LIGHT THE GAS DIRECTLY AS IT COMES OUT OF THE TAP.** This could be dangerous.

It is easy enough to produce some marsh gas. Your project is to see how much you can produce and by which method! In countries where both land and sunlight are plentiful, such as in the desert, there is a shortage of fresh water, but salty water is often available. See if you can produce marsh gas using salty (sea) water.

Do you need soil or would sand do?
What is the best substrate; grass cuttings, kitchen waste, manure???
Would the addition of chemical garden fertilizer help?
How important is sunlight?
Do you have to change the water from time to time?

Now it's your turn to design your own experiments. That is why we call this a project.

EXPERIMENT NO. 147 THE SOLAR POOL

At the southern tip of Israel, near the town of Eilat, is a small lake. At first glance nothing seems remarkable about it. The water is warm and salty and not particularly clean. However, this lake attracts scientists from all over the world because it is a "solar pond." If current research proves successful, this small lake may make a major contribution towards solving the world's energy shortage.

If the sun shines on a pool of water, the top layer becomes slightly hotter since hot water usually rises to the top. But hot water evaporates faster than cold, and when water evaporates, it uses up heat.

You can easily test this by wetting your forearm and blowing on it. When you blow on your wet arm, you speed the process of evaporation. Your arm feels cold during this process because heat is lost from your arm while the water evaporates. The water has used the heat from your arm as a part of the evaporation process.

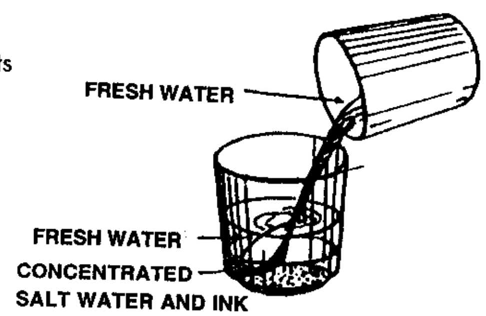
In an ordinary pool the sun shines on the water, adding heat. Then the water evaporates, losing heat. Eventually, an equilibrium is reached where any additional heat causes additional evaporation and the pool acquires a constant temperature.

A solar pool is different. Underground there is a salt-water well so the water at the bottom is much more salty than the layer at the top. The top layer acts as a magnifying glass, focussing the sun's heat onto the lower layer. The salty water is heavier than ordinary water, even when hot. Therefore unlike ordinary water, the heated salty water sinks, instead of rising.

It is now strictly prohibited to bathe in this pool. Before the scientific facts relating to this solar pond were known, swimmers who dove to the bottom were badly scalded.

Today, scientists are investigating the possibility of building artificial solar pools in order to exploit this solar energy trapped in the salt water layer.

You too can try out this idea. Take a colored plastic bowl or glass (not white.) Fill it to 1/3 of its depth with water and put in as much salt as will dissolve. If you have some ink or dark food dye, color this solution. Refer to Experiment No. 96.

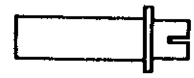


Now, carefully and slowly pour into the bowl or glass some fresh water. Pour it slowly down one side, using a spoon to direct the flow. It is important to prevent the two liquids from mixing. The ink in the salt water will tell you if you have been successful.

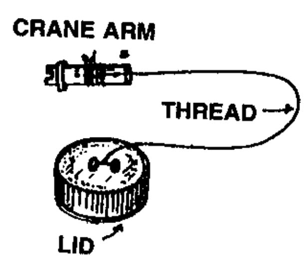
Let it stand in the sun for some time and then measure the temperature at the top, the middle and the bottom.

EXPERIMENT NO. 148 THE CRANE

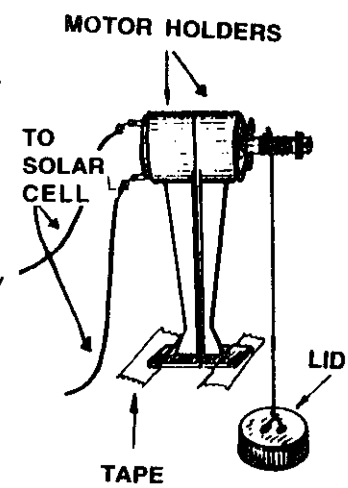
You can use the motor and solar cell to build a crane. Find the plastic part in your kit which looks as illustrated. It has a hole in one end and this fits onto the shaft of the electric motor.. First afix a rubber disc as shown in the diagram.



Next, take a piece of thread, about 1meter (3 feet) long. Tie one end of the thread to the part of the arm which sticks out. Tie a weight to the other end of the thread, as illustrated. The lid of the plastic jar is suitable for this experiment. Pull the thread through the lid and make a knot.



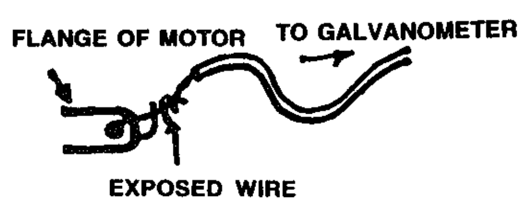
Connect the motor to the solar cell, and expose to sunlight. As the motor revolves, it winds the thread onto the crane arm and so lifts the weight. You may have to turn the crane arm with your fingers to start it revolving. This is a <u>very important experiment</u> as you will see presently.



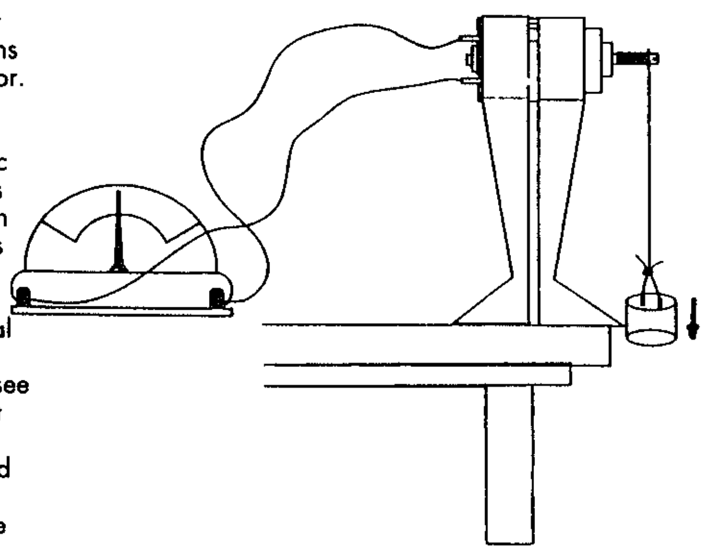
Our crane required electricity, that is to say, energy to lift the weight from a lower position to a higher one. This energy is now stored in the weight, as potential energy. As the weight descends it can be made to produce electricity. This has a very important practical application. You have seen that sunlight can be made to produce electricity. All very well and good, but what about night time, or on a rainy day when the sun is hidden by clouds? You also need electricity then. How do we solve that problem? This experiment gives a possible answer. If we can use sunlight to elevate (lift) a weight to a higher position and then release the weight to descend to its previous position, we can, in theory, store energy during sunlight and later make use of it when there is no sunlight. That is our next experiment.

EXPERIMENT NO. 149 POTENTIAL ENERGY OF POSITION

Disconnect the solar cell from the crane and connect the galvanometer in its place. About half way through this booklet, you learned how to splice electric wires. You were then left with two spare wires 50 cm long which you were then asked to put aside for a later experiment. This is it. Use these two wires to join the motor to the meter. This diagram shows you how to connect the motor to the galvanometer.



When the weight on the crane descends it causes the crane arm to revolve. This turns the electric motor into an electric generator. You produce electricity.



If there is too much friction and the plastic container does not go down, pulled by its own weight, you will have to help it down with your hand, or by placing a few coins into the container.

Industrially, on a large scale, this technical problem of too much friction, can be overcome. Look at the galvanometer to see what happens as you pull. As the weight descends, so much electricity may be produced that the needle jumps to the end of the scale of the meter.
Try to measure the current produced. Use the junt to desensitize the meter.

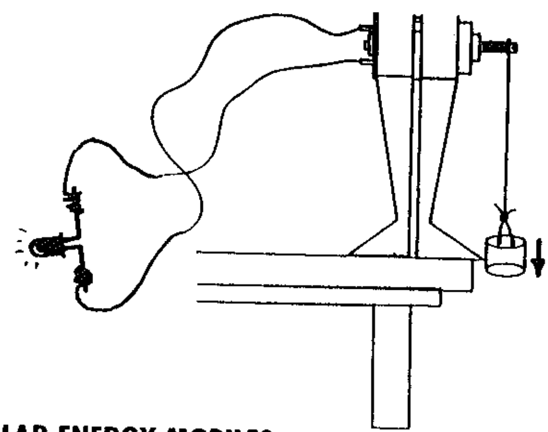
EXPERIMENT NO. 150 THE LIGHT EMITTING DIODE

You will find among the components of this kit a small red article which looks something like this:

It is a light emitting diode, LED for short. Like every diode it conducts electricity in one direction only. When it does, it lights up as a small red bulb. Disconnect the motor from the galvanometer and in its place connect the LED to the wires as shown in the following illustration.

Carry out this experiment in a dark place. Give the weight a sharp pull downwards.

If the bulb does not light up, you have to turn the LED around so that the current now flows in the opposite direction. Now it will light up.



EXPERIMENT NO. 151 - 153 SOLAR ENERGY MOBILES

To construct this aeronautic roundabout (carousel), fit the plastic arm to the electric motor as shown in one of the diagrams.

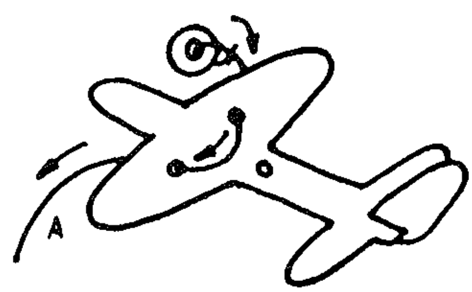
Take two pieces of cotton thread about 20 cm (8 in) long (threads A) and two other pieces of cotton thread about 10 cm (4 in) long (threads B). Attach the two airplanes to the threads and fix them to the plastic arm as illustrated:

1. Tie a small cardboard washer to one end of each thread (A and B) to prevent it from slipping through the holes in plastic arm or airplane.

1.

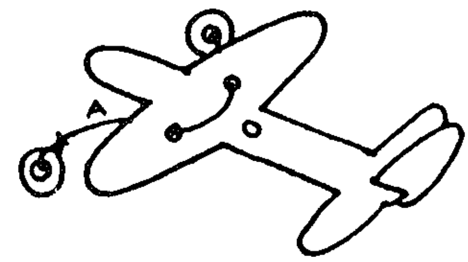
2. Pass the dangling end of thread A through the two holes on the arms of the airplane.
   (Note: The washer should be on the bottom side of the airplane.)

2.



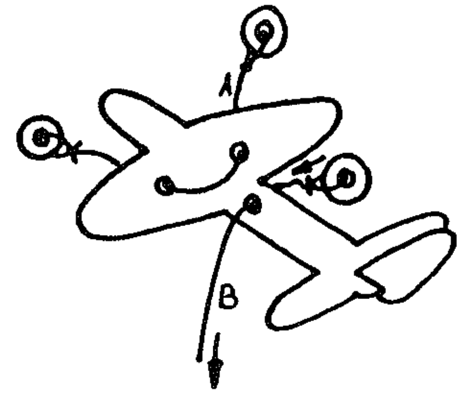
3. Tie a second washer to the second end of thread (A) leaving about 5 cm (2 in) between the two washers.

3.

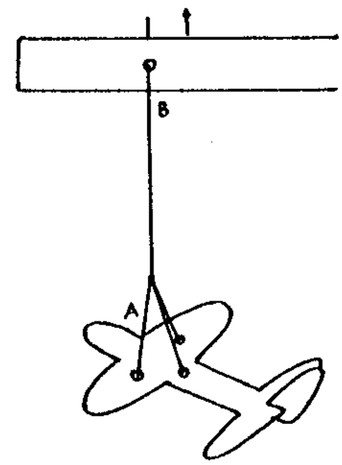


4. Pass the dangling end of thread B through the hole on the body of the airplane.

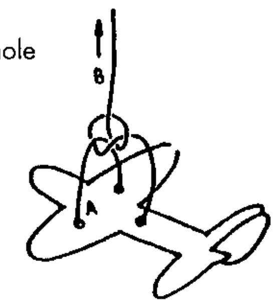
4.



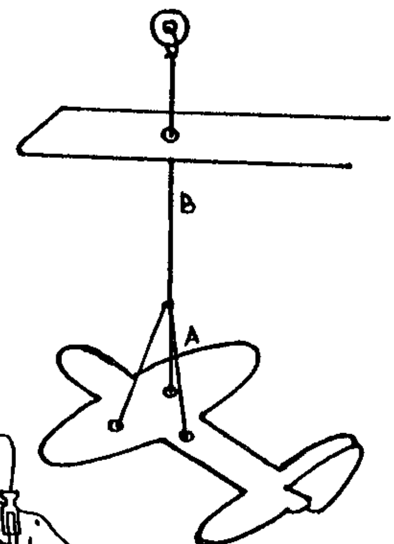
5. Tie thread B to part of the length of thread A and leave longer part dangling free.



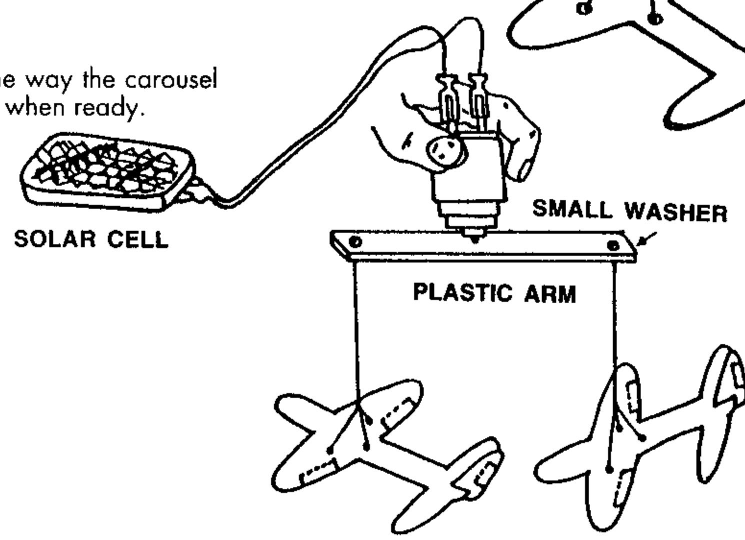
6. Pass the free end of thread B through the hole of the plastic arm.



7. Tie a washer to the free end of thread B.



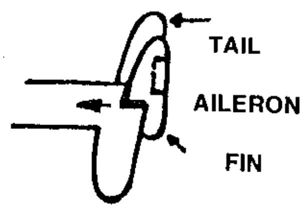
8. This is the way the carousel will look when ready.



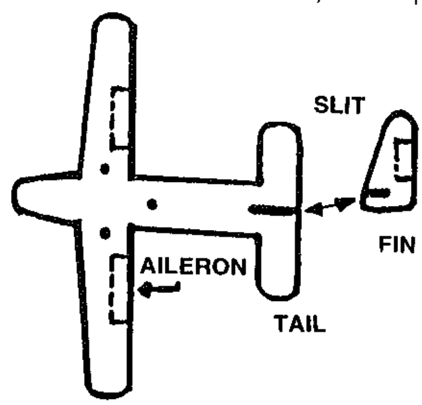
The motor shaft should fit tightly into the plastic arm. If it is too loose, stick one of the rubber discs over the hole and perforate it with a small nail.

Connect the motor to the solar cell and place the S.C. in sunlight or near a strong lamp. The plastic arm will now revolve and with it the model airplanes.

You may have noticed that the airplane is made up from two parts: the body of the plane and the tail. Both have a small slit. See drawing.



SLITS IN FIN FITTED TO SLOTS IN TAIL



Placing one slit over the other, not only enables you to fit the tail onto the body of the model plane, it also enables you to balance the plane so that it hangs in a perfectly horizontal position.

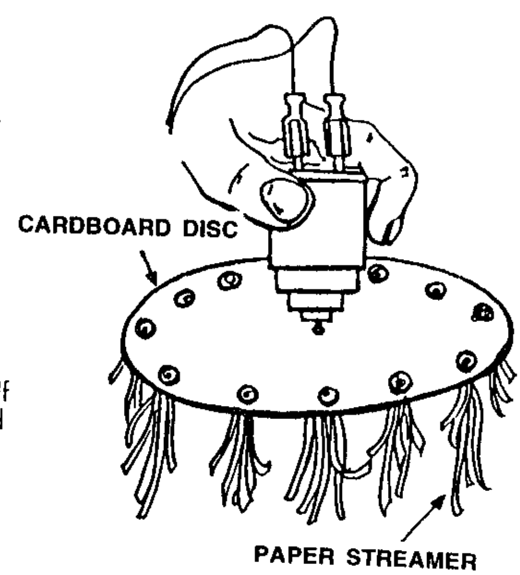
Notice also, that on the wings of the plane there are flaps called AILERON. The pilot uses these to steer the plane up and down. You too can experiment with them. By raising or lowering the flaps you can make the plane go up or down, as the plane makes a circle in the air.

By changing the angle of the tail fin in relation to the body of the plane, you can, moreover, make the plane "dance in the air." Try it.

IMPORTANT: Both planes must be perfectly balanced. If the plane dips forward, slide the tail fin further out. If it dips backwards, slide the fin further in, towards the wings. Should the plane dip to one side, stick a small sticker onto the wing on the other side.

When you attached the airplanes to the revolving arm, you built what is known as a mobile.

If you hang this assembly under an electric light bulb, the mobile will start to work as soon as you switch the light on. If you were to solder the wires to the flanges of both the motor and the solar cell, the mobile would revolve "forever" as long as the light shines!



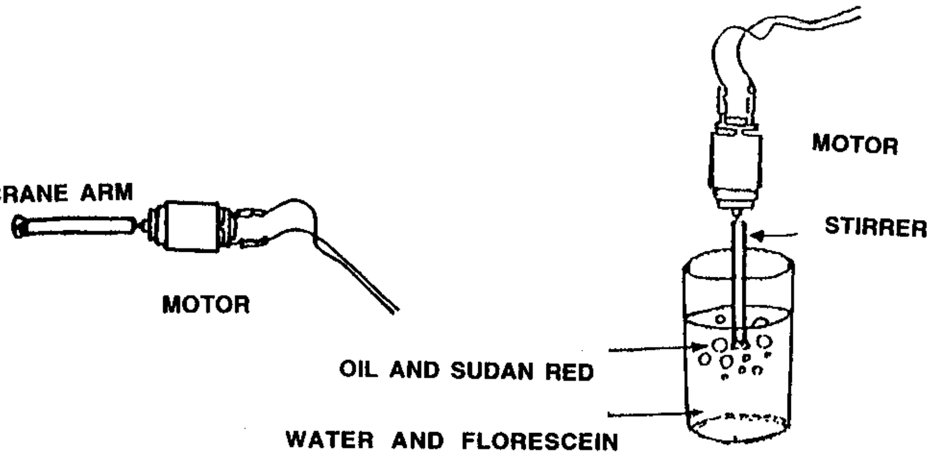
You could try some other ideas. Cut out a disc of some plastic, transparent material. Punch or drill holes in various places and insert strips of colored paper, or wool (see drawing). Connect to motor and you have another mobile.

Another idea is to take a drinking glass, and fill half of it with water. Color the water with a dye called FLORESCEIN. You need only a speck of this dye which you can buy in any drug store, or you may be able to get some from your science teacher.) If you cannot get some, you can use any food dye from the kitchen.

Take some oil, like liquid paraffin or castor oil, and color it with an oil dye such as Sudan Red. Add the colored oil to the water. The two liquids should have the same specific gravity. It is best to choose an oil that is slightly heavier than water and making the water heavier by adding salt. A mixture of 10 ml. Soya Oil and 2ml. CHLOROFORM has the same weight as water. Perhaps your chemistry or science teacher could help you obtain such a mixture. Tell your teacher exactly what it is for.

Next, fit the crane arm to the motor. This makes a good mixer. Insert mixer into glass and stir, connect to solar cell. Since oil and water do not mix, you will have blobs of oil swirling in the water in a most effective display of colors.

These were just 3 suggestions of mobiles you could make. Surely you can think of many more.



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This is IT. You have reached the end of the book. If you are unlike the writer of these lines, who as a child, usually read the end of every book before starting at the beginning, then you have at least attempted every experiment described here. Some experiments were easy, others not.

While carrying out the instructions, you no doubt learned something which you did not know before. Try using this gained knowledge now. Repeat some of the experiments, particularly some of the more difficult ones again. By doing so, you will learn two very important things:

1) With your new knowledge, some things that were difficult before, are now easier.

2) The experiment is now likely to be more interesting.

KNOWLEDGE MAKES LIFE EASIER. IT ALSO MAKES IT MORE INTERESTING.

You see there are many experiments waiting for you. So........

GET STARTED