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Scope of Study: The teaching of general science courses in many public schools is confined solely to text book work. The failure to use laboratory equipment for student experimentation and teacher demonstration may be blamed, in part, on the high cost of such equipment. Many pieces of equipment may be improvised from readily obtainable materials. Such improvised equipment is both inexpensive and useful and the ability to construct and use such apparatus is invaluable to the general science teacher.

Findings and Conclusions: Some of the best sources of materials are drug stores, hardware stores, war surplus stores, automobile parts stores, variety stores, salvage yards, school shops, and radio repair shops. The student body is another useful source.

Certain basic equipment is deemed necessary for the general science classroom. Ring stands, burners and heaters, a water source, flasks and bottles, stoppers, tubing, and electrical wire are indispensable. Some of these items may be constructed by the teacher, others must be bought.

A series of demonstrations from each of several broad areas of science are included in the report. Each demonstration was selected by applying the following criteria: A scientific principle must be involved; some equipment must be used; the equipment must be of a sort easily constructed from simple materials; and construction work must be simple and short. Complete lists of materials, instructions, and, in some cases, drawings are given for each demonstration.

ADVISER'S APPROVAL James H. Zant

LOW COST EQUIPMENT FOR GENERAL SCIENCE DEMONSTRATIONS

By

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LOW COST EQUIPMENT FOR GENERAL

SCIENCE DEMONSTRATIONS

Report Approved:

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CHAPTER I

INTRODUCTION TO THE REPORT

In many school systems today there is a trend toward teaching General Science courses as strictly text book subjects. In far too many cases demonstrations by the teacher and experiments by the students are being curtailed or eliminated. This unfortunate trend may, in many instances, be traced directly to the lack of equipment for use in demonstrations and experiments.

The absence of suitable equipment may, in most cases, be the direct result of the current high prices charged by scientific supply companies. Administrators are often unable or unwilling to purchase expensive equipment for use in General Science classes.

It is the purpose of this report to provide instructions for building simple equipment from inexpensive materials. The following criteria were used to justify the inclusion of the various items in the report:

1. The item must be suitable for use in an ordinary classroom without gas connections, water supply, or laboratory tables.
2. The item must be useful in demonstrating or illustrating a scientific law or principle.
3. The item must be justified in terms of time and

money. An item using expensive materials or requiring excessive time for construction must be capable of extended usage or must have more than one application.

4. The item must be capable of being constructed from relatively inexpensive materials by persons with ordinary mechanical aptitude.

The primary advantage of home built equipment is, of course, its low cost. There are, however, certain other advantages connected with home built equipment. Some of the more obvious advantages are listed below:

1. Home built equipment is usually so inexpensive and easy to construct that several pieces may be built for use by individual students.
2. In many cases it is possible to build useful equipment that is not offered for sale by scientific supply companies.
3. Students are often able to grasp ideas and principles more readily when they see them demonstrated with simple ordinary materials.
4. When students realize that experiments may be performed without complex, expensive equipment, they are often stimulated to work on projects and experiments outside of class.

It should be noted that this report is not a laboratory manual and is not intended to be used as such. The

items included in the report are intended to be used to supplement the text. Items are not arranged in the order in which they might appear in any given text; they are, instead, grouped under various branches of science which they best illustrate. The individual teacher must select those items which are useful to him from a standpoint of agreement with subject matter and personal preference.

The material lists, dimensions, and assembly instructions may, in most cases, be varied to fit the needs of the individual teacher. Minor variations will not affect the functioning of the equipment. Instructions for using the various items are given only when the particular item is not self-explanatory.

The teacher must bear in mind that home built equipment cannot replace certain commercial equipment. It is not wise to allow the administration to get the idea that the teacher and students can make anything and everything; or the teacher may find himself without any funds with which to purchase such items as microscopes, vacuum pumps, voltmeters, etc.

In conclusion it should be stated that every item in this report has been constructed and used in actual classroom teaching. The items will work if they are properly assembled.

It is hoped that this report will prove useful to the General Science teacher. If a teacher finds within this report only one item that may be used to aid his teaching, then the aims of the Author will have been served.

CHAPTER II

SOURCES OF MATERIALS

The teacher should overlook no possible source of materials for use in demonstrations and experiments. Some of the more useful sources and the materials one may expect to find are discussed below.

The variety store and drug store provide a rich source of useful items. Such things as magnets, magnifying lenses, screws, pins, toy balloons, etc. may be purchased at low cost. Most common chemicals and compounds may be obtained at any drug store.

War surplus stores are excellent places to find lenses, wire, cordage, and storage containers of all sorts. Hardware stores usually carry in stock rubber and metal tubing and fittings of all sorts.

Automobile parts stores and salvage yards are a good source of small electric parts such as motors, generators, voltage regulators, coils, etc. Salvage yards in particular are good places to secure automobile batteries and parts from car radios.

One of the most fertile sources of useful materials is the student body. Often students are eager and willing to supply the teacher with old radios, doorbells, electric fans, etc. that have been discarded at home. It is wise

to have the student bring a note from his parents stating that the item being supplied is really no longer useful to the student's parents.

Finally, the teacher should not overlook the resources of his own school. The school shop will usually be able to supply all the wood, nails, screws, and metal needed by the teacher in the construction of equipment. The shop will, also, furnish the necessary tools and working space needed for any construction work.

Before attempting to secure any materials from stores the teacher should reach an understanding with the school administration as to payment. Often the school is able to buy things at a discount.

CHAPTER III

BASIC EQUIPMENT

The following equipment is to be regarded as basic and should be purchased or built if it is not already available. All of these items are so useful in so many demonstrations and experiments that, if they cannot be built, it would probably be worth the teacher's while to buy them himself if the school will not do so.

RING STAND

The ring stand is used basically as a support. With appropriate support arms it may be used in many different ways. If the school does not possess at least two ring stands and at least five assorted support arms, they should be purchased. It is very difficult to build a truly efficient ring stand without investing more time and materials than is practical.

BURNERS AND HEATERS

If a gas outlet is available, a bunsen burner should be purchased. If gas is not available, commercial solid alcohol products such as Sterno may be used. Alcohol type burners may be purchased or built and will give satisfactory service. Directions for building an alcohol burner are given below.

Material List:

Small mouth bottle with screw top.

Large mouth bottle with screw top.

Woven cotton sash cord.

Instructions:

The small mouth bottle should have a wide base to prevent possible tipping over. Remove the tops from both bottles and punch a one quarter inch hole in the center of the small top. Punch three equally spaced holes in the large top. The cord is to be used as wick material. Cut lengths of the cord so that one half inch will protrude above the bottle tops when the wicks are inserted in the holes. The rest of the wick should reach well into the bottle. Secure the wicks in the holes by inserting pins through the wicks above and below the bottle tops.

The small bottle, with its one wick, is a general purpose burner. The large bottle, with its three wicks, should be used for boiling water and other applications requiring concentrated heat. Rubbing alcohol or kerosene may be used for fuel. Do not use gasoline.

WATER SOURCE

If running water is available it is desirable to have a method of connecting small rubber tubing to the faucet. Faucet adapters may be purchased or made as described below.

Material List:

Short length of garden hose.

¼" diameter rubber tubing.

Short length of glass tubing.

Friction tape.

Instructions:

Insert the glass tube into one end of the rubber tube until the glass tube is completely covered. This will serve to stiffen the rubber tube. Wrap friction tape around the stiffened end of the rubber tubing until it is built up enough to fit snugly inside the garden hose. Insert the built up portion in the garden hose and tape it securely in place.

If the water faucet is threaded, attach the garden hose with a standard fitting. If the faucet is smooth, force the garden hose over the faucet and tape it in place.

If running water is not available, a large bucket or can should be used to hold a supply of water. Cut a hole in the bottom of the container and solder a short length of copper tubing in place. The rubber tubing may be fitted to the copper outlet and wired in place. The water flow may be controlled by using the metal pincher from a hot water bottle or by a clothespin. A large can or bucket may be used as a drain.

FLASKS AND BOTTLES

Almost any bottles may be used for demonstrations and experiments. If the bottle is to be used for boiling water, pyrex flasks should be purchased. If ordinary glass bottles are to be used for boiling, great care must be taken.

STOPPERS

Ordinary cork stoppers may be used in some demonstrations and experiments. They may be purchased in drug and hardware stores and are very inexpensive. An assortment of

sizes should be secured.

Rubber stoppers must be used when air tight and water tight connections are to be made. A variety of sizes in solid, one-hole, and two-hole designs should be purchased.

A cutter for forming holes in both cork and rubber stoppers may be constructed from short lengths of small diameter steel stamp tubing. An old automobile radio antenna may be cut into short lengths and used. Sharpen one end of the tube with a file and use a twisting motion to cut holes in the stopper.

TUBING

Rubber tubing is one of the most useful items that may be used for connections of all sorts. Hot water bottle tubing, wind-shield wiper tubing, or surgical rubber tubing will give satisfactory service.

Glass tubing of assorted diameters is probably the best material for making connections between containers and stoppers. If glass tubing is not available, copper tubing may be used in most cases. Copper tubing may be bent most easily by filling the tube with wet sand before applying pressure to form the bend; unfilled tubing may kink when it is bent.

ELECTRICAL WIRE

Single strand, insulated bell wire is suitable for use with dry cells and low power circuits. Bell wire may be purchased in hardware store. It is inexpensive. The wire should be cut in various lengths and, if possible, equipped with clips to facilitate making connections.

Ordinary line current of 115 volts is not suitable for very many demonstrations and experiments. Whenever line current is used, heavy insulated wire must be used.

WORK TABLES

All the items described in this report require no more space than that usually available on an ordinary desk, but some teachers may prefer to have a work table in the classroom. A heavy card table will be suitable or a wooden table may be secured for this purpose.

CHAPTER IV

AIR PRESSURE

1. CAN CRUSH

Material List:

Tin can with air tight cap.

Burner.

Instructions:

Remove the cap and place about one fourth inch of water in the can. Boil the water for about three minutes. Remove the burner and cap the can as swiftly as possible. The can may now be allowed to cool slowly, it may be cooled by wrapping in a wet towel, or it may be cooled by placing it under a stream of cold water. When the can has cooled enough to condense the steam, air pressure will crush the can completely.

2. VACUUM PUMP SUBSTITUTE

Material List:

Large, strong glass bottle.

One-hole rubber stopper.

Short length of rubber tubing.

Pincher for rubber tubing.

Short length of glass tubing.

Instructions:

Insert the glass tube in the stopper and attach the

rubber tubing. The pincher should be open. Place a small amount of water in the bottle and insert the stopper. Boil the water until the bottle is completely filled with steam, remove the burner, and close the pincher. Allow the bottle to cool so that all the steam is condensed. A partial vacuum will now exist inside the bottle.

To use the bottle as a substitute for a vacuum pump, attach the rubber tubing to the container that is to be evacuated and open the pincher. For best results the vacuum bottle should be as much larger than the other container as possible.

3. BALLOON EXPANSION UNDER REDUCED PRESSURE

Material List:

Bottle.

Solid rubber stopper.

Long nail.

Small balloon.

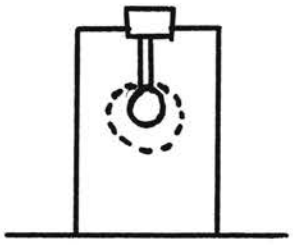


Fig. 1. Balloon Expansion

Instructions:

Inflate the balloon to about one tenth its maximum size and tie the mouth tightly. Fasten the balloon to the head of the nail and push the point of the nail firmly into the base of the stopper. Follow the procedure given for the "Can Crush" and the balloon will expand as the steam condenses.

The demonstration may be varied as follows: Use a bottle with a small mouth. No stopper is required. Boil the water and remove the burner, but close the mouth of the bottle by slipping the mouth of the uninflated balloon over it. As the steam condenses, the balloon will be forced down into the bottle until it lines the interior of the bottle completely.

4. LUNG MODEL

Material List:

Small mouth bottle.

One-hole rubber stopper.

Short length of glass tubing.

Large rubber balloon.

Small rubber balloon.

Metal file.

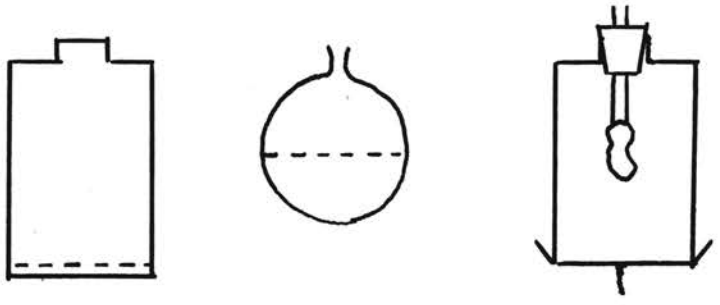


Fig. 2. Working Model of Single Lung

Instructions:

Use the file to scratch a deep groove around the bottle near the base as shown by the dotted line. Heat the groove with a burner and plunge the lower portion of the bottle into cold water. The base of the bottle will break loose. Use caution in performing this operation as the bottle may shatter. The edge of the break will be sharp. Use coarse sandpaper to smooth the edge. Cut the large balloon as indicated by the dotted line and tie a string tightly around the mouth of the balloon. Fasten the cut balloon to the open base of the bottle with rubber bands.

Attach the small balloon to one end of the glass tube and insert the tube into the stopper so that about an inch protrudes above the top of the stopper. Place the stopper in the mouth of the bottle.

The lung model is now complete. The glass tube corresponds to the trachea, the small balloon to the lung, the bottle to the chest cavity, and the rubber base to the diaphragm. When the string on the rubber base is pulled down, the "lung" will expand.

5. ANEROID BAROMETER

Material List:

Unopened one pound can of coffee.

Long broomstraw.

Glue.

Mounting bracket.

Paper strip.

Table or other flat surface.

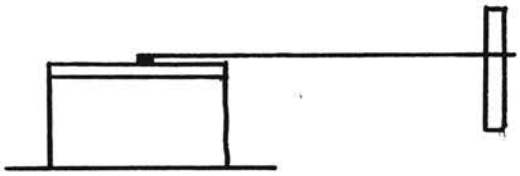


Fig. 3. Aneroid Barometer

Instructions:

Use glue to attach the end of the straw to the center of the coffee can lid. The remainder of the straw is not supported. Arrange a paper strip near the free end of the straw and mark the strip at one eighth inch intervals. Very slight changes in air pressure will cause the can lid, and the straw, to move a noticeable distance. The markings on the scale are not calibrations; they are merely reference points. The can must be kept at a constant temperature because temperature changes will also cause the can lid to move.

CHAPTER V

WATER

1. DENSITY LEVELS AND FLOTATION

Material List:

Tall glass bottle of uniform diameter.

Mercury, carbon tetrachloride, glycerin, and kerosene.

Iron bolt, brick, wood, thumbtacks, and cork.

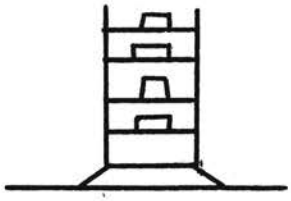


Fig. 4. Density Level Bottle

Instructions:

The various liquids are to be placed in the bottle in levels corresponding to their respective densities. The mercury goes in the bottom, the carbon tetrachloride next, the glycerin next, the water next, and the kerosene on top. The liquids will not mix if they are added slowly. A long stem funnel is useful.

After arranging the liquids in the bottle, the weights

should be added with a pair of long tweezers. The iron bolt will float on the mercury; a small piece of soft brick will float on the carbon tetrachloride; a piece of wood weighted with thumbtacks will float on the glycerin; a plain piece of wood will float on the water; and a piece of cork will float on the kerosene.

2. SURFACE TENSION

Material List:

Flat sided bottle.

Alcohol.

Olive oil.

Instructions:

Prepare a mixture of one half alcohol and one half water in a separate container. Fill the bottle about half full of the mixture. Pour a thin layer of olive oil on the surface of the mixture. If the olive oil sinks, add more water to the mixture. Fill the remainder of the bottle with the alcohol-water mixture. The density of the mixture will be so nearly the same as the density of the olive oil that the olive oil will float near the middle of the bottle. Due to the pull of surface tension, the olive oil will assume a perfect spherical shape.

3. HYDRAULIC LIFT

Material List:

Hot water bottle and rubber tubing.

Funnel.

Three heavy books.

Several quarts of water.

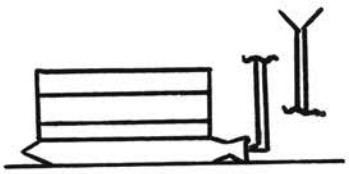


Fig. 5. Hydraulic Lift

Instructions:

Fill the bottle almost full of water and attach the rubber tubing to the standard plug. If the tubing is short, remove it and replace it with one at least four feet long. Place the bottle on the floor and place the books on it. Hold the rubber tube in a vertical position, insert the funnel in the top end, and pour water slowly into the funnel. If a long tube is used, weights as great as fifty pounds may be lifted by the bottle.

4. WATER POWER

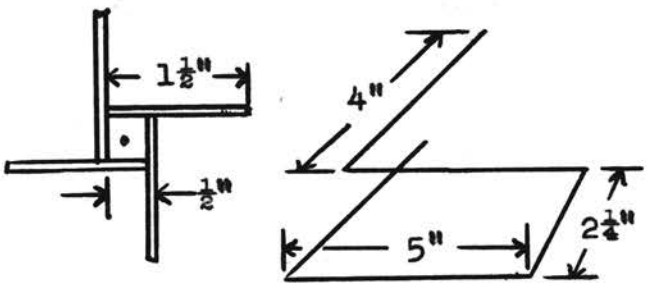
Material List:

One piece of wood, $\frac{1}{2}$" by $\frac{1}{2}$" by 2".

Four pieces of wood, $\frac{1}{4}$" by $1\frac{1}{2}$" by 2".

Nails or screws.

Wire coat hanger.



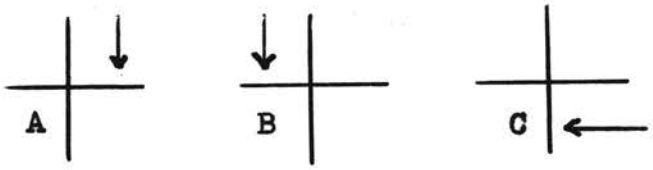


Fig. 6. Model Water Wheel

Instructions:

Assemble the pieces of wood as shown. Drive a nail in each end of the axle piece. Bend a piece of coat hanger wire as shown. Place the water wheel in the wire framework. The axle nails should fit in the hooks at the top of the framework. The water wheel should now turn freely.

Arrange the water supply so that water will be delivered through a rubber tube. When the water is allowed to fall on the wheel as shown in position A, the breast wheel is demonstrated. Position B shows the overshot wheel and position C shows the undershot wheel.

5. WATER REACTION CAN

Material List:

Tin can.

Thin wire.

Swivel.

Ring stand or other support.

Large nail or center punch.

Tin-snips.

Tub or large bucket.

Water supply.

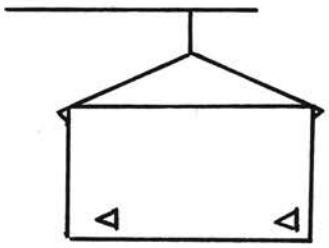


Fig. 7. Water Reaction

Instructions:

Punch two holes near the top of the can with a nail or punch. Attach a wire bail to these holes and attach a swivel to the top of the bail. The swivel may be a common fish line swivel or a short length of ball-type key chain. Attach the other end of the swivel to the support. The can should now spin freely about a vertical axis.

Remove the can from the support and drive four equally spaced outlet holes near the base. The outlet holes are to be made as follows: Drive a nail in the can and, before removing the nail, twist it to the right as far as possible. The holes should all point in the same direction. Replace the can on the support and fill it with water. As the water pours through the angled outlet holes, reaction will spin the can. Use caution in arranging the apparatus. Water will be thrown out for several feet and should be caught in a tub or large bucket.

6. STEAM REACTION CAN

Material List:

Coffee can with lid.

Thin wire.

Swivel.

Ring stand or other support.

Burner.

Large nail or center punch.

Instructions:

The apparatus is arranged as in the preceding demonstration with the following changes: Do not use holes for attaching the wire bail. Wrap wire around the top of the can and attach the bail to this. Drive the outlet holes half way down the side of the can instead of near the bottom.

Put a small amount of water in the can and put the lid in place. Arrange the burner under the can. Allow the water to boil. Steam escaping from the outlet holes will spin the can. Do not stand near the can when it is spinning since small drops of hot water may be thrown from the outlet holes.

CHAPTER VI

SOUND

1. SOUND IN A PARTIAL VACUUM

Material List:

Bottle.

Solid rubber stopper.

Long nail.

Jingle bell.

Instructions:

Attach the jingle bell to the head of the nail and push the nail firmly into the bottom of the stopper. Insert the stopper into the bottle and shake the bottle to show that the bell may be heard. Evacuate the bottle by the method described in Item 3, Chapter IV. Shake the bottle again to show that the sound of the bell does not travel through a partial vacuum as readily as it travels through air.

2. FOCUSING SOUND WAVES

Material List:

Two automobile sealed beam headlights.

Wrist watch or pocket watch.

Candle.

Ring stand or other support.

Meter stick or tape measure.

Wooden plugs.

Instructions:

Remove the glass lens from each headlight. Remove the bulbs by heating the solder that holds them in place. Be careful not to mar the reflecting surface. Plug the holes left by removing the bulbs. Mount the reflectors facing each other. The focal point of each reflector will be that point formerly occupied by the filament of the bulb.

Place the watch at the focal point of one reflector and arrange the candle so that its flame will be at the focal point of the other reflector. When the two reflectors are placed the proper distance apart, the focused sound from the watch will cause the candle flame to flicker violently. The teacher should show that sound from the watch will not affect the flame when the reflectors are removed.

The watch and one reflector may be used to demonstrate to the students that focused sound may be heard at a far greater distance than unfocused sound.

3. ELECTRICITY INTO SOUND

Material List:

Flashlight battery.

Doorbell transformer.

Bell wire.

Permanent magnet radio loud speaker.

Instructions:

This demonstration should be performed only if a microphone is not available. If a microphone may be used, a common telephone hook-up will give much better results.

Connect either pole of the dry cell to either wire of the loudspeaker. When the connection is closed, a loud click will be heard. Another click will sound when the circuit is broken. A telephone receiver or a radio earphone may be used in addition to, or in place of, the loudspeaker.

The doorbell transformer should be the type that produces six volts of alternating current. Connect the output wires of the transformer to the loudspeaker and a loud hum will be produced. The humming sound will have a frequency of sixty cycles per second.

CHAPTER VII

INERTIA, MOMENTUM, AND CENTER OF GRAVITY

1. INERTIA

Material List:

Heavy brick or other weight.

Light string or heavy thread.

Two eye screws.

Ring stand or other support.

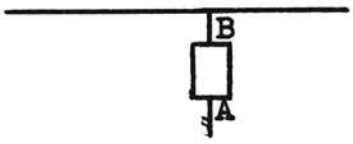


Fig. 8. Inertia of a Suspended Body

Instructions:

Attach the eye screws to each end of the brick and tie a one foot length of string to each screw. Attach string "B" to a support as shown. String "A" should hang free.

A slow, steady, downward pull on string "A" will result in a break in string "B". A sudden jerk on string "A" will cause string "A" to break. Some experimentation may be required to find the proper string sizes.

2. CENTER OF GRAVITY

Material List:

One foot ruler.

Claw hammer.

String loop.

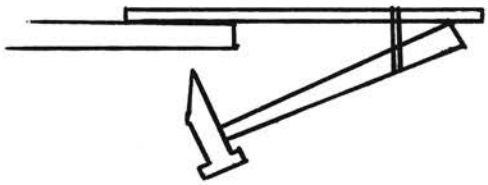


Fig. 9. Center of Gravity Form

Instructions:

Arrange the ruler, hammer, and loop as shown. The strange location of the center of gravity of the assembly may be demonstrated by placing the free end of the ruler on the edge of a table or other support.

3. DOUBLE CONE ROLLER

Material List:

Two plastic or metal funnels.

Wooden dowel of same diameter as funnel spout.

Stiff cardboard.

Friction tape.

Table or other flat surface.

Heavy scissors or tin snips.

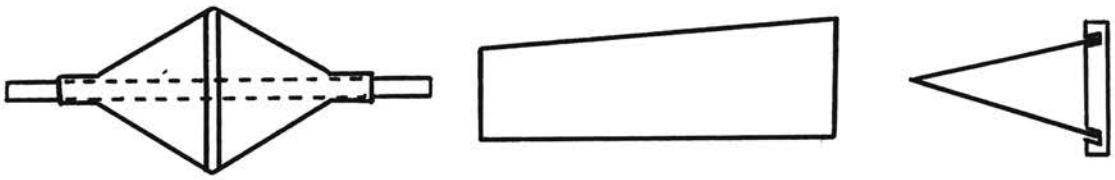


Fig. 10. Double Cone Roller

Instructions:

Force the funnels onto the wooden rod to make a double cone. If the funnels are not held in place by friction, tape the end of each funnel to the wooden rod. The funnels should now be fixed firmly in the shape of a double cone.

Fold the cardboard and cut it into the indicated shape. Spread the cardboard in to the shape of a "V" and arrange another piece of cardboard to act as a brace. When the double cone is placed in the trough at the point of the "V", it will apparently roll up hill as the center of gravity of the roller travels down hill.

4. ROTATION ABOUT AXIS OF MOMENT OF INERTIA

Material List:

Hand drill.

Short length of wooden dowel.

Eye screw.

Coffee can lid.

Long, thin bolt.

Small loop of chain.

Woven fish line.

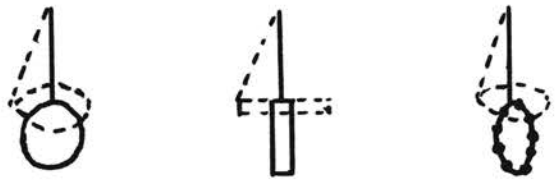


Fig. 11. Rotation About Axis of Center of Gravity

Instructions:

Insert the eye screw into one end of the dowel and place the dowel in the drill chuck. Attach a short length of fish line to a point on the rim of the can lid, another length to one end of the bolt, and a third length to any point on the chain loop. These objects will be used for rotation. The length of line to be used will depend upon the size of the drill and must be determined by trial.

Select one of the objects and attach the free end of the line to the eye screw. Hold the drill in a vertical position and turn the drill handle rapidly. The object will begin to rotate about the axis of its moment of inertia and will assume the position shown by the dotted lines.

5. COLLISION BALLS

Material List:

Steel ball bearings.

Rubber tubing.

One piece of wood, 6" by 12".

Thread.

Small nails.

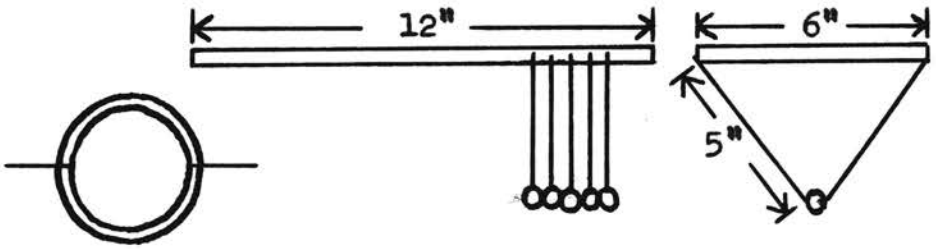


Fig. 12. Collision Balls

Instructions:

Ball bearings of uniform size must be used. Secure a used ball bearing race from a garage and remove the balls by cracking the race in a metal vise.

Cut narrow bands from rubber tubing and attach light thread to the bands as shown. Slip the ball inside the band. The ball should fit nearly too snugly to be removed. The threads must form a perfect extension of the axis of the ball. Prepare all the balls in this fashion.

Drive small nails into the lower edge of each side of the board and attach the free ends of the threads to the nails as shown in the drawing. When all the threads are attached, the balls must barely touch each other and they must be arranged in a perfectly straight line. The rubber bands must not interfere with the contact between the balls.

The board should be supported at one end so that the balls may swing freely. The apparatus may now be used in the usual way to demonstrate elastic collision, impact, conservation of momentum, etc.

6. GYROSCOPE EFFECTS

Material List:

Bicycle front wheel.

Two pieces of soft wood, 1" by 1" by 5".

Instructions:

Remove the front wheel from a bicycle. If the wheel is not equipped with a tube and tire, weight the rim by wrapping it with cord, friction tape, or wire.

Drill a quarter inch diameter hole into one end of each piece of wood. The holes should be about two inches deep. A threaded bolt projects from each side of the wheel hub. "Screw" the pieces of wood onto these bolts. The wooden pieces will be held firmly in place by friction, even though they are not threaded. The pieces of wood will now serve as handles with which to hold the wheel.

A slight push will set the wheel spinning at a rate sufficient for many demonstrations. The following are a few of the more useful effects possible with the wheel:

Hold the wheel vertically, spin it, and place one handle in a loop of rope or other support. Release the other handle. The wheel will remain suspended as long as it is spinning rapidly.

Have a student hold the spinning wheel vertically in front of his chest. The student should then walk in a straight line and attempt to suddenly turn a corner.

Have a student hold the spinning wheel in any position and then attempt to change the plane in which the wheel is spinning.

Have a student hold the spinning wheel vertically in front of his chest and seat him on a stool with a swivel

seat. The student may rotate himself on the stool by merely raising or lowering one of the handles of the wheel.

Many other common gyroscopic effects are possible.

CHAPTER VIII

HEAT

1. HEAT CONDUCTION IN A METAL ROD

Material List:

Metal rod.

Candle or sealing wax.

Burner.

Ring stand or other support.

Instructions:

Place the rod on a flat surface and allow drops of wax from the candle to fall on it. The drops should be spaced at one inch intervals. Allow the drops of wax to cool and harden on the rod.

Clamp one end of the rod in the ring stand. The rod should be in a horizontal position. Heat the free end of the rod with the burner. The progress of the conducted heat through the rod may be observed as the wax drops melt.

2. HEAT CONDUCTION IN DIFFERENT METALS

Material List:

Two wooden strips.

Two heavy rubber bands.

Assorted metal wires.

Candle or sealing wax.

Burner.

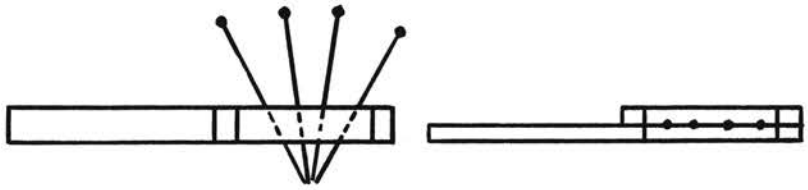


Fig. 13. Heat Conduction in Different Metals

Instructions:

The wires must be of equal length and equal diameter. Place the wires on a wooden strip as shown. Put the other strip over the wires and bind the two strips together with rubber bands.

Place a drop of sealing wax or candle wax on the free end of each wire. Heat the juncture of the wires with a burner. The order in which the wax drops melt will indicate the relative heat conducting ability of the different wires.

3. ABSORPTION OF RADIANT ENERGY

Material List:

Three test tubes or small bottles of equal size.

Three thermometers.

Aluminum foil.

Three pieces of colored cloth or paper.

Instructions:

Prepare the test tubes as follows: One tube should be covered with aluminum foil, one tube should be blackened with soot from a candle flame, and the third tube should not be changed. Fill each tube with an equal amount of water and insert a thermometer in each. Place all three

tubes in strong sunlight for fifteen minutes.

The temperature of the water in each tube will show quite clearly the relative absorption of radiant energy by the three surfaces. If only one thermometer is available, the bottles or tubes may be exposed to the sun one at a time. The demonstration may be varied by covering the clear tubes with paper or cloth of different colors to determine the relative absorption of radiant energy by clothing of different colors.

4. EXPANSION OF METAL

Material List:

Metal rod.

Wooden block.

Ring stand or other support.

Small nail.

Burner.

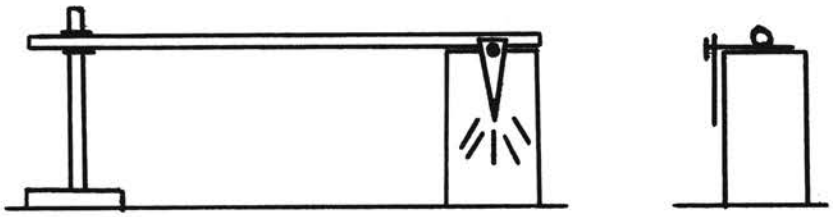


Fig. 14. Metal Expansion Indicator

Instructions:

Clamp one end of the rod so that the rod is supported in a horizontal position. Place the wooden block under the

free end of the rod so that the rod barely touches the block. Cut a thin, wedge-shaped piece of paper to act as a pointer and push the nail through the wide end of the paper. Place the nail between the rod and the wooden block as shown.

The pointer should be in a vertical position with the point down. Place comparison marks on the wooden block so movements of the pointer may be easily detected. The rod may be heated with a burner or any heat source. Linear expansion in the rod will cause the nail to rotate enough to cause a noticeable change in the position of the pointer.

5. EXPANSION AND CONTRACTION OF AIR AND WATER

Material List:

Small mouth bottle.

One-hole stopper.

6 inch length of glass tubing.

Ink.

Instructions:

Place the glass tube in the stopper so that most of the tube projects from the top of the stopper. Place the stopper in the bottle and fill the glass tube about half full of ink-colored water. If the tube is small enough, the water will not run down into the bottle. Heating or cooling the bottle will cause the air in it to expand or contract enough to cause the colored water in the tube to rise or fall.

To show expansion of water, fill the bottle with ink-colored water and force the bottle-stopper into the neck of the bottle until the water rises in the glass tube.

When the bottle is gently heated or cooled, the water in the tube will rise or fall. Do not overheat the bottle. The heat of the teacher's hand should be sufficient. The demonstration may be varied by using liquids other than water.

6. BOILING UNDER REDUCED PRESSURE

Material List:

Bottle.

Solid rubber stopper.

Burner.

Instructions:

Fill the bottle about one third full of water. Boil the water until the air inside the bottle has been completely replaced with steam. Insert the stopper and remove the burner. Allow the bottle to cool until it may be touched with bare hands. The condensation of the steam will have reduced the pressure until the slightest application of heat will cause the water to boil. The heat of the teacher's hands or the heat from a single match will be sufficient.

CHAPTER IX

LIGHT

1. REFRACTION IN LIQUIDS

Material List:

Flat sided bottle.

Black paint or black shoe polish.

Cardboard.

Rubber bands.

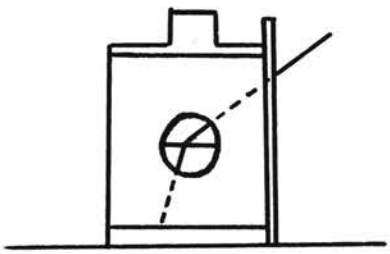


Fig. 15. Refraction Bottle

Instructions:

Paint the bottle black except for one narrow edge and a one inch diameter spot in the center of one large edge. Cut a strip of cardboard to cover the clear edge of the bottle. Cut a thin, horizontal slit near the top of the cardboard strip. Fasten the cardboard to the clear edge

of the bottle with rubber bands. Fill the bottle with water until the lower half of the clear spot is covered. Allow a strong light to fall on the slit in the cardboard strip.

The ray of light that comes through the slit may be observed through the clear spot. Adjust the position of the slit until the ray strikes the water level in the center of the clear spot. The deflection of the ray may now be seen and measured as it passes into the water.

2. MODEL CAMERA

Material List:

Cardboard box.

Cardboard tube.

Tissue paper.

Reading glass or other lens.

Friction tape.

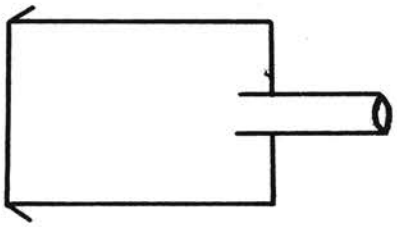


Fig. 16. Model Camera

Instructions:

Find the focal length of the lens by focusing the light from the sun to a tiny point on a flat surface and

measuring the distance from the point to the lens. Cut one end from the box and shorten the box until it is one inch shorter than the focal length of the lens. Cover the open end of the box with tissue paper.

In the center of the solid end of the box, cut a hole of the same diameter as the cardboard tube. Tape the lens to one end of the tube and insert the tube in the hole in the end of the box. The "camera" may now be focused by sliding the tube in or out of the box. The image will be seen on the rear of the box. The tissue paper will correspond to film in a real camera.

3. MAGIC LANTERN

Material List:

Cardboard box.

Cardboard tube.

Two extension cords with light sockets.

Two 75 watt light bulbs.

Reading glass or other lens.

Friction tape.

Photograph or drawing.

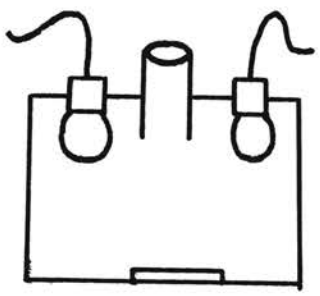


Fig. 17. Magic Lantern

Instructions:

Mount the lens tube in the box as described in the preceding demonstration. On each side of the lens tube, cut holes and insert the sockets of the extension cords. Remove the top from the box and place the bulbs in the sockets. Any picture or drawing may be used for projection. Tape the picture to the inside of the box opposite the lens tube.

Close the box and turn on the light bulbs. The picture may be projected on any flat surface. The room should be darkened for best results. The picture may be focused by adjusting the position of the lens tube. The projector should not be operated for more than a few seconds at a time to prevent the cardboard box from becoming too hot.

4. WATER LENS

Material List:

Two alarm clock lenses.

Waterproof tape.

Instructions:

Hold a lens in each hand and submerge them in a container of water. Bring the lenses together, hold them tightly, and remove them from the water. Have an assistant tape the juncture of the two lenses to keep the water from escaping. The trapped water will show all the properties of a large convex lens.

5. SOLAR POWER

Material List:

Sealed beam automobile headlight.

Two ring stands or other supports.

Test tube.

One-hole rubber stopper.

Length of glass tubing.

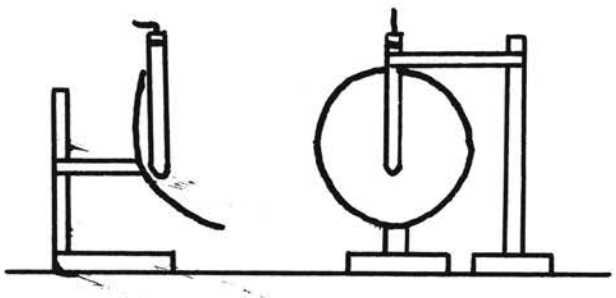


Fig. 18. Solar Boiler

Instructions:

Remove the glass lens from the headlight. Smash the bulb with a hammer, being careful not to mar the surface of the reflector. Clamp the reflector in a ring stand so that it may be turned to face directly at the sun. The base of the bulb is a convenient place to attach the clamp.

Blacken the test tube with candle smoke and clamp the test tube so that its base is located at the focal point of the reflector. The focal point will be found at the place formerly occupied by the filament of the bulb. Insert the glass tube in the stopper, fill the test tube half full of water, and insert the stopper in the tube.

The reflector is now ready to use. Allow the sunlight to fall directly on the reflector. The water will boil in two or three minutes. The force of the steam emerging from

the glass tube may be shown by allowing the steam to drive a small paper pinwheel.

The reflector alone may be used to ignite paper or wood shavings, melt lead wire, etc. Temperatures above 250 degrees Fahrenheit are produced at the focal point. The light at the focal point is strongly actinic. Bright light precautions should be taken. The operator must wear dark glasses or welding goggles.

CHAPTER X

MAGNETISM AND ELECTRICITY

1. PERMANENT RECORD OF MAGNETIC LINES OF FORCE

Material List:

Magnets.

Photographic enlarging paper.

Developing and fixing chemicals.

Iron filings.

Instructions:

The enlarging paper and chemicals may be obtained from any camera store. Get the small package of developing chemicals. Prepare the chemicals according to the directions that are on the package. Any glass bowls may be used for containers.

The process of exposing the paper must be carried out in a darkened room. A red bulb may be used for light. Place the magnet or magnets on a flat surface. Remove a sheet of paper from the package and place it over the magnets. The shiny side must be facing up. Sprinkle iron filings on the paper and tap the paper gently until the filings align themselves along the magnetic lines of force. The sprinkling process will be easier if the filings are kept in a salt shaker.

Cover all the unused paper and hold a 100 watt light

two feet above the paper. Turn on the light for one minute. Develop the paper according to the instructions on the chemical package.

The sheet of developed paper will be black with the positions of the filings in white. If the contrast is not satisfactory, the process should be repeated using longer or shorter exposure times. The developed paper will be a permanent record. Several exposures with different combinations of magnets should be made.

2. FOIL ELECTROSCOPE

Material List:

Thin aluminum foil.

Long nail.

Bottle.

Cork stopper.

Fine copper wire.

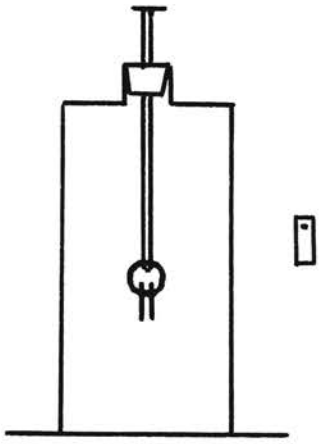


Fig. 19. Foil Electroscope

Instructions:

Commercial aluminum foil is too thick for satisfactory use. Remove the foil from a chewing gum wrapper or from a cigarette package. This foil may be most easily removed by soaking the wrapper in water for a few hours. Cut two small strips from the foil and punch a hole near one end of each strip.

Push the long nail through the cork stopper until the head of the nail is about an inch above the top of the stopper. The point end should be several inches below the base of the stopper. Thread the fine copper wire through the holes in the foil strips and twist the wire into a loop. Attach the loop to the point end of the nail. Insert the stopper into the bottle. The foil strips should be suspended so that they may move freely on the loop without touching the sides of the bottle. The electroscope is now ready to use.

The electroscope may be used in the usual manner. The following materials are useful in producing static charges: nylon, silk, or rayon cloth, glass tubes, plastic tooth brush handles, and combs. A long, uninflated rubber balloon may be streched over a wooden dowel and used in place of a rubber rod.

3. DIRECT CURRENT GALVANOMETER

Material List:

Boy Scout type compass.

Insulated bell wire.

Large cardboard match box.

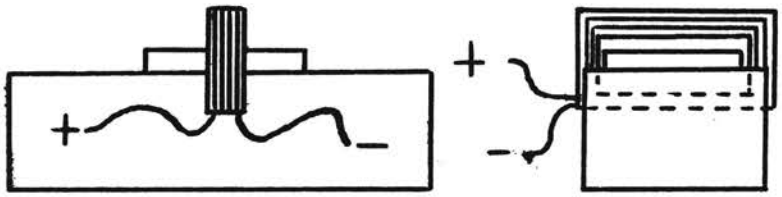


Fig. 20. Direct Current Galvanometer

Instructions:

Turn the empty match box upside down and cut a narrow slot across the box. The slot should be in the middle of the box and at right angles to the long edges. The slot should be about one half inch deep. Wind the insulated wire into a coil whose diameter is slightly greater than the diameter of the compass. The coil should contain from fifty to one hundred turns of wire. Leave the two ends of the wire free so that connections may be easily made. Tape the coil so that it will not come undone.

Place the coil in the vertical slot in the box and tape it in place. The upper half of the coil should extend above the box. Place the compass flat on the box top so that the plane of the compass is perpendicular to the plane of the coil. Tape the compass in position. When a direct current is passed through the coil, the compass needle will be deflected. Very small currents may be detected by using a coil with a large number of turns of wire.

4. ELECTRIC MOTOR

Material List:

Wooden block, 1½" by 3".

Seven long nails.

Two small nails.

Six straight pins.

Insulated bell wire.

Direct current source.

Tin can lid.

Sandpaper.

Cork cylinder, ¼" in diameter.

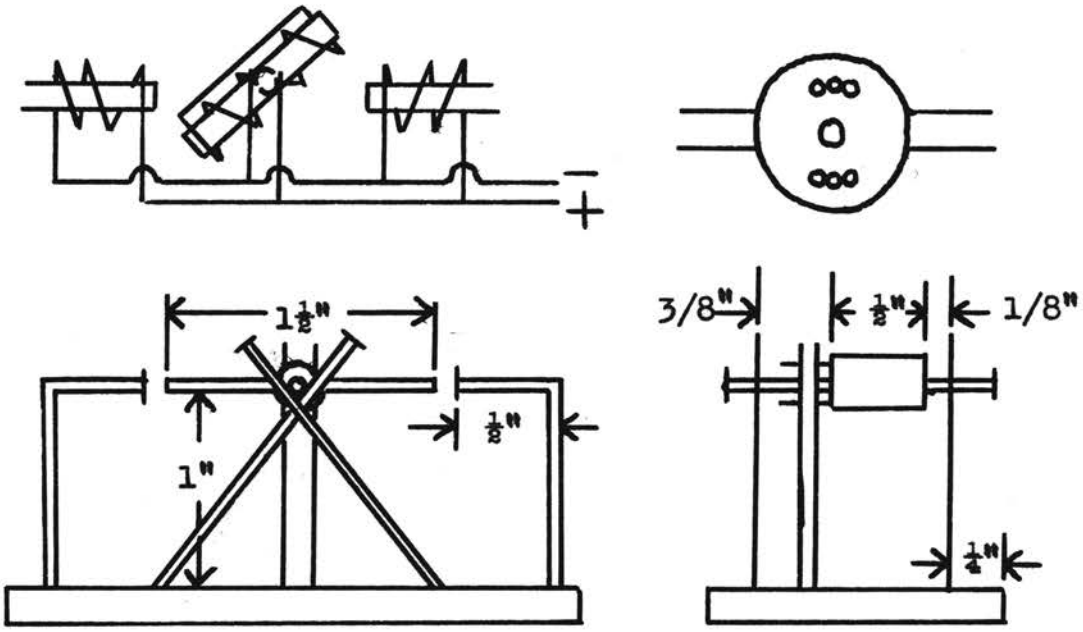


Fig. 21. Electric Motor

Instructions:

Remove the head from one of the long nails. Cut the point off until the nail is one and one half inches long.

This nail will be used for the armature core. Force the nail through the side of the cork until an equal length protrudes from each side. Drive a small nail into the center of each end of the cork. These nails will serve as supports for the armature. The six straight pins are to be driven into one end of the cork to act as the commutator. Arrange the pins in two groups of three each as shown in the drawing. The pins should be driven in until one quarter inch remains free. The pins should touch each other. Wire the armature as shown in the drawing. Each arm of the core should have forty turns of wire about it. The ends of the wire are to be attached to the two pin groups. The wire must be wound in the indicated direction. The armature is now complete.

Place two of the long nails in a vise and bend the head ends into a right angle. The bent segment should be one half inch long. These nails will serve as the cores of the field magnets. Wrap fifty turns of wire about each nail as shown in the drawing.

The remaining four long nails are to be used as supports for the armature. Drive two nails into the board in a slanting position so that the nails touch each other at the point where they cross. The cross should be one inch above the board and directly over a line which bisects the board in the long dimension. Arrange the other two nails in the same manner, parallel to the first pair, and one inch away.

Place the armature supports on the crosses and turn the armature until the core is horizontal. Drive the

field magnet nails into place as shown in the drawing. The gap between the field magnets and the ends of the armature core should be an eighth of an inch or less. Cut two thin strips from a tin can lid and bend them into "L" shaped pieces. These pieces will serve as brushes. Arrange the brushes so that they bear gently on the commutator pins. It may be necessary to file the tin strips to make good contact with the pins. Connect all wires as shown in the drawing.

Connect the motor to a direct current source and it will operate. It may be necessary to spin the armature by hand to strike the contacts to start the motor. Once the motor is started it will run indefinitely. The motor may not be used with voltages greater than about ten volts. The motor may be reversed by switching the current wires.

5. POWER SUPPLY UNIT

Material List:

One wooden piece, 1" by 5" by 8".

Four terminals.

One filament type transformer, 110-10 volt, 5 ampere.

Number 18 insulated copper wire.

Four selenium cell rectifiers, Federal 4D2814AS.

One machine screw, 6/32" by 1¼".

Mounting screws.

Solder.

Connecting cord for line current.

110 volt alternating current source.

Marking pencil.

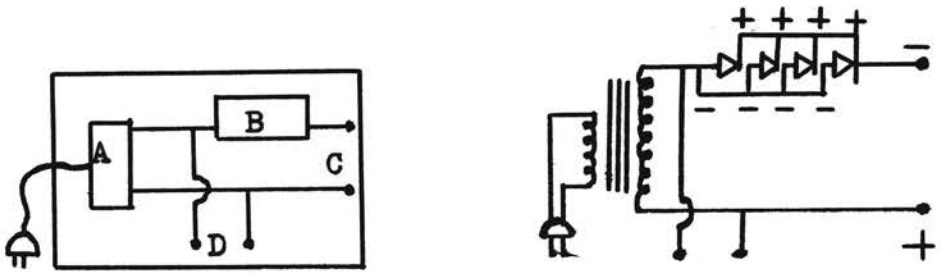


Fig. 22. Direct Current Power Supply Unit

Instructions:

The materials may be purchased at most radio repair shops, or they may be ordered from any radio supply house.

File or sandpaper the center washers on the top surfaces of the rectifier sections so that they will make good contact with each other. Assemble the rectifier sections with the solder lugs up and fasten them together by running the machine screw through them. Mount the rectifier assembly on the base board at position "B".

Mount two terminals at position "C" and two at position "D". Mount the filament transformer at position "A". The output side of the transformer will probably have three wires coming out. One wire will have a different color or pattern than the other two. This wire is the center tap and it will not be used. Attach a 110 volt line cord to the input wires of the transformer.

The power unit is now ready to wire. All connections should be soldered. Connect one of the transformer output wires to the screw upon which the rectifiers are assembled. Connect the other output wire from the transformer to a terminal at "C". Mark this terminal positive. Run two

connections from the terminals at "D" to the output wires from the transformer. Connect the solder lugs of the rectifier together and then run the connection to the other terminal at "C". Mark this terminal negative.

The power supply is now ready to use. Plug the input line of the transformer into any 110 volt socket. Terminals "C" will supply about six volts of direct current at up to three and one half amperes. The terminals at "D" will supply up to five amperes of alternating current at about ten volts. Do not attempt to use both terminals at the same time.

The power unit will function quite well on its open mount. If it is desired to enclose the unit for better protection of the parts, this may be done. The top and sides of an enclosed mount must be pierced to insure cooling of the rectifier assembly.

CHAPTER XI

BIOLOGY

1. COLLECTING NETS

Material List:

Broom handle.

Heavy wire.

Mesh cloth.

Canvas.

Instructions:

Form the heavy wire into a loop with the ends left free. The loop should be about one foot in diameter. If heavy wire is not available, twist two coat hanger wires together to make a length of heavy wire.

Cut and sew the net from mesh cloth. The net should be bag shaped and about two feet deep. Sew a hem of canvas around the mouth of the net. Slip the wire loop through the hem of the net and attach the loop to one end of the broom handle.

The net is now ready for use. The proper length for the handle will be found after some experimentation. If the net is to be used to secure aquatic specimens, the following changes should be made: Flatten the loop on the side opposite the handle. Use two or three thicknesses of material to form the net and reduce the depth to one foot.

2. INSECT KILLING BOTTLE

Material List:

Wide mouth jar with screw top.

Pill bottle with screw top.

Sash cord.

Liquid cement.

Carbon tetrachloride.

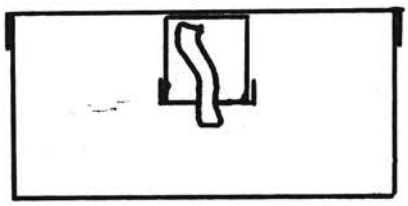


Fig. 23. Insect Killing Jar

Instructions:

Punch a hole in the cap of the pill bottle and insert a short length of sash cord to act as a wick. The cord must fit snugly in the hole. Cement the base of the pill bottle to the center of the inside of the large bottle top. Fill the pill bottle with carbon tetrachloride and screw the top on the large jar. The killing bottle is now ready for use.

3. ANIMAL SKELETON PREPARATION

Material List:

Wooden box.

Rabbit wire.

Red or black ant hill.

Instructions:

Skin the animal and trim away as much flesh as possible without disjointing the skeleton. Place the animal in the box and close all openings with rabbit wire. Anchor the box near an ant hill in such a way that the ants may easily enter and leave the box. In two or three weeks the skeleton will be clean and dry.

4. TERRARIUM

Material List:

Two pieces of window glass, 12¼" by 18½" by ¼".

One wooden board, 1" by 8" by 48".

Friction tape.

Paint.

Router.

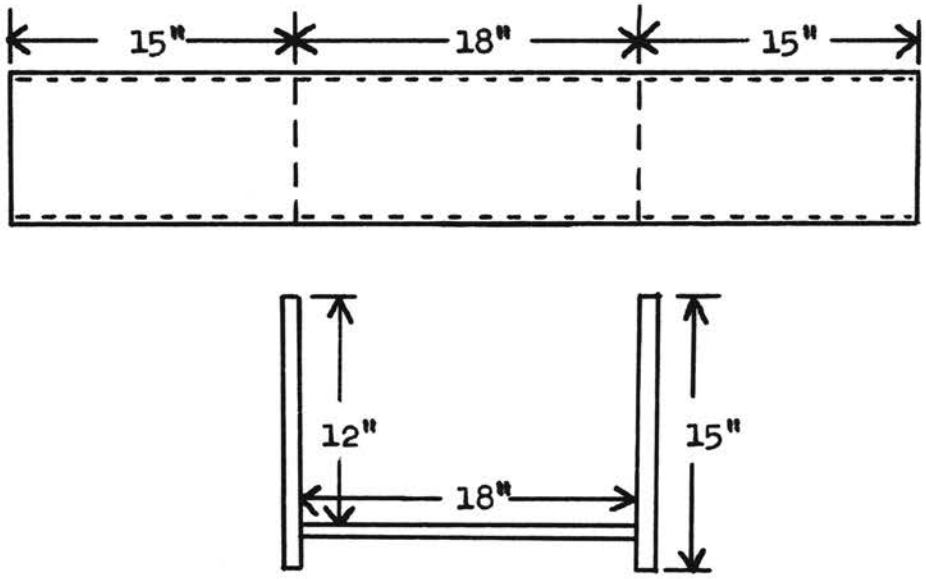


Fig. 24. Terrarium

Instructions:

Rout two grooves one quarter inch wide and one quarter inch deep down each edge of the board as shown by the dotted lines in the drawing. The outside edge of each groove should be one quarter inch from the edge of the board. These routed grooves must be perfectly straight and uniform.

Cut the board into three sections as indicated by the dashed lines. The eighteen inch section will be the base and the two fifteen inch sections will be end pieces. If the work has been done properly, there will be two grooves running down the inside of one end piece, across the top of the base, and up the inside of the other end piece after the three sections have been screwed together.

Slide a piece of glass into each "U" shaped groove. Cover the top edge of each glass piece with tape to prevent cuts while handling the terrarium. Paint the wooden parts and the terrarium is ready for use.

The basic terrarium may be converted into an aquarium by sealing the glass sections in place with putty and using marine paint for the wooden parts. The aquarium should be strengthened by screwing wooden brace strips across the top.

CHAPTER XII

CHEMISTRY

1. CARBON DIOXIDE

Material List:

Large bottle.

Baking soda.

Vinegar or dilute acetic acid.

Candles.

Cardboard.

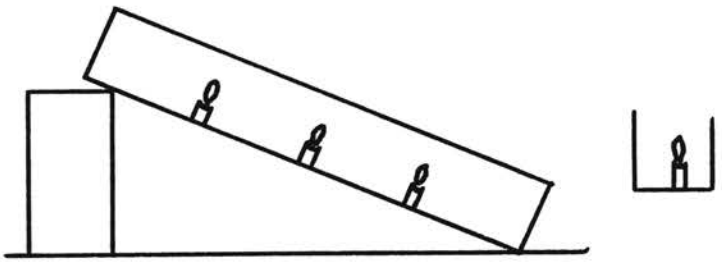


Fig. 25. Carbon Dioxide Candle Trough

Instructions:

Bend the cardboard into an open trough and space the candles at equal intervals in the base of the trough. The sides of the trough must extend above the tops of the candle flames when the candles are ignited. Support the trough at one end to make a ramp.

Place a thin layer of baking soda in the bottom of the bottle and pour in a small amount of vinegar. The mixture will bubble and foam violently as carbon dioxide is formed. Allow the reaction to run until no more bubbling occurs. The bottle will now be filled with carbon dioxide. Light the candles and gently pour the carbon dioxide into the elevated end of the trough. The flow of the gas may be observed as the candles are extinguished, one by one.

2. METAL BURNING

Material List:

Iron dust.

Aluminum dust.

Magnesium wire.

Burner.

Tongs or long tweezers.

Instructions:

Iron and aluminum dust may be obtained by filing pieces of the metals and collecting the resulting fine particles. Sprinkle the particles into a burner flame and they will burn with brilliant flashes.

Magnesium wire may be obtained by carefully breaking a photographic flash bulb and removing the wire from within. Examine the bulb before breaking it. Some bulbs have only a small filament and are not suitable. Use the type that contains a large amount of wire. Hold the wire in tongs or tweezers and ignite it with a match. The wire will burn with a brilliant white glare. Do not hold the burning wire near any inflammable materials.

3. FLOUR BURNING

Material List:

Flour.

Large tin can.

Cardboard.

Candle.

Small funnel.

Rubber tubing.

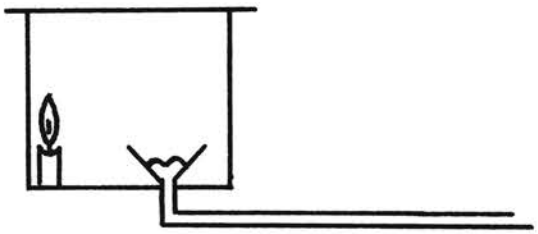


Fig. 26. Flour Explosion Can

Instructions:

Punch a hole in the bottom of the can and insert the funnel so that the stem of the funnel protrudes from the bottom of the can. Attach a length of rubber tubing to the stem of the funnel. Place a spoonful of flour in the wide portion of the funnel. Mount a lighted candle in the bottom of the can. The candle should be as far from the funnel as possible.

The can must not be closed with a tight fitting lid. Cover the can with a piece of cardboard and blow gently into the rubber tube. Flour particles will fill the can

and be ignited by the candle. The resulting explosion will be strong enough to blow the cover from the can. Talcum powder, cornstarch, or other finely divided solids may be used in place of flour.

4. DECOMPOSITION OF WATER

Material List:

Glass tray or dish.

Two test tubes or small bottles.

Ring stand or other support.

Insulated bell wire.

Ring stand clamps.

Direct current source.

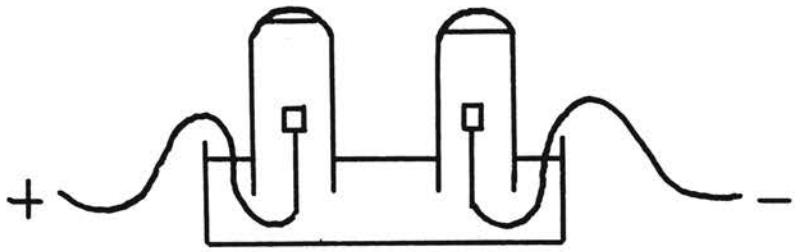


Fig. 27. Electrolysis of Water

Instructions:

Place the test tubes in the tray and fill the tray with water. Lift the tubes by the closed ends and raise them until only the mouths remain under water. Clamp the tubes in this position. The tubes should be completely filled with water. No air should be present in the tubes.

Remove one inch of insulation from each end of two lengths of wire. Bend each wire so that one uninsulated end projects well up into the water filled tubes. Connect the wires to the direct current source. Add a few drops of any acid to the water in the tray to make the water a better conductor of electricity. Hydrogen will collect in the tube containing the negative wire and oxygen will collect in the other tube.

5. WET CELL BATTERY

Material List:

Wide mouth jar.

Copper strip.

Zinc strip.

Sulfuric acid.

Insulated bell wire.

Direct current galvanometer.

Instructions:

Clean each metal strip by dipping briefly in acid. Rinse the strips in water and bend a hook into one end of each strip. Attach a length of bell wire to the hook end of each strip. Hook both strips over the rim of the jar so that the main portion of each strip is inside the jar. Do not allow the strips to touch each other.

In a separate container prepare a mixture of one part acid to five parts water. Handle both the acid and the mixture with extreme caution. Connect the bell wires to the galvanometer and pour the acid and water mixture into the jar. Enough current will be generated to show

a response on the galvanometer. If large, clean metal strips are used, enough current may be generated to light a flash light bulb.

6. COPPER PLATING

Material List:

Door key or other small, metal object.

Copper sulfate.

Copper strip or coil of uninsulated copper wire.

Insulated bell wire.

Direct current source.

Wide mouth jar.

Instructions:

The object to be plated must be thoroughly cleaned. Attach a length of bell wire to the object and another length to the copper strip. Fill the jar with water and slowly add copper sulfate crystals until the water takes on a blue tinge. Suspend the object and the copper strip in the solution. The object and strip must not touch.

Connect the copper strip wire to the positive terminal of the current source and the object wire to the negative terminal. Copper will immediately begin to plate on the object. The plating may be removed by reversing the terminal connections.

Silver plating may be done by substituting a silver strip for the copper strip and silver nitrate for copper sulfate.

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