SCIENTIFIC PROJECTS FOR THE SCHOOL SHOP

By

JOHN ELDRED WINTERS

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1959

Submitted to the faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
August, 1963

SCIENTIFIC PROJECTS FOR THE SCHOOL SHOP

Thesis Approved:

L. H. Bengtson
Thesis Adviser and Chairman,
Department of Industrial Arts Education

C. E. Hoffman
Associate Professor,
Department of Industrial Arts Education

[illegible]
Dean of the Graduate School

ACKNOWLEDGEMENT

My special appreciation to Mr. L. H. Bengtson, Thesis Adviser and Chairman, Department of Industrial Arts Education, for his timely comments and advise, without which this report would have been less meaningful.

To my lovely wife, whose patience and help in the preparation of this report have been invaluable, I give my fondest admiration and deepest gratitude.

J. E. W.

TABLE OF CONTENTS

Chapter | Page

LIST OF FIGURES

Figure | Page

Figure Page

CHAPTER I

SPACE AGE INDUSTRIAL ARTS

The launching of Sputnik on October 4, 1957 has had far reaching effects on education in America. The United States educational system has been sharply scrutinized and severely criticized in recent years due to the lag of the United States in the so called "space race" with Russia. One critic has termed this dilemma as "...Fifty years of stagnation" in an inflexible program of education (15, page 20), and proposes sweeping changes in the educational system of America. These proposed changes would take the form of expanded programs in science and mathematics, including testing, counseling, and facilities on the elementary and secondary levels, and financial aid to superior science and mathematics students in an expanded college program. Many Legislators and leading educators, however, fear a one-sided approach to the problem of science education, and are proposing changes which affect not only science, but other areas as well. Educators are seeking better ways to teach the various subject areas.

Selected Teaching Methods. Considerable attention has been given to the functionalization of subject matter. (4, page 288) Three modern trends in functionalization are apparent: (1) functionalization through the use of skills in the construction of projects, as in industrial arts; (2) functionalization through the use of facts in problem solution; and (3) functionalization through the application of principles, as in the application of science to technological products and industry. Attention also has been given to the correlation of subject matter. Correlation may be obtained in a number of ways, but the writer wishes to consider it here in view of correlating industrial arts and science through functional scientific projects which may be constructed in the industrial arts shop.

A Statement of the Problem. The problem dealt with in this study is that of the correlation of industrial arts and science through the use of the scientific project, and the functionalization of the subject matter of both areas of study through the project media. The project has long been used as a method of teaching the industrial arts, and is becoming more popular as a teaching method in science. Student preparation for science fairs has brought about the construction of scientific projects to a considerable degree. (27, page 306) Many of these projects are constructed in the school shop due to lack of facilities and space elsewhere. (34, page 277) One author expresses the problem in these words, "Projects are misplaced in the academic class room--take them to the shop." (39, page 53)

From the standpoint of industrial arts, the skills taught and the dissemination of information would remain approximately the same with the scientific project as with the traditional project. "Emphasis would change with respect to the project. Scientific projects will be the watchword." (42, page 213) The future contributions of industrial arts to education may well hinge upon how well industrial arts is able to integrate with other subjects. "If we cannot integrate, we are doomed to mediocrity and eventual obscurity." (49, page 224)

From the standpoint of good science teaching in a correlated program of industrial arts and science, the program needs to be considered from the viewpoint of applied science and its value to the total education program. "...A science education program should be science, not about science, ...should include all learners but should be administered in such a way that each youngster progresses at his own rate." (18, page 310)

The development of a public school program of correlation of industrial arts and science causes some problems in programming which the writer wishes to recognize, but which will not be discussed in this study. There are, however, other basic considerations in developing a program of this type. The program should:

1. Offer something for every student. (49, page 224)
2. Motivate students to further study. (20, page 53)
3. Offer projects which reveal the spirit of Science, the spirit of curosity, and create a desire to search out answers. (25, page 287)
4. Create student interest beyond the classroom. (31, page 308)
5. Make other subjects "come alive" for the student in the shop. (37, page 31)
6. Develop in the student an appreciation for the manual, creative, and aesthetic arts. (41, page 282)
7. Teach the student how to plan an activity and carry it to a logical conclusion. (8, page 81)

These criteria, then, should give direction to the planning of a program of this nature.

Purpose of the Study. The writer's purpose in making this study is to deal with the problem stated above. The basic assumption in this study is that the project is the common meeting zone for industrial arts and science, and that through the design and construction in the industrial arts shop of a project which demonstrates some principle of science, much will have been gained toward meeting the goals of both areas of study. The author feels that the logical place for students to apply many of the scientific principles learned in the academic classroom is the industrial arts shop. The principal purpose of this study is to compile a collection of such project ideas and to arrange them into a logical and useful form.

The writer's purpose in preparing this study was not to attempt to replace either industrial arts or science, but to enrich both areas of study.

Delimitations. Due to the vast number of projects which could conceivably be included in a study of this type, the writer will place the following limitations on the selection of projects: (1) the project will be selected from one of the physical sciences, principally physics and chemistry; (2) the project will demonstrate some scientific principle of the fields selected; and (3) the project will be suitable for construction in the school shop with respect to materials, skills, and tool processes involved in its completion.

Methods of Research. The library method of research is the principal method used in this report. A review of books, periodicals and other literature has been necessary to compile the collection of projects included in the study. Sketches have in some cases been made from observations of the actual equipment. At the special request of Dr. Robert C. Fite, formerly of the Arts and Sciences Extension Department, Oklahoma State University, drawings of equipment designed and built in the Traveling Science Teacher Training Program are included in this study.

Definitions of Significant Terms. The following terms used in this study need some qualification as to their application.

Project. The term project in this study may be interpreted as meaning any activity which requires the application of the basic principles of design and the use of fundamental tool skills and industrial processes to carry it to a logical conclusion.

Process. This term as applied in this study means any shop process which is required for the completion of a project.

Industrial Arts. Those phases of general education which deal with industry--its organization, materials, processes, occupations and products--and with the problems resulting from the industrial and technological nature of society.

Science. In order to facilitate the preparation of this report and to save endless repetition of qualifications, the term science in this report shall include only the physical sciences.

Scientific Project. The term as used in this study should be interpreted to mean any project which illustrates or demonstrates some scientific principle.

Skills. The skills which the author mentions in this study are the basic skills developed in the use of tools in the industrial arts shop.

Review of Similar Studies. A review of several indexed references has revealed no similiar studies of this type. Considerable work has been done with respect to correlation and integration of subjects, but no collection of projects has been made at this level. The Oak Ridge Institute of Nuclear Studies has published a series of project sheets in the form of a manual, part of which are included in this report. This work was done at the college level, but is included here by special request already mentioned.

Plan for Presentation of Materials. The presentation of the projects included in this study is in the form of pictorial drawings and schematic diagrams, with a bill of materials and instructions on each project sheet. The instructions are of necessity general in nature and cover only the most important points for a particular project. Suggestions for variations are in some cases made in the form of notes at the bottom of the sheet. The drawings are representative only, and the reader should not attempt to scale dimensions from them, as many of them are not drawn to scale.

In the interest of conserving space and avoiding endless repetition, such small words as a, and, and the are often omitted in the instructions on the project sheets. Numbers, symbols, and abbreviations are also used extensively throughout the instructions rather than words. The meanings of the abbreviations and symbols may be found in the Appendix.

The problems, purpose, and requirements of a correlated program of industrial arts and science have been set forth. Before selecting course content, however, the more specific teaching objectives and methods of this program need to be considered.

CHAPTER II

THE PROJECT METHOD OF TEACHING

The use of individual and group projects has long been a recognized method of teaching, and is the primary method of teaching the industrial arts. The industrial arts teacher uses the project not as an ultimate goal, but as a vehicle of conveyance for certain facts, skills, and processes which he wishes the student to learn. The project is only a secondary goal -- a result of learning. (8, page 163) The project has an intrinsic motivational value which is not present in many other methods of instruction, as it is the visible result of applied facts, principles, and processes which the student has learned before beginning and during construction of the project. In the mind of the student, the project often ranks as the most important part of industrial arts. (8, page 162)

The project method of teaching has also been used considerably in the teaching of science, especially in the preparation of student projects as entries in science fairs. Again, however, the ultimate goal of this activity is not the project, but good science teaching, and the project is only the vehicle for relaying information. (31, page 306) The National Science Fair is dedicated to inspiring greater interest amoung students in the fields of pure and applied science, and motivates students to prepare projects for exhibit. (28, page 265)

The preparation of projects is the area in which the writer feels that industrial arts may contribute most to the final fulfillment of the student's project ideas, and make possible the project application of academic theory.

Teaching objectives must of necessity be considered in preparing a program of this type. The writer will not attempt to relate all objectives of both industrial arts and science, but only those which are most pertinent to this study. The objectives of general education will also be listed for consideration.

Part A

General Education Objectives

The purposes of general education have been the object of much discussion and controversy. From the standpoint of education in a democratic nation, however, certain educational purposes seem to be prevalent. The Educational Policies Commission lists four general purposes of education: (1) self-realization; (2) human relationships; (3) economic efficiency in both vocational and consumer knowledge; and (4) civic responsibility. Another writer has listed five purposes of education, basically the same as those listed above, to which he has added the enhancement of leisure time. (3, page 103)

From these broad purposes of education, a set of objectives may be formulated. Wilbur (8, page 3) sums up the objectives of general education into three objectives which are short and to the point:

> _To transmit a way of life._
>
> _To improve the emergent culture._
>
> _To meet the needs of the individual._

Certainly no one can deny the impact of the Industrial Revolution on social and economic patterns of today, and that the American way of life is ever changing, even though rooted in a heritage which American education is helping to preserve. The freedoms we enjoy have allowed men to work and study as they willed, and science and craftsmanship have gone hand in hand into the inventions which have made this a great industrial nation. (9, page 424)

Part B

Industrial Arts Objectives

Industrial Arts is considered to be a part of General Education; therefore, the objectives of industrial arts should contribute to the objectives of general education. The objectives included here are not all-inclusive of the industrial arts field, but are the ones most pertinent to this study. They are:

> The provision of experience in construction of projects related to scientific principles peculiar to the industrial processes, thereby enabling the student to develop and apply scientific knowledge, and an opportunity to express themselves and experiment with creative ideas. (51, page 34)
>
> The Development of Avocational Interests. This objective may be perceptibly broadened by the introduction of the scientific project into the school shop program. Not only does the student have the various areas of industrial arts to select hobbies from, but several areas of science as well. (8, page 43)
>
> The Development of Cooperative Attitude. Any number of science projects may be selected which require the cooperative effort of two or more students. (8, page 43)
>
> The Appreciation of Good Craftsmanship and Design. This objective is applicable to any project which requires tool skills. The design function will in many cases be very important in the scientific project in determining its functional worth. (8, page 43)
>
> The Development of Vocational Interest. The introduction of the science project into the school shop does not hinder the attainment of this objective and may en-

hance it considerably. The teacher will continue to teach the same basic processes, skills, and information about industry. (8, page 43)

The Acquisition of Consumer Knowledge. Due to the technological nature of society today, this objective may be met better by a correlated program. The student will not only learn to appreciate the value of his own project but will appreciate the value of commercial items in terms of materials, design, and construction. (8, page 43)

The Development of Basic Tool Skills. The basic tool skills can be taught with any project requiring the use of these tools, whether the project is "traditional" or scientific. (8, page 43)

The Opportunity for Creative Expression in Terms of Industrial Materials. The materials used in both types of projects will be the same, and creative expression is evident in student designed and student built projects. (8, pag 43)

The Development of Safe Working Practices. Safe working practices are taught in any process involving the use of tools. (8, page 43)

Part C

Science Objectives

The science objectives considered here are principally those generally considered in preparation of exhibits for the science fair. They are:

The Motivation of Students to Learn. The application of academic theory on a scientific project affords the student a feeling of satisfaction which he does not attain in any other way. (26, page 246)

The Motivation of Students to Continue Work at Home. A knowledge of industrial materials and possession of skills in the use of tools encourages the student to work at home. (44, page 67)

The Acquisition of Information. Before designing and constructing the project, the student must acquire the necessary information about its function and application. (43, page 183)

The Application of Scientific Principles. The science project is the one place where the student's scientific knowledge really comes alive. (43, page 183)

<u>The Opportunity for Creative Expression</u>. The creative expression of the student must take some tangible form--the scientific project. (41, page 282)

<u>The Opportunity to Work With the Materials and Equipment of Science</u>. This is a rather broad objective applicable to a number of phases or areas of science, but the writer uses it here with respect to equipment. What better way for a student to understand the function of a piece of equipment than to build it? (24, page 320)

<u>The Appreciation of Good Design</u>. Appreciation of good design will become paramount as the student plans and designs his project. (34, page 275)

<u>Aesthetic Appreciation</u>. The student will learn to appreciate not only the function of his project, but the beauty of his craftsmanship as well. (41, page 282)

The similarity of the two lists of objectives becomes the working base for the next part of this study. The following projects have been compiled by the author and carefully studied and selected on their qualities as suitable scientific projects which may be built in the school shop.

CHAPTER III

SCIENTIFIC PROJECTS

The selection of suitable projects for industrial arts has long been a major problem for the shop student and instructor alike. The importance of the project becomes apparent in that the project method of teaching is the principal method used in teaching the industrial arts, and, as has been pointed out earlier in this study, is also used considerably in science teaching. There are many qualifications to be considered in project selection. Wilbur, in his book Industrial Arts in General Education, lists the following criteria for the selection of the project. (8, page 165) The project should:

1. Contribute to the attainment of at least one major objective.
2. Have "boy interest."
3. Be within the student's ability.
4. Present a challenge.
5. Be well designed.
6. Be such that the student can complete it in a reasonable length of time.
7. Be economical of materials.
8. Illustrate some industrial or craft process which is new to the learner.
9. Allow students to cooperate and work together on a common problem.

For the purpose of this study, the writer has added one item to this list of criteria; that the project should illustrate some principle of science.

Project Design. The basic design rule followed in designing these projects is that "Form Follows Function." The writer has not attempted to design complicated projects, and has intentionally not refined or streamlined the designs so that the student may be more creative in his own designing. These designs are intended primarily to transmit an idea to the student from which he can work, and thus go as far as his creative ability and skills will allow. The shop teacher will readily recognize the possibilities of a multitude of applications and variations in terms of tool processes, materials, and design without changing the basic functional aspects of the finished project, and may thus advise the student in designing his project. The material lists and instructions included are applicable to the projects as shown, but may be varied as the need arises.

Project Use. The writer has attempted to arrange these designs into the approximate order of their increasing difficulty, and feels that projects are included which will challenge not only the average and slow learner, but the superior student as well. The superior student may wish to incorporate several of these design ideas into one project; as an example, the student may easily incorporate the friction wheels, gears, "V" pulleys, and the screw thread into one design which demonstrates power transmission and speed ratio. Many other variations are possible by varying design techniques.

The following projects were selected from more than one hundred such scientific project ideas as being the most suitable for including in this study. They are not thought to be all inclusive of the scientific fields of study represented. Two of the projects included serve as supporting pieces of equipment which may be used along with some of the other projects presented. The designs obtained from the Oak Ridge Institute of Nuclear Studies are included with only minor changes. The writer submits these projects with the sincere hope that they may prove helpful in motivating students to exert greater effort both in the industrial arts and science.

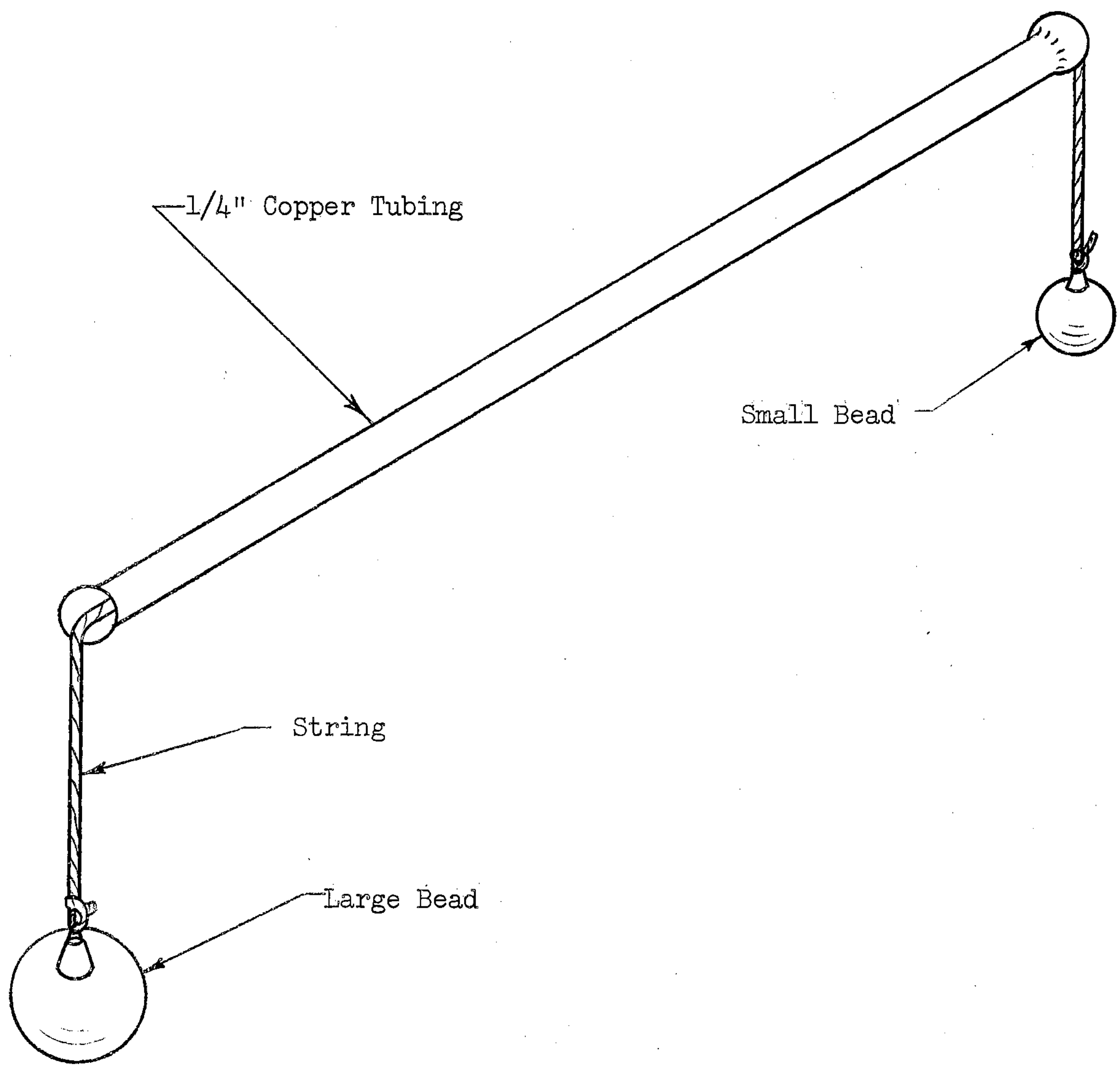


Figure 1

Centrifugal Force Apparatus

Material List
1 pc. 1/4" dia. copper tubing
1 pc. 25 lb. test string, 24" long
1 ea. large bead (about 10 grams)
1 ea. small bead (about 5 grams)

Flare each end of the copper tubing and drop the string through the copper tube. Secure a bead to each end of the string.
Note: Bell fishing sinkers may be substituted for the beads.

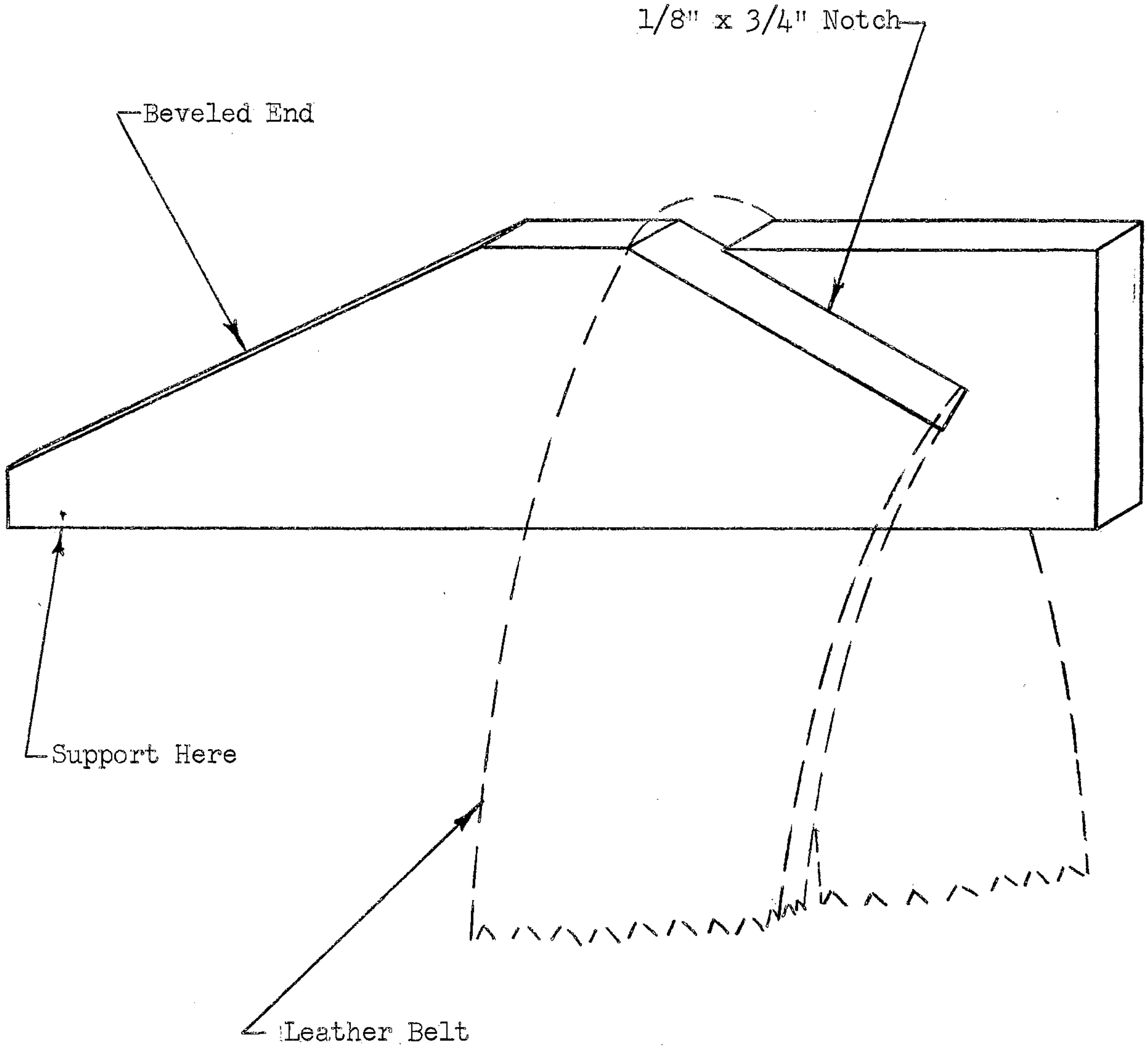


Figure 2

"Sky Hook"

<u>Material</u> <u>List</u>
1 pc. aluminum, 1/8" x 3/4" x 3-1/2"

Cut the material and square the ends. Lay out a 1/8" x 3/4" notch at a 30° angle from the edge, beginning 1" from the end. Drill a 1/8" hole through at the bottom of the notch and saw out the intervening metal. Smooth the inside of the notch with a file.

Bevel the end as shown.

Clean and smooth the metal with emery cloth and polish on a buffer.

A leather belt inserted in the groove will hang in space when the end of the piece is supported on the finger.

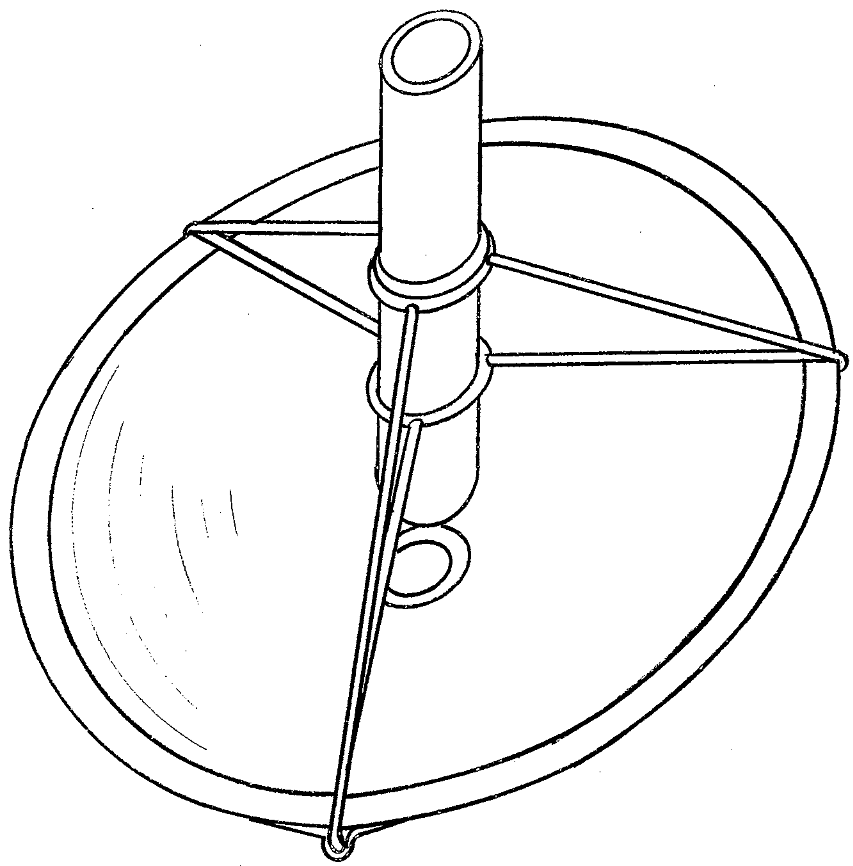


Figure 3

Solar Furnace

Material List
1 ea. Auto headlight reflector
1 ea. Brass wire 1/16" dia. x 36" long
1 ea. Test tube 25 Ml.

Form two rings out of 1/16" dia. brass wire by wrapping around a piece of 1" dia. rod or dowel. Make two tripods with these rings soldered in the center as shown in the illustration, one tripod being approximately one inch shorter than the other. These tripods should be fitted to the reflector either by utilizing holes in the rim of the reflector or by forming feet on the tripods which will snap over the rim.

Make another ring which will be a tight fit on the test tube, by wrapping the 1/16" dia. brass wire around a 3/4" dia. rod. Do not solder the joint together so the ring may spring open and slip on the test tube. By adjusting this ring, the test tube may be adjusted up or down for best results.

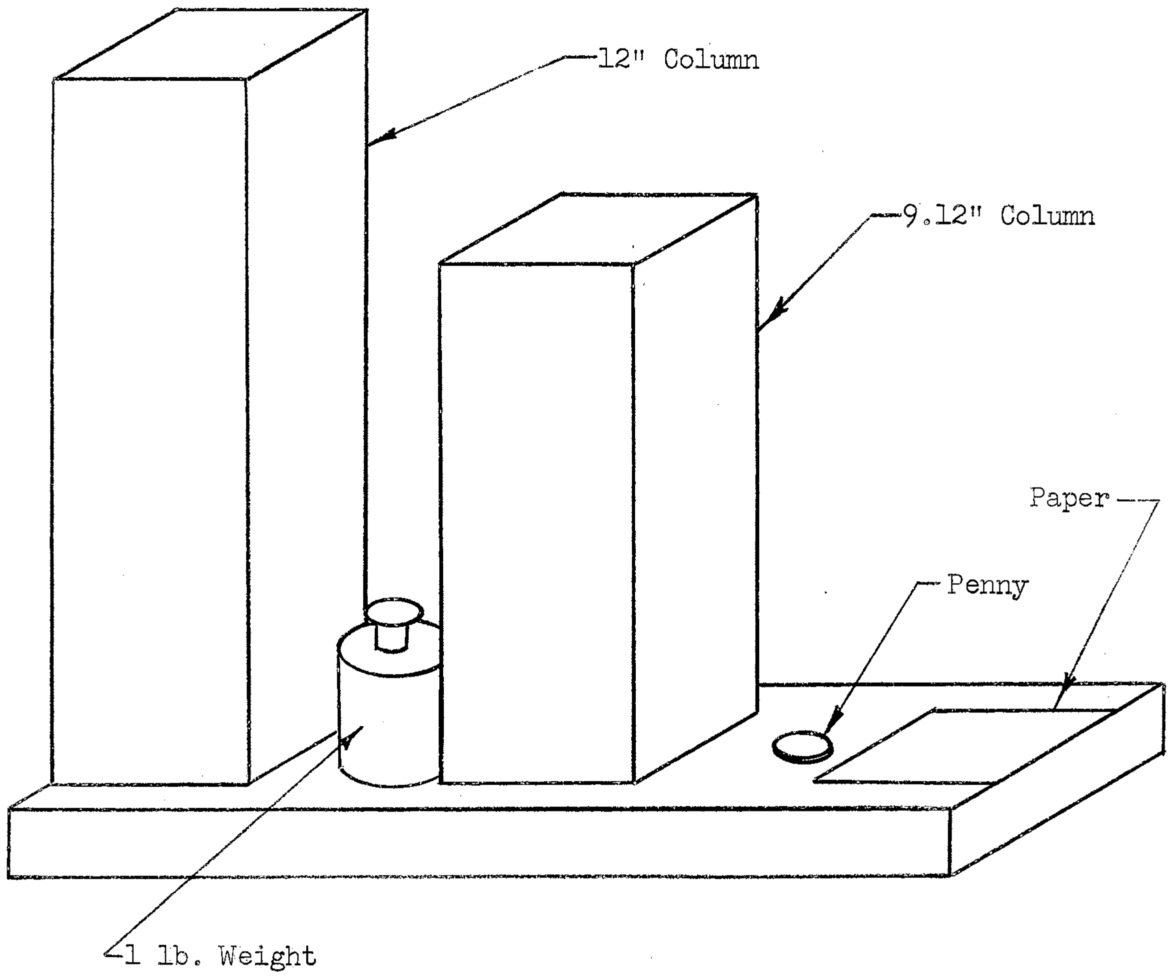


Figure 4

Units of Work

<u>Material List</u>
1 pc. hardwood, 1" x 4" x 10"
1 pc. hardwood, 2" x 2" x 12"
1 pc. Hardwood, 2" x 2" x 9.12"
1 weight, 1 lb.
1 penny
1 pc. paper, 2" square
2 wood screws, #10 x 2" F. H. B.

Work the boards to size and sand smooth. Mount the columns on the base as shown. Countersink the screw heads. Apply a protective finish.

Glue the paper on the board.

The 1 lb. weight lifted to the top of the 12" column illustrates a foot pound of work done.

The 1 lb. weight lifted to the top of the 9.12" column illustrates a joule of work done.

The penny lifted onto the piece of paper illustrates an erg of work done.

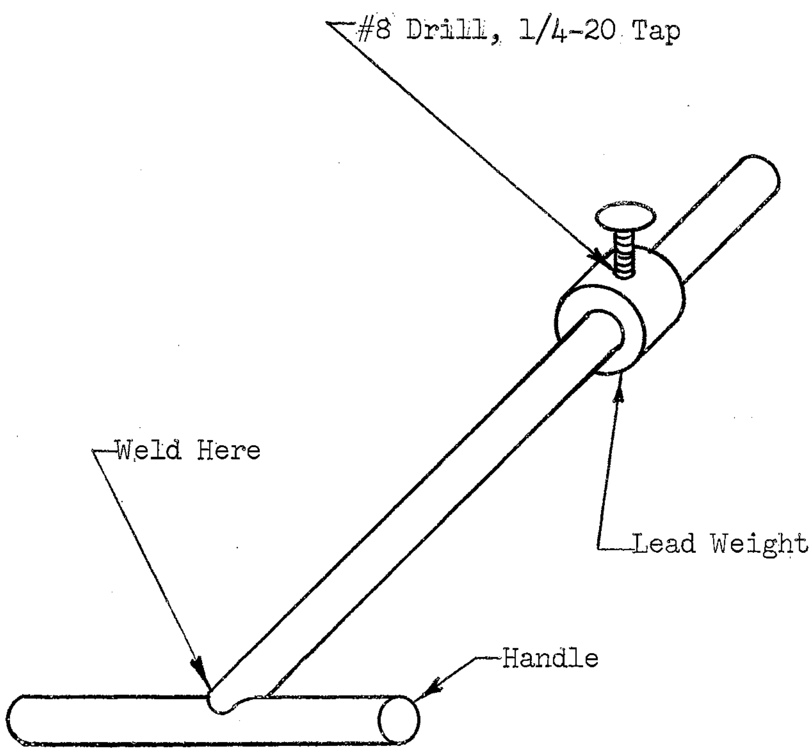


Figure 5

Simple Torque

Material List
1 pc. steel tubing, 1" dia. x 12"
1 pc. steel tubing, 1" dia. x 24"
1 thumb screw, 1/4-20 x 1-1/2" long
2 lbs. lead

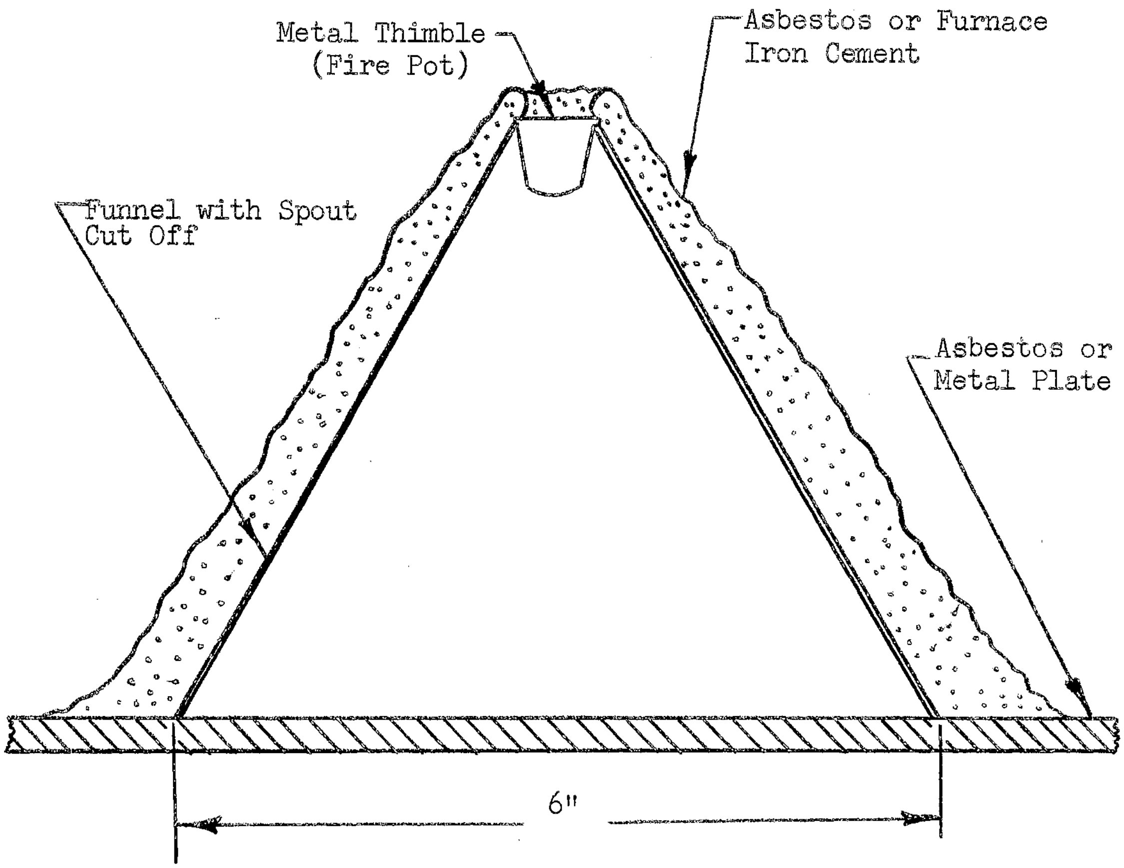
Cut out one end of the 24" tube to a 1/2" radius to fit the contour of the other tube and weld the two together with the long tube centered on, and at a 90° angle to, the axis of the handle.

The lead weight may be cast by placing a short piece of 2" pipe (with end reamed) on end on a flat metal surface and centering a piece of 3/4" pipe inside it. Melt the lead and pour between the two pieces of pipe while holding them down snug on the flat surface. After the lead has cooled, tap out with a mallet and remove any burrs with a file.

Drill a hole (#8 drill) through one side of the weight on the center line and thread with a 1/4-20 tap.

Slip the weight over the bar and insert the thumb screw.

May be primed and painted if desired.



Cross Section View

Figure 6

Volcano

Material List
1 pc. asbestos or metal 18" square
(Other fireproof material may be used)
1 ea. large funnel
1 ea. large metal sewing thimble
1 lb. asbestos or furnace iron cement

Remove the spout from the funnel, invert the funnel on the metal plate and insert the thimble at the top of the "volcano." If using ready-mixed furnace cement, apply about 1/2" of thickness over the funnel and shape to a rough surface with the fingers. If using asbestos or other type of powder or fiber which is mixed with water, mix to the consistency of soft clay and apply in the same manner.

If desired, the volcano may be painted for a more realistic effect. Fire-resistant paint is more desirable, but ordinary house or wall paint may be used. Lacquer and rubber base paints <u>should</u> <u>not</u> be used.

Note: Small amounts of magnesium ribbon or ammonium bichromate may be used as "fuel."

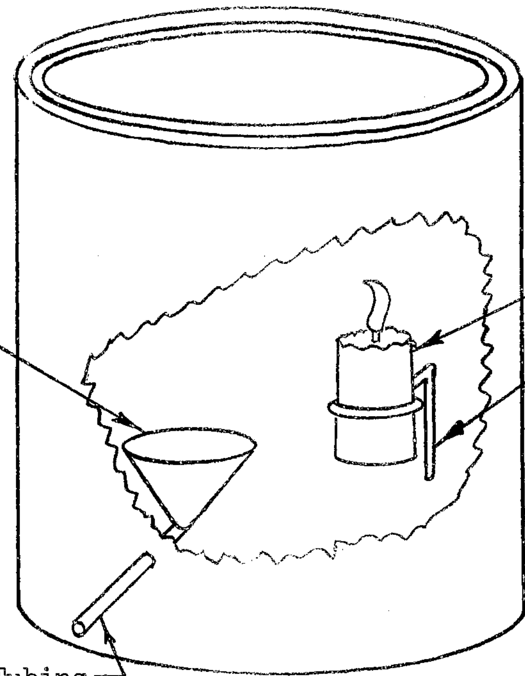


Figure 7

Dust-Explosion Can

Material List
1 Gallon paint can (one-piece lid type with tight fit), or quart paint can.
1 Small tin funnel (or metal cap from paint spray can, etc.)
1 pc. copper tubing 1/4" dia. x 3" long
1 candle holder

CAUTION: Use about 36" of rubber tubing for blowing. A small amount of Lycopodium powder may be used for fuel.

Pinch one end of the copper tubing in a vise completely closing the end and drill a 1/8" hole through one wall of the tubing about 1/4" from the closed end. Cut the spout off of the funnel (or drill suitable hole in tin cap), and solder in position over the 1/8" hole in the tubing. Drill 1/4" hole in the side of the can about 1-1/2" from the bottom and insert the 1/4" copper tubing through the can from inside and solder in place.

The candle holder may be made from any number of materials, such as wire, a small bottle, sheet metal, etc. The candle should be positioned near the side opposite the funnel about half-way up the side. A 1/16" dia. wire bent into a loop with a 90° bend about 1" from the loop and soldered to the can side is an easy and inexpensive method.

DO NOT cut the side of the can as shown in the cutaway illustration.

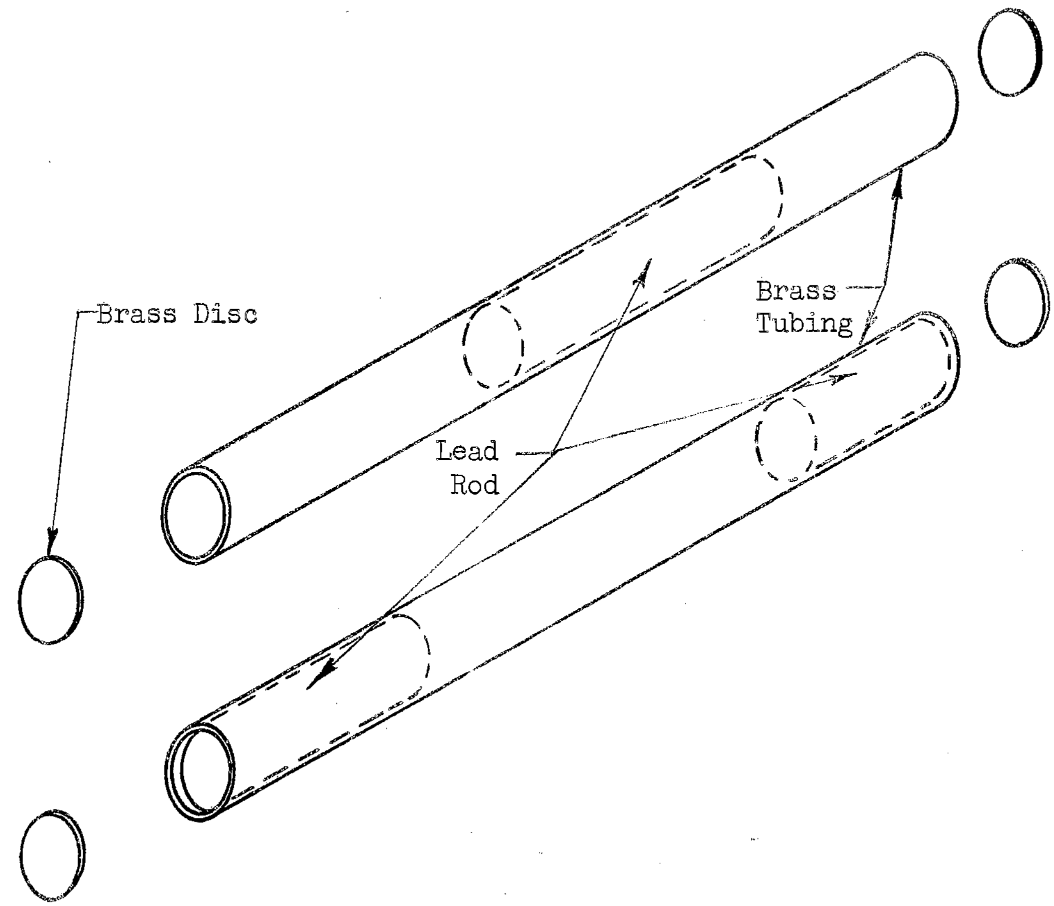


Figure 8

Rotational Inertia rods

Identical in Weight and Appearance

Material List
2 pcs. brass tubing, 1/2" I. D. x 28" long
4 pcs. brass disc, 1/16" thick x 1/2" dia.
2 pcs. lead rod, 1/2" dia. x 3-1/2" long
1 pc. lead rod, 1/2" dia. x 7" long

One end of the lead rods should be very slightly tapered to within 1" of the other end, which allows the rods to be inserted into the brass tubing with the 1" portion which is not tapered being a light drive fit in the brass tubing.

Insert the 7" lead rod into one tube and, using a dowel slightly smaller than the I. D. of the tube, drive the rod to a depth of 10-1/2" or until it is centered in the tube.

Drive one of the 3-1/2" lead rods into each end of the other tube to a depth of 1/16", which will allow the brass disc to fit flush with the end of the tube.

Solder a brass disc in each end of the two tubes and hold the ends lightly against a belt sander.

Note: Dimensions may be varied to suit available material.

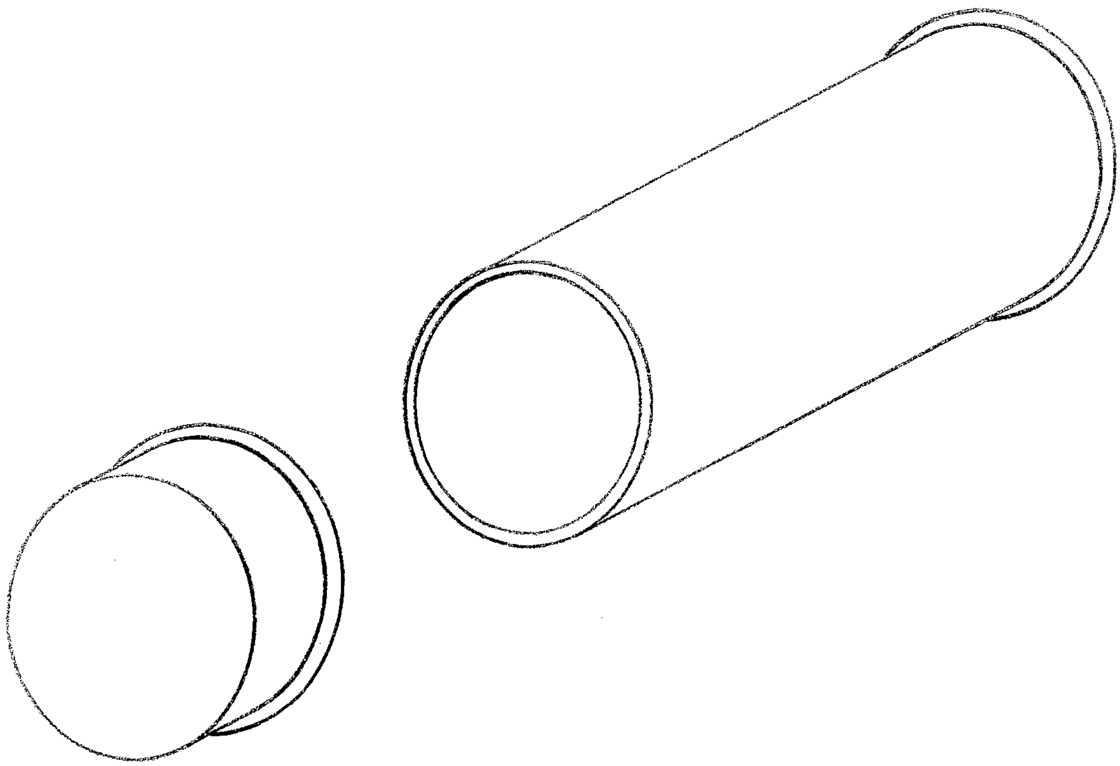


Figure 9

Inertia Cylinders

Material List
4 Soup or larger cans with one end removed
4 Lids from typewriter ribbon containers
Lead sheet about 1/8" thickness
Mercury
Tungsten

Fill one of the cans with Tungsten powder (or any other heavy powder available) and weigh. Cut an amount of lead sheet of a length equal to that of the can so that the weight of this, together with a can, is equal to the weight of powder and can. Roll this lead into a tight cylinder and secure it along the axis of a can, holding it by screws in the top and bottom. Choose a similar piece of lead as above and place this along the inside walls of a can. Secure it by melting and joining the end of the lead by a soldering iron. Weigh some mercury in a can equal to the weight of the powder and can. See that the mercury does not leak by pulling plasticene over the end lid.

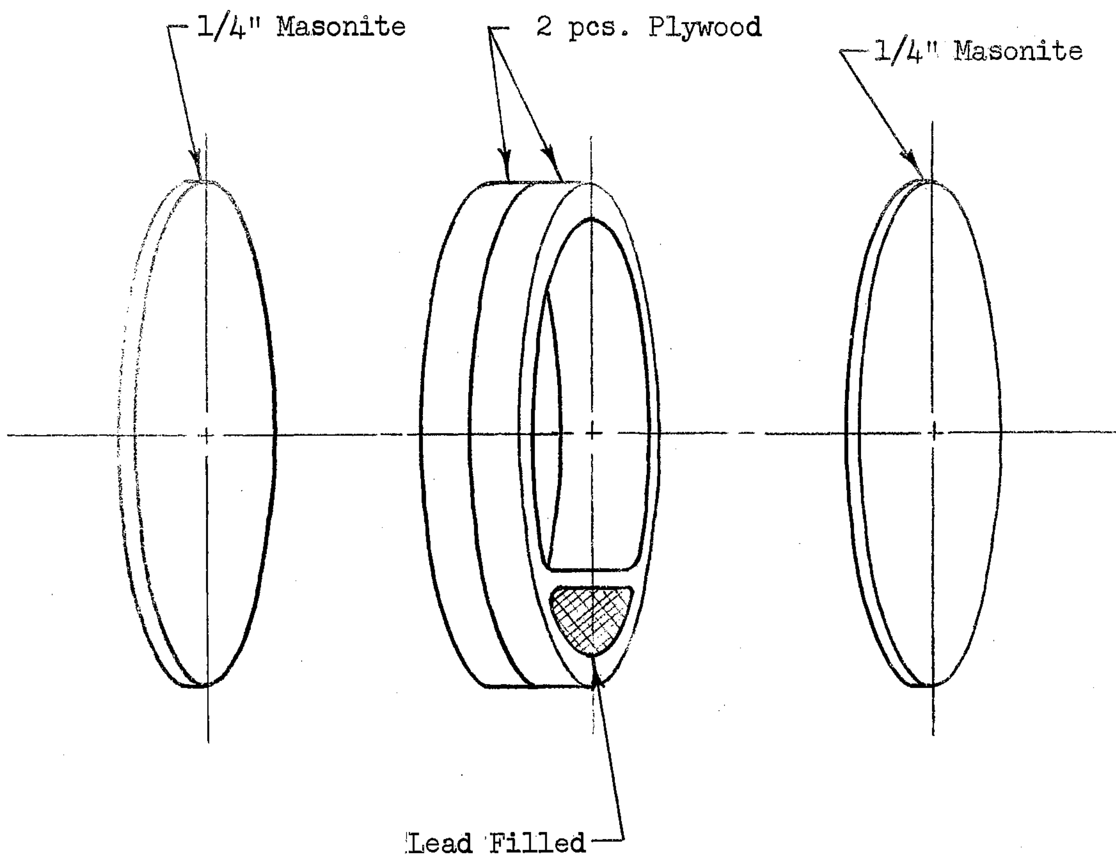


Figure 10

Uphill Roller

Material List
2 pcs. plywood, 3/4" x 10" or 12" dia.
2 pcs. masonite, 1/4" x 10" or 12" dia.
5 lbs. lead

Glue the two plywood discs together and saw out the two sections from the inside of the disc as shown in the illustration. Leave 3/4" to 1" all around the edge of the disc and the partition between the two cutouts.

Nail one of the masonite discs in place, using plenty of small nails particularly around the smaller cutout. Melt the lead in a ladle and pour the smaller cavity full. Do not overheat the lead; have adequate ventilation while melting.

When the lead has cooled, nail the other masonite disc in place.

A strip of rubber floor matting, about 1-1/4" wide, may be nailed or cemented around the periphery of the disc to improve its traction.

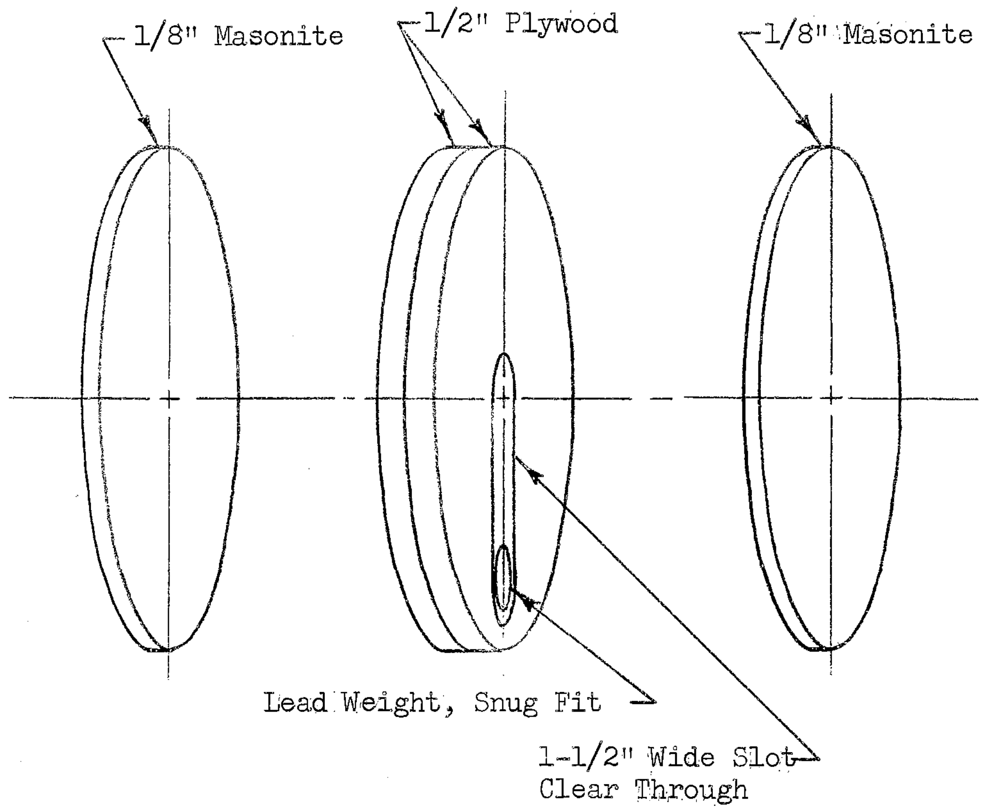


Figure 11

Center of Gravity Disc

Material List
2 pcs. plywood 1/2" x 8" dia.
2 pcs. masonite 1/8" x 8" dia.
1 pc. lead, ball or cylindrical, 1-1/2" dia.

Nail the two plywood discs together and drill two 1-1/2" dia. holes on a line running through the center of the disc; the center of one hole is located at the center of the disc, and the center of the other hole is located 1-1/2" from the outer edge of the disc (see illustration). Saw out the portion between the two holes.

Make a cylinder of lead 1-1/2" dia. x 7/8" long. This may be cut from a lead rod or cast by melting scrap lead and pouring into a suitable mold. (If no lead is available, a steel rod will do as well.)

Insert the cylinder in the slot and nail the two masonite discs in place.

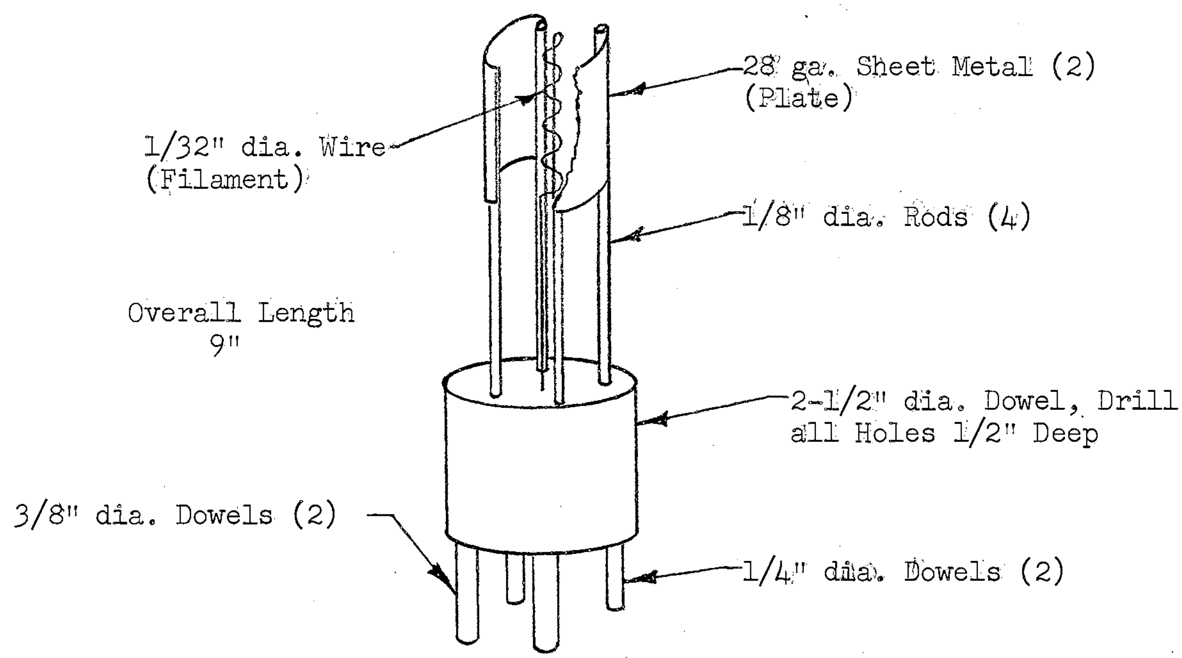


Figure 12

Diode Model

Full Wave-Two Plates

<u>Material List</u>

2 pcs. 28-gage sheet metal 3" x 2-1/4"
1 pc. 1/32" dia. wire 14" long
1 pc. 2-1/2" dia. wood dowel 1 - 5/8" long
4 pcs. 1/8" dia. brass rod 6" long
3 pcs. 1/4" dia. wood dowel 2" long
2 pcs. 3/8" dia. wood dowel 2" long

Using a 3/8" dia. rod or dowel, lay the 1/32" dia. wire along the axis of the rod and, about 6" from one end of the wire, make a 90° bend and wrap the wire around the rod toward the other end of the wire. Make each turn about 1/2" along the rod, forming a coil about 2-1/2" long, or about 5 turns of wire. Straighten the remaining portion of the wire to form the "heater," as shown in the illustration.

Lay the sheet-metal pieces on a 2" dia. rod with the 3" dimension of the metal along the axis of the rod, and form to a curvature with a wooden mallet or block of wood. Solder a 1/8" dia. brass rod at the straight edges of each piece on the inside of the curvature (see illustration).

Drill the holes in the large wooden dowel in the approximate positions shown, using the parts mentioned above as a guide in drilling the small holes. Glue the wooden dowels in the larger holes. Paint the tube base black, the prongs aluminum, the heater red, and the plates blue.

Place the wires and rods in their places and make final adjustment of the heater by bending the wires slightly until they are centered between the plates.

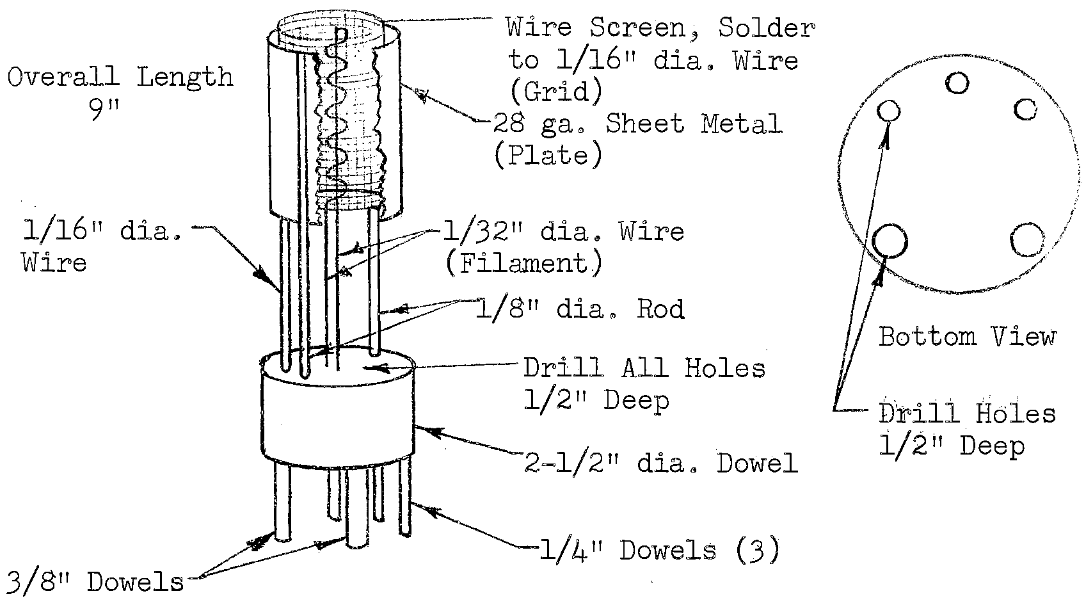


Figure 13

Triode Model

<u>Material List</u>
1 pc. screen door wire, 2-3/4" x 4-7/8" long
1 pc. 28 gage sheet metal, 3" x 6-5/16" long
1 pc. 1/16" dia. wire 6" long
1 pc. 1/32" dia. wire 14" long
1 pc. 2-1/2" dia. wood dowel, 1-5/8" long
2 pcs. 1/8" dia. brass rod 6" long
3 pcs. 1/4" dia. wood dowel 2" long
2 pcs. 3/8" dia. wood dowel 2" long

Wrap the screen wire around a 1-1/2" dia. dowel or mailing tube, lay the 1/16" wire along the joint flush with one end, and solder the wire and joint together. Remove the dowel or mailing tube.

Using a 3/8" dia. rod or dowel, lay the 1/32" dia. wire along the axis of the rod, and about 6" from one end of the wire make a 90° bend and wrap the wire around the rod toward the other end of the wire. Make each turn about 1/2" along the rod, forming a coil about 2-1/2" long or about 5 turns of wire. Straighten the remaining portion of wire to form the heater as shown in the illustration.

Roll the sheet metal around a 2" dowel or rod, and solder the 1/8" rods flush with one end of the cylinder and 180° apart, one of them being soldered at the joint. Drill holes in the large wooden dowel in the approximate positions shown in the illustration, using the parts mentioned above as guides in drilling the smaller holes. Glue the wooden dowels in their respective holes and paint the tube base black, the prongs aluminum, the heater red, the grid yellow, and the plate blue.

Place the wires and rods in their places and make final adjustment of the heater and grid by bending the wires slightly until they are centered with each other and the plates.

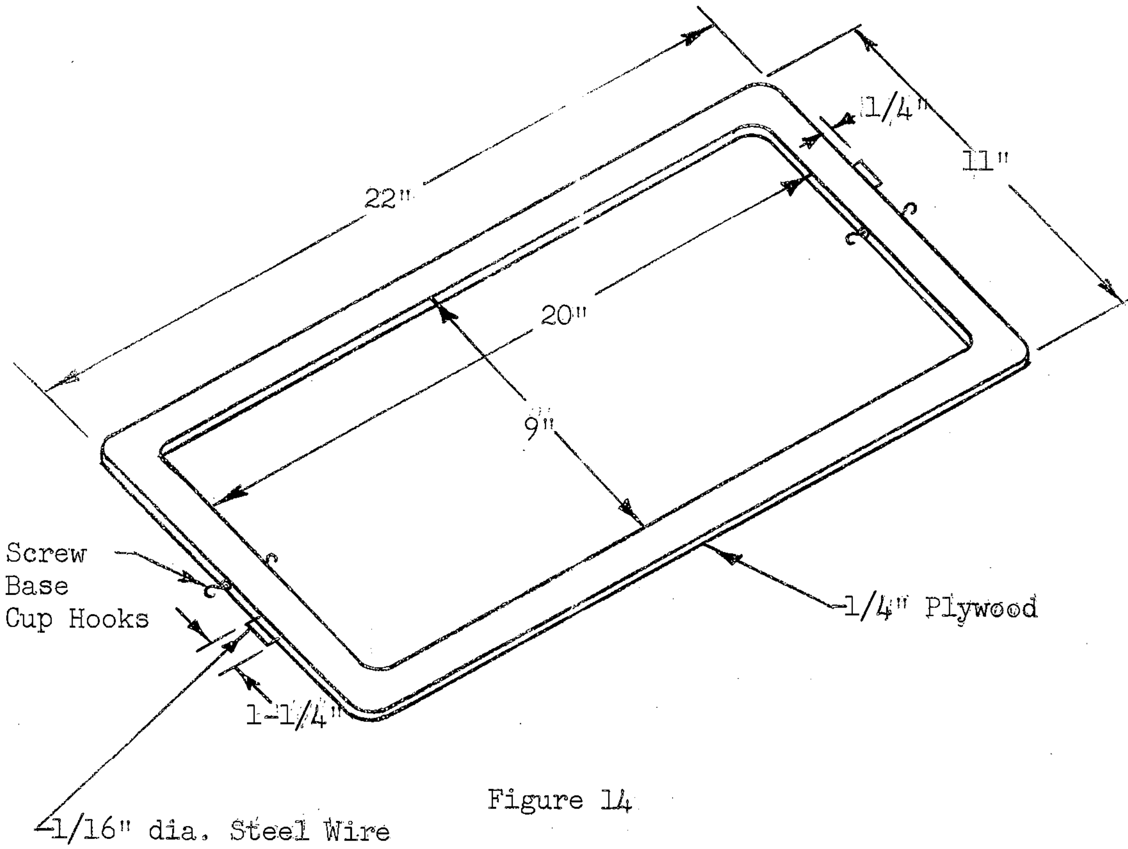


Figure 14

Forces Frame

<u>Material List</u>
4 ea. cup hooks
2 pcs. steel wire 1/16" dia. x 3-1/2" long
1 pc. plywood 1/4" x 11" x 22" long
2 ea. 2" dia. single sheave pulleys
2 ea. demonstration spring balances

Using a keyhole saw or jigsaw, cut out the center of the plywood panel as shown. Corners do not necessarily have to be rounded, but it does make a neater job and adds somewhat to the strength of the piece. Inside corners may be rounded by drilling a 1" or larger hole in the corners before sawing.

Screw the cup hooks in place on the 9" side at the centerline as shown. If cup hooks are not available, bend the hooks from wire and secure to the wood with small nails or staples.

Drill two 1/16" holes in each end of the frame 1-1/4" apart, with the centerline between the two holes approximately 2" from the centerline of the frame. The pair of holes on one end shall be on the opposite side of the centerline from the pair of holes on the other end. Make a "U" shaped bend in the two pieces of wire and insert the ends into the holes with about 1/2" of wire projecting through to the inside, and bend outward to secure in position in the frame.

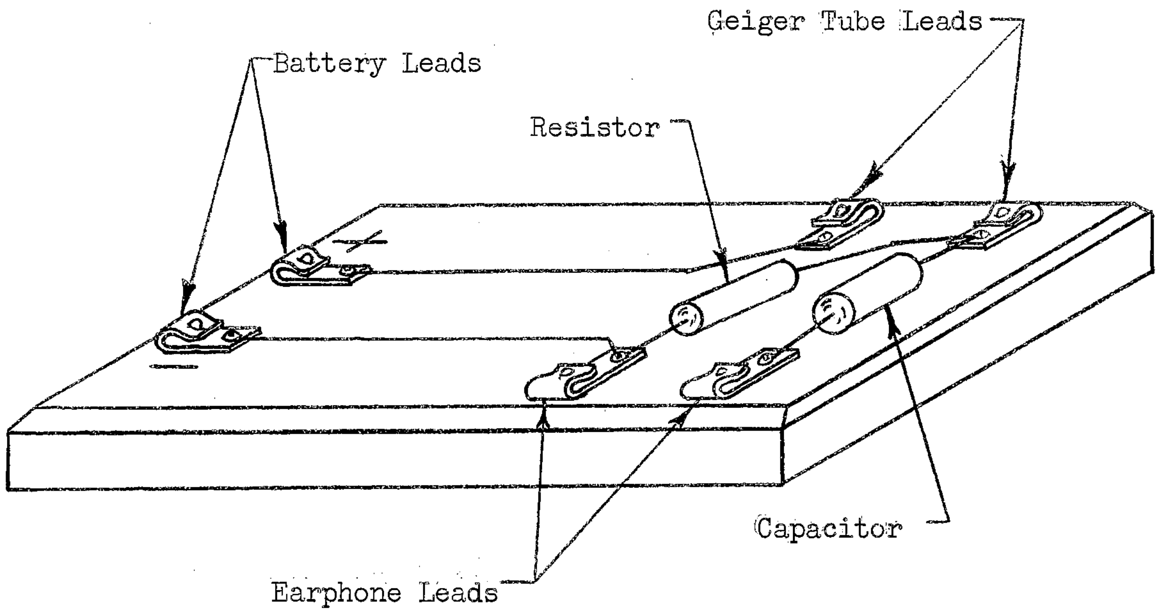


Figure 15

Geiger Counter

Material List
1 pc. plywood, 3/4" x 8" x 8"
6 Fahnstock clips
6 wood screws, #6 x 1/2 R. H. brass
1 resistor, meg-ohm, 1/4 watt
1 capacitor, 0.0005 micro-farad, 400 volts
1 Geiger tube, Victoreen #1B86 or equivalent
1 Battery, dry cell, 275-300 volts
1 set of inexpensive ear phones
(telephone receiver will do)
14" 16 ga. insulated copper wire

Cut out a piece of 3/4" plywood 8" square. Cut a 1/4" chamfer around the top edge of the plywood and sand the block smooth.

Apply a protective finish such as shellac or lacquer.

Locate the positions of the Fahnstock clips and drill pilot holes for the #6 wood screws.

Cut and strip the ends of all connecting wires.

As the clips are mounted on the block, the wires may be connected beneath the screw heads.

Mount the resistor and capacitor as shown.

By connecting the battery, tube, and ear phones, the counter is complete and ready to work.

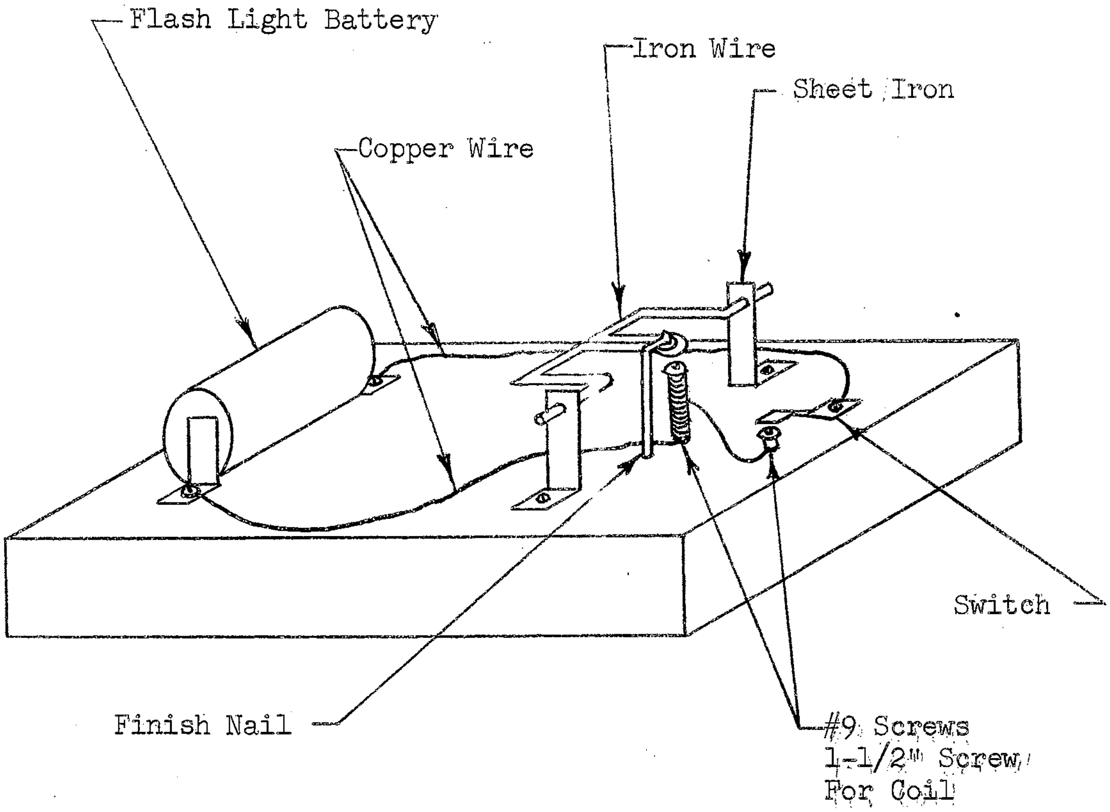


Figure 16

Magnetism: Toy Telegraph

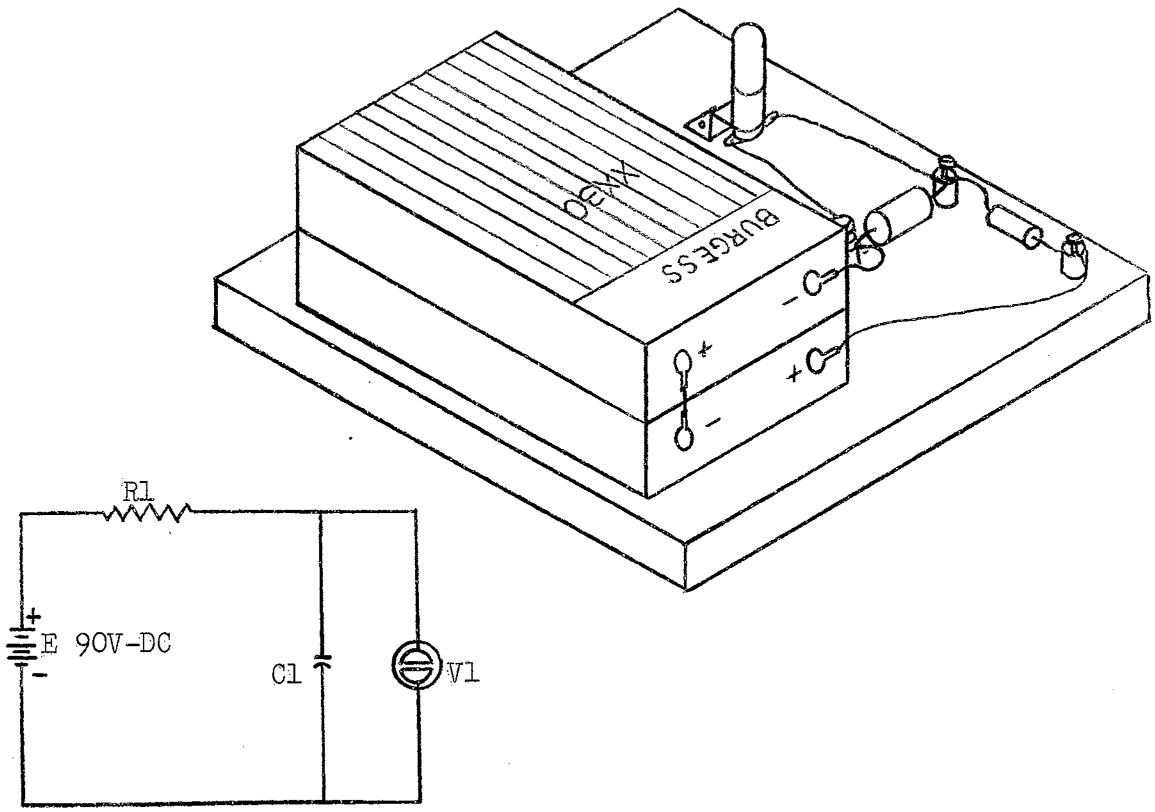
<u>Material List</u>
1 pc. hardwood, 1" x 4" x 7"
1 flash light battery
2 pcs. sheet iron, 26 ga., 1/2" x 2"
3 pcs. sheet copper, 16 ga., 1/2" x 1-1/2"
1 wood screw, #9 x 3/4" R. H. B.
1 wood screw, #9 x 1-1/2" R. H. B.
5 wood screws, #8 x 1/2" R. H. B.
1 pc. soft iron wire, 16 ga., 7" long
16" copper wire, 16 ga.

Work the base to size and apply a protective finish.

Mount the battery clips and switch (copper strips) on the base as illustrated. Make the ticker out of the iron wire and mount between the strips of sheet iron.

The coil is made by wrapping the screw with the copper wire. Connect the wires as the clips are mounted.

A stop may be made for the ticker by driving a small finish nail near the coil and bending it over the ticker.



Schematic

Figure 17

Relaxation Oscillator

<u>Material</u> <u>List</u>
V1 Bayonet-base neon lamp NESI
R1 1 meg ohm (variable)
C1 1 mfd. (variable)
E 2 no. xx-30 Burgess 45 v batteries
1 ea. lamp socket, bayonet base
3 ea. binding post

The relaxation oscillator may be used to illustrate various time constants

$$T=RC$$

Time in seconds, = Resistance times capacitance where
R = ohms and C = Farads or R = megohms and c = microfarads.
In the above case where R = 1 and C = 1, T = 1. V1 will flash at one second intervals.
Various combinations of R1 and C1 will change the time constant.
If R1 = 2 and C1 = 4, then T = R x C, or 8 seconds.
Mount the components on a small square of plywood or in a cigar box and wire according the diagram. The binding posts allow easy removal of R and C for other variations.

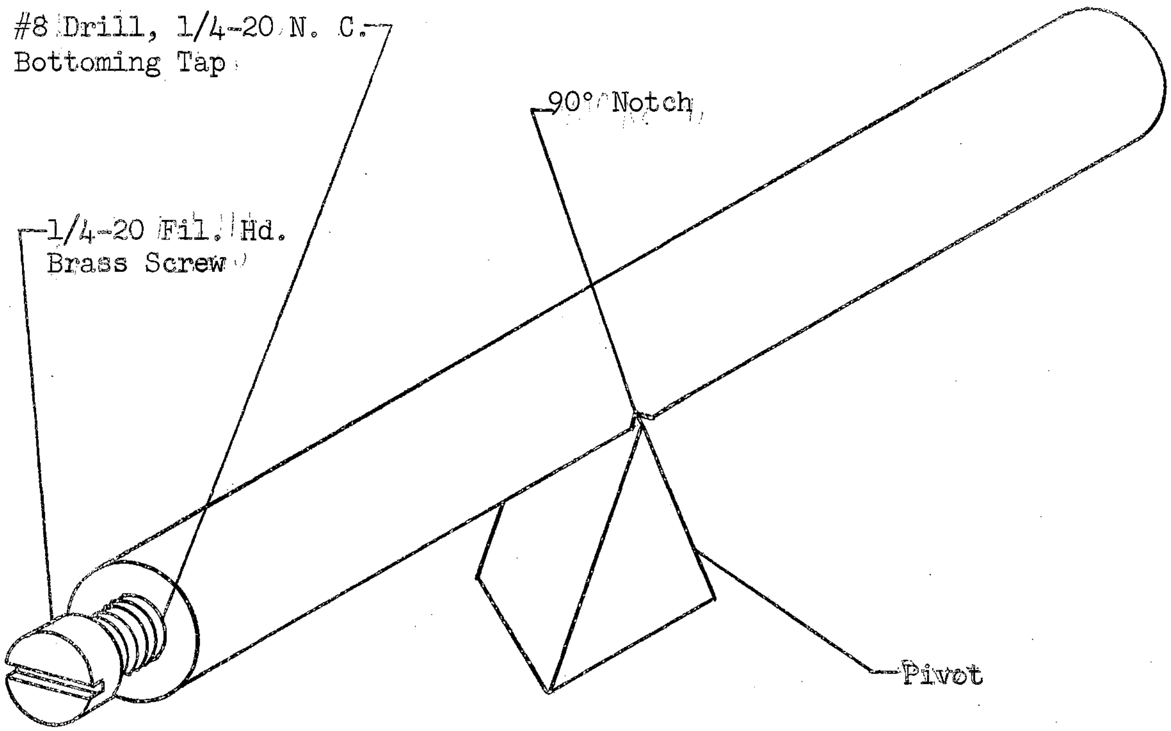


Figure 18

Thermal Expansion and Contraction

<u>Material</u> <u>List</u>
1 pc. brass rod, 3/8" dia. x 12"
1 brass machine screw, 1/4-20 x 1" fil. hd.
1 pc. steel, 1" x 1-1/2" x 2"

Drill a hole 1" deep into the center of one end of the brass rod with a #8 drill and tap with a 1/4-20 bottoming tap.

Insert the screw into the end of the rod 1/2" and locate the exact center of gravity. Cut a 90° included angle groove straight across the bar at the center of gravity with the corner of a small hand file tipped at a 45° angle.

Make the pivot from the piece of steel as illustrated with the 2" dimension being the height. The balancing edge should be straight, clean and sharp. Polish and oil lightly to prevent rusting.

Throw the bar off balance by moving the screw, then rebalance by heating the light end.

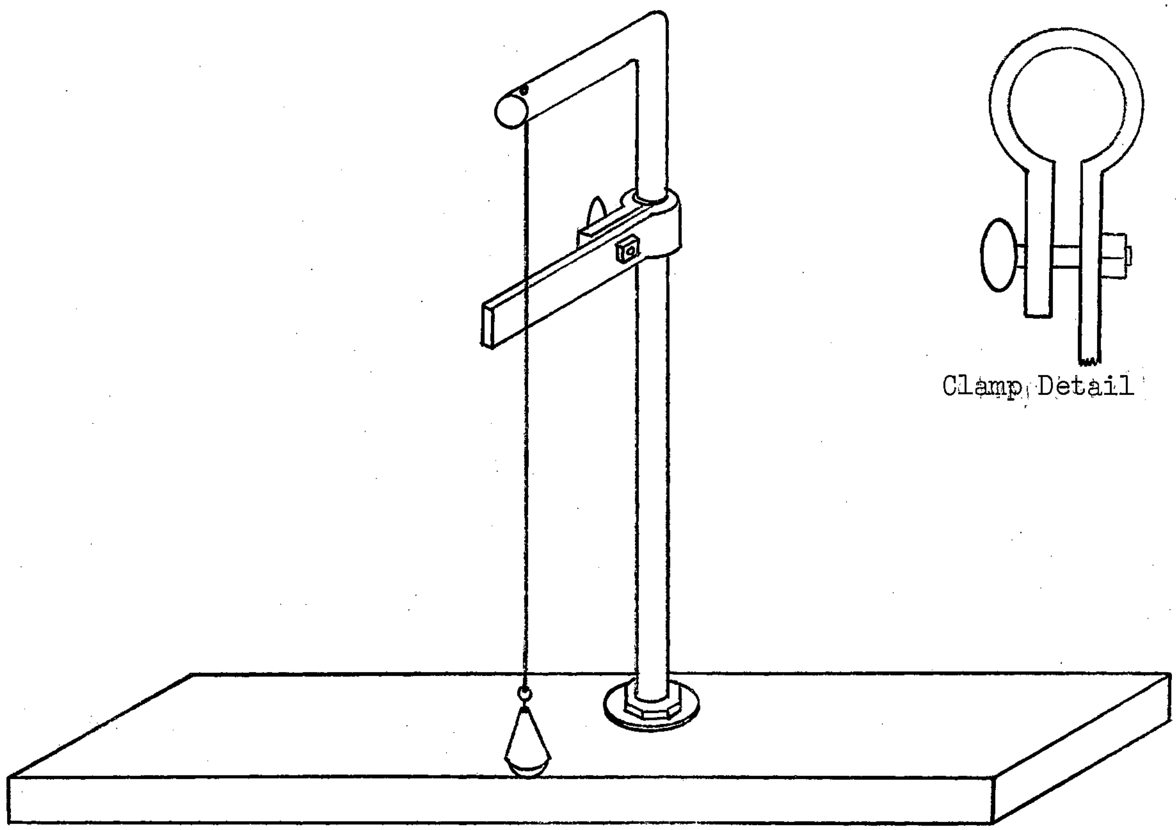


Figure 19

Pendulum

Material List
1 pc. hardwood, 1" x 6" x 18"
1 pc. H. R. S. round rod, 3/8" x 23"
1 pc. nylon cord, 30 lb. test, 17" long
1 pc. H. R. S. band iron, 1/8" x 1/2" x 6"
2 washers, 3/8"
2 thin nuts, 3/8-24 N. F.
1 large bell sinker, 2 to 4 oz.
1 thumb screw, 1/4-20 N. C. x 3/4", with nut

Make a 90° angle bend 4" from one end of the 3/8" rod, and thread the other end 1" with a 3/8-24 die. Drill a 3/32" hole parallel to the main axis 1/4" from the unthreaded end.

Work the base to size and drill a 25/64" hole through 1" from one edge at the middle of the board. Counterbore the bottom side to a depth of 1/2".

Make the obstruction clamp (see detail). Assemble the apparatus as illustrated. Apply a protective finish.

Moving the obstruction up and down will change the arc of swing; if moved down far enough, the pendulum will loop completely over.

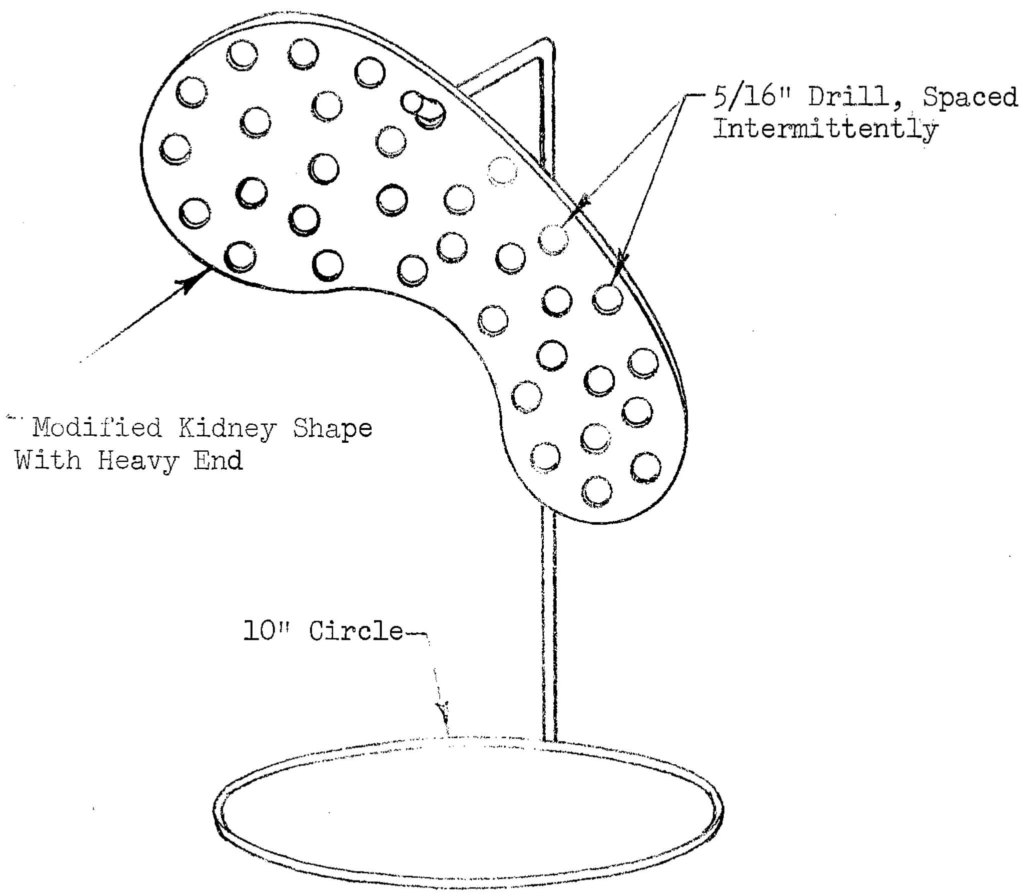


Figure 20

Equilibrium Balance

Material List
1 pc. C. R. S. round rod, 1/4" x 52"
1 pc. 16 ga. B. I. sheet, 6" x 12"

Bend a 10" dia. circle at one end of the 1/4" rod, and bend the circle at 90° to the rod axis.

Bend the top 6" of the rod over until it angles slightly down and hook the end up so the balance weight will rotate freely without falling off.

Use a pair of dividers and a beam compass to lay out a modified kidney shape on the sheet iron. Make one end larger than the other. Cut out with heavy hand shears or metal band saw and file the edges smooth.

Drill 5/16" holes at various intervals along the full length and width of the balance weight, and remove the drilling burrs on a grinder.

Clean the metal and apply a coat of metal primer. Paint to suit.

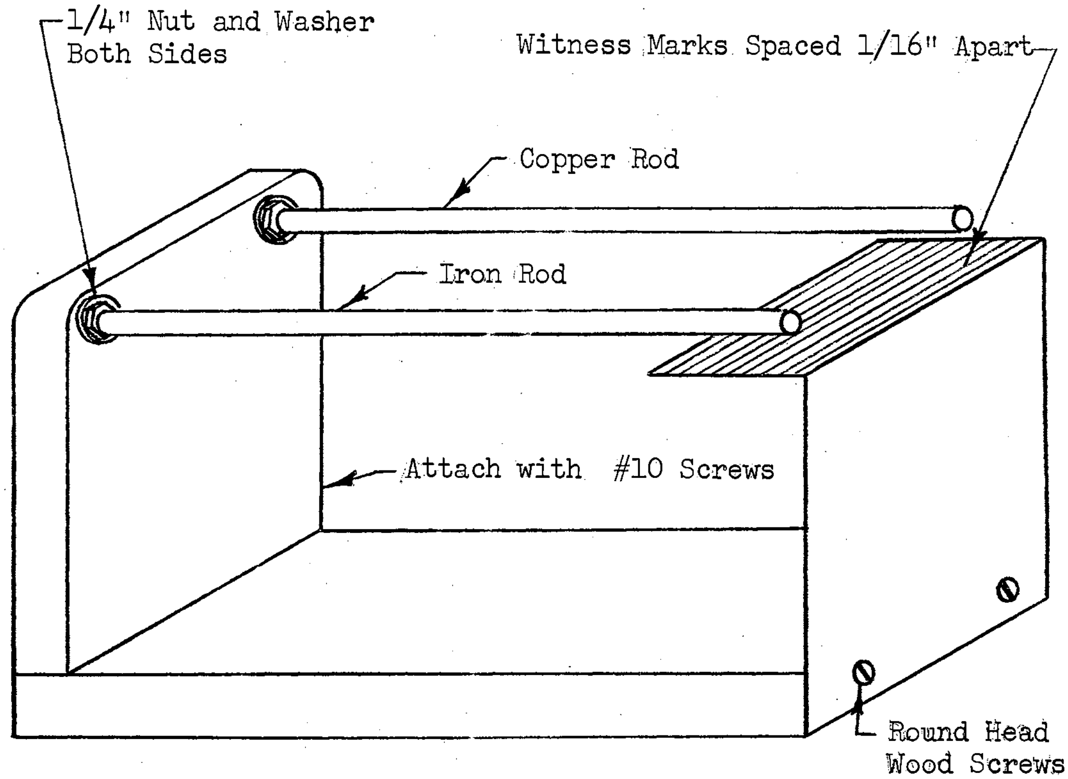


Figure 21

Thermal Expansion and Contraction

<u>Material</u> <u>List</u>
1 pc. maple, 1" x 4" x 14"
1 pc. maple, 3/4" x 4" x 6"
1 pc. C. R. S. round rod, 1/4" x 13"
1 pc. copper rod, 1/4" x 13"
1 pc. 22 ga. gal. sheet iron, 4" x 8-1/2"
2 wood screws, #10 x 2" F. H. B.
2 wood screws, #9 x 3/4" R. H. B.
4 hex nuts, 1/4-20 N. C.
4 gal. washers, 1/4"

Plane the boards to size and round the top corners of the 6" piece to a 1/2" radius. Using these same radii centers, drill the 1/4" holes for the rods. Locate and drill the pilot holes for the wood screws; and countersink the heads of the #10 screws.

Make a 90° angle bend 2-1/4" from one end of the sheet metal and drill the holes for the screws through the metal with a #15 drill. Use a sharp metal scriber to draw the witness marks on the metal as indicated.

Sand the wood pieces smooth and apply a protective finish.

Thread the rods 1-1/4" and assemble the project as illustrated.

Note: If the amount of heat to be used exceeds 200° Fahrenheit, the wood may be finished with a heat-resistant paint. If the temperature is to exceed 350° Fahrenheit, Transite or some other insulating material should be substituted in place of the wood.

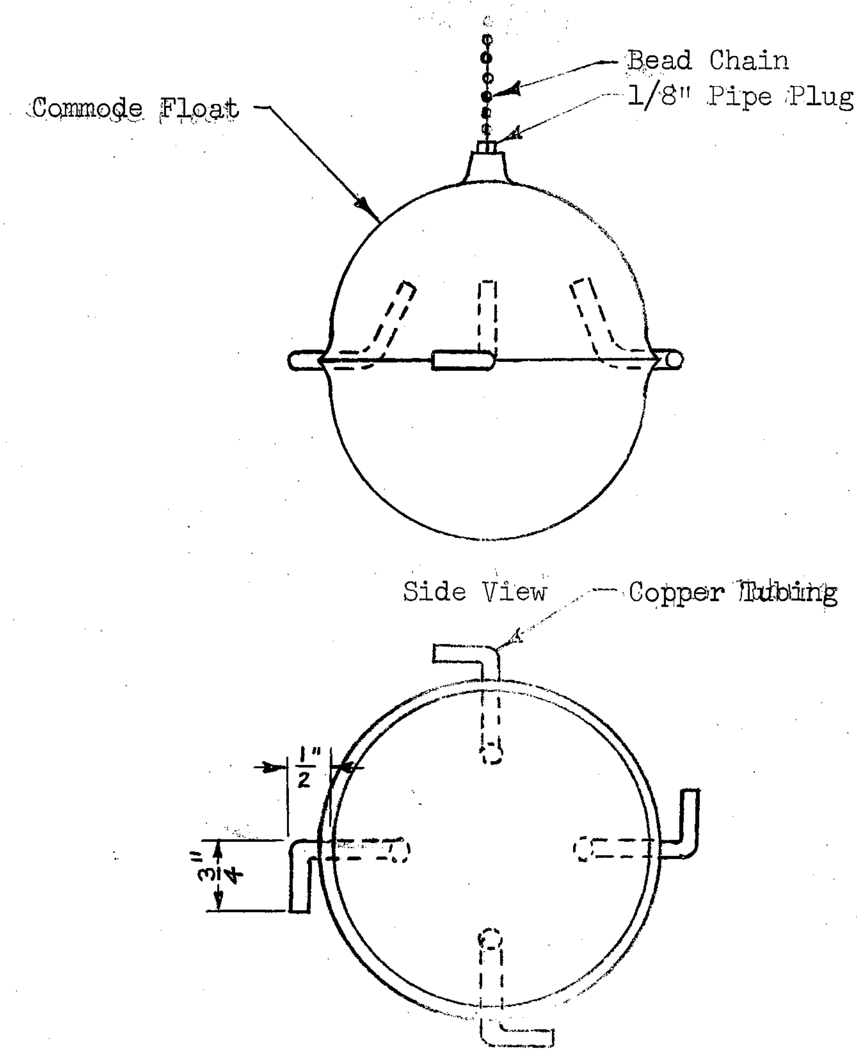


Figure 22

Hero's Engine

Material List
1 ea. copper tank float
4 pcs. copper tubing, soft 1/8" dia. 3" long
1 ea. 1/8" brass pipe plug
1 ea. bead chain 12" long

Select a float which has a neck in one end large enough to allow drilling and tapping to a 1/8" pipe thread. Drill a hole the size of the bead chain all the way through the brass pipe plug, drop the chain through this hole with one or two beads projecting through the end opposite the square, and fill the hole with solder.

Drill four 1/8" holes 90° apart around the center of the ball, bend the copper tubes as shown, insert in the holes provided and solder in place.

Pour about 1 ounce of water into the ball and screw the pipe plug in place. When held over a burner until the water boils, the ball will turn.

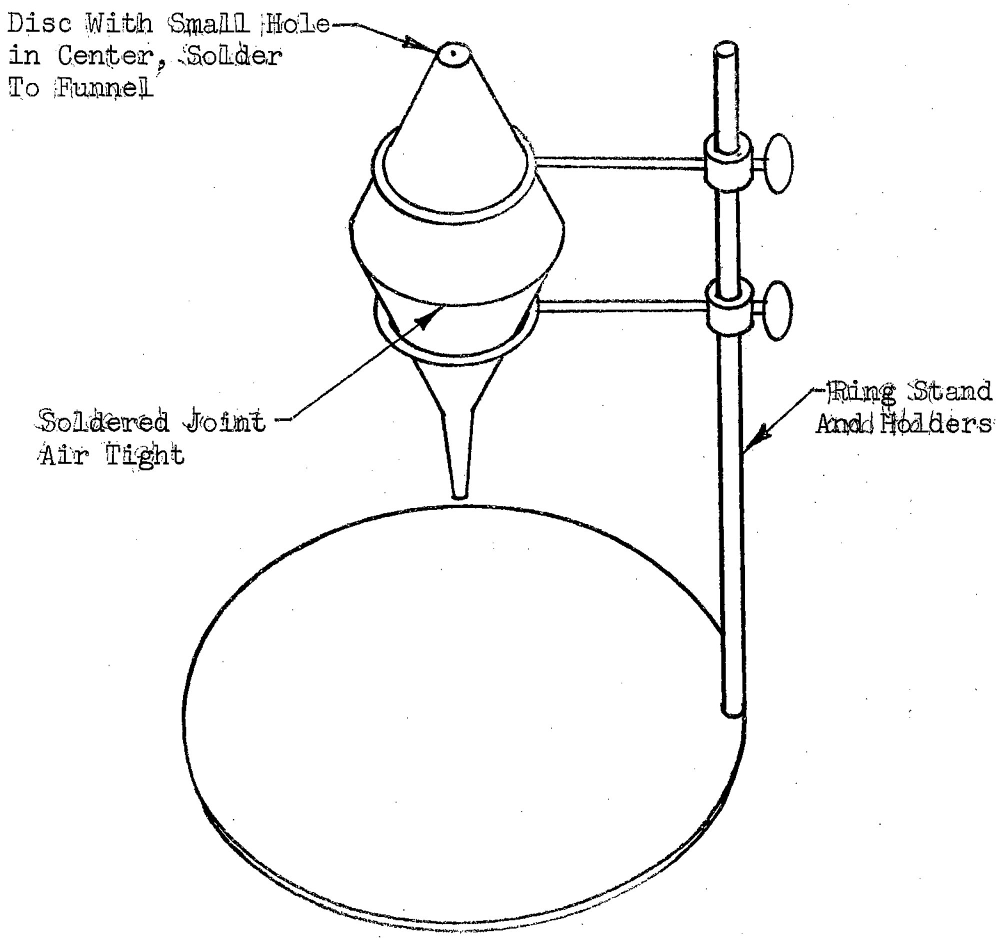


Figure 23

Gas-Explosion Apparatus

Material List
2 ea. funnels 4" to 6" dia. tin
2 ea. ring supports 3" to 4" with clamps,
(Cenco no. 18005 or equal)
1 ring stand

Cut the spout off of one funnel and unroll the spout into a flat piece of metal. Snip a small disc from this piece of scrap slightly larger than the hole where the spout was removed. Drill a small hole (1/32" or 1/64") in the center of the disc and solder in position.

Solder the two funnels together at the large ends. Test for leaks by rubbing liquid soap around the seams; blow through the spout while holding a finger tightly over the small hole. After the seams have been made tight, place the funnels (spout down as in illustration) Between two rings and clamp to the ring stand. The ring stand should have a fairly heavy base or should be weighted down.

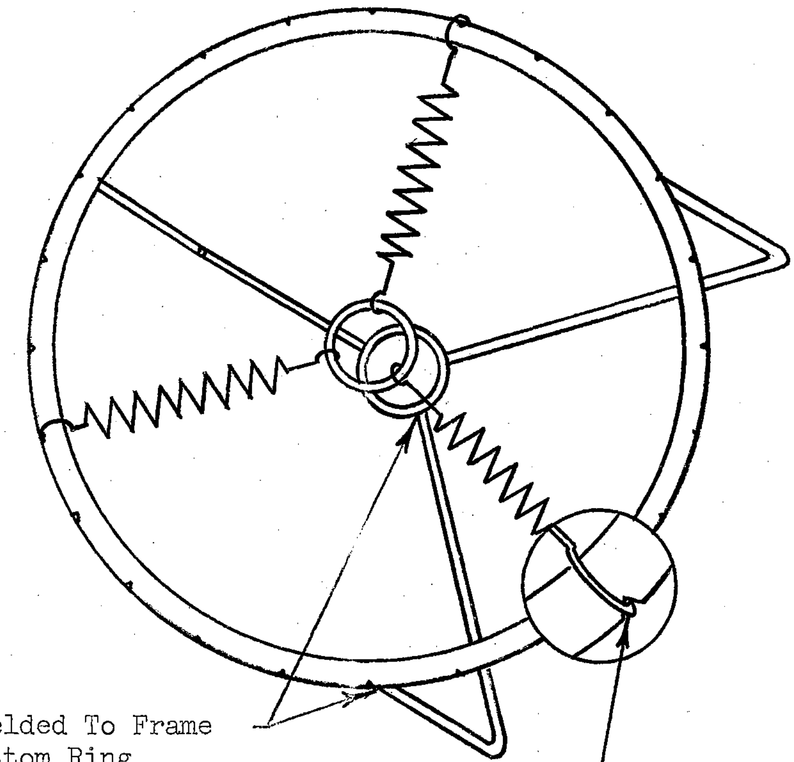


Figure 24

Forces Frame

<u>Material List</u>
1 pc. H. R. S. round rod, 3/8" x 44"
2 pcs. H. R. S. round rod, 1/4" x 10"
3 pcs. H. R. S. round rod, 1/4" x 8-1/2"
3 springs, full loop, open end, 16 ga.
1" dia. x 4" free length

Bend the long rod into a circle and weld the ends together.

Make the legs by making a 90° angle bend 3" from one end of the 8-1/2" pieces.

Bend the 10" rods into circles and weld the ends together.

Weld the assembly together as shown. The small fixed ring should be exactly centered inside the large ring, and 1/2" below the bottom face of the large ring.

With a protractor or divider, lay out witness marks each 15° (closer if desired) along the outside perimeter of the large circle. Cut a retaining groove on each mark with a three-square file to hold the spring loop.

The springs may be moved to various positions to change the angle of force. The fixed and floating rings will coincide when the springs are hooked equilaterally.

Accurate measurement of forces may be obtained by substituting spring balances in place of the springs.

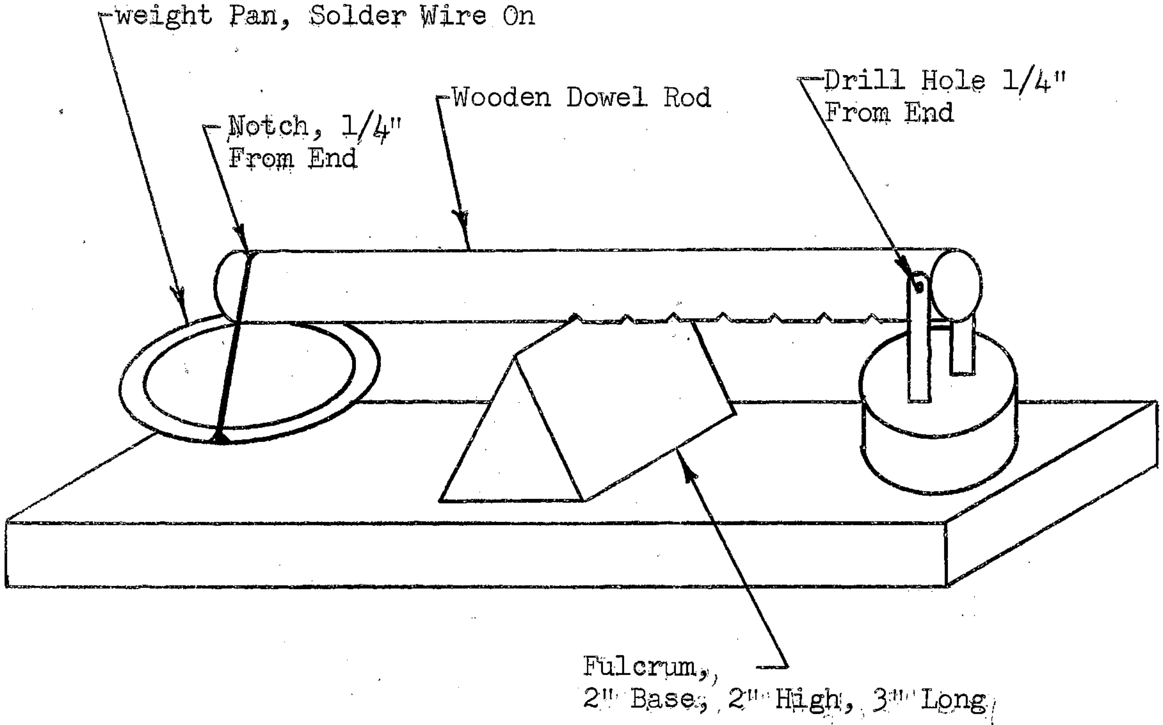


Figure 25

Fulcrum and Lever

<u>Material List</u>
1 pc. hardwood, 1" x 4" x 14"
1 pc. hardwood, 2" x 2" x 3"
1 pc. wood dowel rod, 1" dia. x 12-1/2"
1 lead weight, approximately 2 lbs.
1 pc. sheet metal, 26 ga., 3" dia.
2 lbs. of weights, various sizes
1 pc. wire, 18 ga., 6" long

Work the wood pieces to size, making the fulcrum as shown.

Mount the weight pan on the beam and drill the hole for the pin which holds the fixed weight. Locate the exact center of gravity of the beam and cut a small groove across at this point. Cut a series of grooves across at 1/4" to 1/2" intervals toward the end with the fixed weight.

Finish as desired.

Assemble as illustrated.

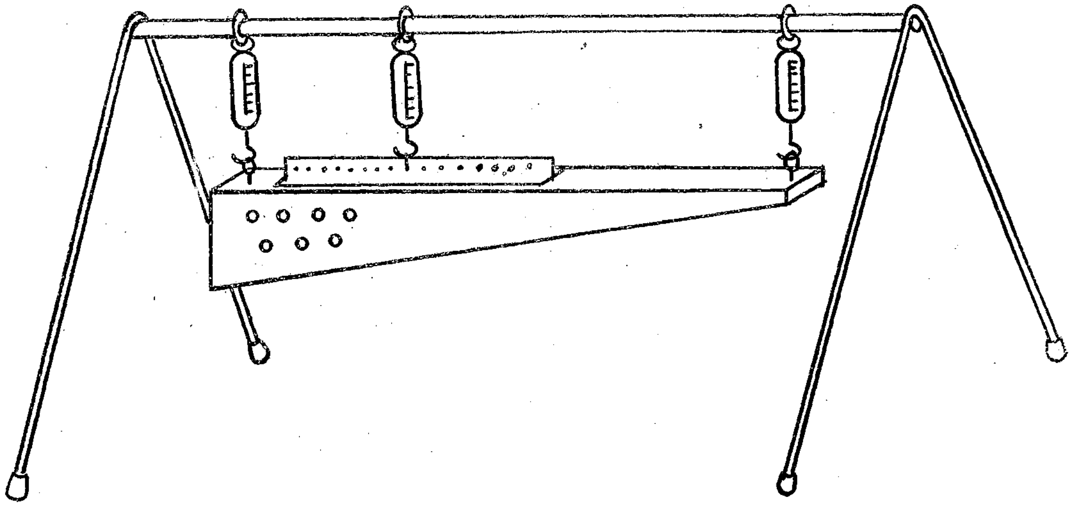


Figure 26

Parallel Forces Spring Balance

Material List
1 pc. 1/2" pipe, 30" long
2 pcs. C. R. S. round rod, 3/8" x 40"
3 spring balances
1 pc. sheet metal, 26 ga. 3" x 10"
1 pc. pine, 2" x 4" x 24"
2 screw eyes
4 rubber crutch tips, #15
1 lb. of B. B. or smaller lead shot
7 corks, 1/2" dia.

Taper the pine board to 1/2" at one end, and sand and finish to suit.

Mount the rings for the spring balances of the 1/2" pipe, then bend the 3/8" steel rods to the outside diameter of the pipe, with 14" maximum spread at the base. Weld in place as shown and put the #15 crutch tips on the legs.

Bend the sheet metal as shown and drill 1/8" holes at 1/4" intervals for its entire length. Mount on board so that the left end is over the center of the shot holes.

Drill the shot holes 1/2" dia. x 1-1/2" deep

Mount the screw eyes 1/2" from each end of the board.

Very thin guage metal clips which can be nipped with scissors may be used to hang the beam from the balance hooks.

Ready for use when assembled.

Shot may be poured into the holes and secured with corks to shift the center of gravity.

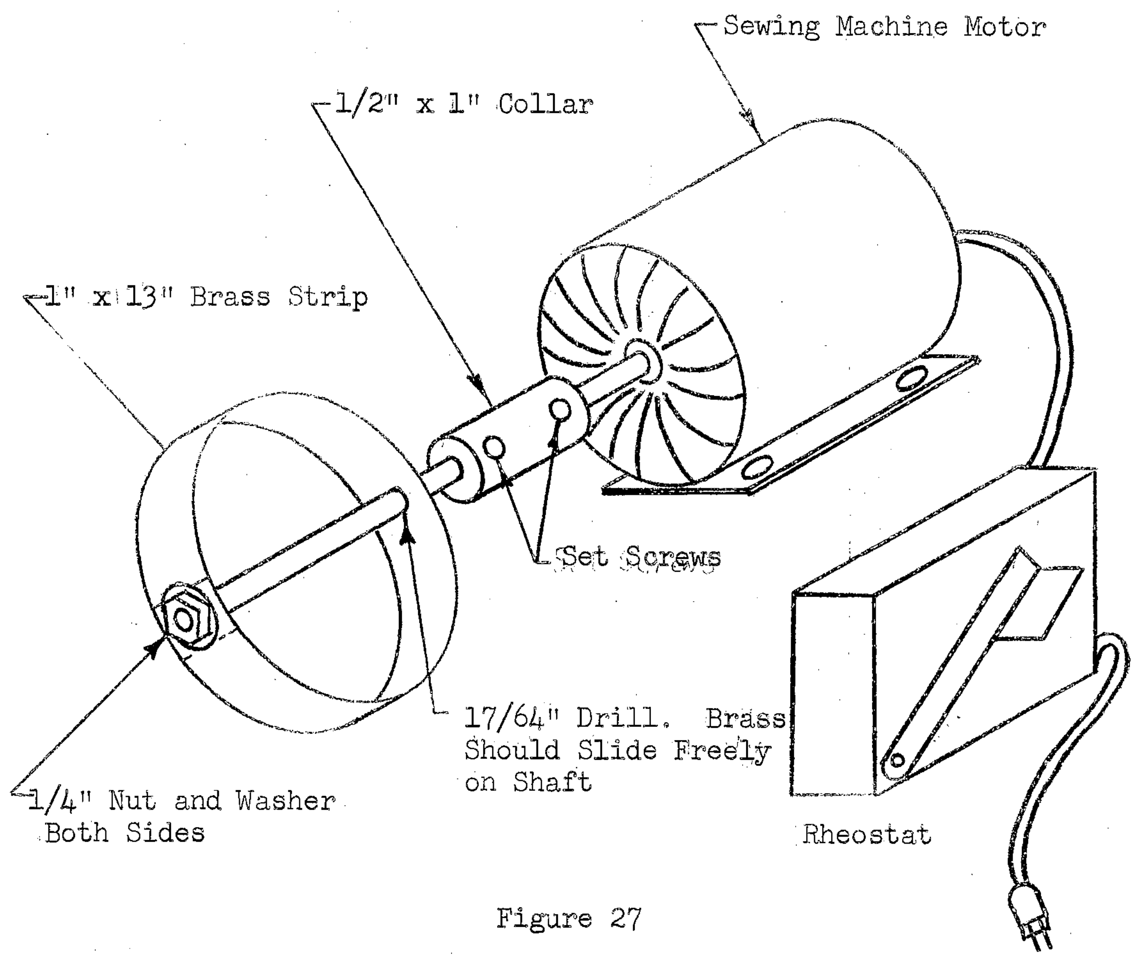


Figure 27

Centrifugal Force Apparatus

Material List
1 sewing machine motor, 1/15 h.p.
1 rheostat for motor speed control
1 pc. C. R. S. round rod, 1/4" x 6"
1 pc. C. R. S. round rod, 1/2" x 1"
1 pc. hard annealed brass, 18 ga., 1" x 13"
2 hex nuts, 1/4-20 N. C.
2 allen set screws, 10-24 N. C. x 3/16"
2 washers, 1/4"

Drill a 17/64" hole in the exact center of the brass strip and a 17/64" hole located 1/2" from each end on the center line. Bend the strip into a circle on the slip roll.

Thread one end of the 1/4" rod 1" with a 1/4-20 die.

Drill a 1/4" hole lengthwise through the center of the 1/2" rod, and drill an intersecting hole 1/4" from each end with a #25 bit. Thread these two holes with a 10-24 tap.

Assemble as shown. A small flat may be filed on the shaft for the set screw point.

As motor speed is slowly increased, the brass circle will become oval.

Note: Rheostat and motor may be mounted on a common base if desired.

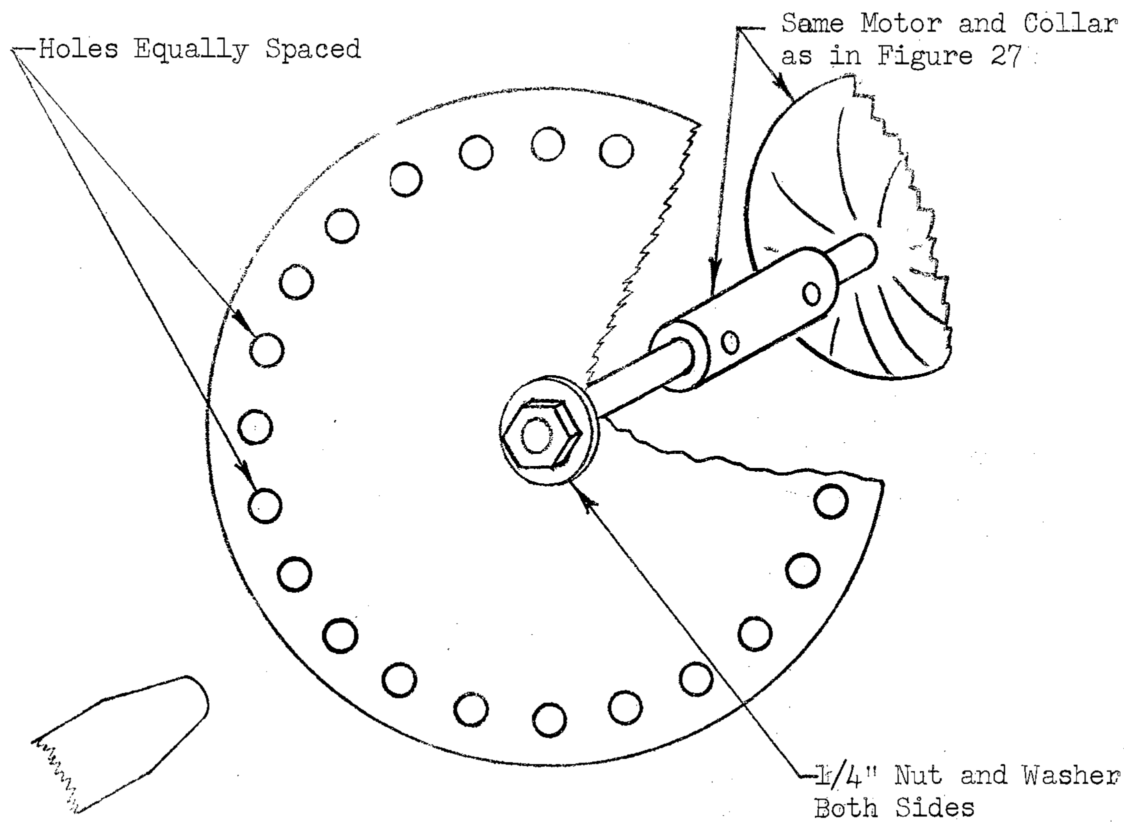


Figure 28

Siren

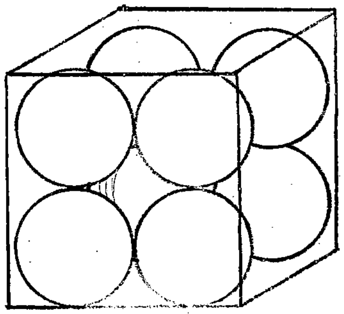
Material List
1 pc. C. R. S. round rod, 1/4" x 2"
1 pc. 22 ga. gal. sheet iron, 5" x 5"
2 hex nuts, 1/4-20 N. C.
2 washers, 1/4"

Thread one end of the 1/4" rod 1" with a 1/4-20 die, and file a small flat on the other end for the set screw.

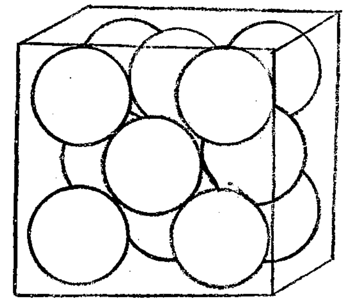
Lay out a 5" circle on the sheet metal, cut out with hand shears, and file the edges smooth. Lay out a concentric circle 4" in diameter on the sheet metal and locate an even number (8, 12, 18, etc.) of equally spaced holes on this circle with a protractor or divider. Mark the holes with a center punch and drill with a 1/4" bit. Also drill a 1/4" hole in the center of the disc.

Remove the drilling burrs with a file and assemble as shown.

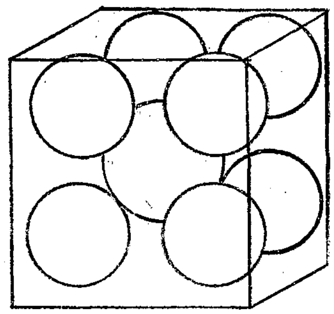
Note: A certain sound is produced when an air flow is introduced while the motor is running. Other plates may be made with various numbers and sizes of holes to produce different sounds.



Simple Cubic



Face Centered Cube



Body Centered Cube

Figure 29

Crystal Structure of a Cube

Molecular Arrangement

<u>Material List</u>
32 colored beads or marbles
Castolite casting plastic
hardening agent
cold set promoter
mold release

The size of the mold needed to cast these cubes will depend on the size of the beads or marbles used. A small square tin or plastic box of the proper size will do, or a metal mold may be easily constructed with thin sheet tin and solder.

Prepare the mold by coating the inside with mold release. Place the spheres in the desired arrangement and mix the Castolite, hardener, and cold set promoter, pouring it into the mold as soon as it is mixed.

After casting, remove from the mold and clean the casting utensils with Castolite cleaning fluid.

Polish the cubes on a soft cloth buffer if necessary.

Note: Careful selection of bead sizes will allow the use of the same mold for all models. Molecular arrangements of other than cubes may be made in the same way.

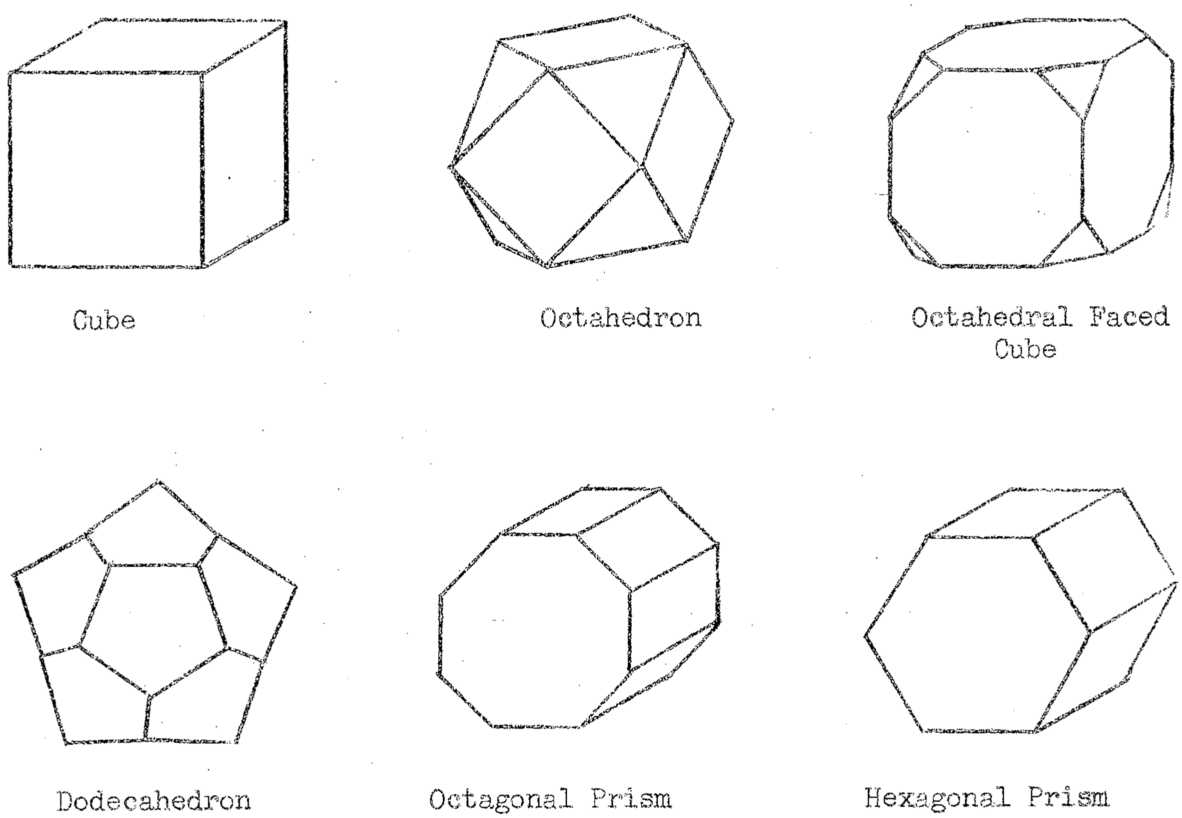


Figure 30

Crystal Models

<u>Material List</u>
6 pcs. clear plexiglass, 1-1/2" cubes

Cut the cubes from a 1-1/2" thick sheet of clear plexiglass. Cut slightly large to allow for finishing.

File or sand the faces flat.

Mark off the necessary angles on all faces of the cubes.

With a saw, rasp, file, or belt sander take off excess plastic to bring the models down to rough shape.

With a fine file and fine grit sandpaper, smooth the models to their final shape.

Polish on a soft cloth buffer.

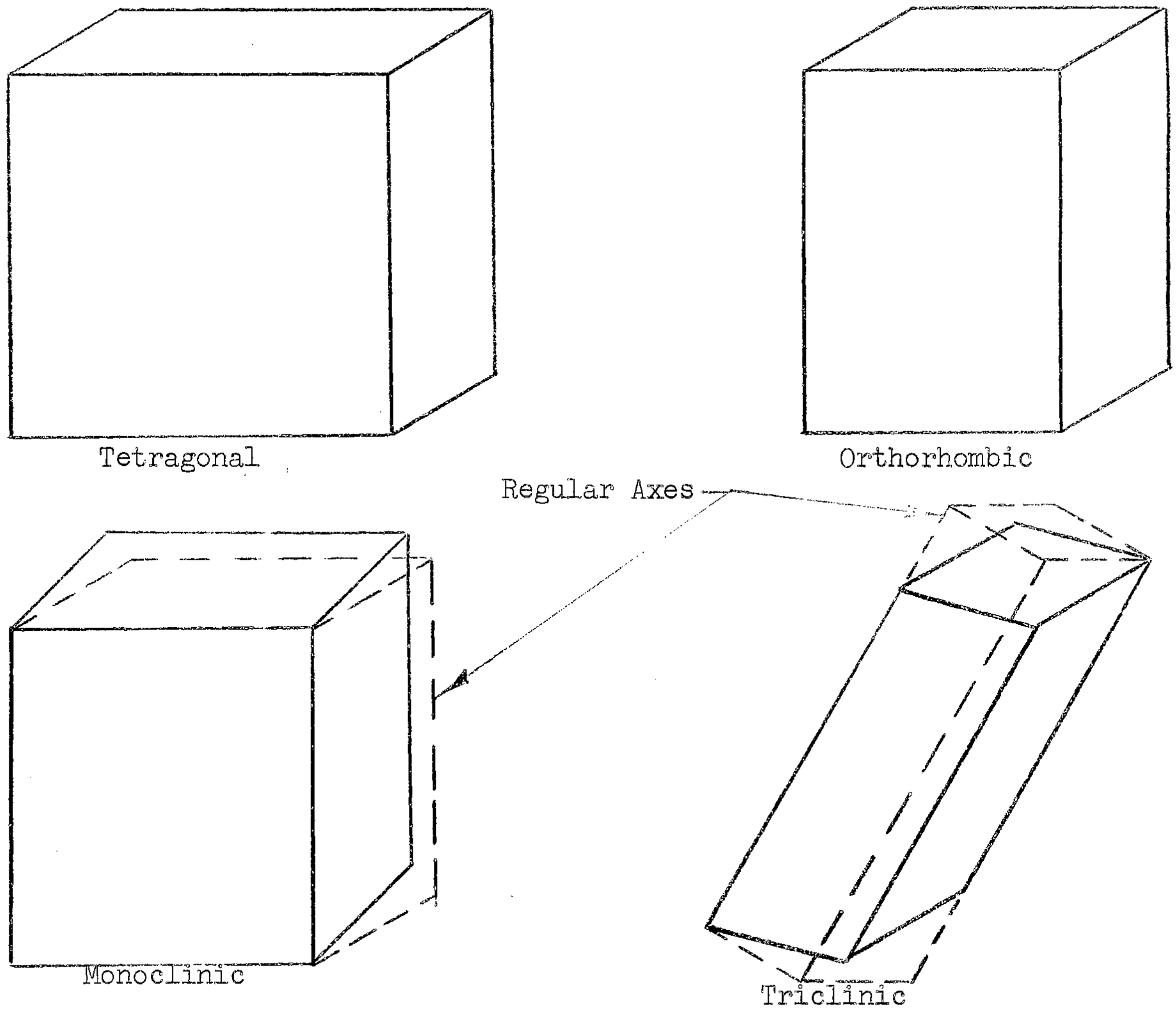


Figure 31

Crystal Models

Material List
1 pc. clear plexiglass, 1/2" x 1-1/2" x 1-1/2"
3 pcs. clear plexiglass, 1/2" x 1" x 1-1/2"

Cut the pieces to rough size. Lay out the necessary angles and rough out the pieces with a file, rasp, or belt sander. Smooth with a fine file and fine sand paper. Polish on a soft cloth buffer.

The axes for each model are as follows:

Tetragonal-3 axes at 90°, 2 of equal length and one shorter.
Orthorhombic-3 axes at 90°, all of a different length.
Monoclinic-3 axes, 2 at 90°, one at some other angle.
Triclinic-3 axes, none at 90° to another.

On all models, the opposite faces are parallel.

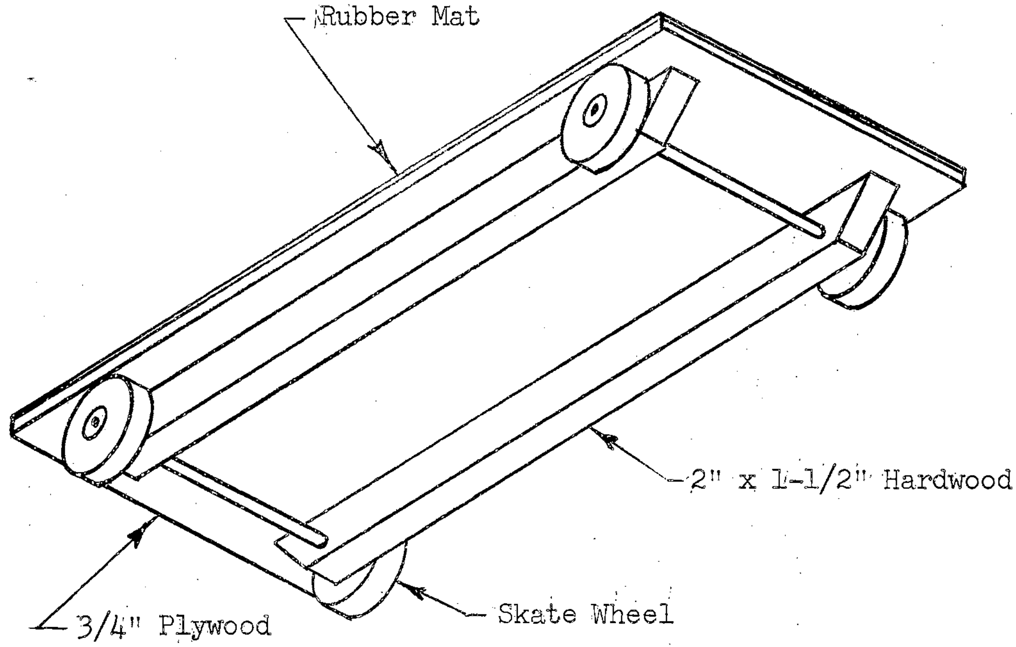


Figure 32

Skate-Wheeled Platform Action-Reaction Chart

<u>Material List</u>
1 pc. plywood 3/4" x 16" x 36"
2 pcs. maple 1-1/2" x 2" x 34"
2 pcs. steel rod 1/4" dia. x 16"
4 ea. skate wheels
1 pc. rubber matting 16" x 36"

Drill a 1/4" hole 1-1/2" from the end and 1" from the edge in each end of the two pieces of maple and cut the end off at a 45° angle. Nail these pieces to one side of the plywood approximately 1-1/4" from the edge.

Place the 1/4" rods in the holes, place the wheels in place on the rods, and peen the ends of the rod.

Tack the rubber matting in place on the other side of the platform.

Note: This platform may be used with the "Uphill Roller."

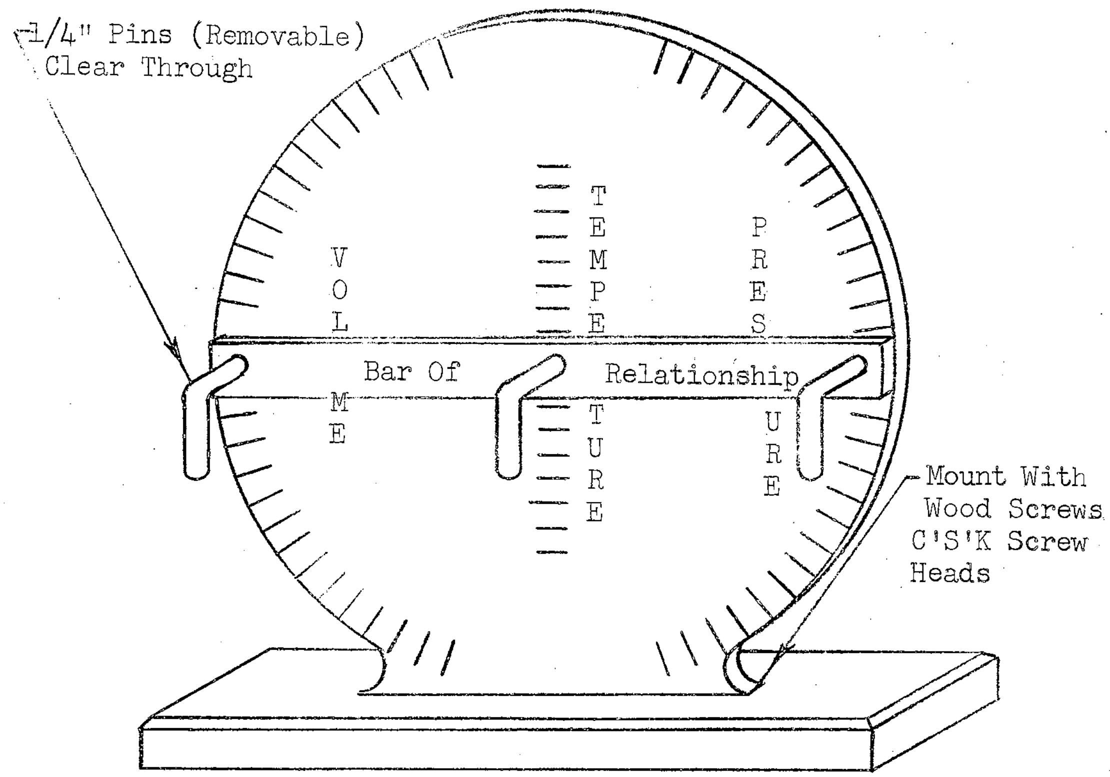


Figure 33

Gas Laws Apparatus

Material List
1 pc. plywood, 3/4" x 15" x 15"
1 pc. hardwood, 1" x 6" x 15"
1 pc. hardwood, 1/4" x 1" x 15"
3 pcs. C. R. S. round rod, 1/4" x 2"
3 wood screws, #9 x 1-1/2" F. H. B.

Lay out a 15" dia. circle on the plywood, leaving 8" of one side attached for mounting on the base, and saw out with a band saw or jig saw.

Work the bar to size and clamp it over the center line of the circle parallel to the straight edge. Drill a 17/64" hole at the center of the bar and 3/4" from each end on the center line through both pieces.

Square and chamfer the ends of the rods on a grinder and make a 90° bend 1/2" from one end.

Work the base piece to size and chamfer the top with a 1/4" chamfer.

Sand all pieces smooth and apply a protective finish. Assemble as shown.

Proper labels may be painted on or decal letters may be used.

One fixed pin will demonstrate a certain relationship: example; when the temperature remains constant an increase in pressure forces the volume to decrease. Other combinations demonstrate other relationships.

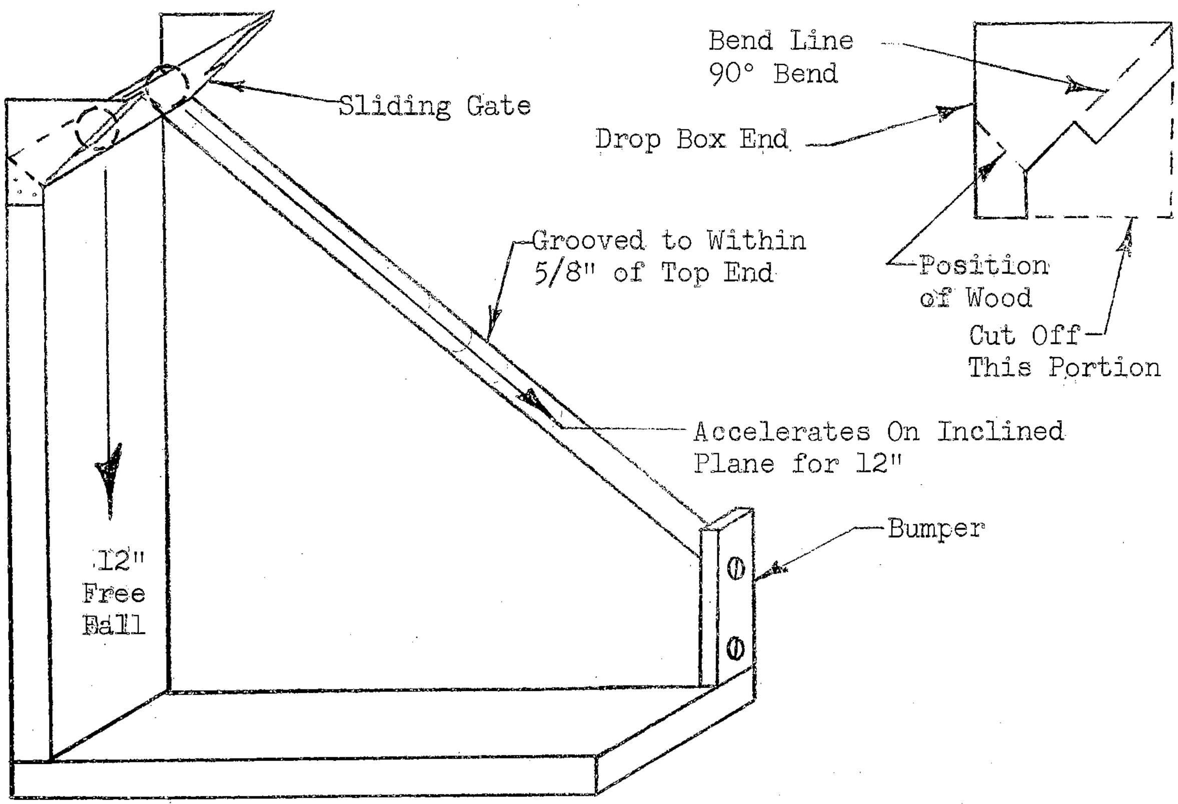


Figure 34

Acceleration

Material List
1 pc. plywood, 3/4" x 9" x 12"
1 pc. hardwood, 1" x 2" x 9-1/2"
1 pc. hardwood, 1/2" x 1-1/4" x 12-1/2"
1 pc. hardwood, 1/2" x 3/4" x 4"
3 pcs. sheet metal, 26 ga., 2" x 2"
2 wood screws, #9 x 1" R. H. B.
3 wood screws, #9 x 1-1/4" R. H. B.
4 wood screws, #9 x 2" F. H. B.
2 ball bearings or marbles

Cut a 45° angle from one corner of the plywood piece and shape a rounded groove into this inclined surface. Mount the bumper at the lower end of this groove as indicated.

Cut a 45° angle at the top end of the upright piece of hardwood and mount on the back edge of the plywood with #9 x 1-1/4" wood screws. Attach these pieces to the base with the 2" screws.

Apply a protective finish to the wood.

Make the sheet metal drop box as shown and attach with small nails. Adjust so that both balls are released at exactly the same time.

Other segments with a different angle of fall may be added.

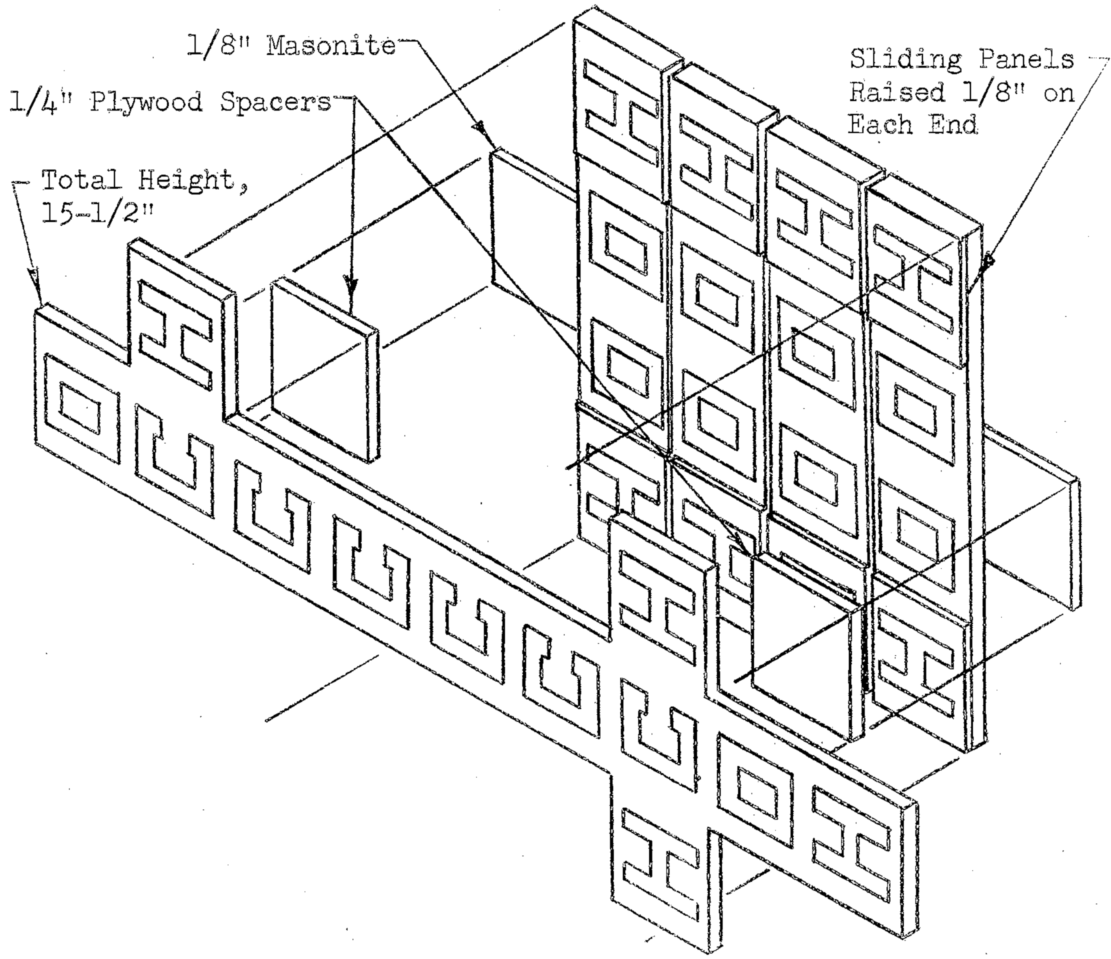


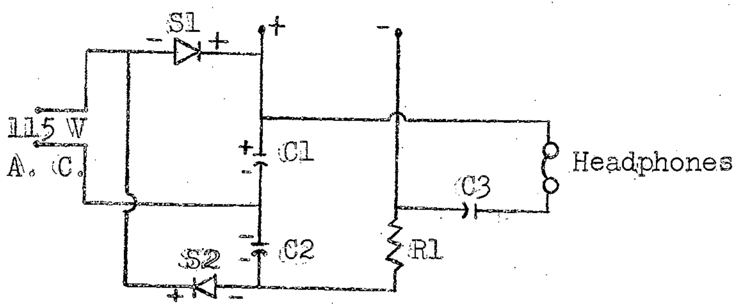
Figure 35

Sugar-Molecule Demonstration Board

Material List
1 pc. plywood 1/4" x 3-3/4" x 15-1/2"
4 pcs. plywood 1/4" x 1-3/4" x 5"
8 pcs. plywood 1/8" x 1-1/4" x 1-3/4"
2 pcs. plywood 1/4" x 1-1/4" x 1-3/4"
1 pc. masonite 1/8" x 1-1/4" x 10-1/2"

Saw the 3-3/4" x 15-1/2" pc. of 1/4" plywood to shape as shown in the illustration. Glue the 1-1/4" x 1-3/4" pcs. of 1/8" plywood at the ends of the 1-3/4" x 5" pcs. of 1/4" plywood (see illustration). Glue the two spacer blocks on the back of the front piece and paint the letters on the front piece and sliding panels.

When the paint has dried, place the sliding panels in position behind the front piece, making sure there is room enough to allow sliding; if not, sandpaper the edges of the sliding panels until they will slide freely. Next, place the 1/8" masonite backing plate in position with a small piece of heavy wrapping paper between the masonite and spacer block to allow clearance for sliding; with small wire nails fasten the backing plate in position.



Schematic

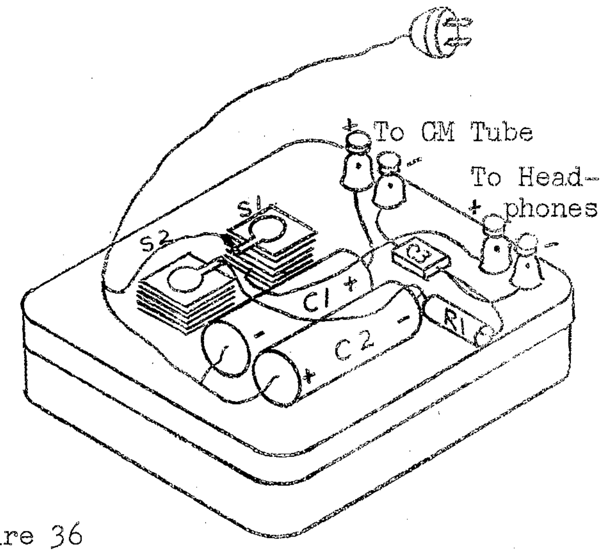


Figure 36

Geiger Counter

Material List
S1-S2 100 ma. selenium rectifier
C1-C2 16 mfd.-150 volt electrolytic condenser
C3 .0002 mfd. blocking condenser, 600v
R1 1 megohm, 1/2 watt resistor
1 ea. 300 volt Geiger tube (Elec. Prod. Inc., type 30-G)
1 pr. headphones, 2000 ohms
4 ea. binding posts

Components for the simple Geiger Counter diagrammed above may be mounted in a plastic sandwich box or other suitable mounting, such as a cigar box. The counter circuit is much simpler than the usual radio circuit and most components are available at most radio and electronic-supply stores. The Geiger tube may be obtained from Electronic Products Inc., 111 East Third Street, Mount Vernon, New York, and Victoreen Electronics, Chicago, Illinois.

Mount all the components except the tube and headphones inside the plastic box with the binding posts mounted on the lid of the box projecting to the outside of the box. Complete the wiring as shown in the diagram, using ordinary lamp cord or other plastic or rubber-insulated 16 to 20 ga. copper wire. The binding posts used for the tube should be coded or marked to ensure proper connection of the tube.

The tube should have a protective shield made of cardboard or plastic tubing.

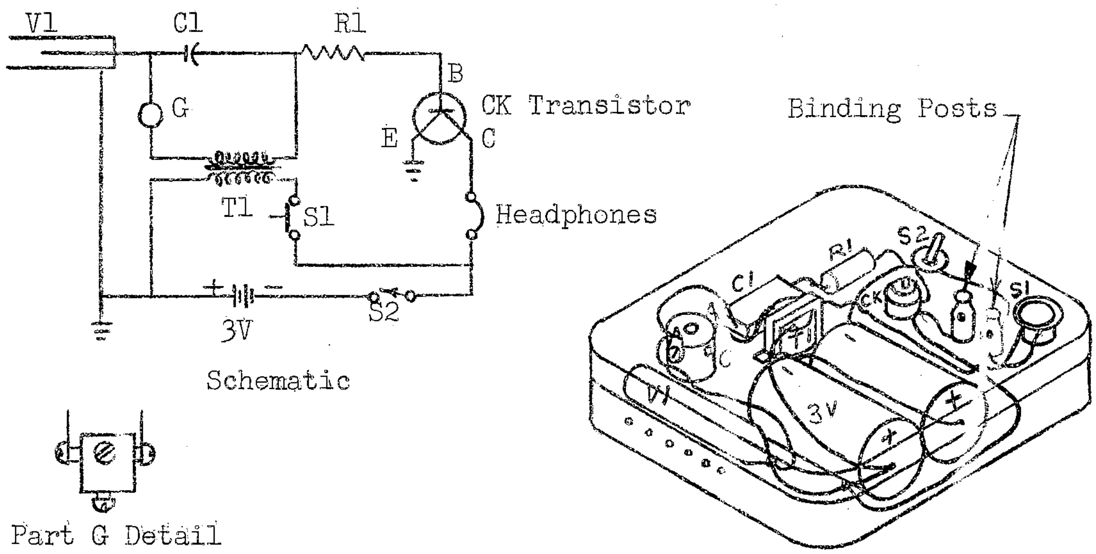


Figure 37

Portable Geiger Counter

<u>Material List</u>

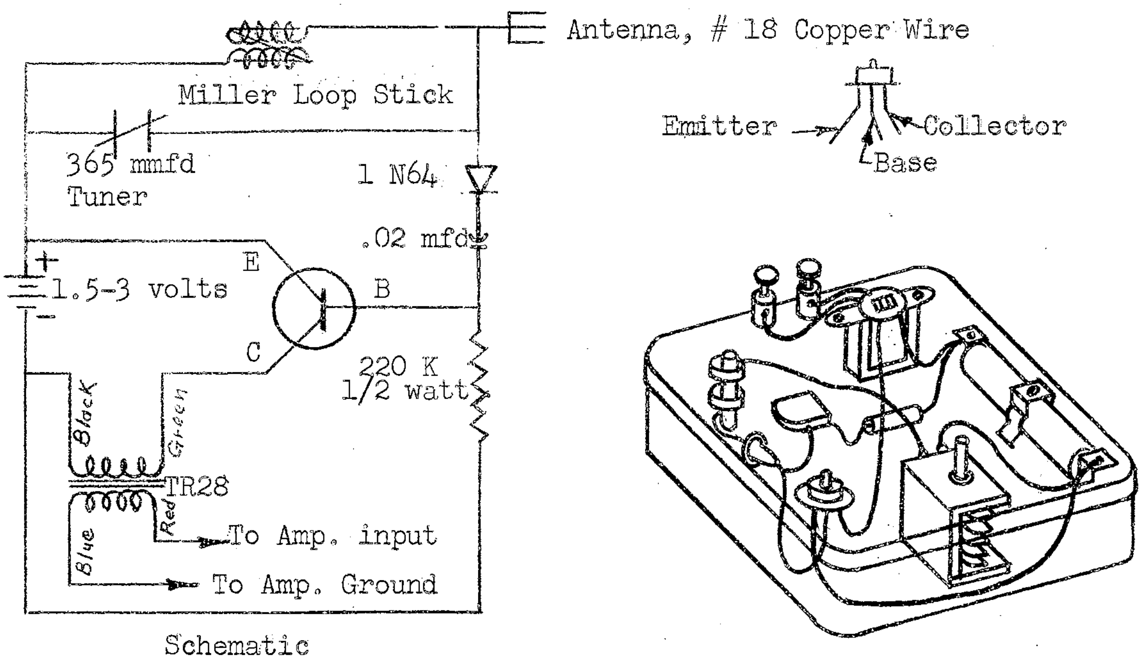
3V	2-size D flashlight batteries
C1	.05 mfd. 1000-volt condenser
R1	1-megohm 1/2-watt resistor
S1	Pushbutton switch (door-bell)
S2	SPST toogle switch
T1	Transformer 4000-ohm pri. 3.5 ohm sec. 3 watt (stancor no. A3328)
V1	300-volt geiger tube (Elec. Prod. no. 30-g)
CK	Transistor no. 2N107 (General Electric)
G	3/4" dia. 3/4" long plastic rod (see detail)

1 pr. headphones (2000 ohms)
2 ea. binding posts (for headphones)

Drill two holes in the plastic rod and insert the two sheet-metal screws with lugs attached as shown. Adjust the gap between the screw points to the thickness of paper. Drill and tap a hole for mounting and install inside plastic box. Drill several small holes in the side of the plastic box where the tube will be mounted. Mount the other components in the box and complete the wiring as shown in the diagram.

To put the counter in operation, turn the toggle switch "on" and push the button switch several times until clicks are heard in the headphones. Repeat this procedure periodically to recharge the counter.

All components for the counter are available from electronics supply stores.



Schematic

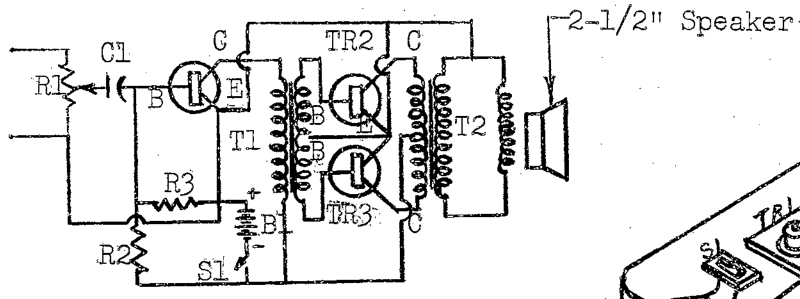
Figure 38

Transistor Radio Receiver

Material List
1 Ferrite antenna coil, 540-1700 kilocycles
(J. W. Miller Co. type 6300
allied radio #60-H-883)
1 Diode, Germanium, G. E. 1N64
1 Transistor, Germanium, G. E. 2N107
1 Capacitor, fixed, 0.02 UF, 30WVDC centralab
type 203 (Allied Radio #11-L-627)
1 Resistor, 220 K, 20%, LRC type BTS-
1/2 (Allied Radio 1MM000)
1 Transformer, transistor, 14.1:1 turns ratio
Thordarson type TR-28 (Allied Radio 63-G-262)
1 Capacitor, Receiver-type variable midget
(Allied Radio 61-H-009)
1 pr. Headphones, 2000 ohms

Mount the components on the underside of a plastic sandwich box lid with the shaft on the variable condenser protruding through the lid. Use small strips of thin sheet metal for battery clips.

Wire the components as shown in the schematic diagram, using rosin core solder, Not acid core. Make sure the correct wires from the transistor (see detail) are hooked up with the correct wire from the transformer and battery, and that the color coded wires from the transformer are correctly wired. In remote areas an antenna may be necessary. The antenna connection as well as the amplifier or headphone connections may be brought out through holes in the box lid or may be connected to binding posts. Use a strip of cellulose tape to secure the lid to the box.



Schematic

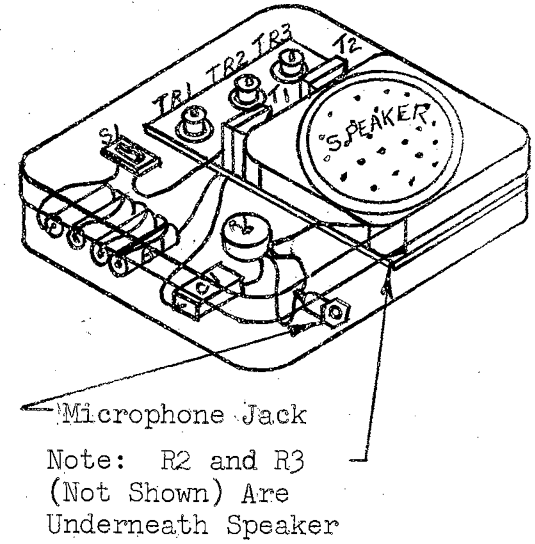


Figure 39

Transistor Amplifier

<u>Material List</u>
B1 = Four mercury cells in series (Mallory RM-R)
C1 = 0.5mfd 200 volt capacitor
R1 = 15,000 ohm subminiature car. pot.
R2 = 22,000 ohm 1/2 watt resistor
R3 = 1,000 ohm 1/2 watt resistor
S1 = S.P.S.T. Slide switch
T1 = Transistor driver transformer 10,000 ohms to 2,000 ohms, center tapped
T2 = Transistor output transformer 500 ohms to 3.2 ohms, center tapped
TR1, TR2, and TR3 = Junction transistor P.N.P.
Miniature speaker 3.2 ohms voice coil
Microphone Jack

Mount the transformers, three transistors, the R2 resistors, and the miniature speaker on a sheet of 1/8" plastic about one-half the size of a large sandwich or other plastic box. Complete the wiring of these components as shown in the wiring diagram, leaving the wires for the other components long enough to allow removal of the cover of the box. Cement this assembly inside the plastic box, leaving room on the other half of the box to mount the mercury cells, etc.

Mount the slide switch and the subminiature carbon pot to the lid of the box and all remaining components in the bottom of the box, with the microphone Jack in one side. Complete the wiring as shown in the diagram and the amplifier is ready for testing.

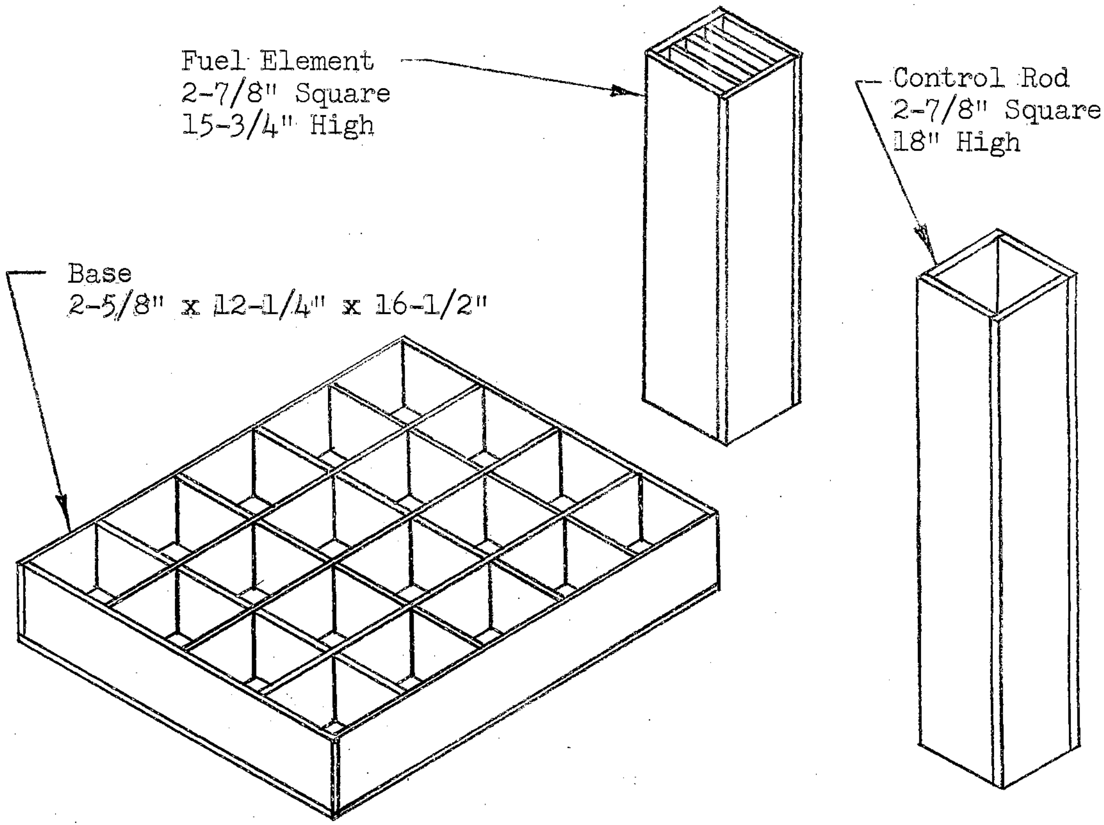


Figure 40

Swimming Pool Reactor

<u>Material List</u>
(All 1/4" Plywood)
8 pcs. 2-5/8" x 18"
40 pcs. 2-5/8" x 15-3/4"
6 pcs. 2-3/8" x 15-3/4"
6 pcs. 2-5/8" x 11-3/4"
3 pcs. 2-5/8" x 16"
2 pcs. 2-5/8" x 16-1/2"
1 pc. 12-1/4" x 16-1/2"

Note that, by alternating the lapped joints in construction of the control rods and fuel elements, all four sides of the box are the same width and the sides, ends, and divider pieces of the base are also the same width.

In constructing the base, slot the three 16" lengths of plywood and four of the 11-3/4" lengths of plywood, allowing these pieces to be assembled in "egg-crate" fashion. Nail the sides, ends, and bottoms to this assembly to complete the base.

Assemble the two control rods by nailing together four of the 18" lengths of plywood. Do the same with the 15-3/4" lengths and insert three equally spaced pieces of the 2-3/8" long plywood in two of the fuel elements.

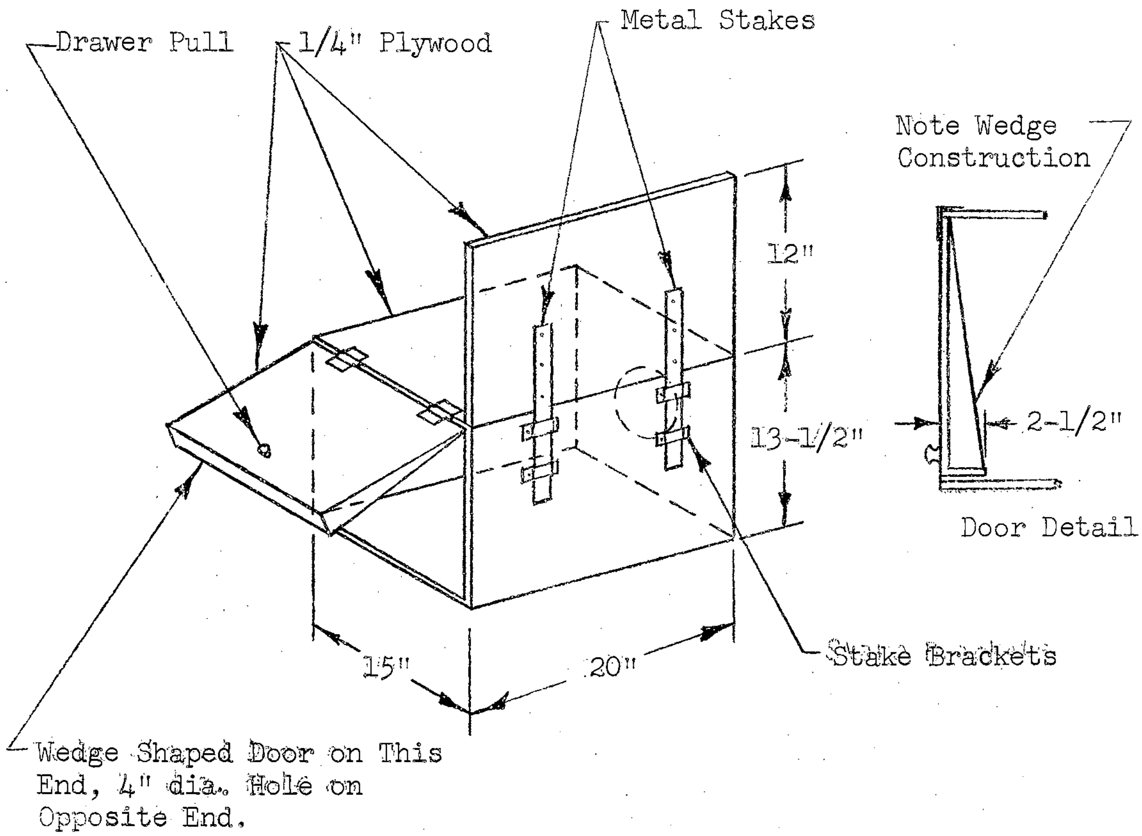


Figure 41

Smoke-Box Demonstration Table

Material List
1 pc. plywood 1/4" x 12 sq. ft.
2 pcs. alum., brass, or steel, 1/8" x 1" x 12" long
4 pcs. sheet metal 26-28 gage 3/4" x 1-1/2" long
2 ea. hinges (loose) 1-1/2" x 1-1/2"
1 ea. drawer pull

Construct a box of 1/4" plywood, open at one end and having a 4" dia. hole in the center of the opposite end. Use conventional box construction nailing the edges together with small wire nails about 1" long. Cut a piece of plywood equal to the length and height of the box for the background panel and attach two 1/8" x 1" x 12" metal stakes to one side of this panel with small wood screws or stove bolts. Form the sheet-metal pieces into "stake pockets" as shown, and, with the background panel in place, locate them on the box and secure with wood screws.

The door of the box is made of 4 pieces of 1/2" plywood and must fit inside the box with the hinges at the top so that when released it will fall in place. Make sure that the bottom piece of the door is slightly angulated in order to swing clear of the edge of the box.

Paint the background to suit for demonstrations used.

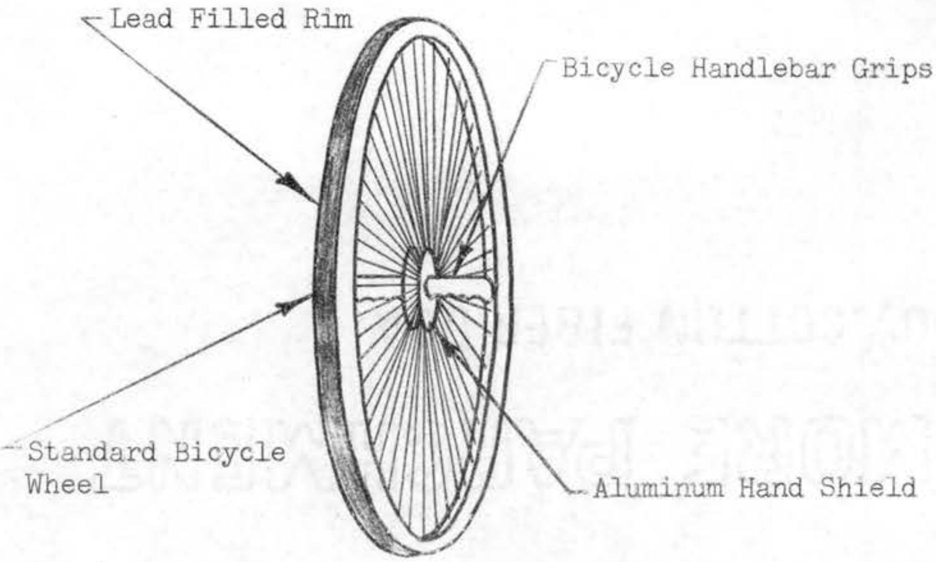


Figure 42

Bike-Wheel Gyroscope

<u>Material List</u>
2 pcs. aluminum 1/16" x 5" dia.
2 pcs. pipe 1/2" x 5" long
2 pcs. brass rod 5/8" dia. x 1" long
1 pr. bicycle handlebar grips
15 lb. lead, sheet or wire (1/8" to 1/4")
1 ea. bicycle wheel

Force a piece of 5/8" dia. brass rod into one end of the two pieces of pipe and secure in place by silver soldering or brazing. Drill a 25/64" hole in the brass plug and tap 3/8"-24 N. F. threads. Drill a 3/8" hole in the center of the 5" dia. aluminum discs and place over the threaded portion of the spindle on each side of the wheel. Screw the two pieces of pipe onto the spindle and force the handlebar grips over the pipe.

The lead must be <u>securely fastened</u> between the flanges of the wheel rim, and the method will depend on the type of lead used. If using sheet lead, cut the sheet into strips about 1/16" wider than the distance between the flanges. Drive these strips in place using a hammer and wood block, and burn the ends of each piece together. One layer of 1/4" lead or two layers of 1/8" lead will suffice. If using lead wire or rod, wind one layer as tightly as possible around the rim and burn the edges together in several spots; then continue with another layer, making certain that all the wires or rods are burned together when finished.

Keep the lead as uniform as possible to minimize balancing, which may be done by drilling or filing at the heavy side or by melting additional lead onto the light side.

As an added precaution against "blowouts," an old tire may be put on the wheel over the lead.

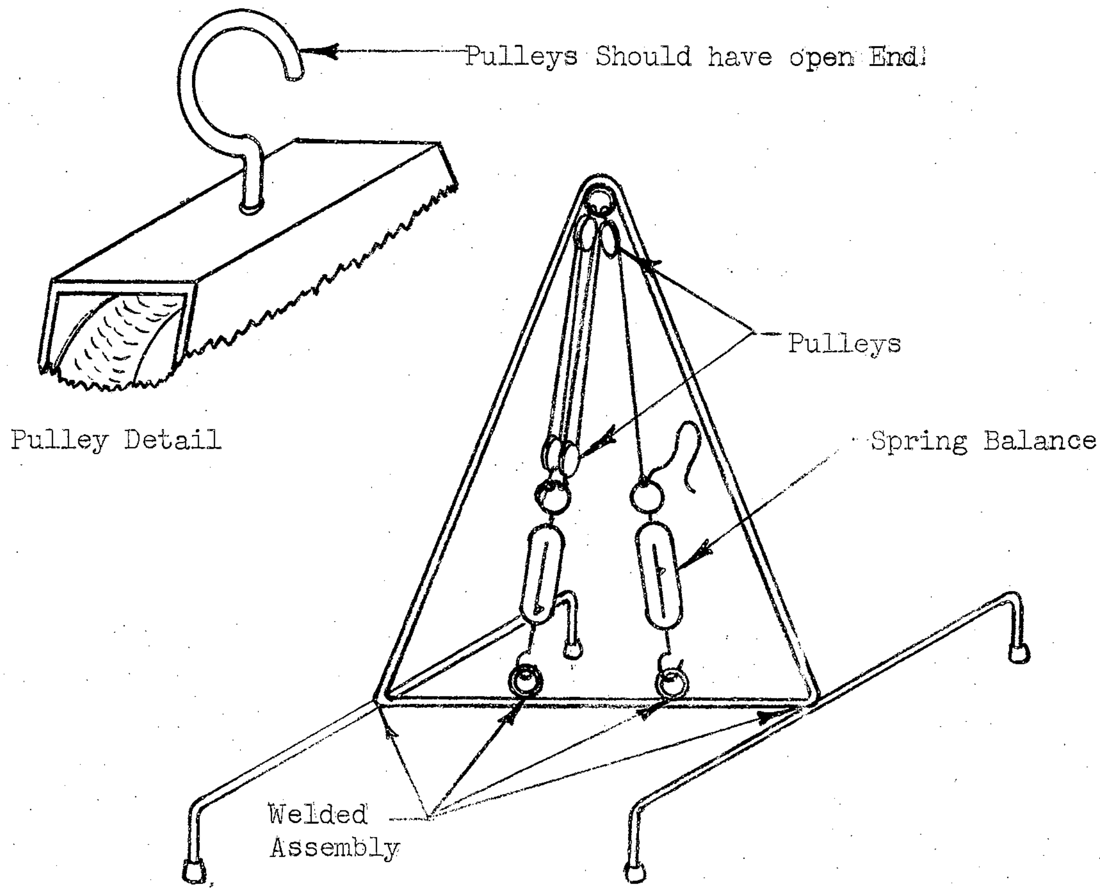


Figure 43

Pulley System

<u>Material</u> <u>List</u>
1 pc. H. R. S. round rod, 3/8" x 60"
2 pcs. H. R. S. round rod, 3/8" x 16"
3 pcs. H. R. S. round rod, 1/4" x 6"
4 single pulleys, 1/4" x 3/4" dia. sheaves
4 rubber crutch tips, #15
2 spring balances
6 ft. venetian blind cord

Bend the long rod into an Isosceles triangle with a 12" base.

Bend 2" legs down on each end of the 16" pieces.

Bend the 1/4" rods into circles for the pulley rings, and weld the legs, rings, and triangle together as shown.

Clean the metal and apply a coat of metal primer. Paint to suit.

Assemble by threading the cord through the pulleys and mounting the spring balances and pulleys on the rings.

Note: Several combinations may be obtained with the apparatus as shown. Added pulleys, rings, and spring balances will give added combinations.

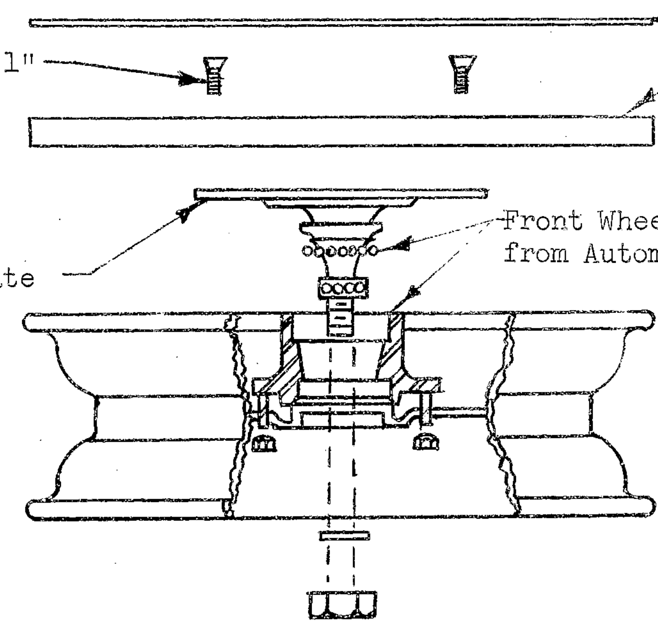


Figure 44

Rotating Platform

<u>Material List</u>
4 ea. stove bolts, 1/4-20 N. C. x 1" long
1 pc. plywood, 3/4" x 16" dia.
1 pc. rubber mat, 16" dia.
1 pc. boiler plate, 1/4" x 6" x 6"
1 ea. automobile front wheel assembly('49-'51 Ford)

Disassemble the spindle bearing assembly and clean all parts. Remove the projections containing the kingpin holes on the rear of the spindle and machine the surface smooth and perpendicular to the axis of the spindle. Weld the 1/4" plate to this surface, being careful not to warp the plate during welding. Drill and tap a hole in each corner of the 1/4" plate (#8 drill, 1/4-20 tap), and drill and countersink four 1/4" holes in the 3/4" plywood disc to match the tapped holes in the 1/4" plate. Assemble the two pieces with the 1/4-20 N. C. bolts.

Remove the drum from the spindle hub. This may be done in a large arbor press or with a heavy machine hammer or sledge.

Reassemble the spindle and hub assembly, grease the bearings, and insert this assembly into the "wrong" (outside) side of the wheel. This method of assembly allows ample clearance between the wheel and plywood.

Tighten the lug-bolt nuts, securing the wheel to the spindle assembly hub. Check the bearing assembly for "wobble". With bearing assembly properly adjusted, insert the cotter pin in place.

Note: The wheel and spindle assemblies of other than the one mentioned above may be used, but due to variation of design, the steps outlined in the above instructions may vary somewhat.

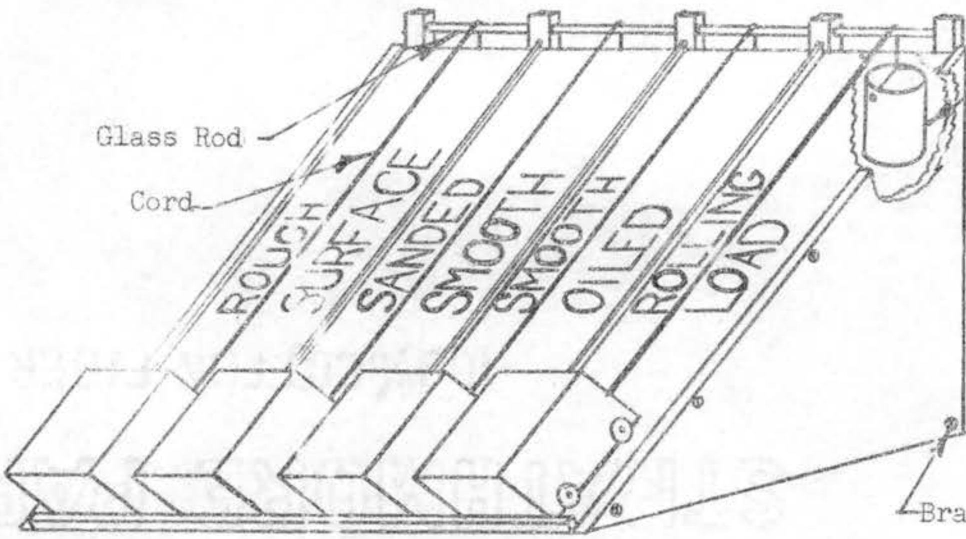


Figure 45

Friction Carts

Material List
4 pcs. hardwood, 2" x 3" x 4"
5 pcs. hardwood, 1/2" x 1" x 2-1/4"
1 pc. hardwood, 1/2" x 1/2" 16"
3 pcs. hardwood, 1/4" x 1/2" x 17"
1 pc. plywood, 3/4" x 12-1/4" x 12-1/4"
1 pc. plywood, 3/4" x 16" x 17"
1 pc. glass rod, 1/4" dia. x 15"
4 pcs. nylon cord, 20 lb. test, 18" long
4 small wheels, good toy wheels will do
4 plastic pill containers, 2" dia. x 3" deep
4 cup hooks
10 wood screws, #9 x 1-1/2" F. H. B.
8 wood screws, #9 x 1" F. H. B.
2 lbs. lead shot

Saw the 12-1/4" plywood diagonally to obtain the two end pieces, and bevel the ends of the other piece at a 45° angle to fit the end pieces. Saw 3 lengthwise grooves, 1/4" x 1/4", equally spaced, in the large piece. Make the other pieces called for.

Mount the splines, bumper, and brace as shown. The glass rod standards are drilled before mounting and mounted even with the splines and ends. The end standards are not drilled clear through in order to retain the glass rod, which is inserted before installing one end. Mount in such a way that the glass rod is approximately 1" above the slide board.

The carts may be made to any desired shape, so long as uniformity is maintained. Mount the wheels on one cart with small round head nails and screw the cup hooks into the front center of each cart.

Attach the cord and shot cups as shown. Finish as desired.

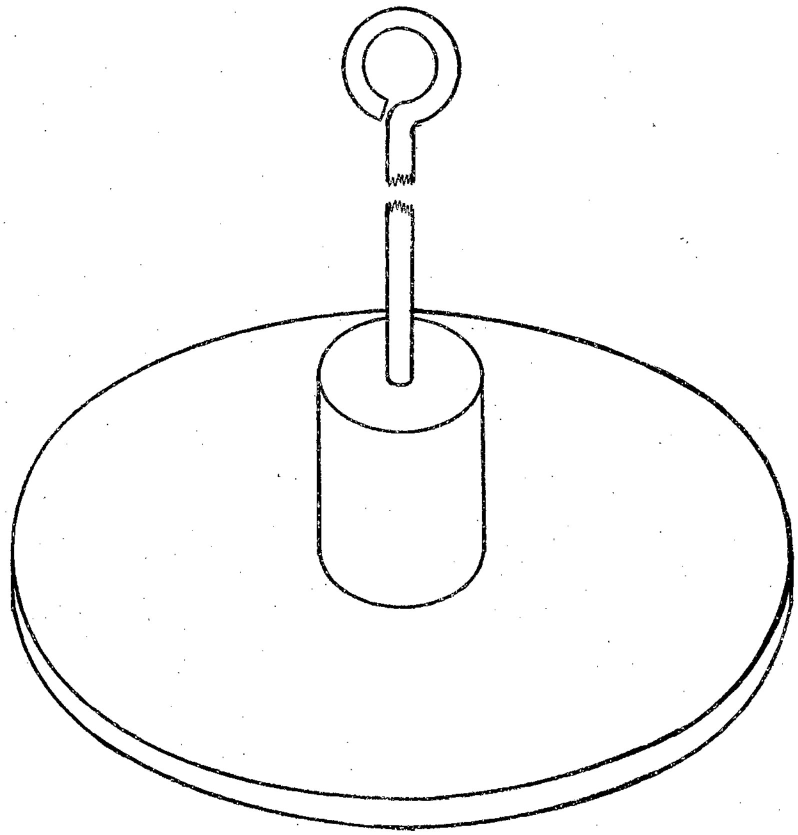


Figure 46

Vacuum

Material List
1 pc. C. R. S. round rod, 1" x 1"
1 pc. C. R. S. round rod, 3/16" x 10"
1 pc. steel plate, 1/4" x 5" dia.

Cut out the 5" circle on a metal cutting band saw, and smooth the edges, being careful to maintain the circle. Lap and polish one face perfectly flat.

Machine the ends flat on the 1" rod. Lap and polish one end. The mating surfaces must be perfectly flat and smooth. Drill a hole (#25 drill) 3/4" into the center of the other end and thread with a 10-24 tap.

Thread one end of the 3/16" rod 1/2", and bend an eye into the other end as shown.

A light coat of oil will retard rust and fill any pores in the metal to assure that no air will get between the pieces.

When the polished end of the rod is set in the center of the polished face of the plate, all air will be driven from between the two, and the rod will lift the plate by virtue of the vacuum formed.

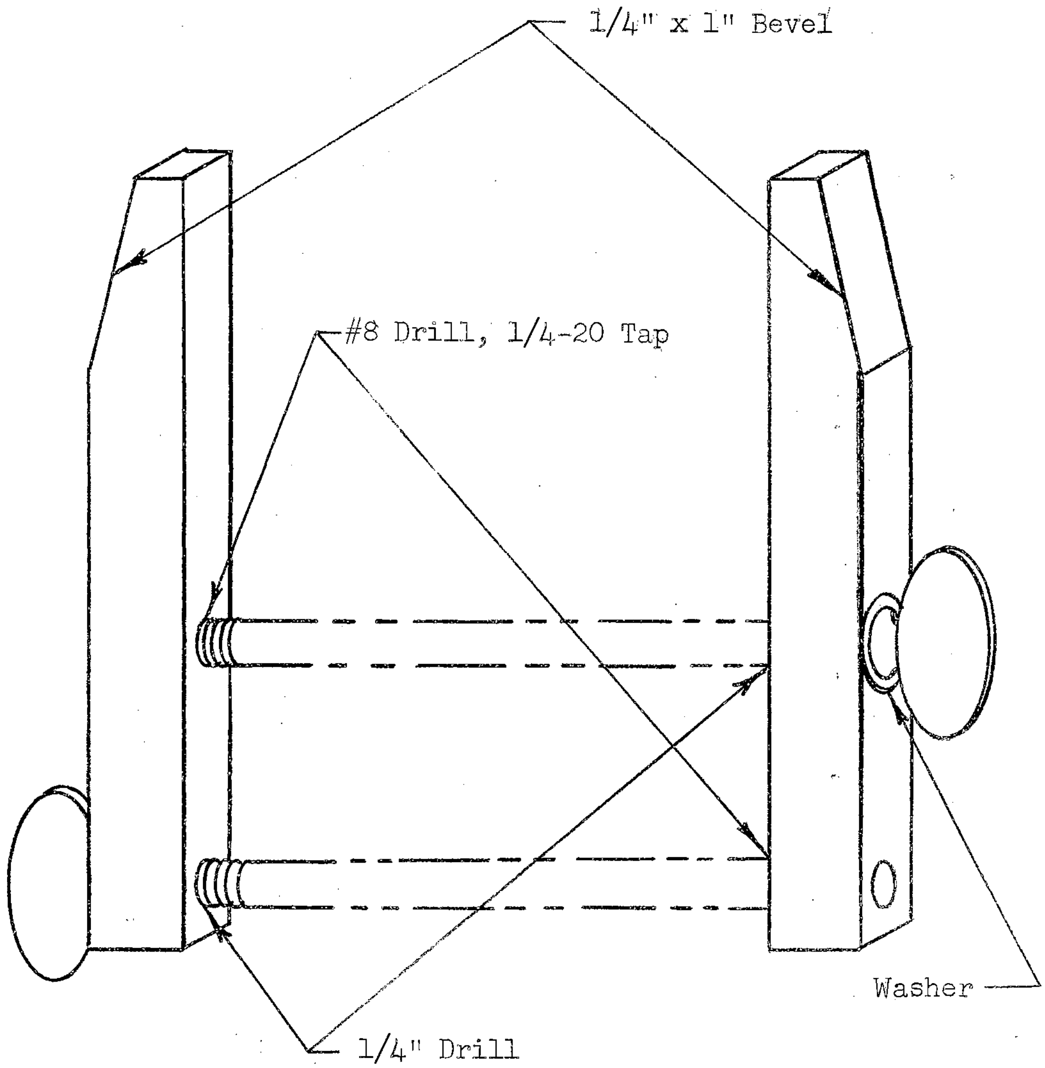


Figure 47

Power Transmission: Parallel Screw Clamp

<u>Material List</u>
2 pcs. tool steel, 1/2" x 1/2" x 4"
2 hardened steel washers, 1/4"
2 thumb screws, with shoulder, 1/4-20 N. C. x 4"

Bevel the ends of the clamp jaws and lay out the holes. Locate the holes 1/4" and 1-1/2" from the butt end of the jaws on the center line. Drill and tap the holes as indicated. One hole in each jaw is a clear hole and the other is a threaded hole.

Polish as desired and assemble as shown. A light coat of oil will retard rust and facilitate the moving parts.

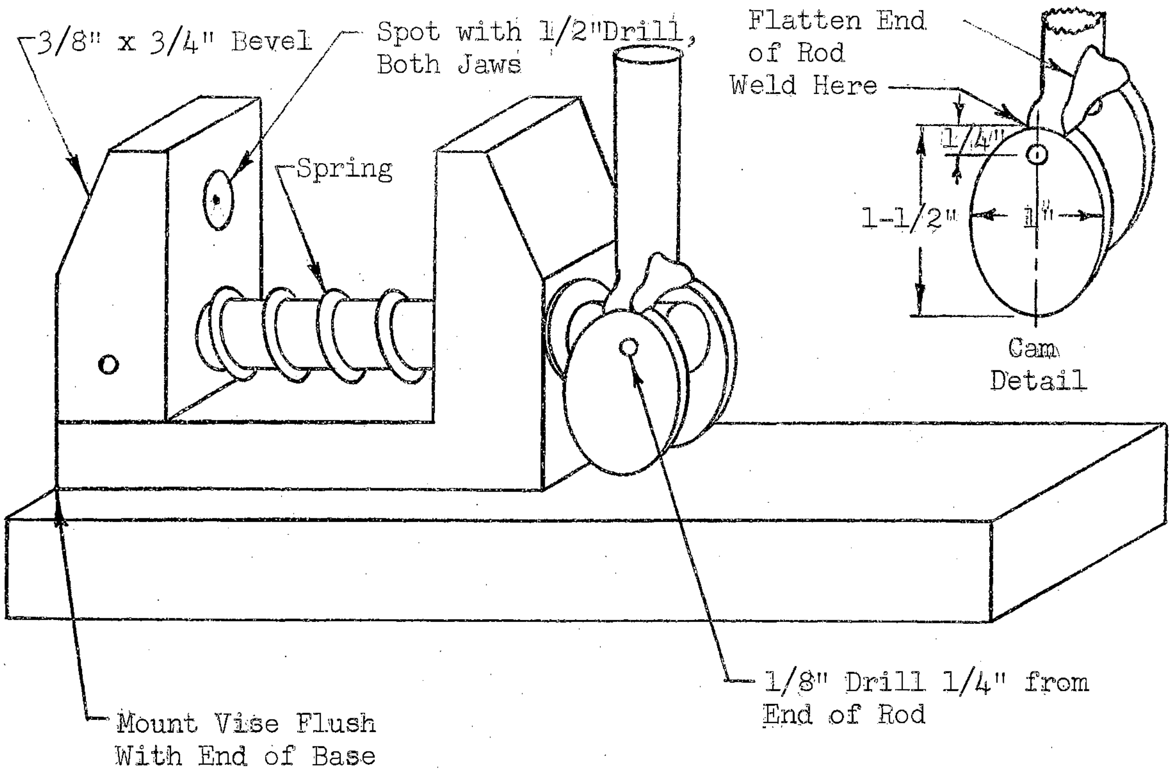


Figure 48

Cam Action Vise (Nut Cracker)

Material List

1 pc. hard annealed aluminum, 1" x 2-1/2" x 3-1/4"
1 pc. steel shafting, 1/2" dia. x 4"
2 pcs. C. R. S. round rod, 1/8" x 1"
1 compression spring, 16 ga., 2" max., 1/2" min.
1 hardened steel washer, 1/2" I. D., 1" O. D.
2 pcs. C. R. S. plate, 1/8" x 1" x 1-1/2"
1 pc. C. R. S. round rod, 1/2" x 3"
1 pc. hardwood, 1" x 3" x 7"
2 machine screws, 1/4-20 N. C. x 1-1/4" F. H.

Lay out the body of the vise. The fixed jaw is 3/4" wide and the bottom is 1/2" wide. Saw out on a metal band saw. Use the pieces sawed out to make the movable jaw (3/4" wide). Smooth the inside faces of the pieces and fit the movable jaw against the fixed jaw and drill the 1/2" hole through both pieces at the same time. Locate the hole 1" up from the bottom and on the center line. The hole must be square with the piece in order for the jaws to stay aligned.

Insert the rod into the movable jaw and drill a 1/8" hole clear through for the retaining pin. Place spring over the shaft and slide the movable jaw into position and clamp in place. Drill a 1/8" hole for the cam retaining pin as shown. See cam lever detail for construction of cam. The piece may be polished on a buffer.

Assemble the project as illustrated.

Mount the piece on the base with machine screws (#8 drill, 1/4-20 tap).

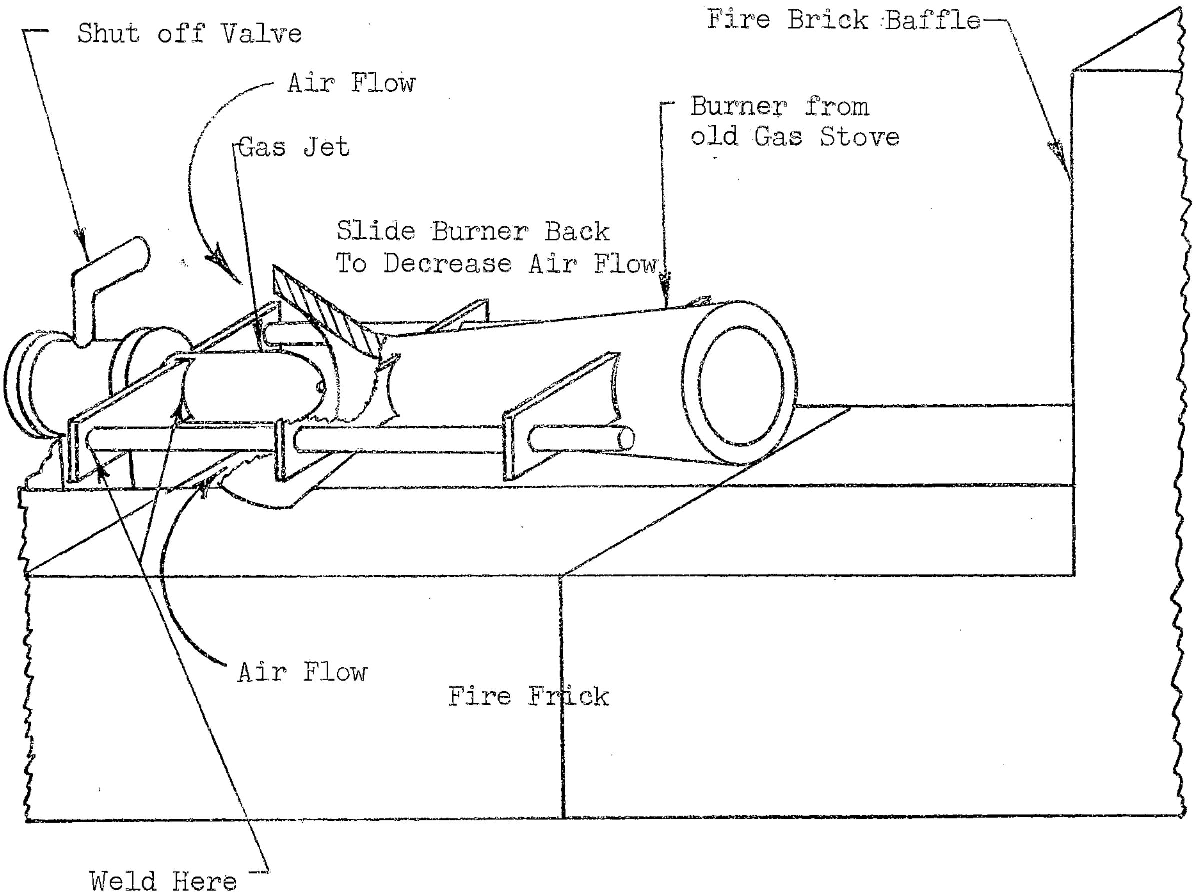


Figure 49

Ventura Burner: Gas-Air Mixture

Material List
1 gas cook stove burner
1 pc. 1/2" pipe, 2" long
1 shut off valve, 1/2"
2 pcs. C. R. S. round rod, 1/4" x 8"
6 pcs. band iron, 1/8" x 1/2" x 2"
1 pc. band iron, 1/8" x 1" x 10"
fire brick

Saw off the front and back parts of the burner, leaving a piece about 6" long.

Make the jet by closing one end of the pipe. This may be done by sawing out segments of the end, bending the ends together, and welding. Drill a 3/32" hole into the end for gas outlet. Round end on a grinder.

Braze the supporting pieces onto the burner and drill 17/64" holes for the rods to slide through. Weld the rod retainer to the jet near the valve, and assemble as shown.

This whole assembly may be mounted on a piece of transite for safety.

A burner such as this will develop a temperature of approximately 1500° inside a small melting furnace.

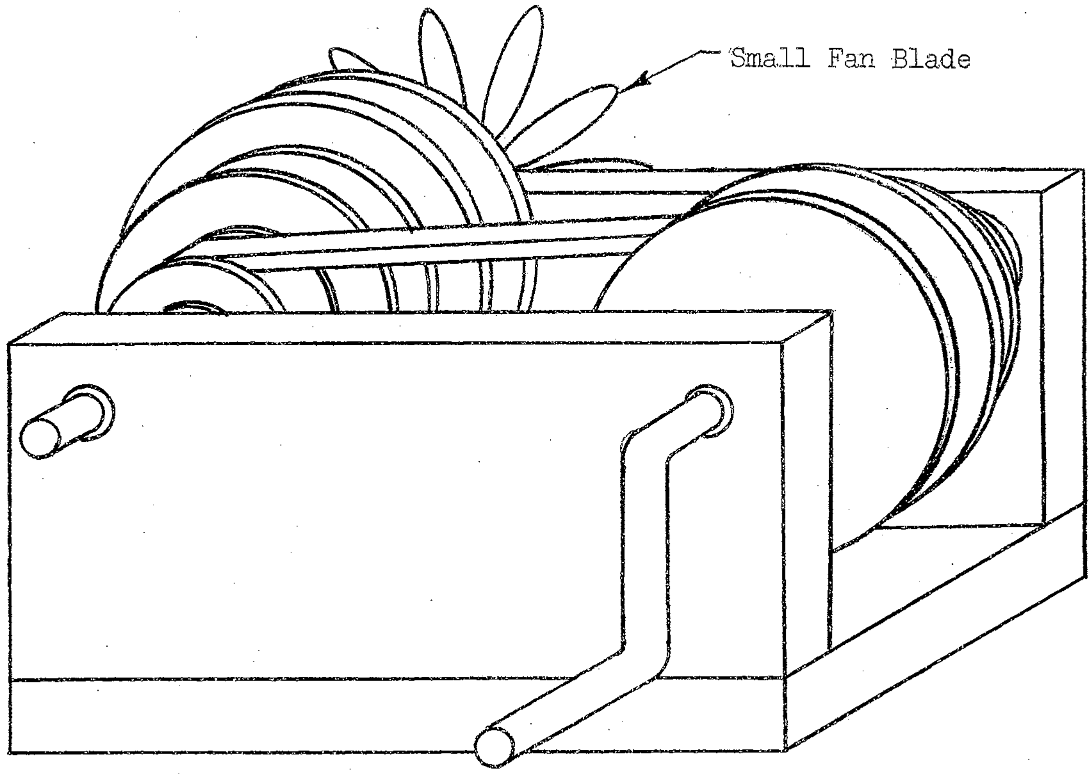


Figure 50

Step Cone Pulleys: Belt Drive, Speed Ratio

Material List
2 step cone "v" pulleys, 4 section, 6" max., 1-1/2" min.
1 pc. C. R. S. round rod, 1/2" x 14"
1 pc. C. R. S. round rod, 1/2" x 8"
1 v-belt 1/2" x 23"
1 pc. hardwood, 1" x 6" 14"
2 pcs. plywood, 3/4" x 5" x 14"
4 bronze bushings, 1/2" I. D. x 3/4" long
8 wood screws, #9 x 2" F. H. B.

Work the boards to size and mount one upright onto the base. Clamp the other upright piece to the inside face of the one already mounted and drill the bushing holes through both boards at the same time. Locate the holes 1" below the top edge of the board and 12" apart. The bushings should be a drive fit.

The handle is offset 3" from the shaft axis with a 4" hand grip.

Mount the other upright and slide the shafts through the bushings with the pulleys and belt between the uprights. Tighten the set screws in the pulleys. The pulleys should point in opposite directions.

In order to make the speed changes more visible, mount a small fan blade on the end of the driven shaft.

Washers or shims may be used to align the pulleys if necessary.

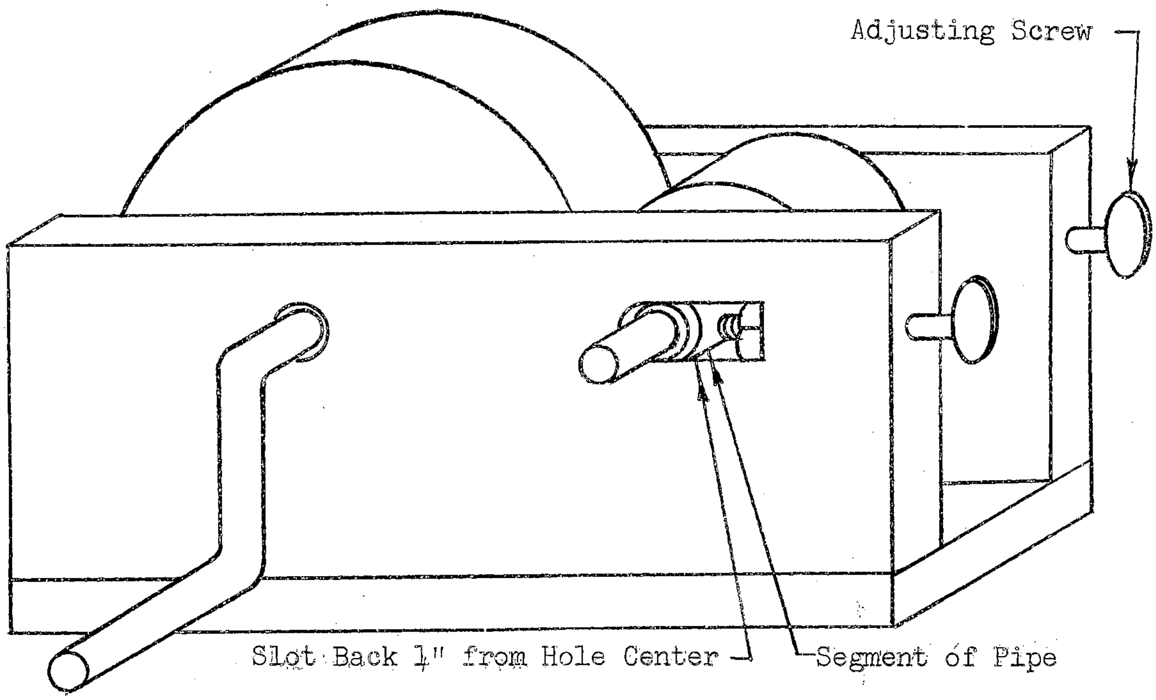


Figure 51

Friction Wheels: Power Transmission

<u>Material List</u>
1 friction wheel, 1" x 6"
1 friction wheel, 1" x 2"
4 bronze bushings, 1/2" I. D. x 3/4" long
1 pc. hardwood, 1" x 6" x 9"
2 pcs. plywood, 3/4" x 5" x 9"
1 pc. C. R. S. round rod, 1/2" x 6"
1 pc. C. R. S. round rod, 1/2" x 13"
2 thumb screws, with square nuts,
  1/4-20 N. C. x 2" long
6 wood screws, #10 x 2" F. H. B.
2 segements 1/2" pipe, 1/2" x 3/4"
4 washers, 1/2"

The gears may be easily made in a machine shop.

Work the boards to size and bore the bushing holes through both pieces at the same time. Locate the holes 1" from the top edge and 3-3/4" apart. The bushings should be a drive fit. Cut the adjustment slot and drill a 17/64" hole in from the ends of the boards for the thumb screws.

Assemble the wood pieces and apply a protective finish.

Place the gears between the uprights with one washer on each side of the gear and slide the shafts through. The handle is offset 3" and has a 4" hand grip.

The machine may be given some task to perform, such as turning a fan or another machine.

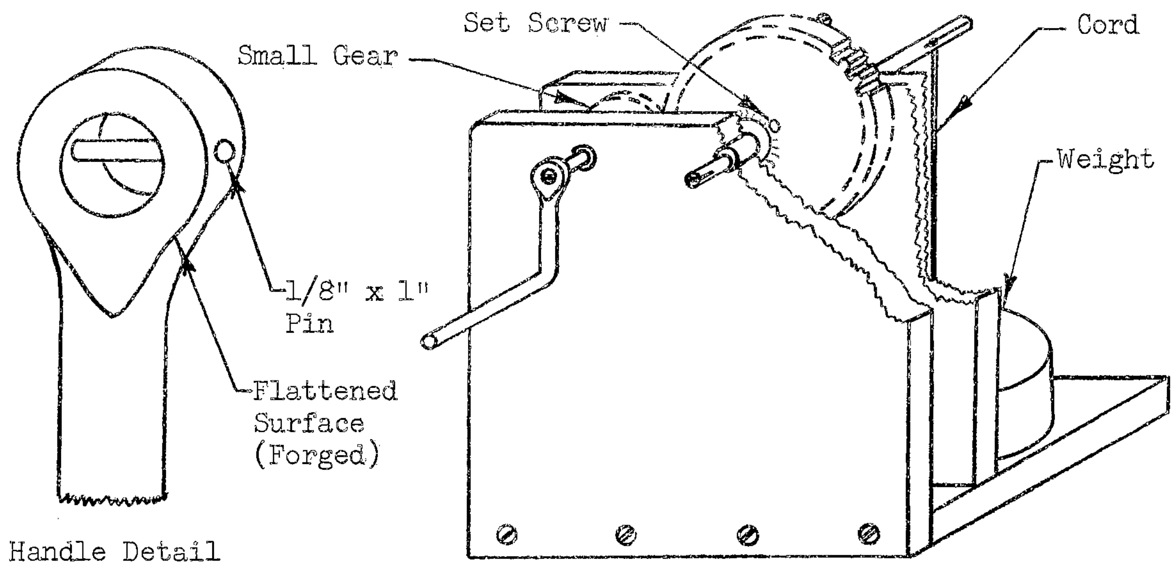


Figure 52

Power Transmission: Gear Ratio

Material List
1 spur gear, 6" dia., to fit 1/2" shaft
1 pinion gear, 2" dia., to fit 1/2" shaft
2 pcs. C. R. S. round rod, 1/2" x 9"
1 pc. C. R. S. round rod, 1/2" x 8"
1 pc. C. R. S. round rod, 1/8" x 1"
4 brz. bushings, 1/2" I. D. x 3/4" long
1 pc. hardwood, 1" x 8" x 12"
1 pc. plywood, 3/4" x 11" x 12"
1 pc. plywood, 3/4" x 12" x 12"
8 wood screws, #9 x 1-1/2" F. H. B.
2 allen set screws, #10-24 x 1/4"
1 pc. nylon cord, 30 lb. test, 12" long
1 weight, 5 to 10 lb.

Work the boards to size. The top corners of the plywood pieces may be rounded for appearance. Mount the larger plywood piece to the edge of the base. Clamp the smaller plywood piece to the inside face of the piece already mounted and bore the bushing holes through both pieces at the same time. Locate the holes 1" from the top and the proper distance apart so the gears will mesh. The bushings should be a drive fit.

The shafts should have a saw cut 1/16" wide x 3" long at one end, and 1/8" wide x 1/2" long at the other end. For handle construction see detail. Mount the smaller plywood piece and apply a protective finish.

Slide the shafts through, placing the gear and pinion between the plywood pieces. Washers may be used to align the gears if necessary. The set screw holes are made with a #25 drill and a #10-24 tap.

Note: the speed and ease with which the weight is lifted will depend on which shaft is used to drive the unit.

Uranium-Graphite Reactor Model

See Figure 53

Material List

1 pc. pine, 1-3/4" x 9-1/2" x 12"	1 pc. plywood, 1/4" x 11-3/4" x 12"
1 pc. pine, 1-3/4" x 12" x 11-3/4"	2 pcs. plywood, 1/4" x 6-1/2" x 11"
1 pc. pine, 1-3/4" x 9-1/2" x 11-3/4"	2 pcs. plywood, 1/4" x 9" x 11"
1 pc. pine, 1-3/4" x 2" x 12"	1 pc. plywood, 1/4" x 6-1/2" x 9"
1 pc. plywood, 1/4" x 9-1/2" x 11-3/4"	1 pc. plywood, 1/2" x 16" x 20"
1 pc. pine, 3/4" x 2" x 11"	1 pc. plywood, 1/2" x 4" x 48"

Miscellaneous pieces of 1/4" and 1/2" plywood, wire, tin, and 1/8" dowel.

The "Graphite Pile" model is composed of three major parts: the shielding, the floors, and the core.

The shielding is made from three pieces of 1-3/4" thick white pine and two pieces of 1/4" plywood. These pieces are to be assembled such that the 1-3/4" pine comprises the bottom and two adjacent sides of an open-top box, with the 1/4" plywood forming the remaining two sides. Outside dimensions of the box should be 9-1/2" x 12" x 13-1/2" high. The cutaway portion of the shielding should be cut before assembly to facilitate sawing. After assembly add the two pieces simulating the base and column of the elevator. The base piece should be 1-3/4" x 2" x 12" and the column 3/4" x 2" x 11".

The first floor is a piece of 1/2" plywood 16" wide and 20" long and the second floor may be made of 1/2" plywood pieces (3) 4" wide which are fastened on 3 sides of the shielding and cut to match the cutaway in the shielding (see sketch).

The core is a simple six-sided box approximately 6-1/2" x 9" x 11" high and is scored on two adjacent sides and top with a saw, or other suitable tool both horizontally and vertically, approximately 1-1/4" on centers. Drill 1/8" holes for the simulated control rods and uranium slugs and glue short lengths of 1/8" dowel in a few holes to simulate these rods and slugs.

At this stage it is advisable to paint the finished parts and set them aside to dry while working on the "coffin", elevator, and other small parts. Paint the shielding a concrete color, and while the paint is still tacky, carefully apply sand or fine bird gravel to the edges of the cutaway to simulate broken concrete. Paint the core flat black to simulate the graphite blocks.

Make the elevator end and bottom of 1/4" thick wood or masonite and glue cardboard strips to these to form the sides of the elevator. Make the pulley brackets out of thin metal scraps (tin can stock, etc.) and the pulleys out of washers or large dress snaps with thread simulating the cables. The coffin may be made of small blocks of wood set on a 1/8" dowel frame for the stand.

When the parts which were previously painted have dried, secure the core in the approximate center of the first floor and locate the shielding over the core with an air gap of approximately 1/2" between the core and the shielding and turned so that the scored lines of the core are showing through the cutaway portion of the shielding.

Paint the other small parts to suit and attach them to the model as shown in the sketch. Small plastic figures may be obtained from the dime store, and for proper scale should be approximately 2" high.

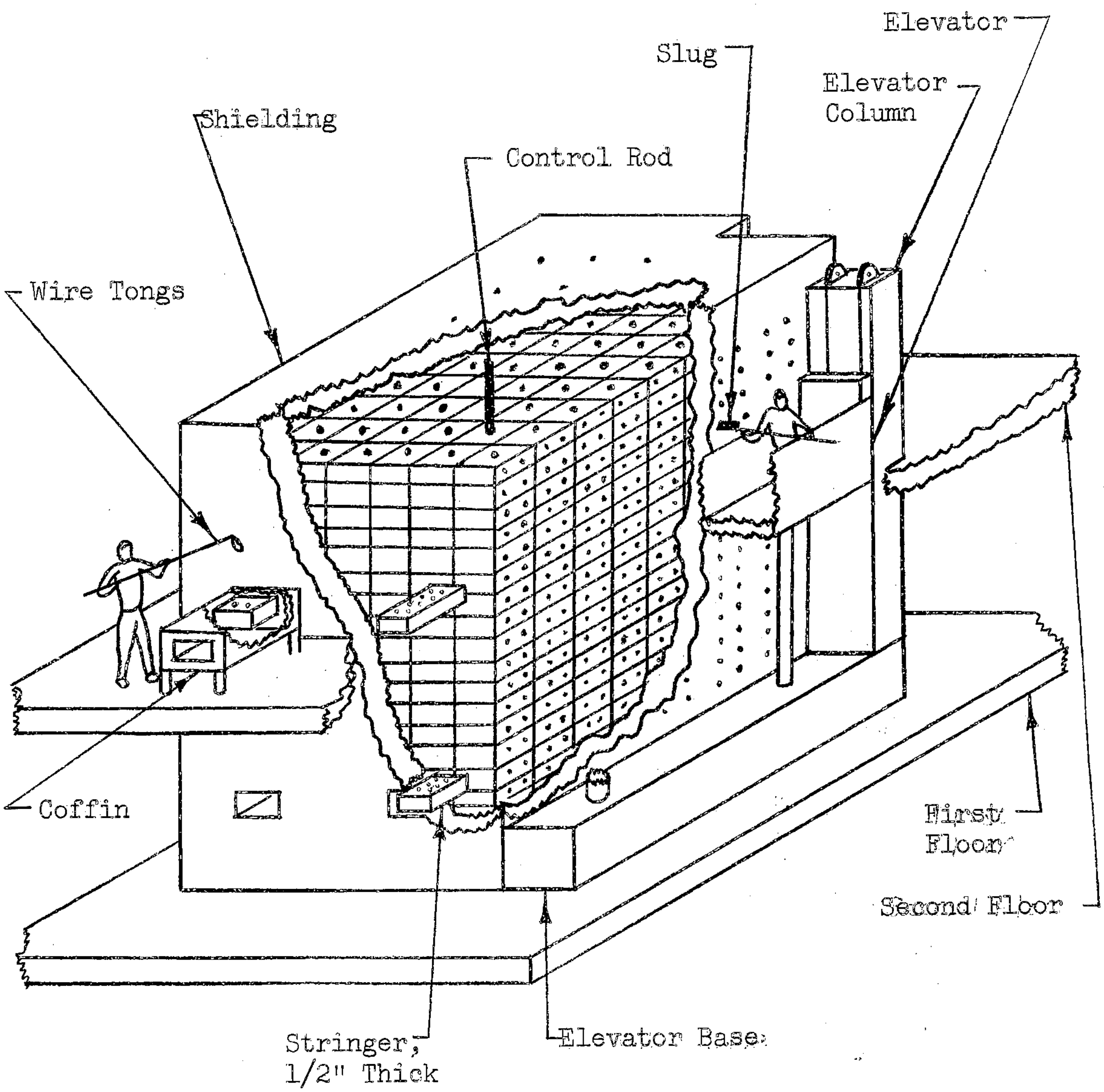


Figure 53

Uranium-Graphite Reactor Model

See Preceeding Page
for Instructions

CHAPTER IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This study was made in an attempt to compile a collection of scientific projects which may be built in the school shop. The writer feels that the use of the project is the logical method of correlating and integrating industrial arts and science, and that each field may make valuable contributions to the other. The objectives of General Education, Industrial Arts, and Science are considered in making a study of this type.

The basic assumption in making this study was that the project is the common meeting zone of industrial arts and science, and that through the design and construction in the industrial arts shop of a project which demonstrates some principle of science, much will have been gained toward meeting the goals of both areas of study.

The collection of projects presented in the study are projects which the author feels will challenge students at all levels in the shop classes. Many of the projects will almost certainly require some research on the part of the student before construction begins. The method of presentation of these projects to the students will greatly determine their value as instructional materials. The instructor should encourage the students to work from these basic designs into something which is their own creation. Many variations and applications are possible in the use of these projects without changing the function of the completed equipment.

The worth of some of these projects as teaching aids has already been proved in the Traveling Science Demonstration Lectures. (17, page 92) The writer feels that these scientific projects may also be very valuable as projects which will motivate the students in the public schools to learn more about science and industrial arts.

Conclusions. The writer feels that the facts revealed in this study indicate a definite workable method of correlating and integrating industrial arts and science in the area of the project method of teaching, and that the scientific project, if presented properly, may greatly enhance the student's appreciation of scientific principles and at the same time act as a vehicle for teaching him the industrial arts.

The facts revealed seem to indicate a definite changing trend in education, with greater emphasis on Science. One form of this trend is the greater emphasis being placed on the project method of teaching. With the emphasis shifting more and more to Science, the place of industrial arts teachers to incorporate scientific instruction into their shop courses. One logical solution to this problem is the introduction of the scientific project into the school shop program.

Recommendations. The writer assumes that the plan presented in this study is a workable one, and facts seem to indicate such, but exhaustive trial and evaluation needs to be made and any necessary changes or recommendations executed. A study also needs to be made of the financing of such projects as are included in this study.

The writer recommends studies of this nature into other phases of Science. Contributions may be made in the construction of laboratory apparatus, projects in other fields of science, models of rockets and other space equipment, and in trial and evaluation of these studies.

Recommendation is also made for a study of applied science in the school shop in terms of equipment, materials, and techniques used in the construction of projects. One such study has been made in Los Angeles, California. This study is general in nature, however, and may be elaborated upon considerably. (52, page 41)

The writer wishes to recommend that studies of this nature also be made into fields other than science, especially trigonometry, geometry, and related subjects.

A SELECTED BIBLIOGRAPHY

A. BOOKS

1. Durbin, Frank M., Introduction to Physics, New York: Prentice-Hall, 1954, 756 pages.

2. Ericson, E. E., Teaching the Industrial Arts, Peoria: Bennet Co., 1946, 377 pages.

3. Lee, Gordon C., Education in Modern America, New York: Henry Holt and Company, Inc., 1953, 540 pages.

4. Leese, Joseph, Kenneth Frasure, and Mauritz Johnson, Jr., The Teacher in Curriculum Making, New York: Harper and Brothers, 1961, 488 pages.

5. Markham, E. C., and S. E. Smith, General Chemistry, Cambridge: Houghton Miflin Co., 1954, 593 pages.

6. Silvius, G. H., and H. E. Curry, Teaching Multiple Activities in Industrial Education, Bloomington: McKnight and McKnight, 1956, 484 pages.

7. Varnum, William H., Industrial Arts Design, Peoria: Chas. A. Bennet Co., Inc., 1948, 244 pages.

8. Wilbur, G. O., Industrial Arts in General Education, Scranton: International Textbooks Co., 1954, 401 pages.

9. Wilson, Mitchell, American Science and Invention, New York: Simon and Schuster, 1954, 425 pages.

B. MANUALS

10. Oak Ridge Institute of Nuclear Studies, Science Demonstration Equipment, U. R. D.- T. S. T. 1958-59, 27 pages.

11. Thomas Alva Edison Foundation, Seventh Institute Proceedings, Strengthening Science Education for Youth and Industry, Albany, New York University Press, 1956, 162 pages.

12. United Nations Educational, Scientific, and Culural Organization, Construction of Laboratory Apparatus for Schools, Series II, New York, Columbia University Press, 1955, 88 pages.

C. PERIODICALS

13. Bultman, J. D., and Leonard, J. M. "Laboratory Mixer" The Journal of Chemical Education, 33:87. February 1956.

14. Chemical and Engineering News Reviews and Previews. "Changing Pattern Showed in Science Education," Chemical and Engineering News, 38:62-3. January 4, 1960.

15. Chemical and Engineering News Reviews and Previews. "Education Crash Program in Works," Chemical and Engineering News, 35:19-20. December 16, 1957.

16. Chemical and Engineering News Reviews and Previews. "Education Strikes it Rich," Chemical and Engineering News, 36:23-25.

17. Chemical and Engineering News Reviews and Previews. "Science Goes on the Road; Oak Ridge Institute of Nuclear Studies Trains Teachers for Traveling Service Demonstration Lectures," Chemical and Engineering News, 36:92-3, February 17, 1958.

18. Chesick, John P., and Patterson, Andrew Jr. "Potentiometric Measurements of Equilibria," Journal of Chemical Education, 36:497, October 1959.

19. Coutant, M. F. "The Science Congress: Training Ground for Future Scientists," High School Journal, 39:278-81, February 1956.

20. Edwards, G. I. "Motivation in General Science," High Points, 38:53-59, September 1956

21. Gladieux, R. J. "An Industry-Sponsored In-Service Training Program for High School Science Teachers," Journal of Chemical Education, 33:460-1, September 1956.

22. Harlow, J. G. "Science Programs and the Development of Scientists," Teachers College Record, 60:306-17, March 1959.

23. Hodges, E. W. "The Role of the Secondary School in Science Training," Journal of Chemical Education, 33:404-5, August 1956.

24. Jacobson, W. J. "Science for all Children and Youth," Teachers College Record, 60:318-26, March 1959.

25. Johnson, P. G. "Motivating Students and Selecting Projects," High School Journal, 39:286-90, February 1956.

26. Jones, E. K. "Science Fair Evokes Keen Interest," School Activities, 27:246-7, April 1956.

27. Kenyon, R. G. "There's Science in Children's Toys," Instructor, 65:63+, March 1956.

28. Kraus, J. H. "The National Science Fair: Purposes and Program," High School Journal, 39:265-269, February 1956.

29. Kurland, B. "Are we on the Right Road?" Education Digest, 22:40-41. May 1957.

30. Large, D. E. "Activities of the Oak Ridge Institute of Nuclear Studies," High School Journal, 39:261-64, February 1956.

31. Lefler, R. W. "Educational Implications of Science Fairs," High School Journal, 39:306-9, February 1956.

32. Lewin, S. Z. "Chemical Instrumentation," Journal of Chemical Education, 36:A67, February 1959.

33. Lewin, S.Z. "Chemical Instrumentation," Journal of Chemical Education, 36:A668, November 1959.

34. Lewis, D. C., and M. E. Copeland, "Our First Science Fair: Problems Pitfalls, and Satisfactions," High School Journal, 39:275-277+

35. Long, R. H. "Philosophical Roots of General Education Science," Junior College Journal, 27:248-50, January, 1957.

36. McGrath, E. J. "Sputnik and American Education," Teachers College Record, 59:379-95, April 1958.

37. Micheels, W. J. "Industrial Arts Teacher Education in 1970," Industrial Arts and Vocational Education, 47:29-32, February 1958.

38. Mikhail, M. K. "Contributing of Science to Selected Problem Areas Proposed for a Program of General Education in the Secondary School," Science Education, 39:300-04, October 1955.

39. Morris, W. E. "Industrial Arts: a Workshop for Academic Learnings," High Points, 41:53-57, April 1959.

40. Parker, J. A. "Course of Study in Related Physics for Machinists," Industrial Arts and Vocational Education, 45:111-14, March 1956.

41. Read, J. G. "Fitting Science Fairs into the Total Academic Program," High School Journal, 39:282-85, February 1956.

42. Richards, M. F. "Sputnik Education and Industrial Arts," Industrial Arts and Vocational Education, 47:213-14, September 1958.

43. Roberts M. P. "A Classroom Teacher Looks at Science Teaching Objectives," High School Journal, 40:183-87, February 1957.

44. Schneider, H. "How Much Science for a Dollar?" Instructor, 66:67+, January 1957.

45. Slabaugh, W. H. "Crystal Models," Journal of Chemical Education, 36:288, June 1959.

46. Smith, D. T. "Demonstration Experiment on Parallel Forces," Science Teacher, 25:277, September 1958.

47. Suhi, A. G. "Ohm's Law," Science Teacher, 26:255, May 1959.

48. Weaver, W. "Encouragement of Science," Scientific American, 199: 170-76+, September 1958.

49. Wright, L. S. "Space Age Industrial Arts," Industrial Arts and Vocational Education, 48:223-24, October 1959.

D. UNPUBLISHED PAPERS

50. Evans, D. C. "A Collection of Classroom Demonstrations and Devices for the Teaching of Science," Paper prepared for the Traveling Science Teacher Training Program, Oklahoma State University.

51. Keck, Frank D. "Suggested Revisions of Industrial Arts Objectives," Masters Degree Report, Oklahoma State University, 1960.

52. Los Angeles City School Districts, Division of Industrial Services, Curriculum Branch, Vocational and Practical Arts Section. "Applied Science in the Areas of Junior High School Handicraft, General Electricity, General Metal, General Wood, Graphic Arts, and Industrial Drawing."

APPENDIX A

Abbreviations and Symbols

Abbreviation	Meaning
Amp	Ampere
B. I.	Black Iron
Br.	Brass
Bro	Bronze
Cap.	Capacitor
C'Bore	Counterbore
C. R. S.	Cold Rolled Steel
C' S'K'	Counter sink
Dia.	Diameter
°	Degree
Ea.	Each
Fil. hd.	Fillister Head
F. H. B.	Flat Head Bright
Ft.	Foot
Ga.	Guage
Gal.	Galvanized
Hex.	Hexagonal
H. R. S.	Hot Rolled Steel
I. D.	Inside Diameter
In,"	Inch
Lb.	Pound
mfd.	Micro-farad

Appendix A continued

No., #..Number

O. D...Outside Diameter

Pc...Piece

R...Resistor

S. M...Sheet Metal

T..Transformer

Tr..Transistor

Vita

John Eldred Winters

Candidate for the Degree of

Master of Science

Thesis: SCIENTIFIC PROJECTS FOR THE SCHOOL SHOP

Major Field: Industrial Arts Education

Biographical:

Personal Data: Born in Jackson county, Oklahoma, April 17, 1931.

Education: Attended grade school at Warren and Centralview, Oklahoma; junior high school at Mangum, Oklahoma; received a high school diploma from the Portales High School, Portales, New Mexico, in 1949. Received a Bachelor of Science Degree, College of Education, Oklahoma State University, with a major in Industrial Arts Education in May, 1959. Will complete requirements for the Master of Science Degree, major in Industrial Arts Education in August, 1963.

Professional Experience: Three and one-half years teaching experience as General Metals Instructor at the Alice Robertson Junior High School in Muskogee, Oklahoma.

Member: National Education Association, Oklahoma Education Association, Oklahoma Industrial Arts Association, Phi Delta Kappa, Phi Kappa Phi.