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*The*  
PHYSICS TEACHER'S GUIDE

**FOR USE WITH THE TEXT**

PHYSICS

A Basic Science

BY

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## PREL I E

The purpose of this guide is to offer helpful suggestions. Every teacher will work out for himself the plan best adapted to the conditions in his school but every successful teacher will welcome suggestions. The guide is intended to accompany the textbook, *Physics, a Basic Science*. It provides a time-budgeting plan for the best use of available time and supplementary activity for the purpose of illustrating the basic principles of physics.

The larger part of the book consists of demonstrations to be given by the teacher or by a pupil under the teacher's direction. As a general rule not more than one or two demonstrations can be given in connection with one lesson. There is not time for more. This will mean, perhaps, not more than three or four per week except where the demonstrations are short.

It will be gratifying to the authors if this book serves as a starting point so that the teacher works out other demonstrations or other ways of doing things. The material here is not complete nor the final word but it is hoped that it will prove to be stimulating.

THE AUTHORS

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## BUDGETING THE TIME

Our subject is broad and the time is short. We must, therefore, carefully budget both the time and the energy to be expended so that we may attain our objective.

The following outline of lessons is a suggestion based on a school year of thirty-six weeks. If more time is available, it can be used profitably in solving more problems, making more frequent reviews, giving further opportunity for active student participation in the form of practice work, special reports, and many other ways which will occur to the teacher. If less time is available, the starred chapters and paragraphs may be omitted. Obviously, a fixed calendar of activities cannot be followed rigidly. The nature of the laboratory and demonstration equipment, the particular interests and training of the teacher, and other factors combine to make each school situation a unique one. Even in a particular school various vacations and interrupted periods will make it impossible to carry out a schedule exactly. Nevertheless, a program of activities must be made and used as a guide in the interest of a balanced distribution of time.

Each chapter in the text is designed for a single lesson, but not necessarily for a single class period. The lesson should include all the summary questions and most of the general questions and problems. The teacher is expected to choose those general questions and problems which will be of most value to his class.

## OUTLINE OF LESSONS

Laboratory experiments should accompany the study of the textbook. A suitable division of time, to be modified according to conditions, might be three periods a week for class discussions and tests and two periods a week for students' laboratory experiments. The latter might be double periods, depending upon the program of the school. Demonstrations may be included in the time for class discussions or, at the teacher's option, some laboratory periods may be utilized for demonstrations. The whole program should be somewhat flexible, depending upon the needs of the class at any given time.

### *First Semester*

<i>Week</i>	<i>Chapters in Textbook</i>
1st .....	1, 2
2d .....	3, 4, 5
3d .....	6 and Review Problems Unit 1 and Test Cover- ing Unit 1
4th .....	7, 8, 9
5th .....	10, 11, 12
6th .....	Review, Review Problems Unit 3, Test
7th .....	13, 14, Review Problems Unit 4
8th .....	15, 16, Review Problems Unit 5
9th .....	17, 18, 19
10th .....	20, 21, Review Problems Unit 6. Chapter 21 may be considered optional by the teacher.
11th .....	22, 23, 24
12th .....	25, Review and Review Problems Unit 7

## OUTLINE OF LESSONS

<i>Week</i>	<i>Chapters in Textbook</i>
13th .....	26, 27, Review Problems Unit 8
14th .....	28, 29, 30
15th .....	31, Review Problems Unit 9, and Chapter 32
16th .....	33, 34, 35
17th .....	Review Problems Unit 10, Review Unit 10, Test
18th .....	36, 37, Review and Review Problems Unit 11

### *Second Semester*

1st .....	38, 39, 40
2d .....	41, 42, 43
3d .....	Review Problems Unit 12, Chapters 44, 45
4th .....	Review Problems Unit 13, Chapters 46, 47
5th .....	48, 49, 50
6th .....	Review Problems Unit 15, Chapter 51, Test
7th .....	52, 53, 54
8th .....	55, 56, 57
9th .....	58, 59, 60
10th .....	61, Review and Review Problems Unit 20, Chap- ter 62
11th .....	63, 64, Review Problems Unit 21
12th .....	65, Review, Test
13th .....	66, 67, 68
14th .....	69, 70, 71
15th .....	Problems, 72, 73
16th .....	74, 75, 76
17th .....	77, 78, 79
18th .....	80, Review, Test

## SUGGESTIONS RELATING TO FIELD TRIPS

A visit to an industrial plant, or to any structure which offers a demonstration of applications of the principles of physics, is of some value to the student. Industrial firms as a rule welcome the opportunity of conducting high school classes through their plants. The students are their future customers. A judicious use of such trips adds interest to class work. Care must be taken, however, to make such an excursion worth while and not allow it to degenerate into a mere picnic.

Do not take many trips. Too many will mean time lost from more important work. The purpose of field trips is not primarily to learn the method of operation of a large number of machines, but to grasp the idea that the principles of physics are the basis of many of our industries and therefore are closely related to our daily lives. Incidentally, some of the pupils may see that their future success in industry depends on a knowledge of physics.

Prepare the pupils for the trip. They should know what features to look for and these should be applications of principles they have studied.

It is best to visit plants in which the mechanism is comparatively simple. Pupils are confused by a large power plant. They can understand a small one better.

The visit should be followed up with an oral discussion or a written quiz. The oral discussion is better as a general rule. In this discussion attention should be focused on principles.

## DEMONSTRATIONS

Skillful and well chosen demonstrations are a vital part of successful physics teaching. They arouse interest and drive home facts and principles effectively. In the following list of suggested demonstrations a larger number are described than any teacher will have time to give. This procedure is followed so that the teacher may select those that are adapted to his equipment and the time he may have for preparation. Some of these demonstration experiments, when once set up, may be kept from year to year. Experiments thus assembled and stored effect a great saving of time.

In some cases the apparatus suggested for a particularly desirable demonstration will not be on hand. It is then that a skillful teacher will use his ingenuity to adapt what he has or improvise a substitute arrangement of apparatus to perform the experiment in a modified form. Physics experiments offer boundless opportunities to a teacher with an inventive turn of mind. A few tools and materials plus an occasional bright idea are all that are needed to build, develop, or invent a new combination of apparatus. There are few greater satisfactions for a physics teacher with a creative urge than the construction of a new demonstration experiment.

Since time is such an important element, ineffective experiments should be avoided. Every demonstration should help to make vivid and clear some one principle of physics. Spectacular experiments are justified because of the strong impression they make, but if an experiment is spectacular only, it is not worth while. Every experiment should have a teaching value.

It is recommended that the following suggestions for demonstration experiments be made the basis of a notebook of demonstrations by each individual teacher, and that the number of experiments be supplemented and expanded by observation, reading, and invention. As better demonstrations are found or developed, the old ones may be discarded or revised. In this way a valuable program of effective demonstrations will grow from year to year.

The demonstrations that follow are arranged in the order of the chapters of the authors' text, *Physics, a Basic Science*. Figure numbers in the text are designated 2-1, 2-2, etc., whereas in the guide they are denoted by 2a, 2b, etc. This has been done for the purpose of distinguishing between figures in the textbook and figures in the guide.



## CHAPTER 2. FORCE AND PRESSURE IN LIQUIDS

- a. Figures 2-4 and 2-5 in textbook. Demonstrate that pressure in a liquid depends on depth but not on shape of container.
- b. Figure 2-6 in textbook. Urge students to work project at home.
- c. Figure 2a.\* Demonstrate pressure of illuminating gas.

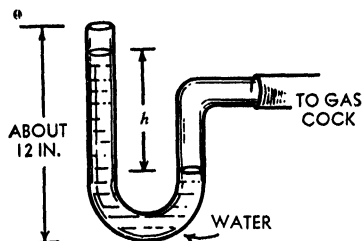


FIG. 2a. A water manometer. The difference of level of the water in the two arms of the tube is a measure of the gas pressure. In other words, the gas pressure is equal to the pressure of the column of water of height  $h$

- d. Figure 2b. Use connected tubes of different shapes.

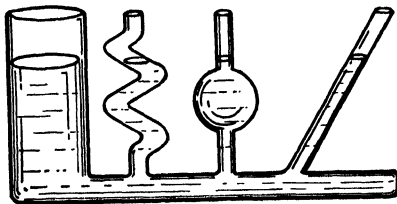


FIG. 2b. Pressure is independent of shape of vessel

- e. The Pascal's vase apparatus which can be purchased from a scientific company may also be used.

## CHAPTER 3. WATER SYSTEMS AND DAMS

- a. Figures 3-2 and 3-3 in textbook. Demonstrate effect of flow on water pressure.

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\* Note that figures designated by numbers (2-4, 2-5, etc.) are in the textbook, whereas figures designated by a number and a letter (2a, 2b, etc.) are in the Teacher's Guide.

## CHAPTER 4. PASCAL'S LAW AND THE HYDRAULIC PRESS

a. Figure 4a. Demonstrate that pressure at a given point in a liquid is equal in all directions.

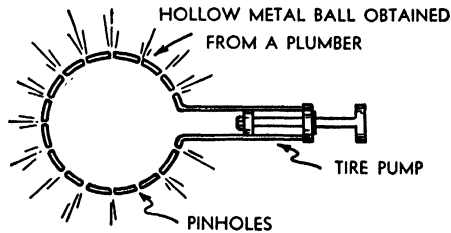


FIG. 4a. Pressure is equal in all directions

b. Figure 4b. If a demonstration hydraulic press is not at hand, make one out of a hot water bottle. The heavy rubber tube may well be longer in proportion than the one shown in the drawing.

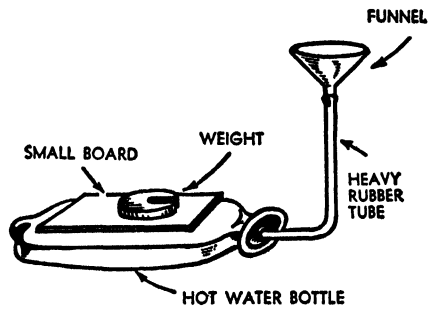


FIG. 4b. A hot water bottle serves as a hydraulic press

## CHAPTER 5. ARCHIMEDES' PRINCIPLE

a. Figures 5-1 and 5-2 in textbook or 5a in Teacher's Guide. Demonstrate Archimedes' principle.

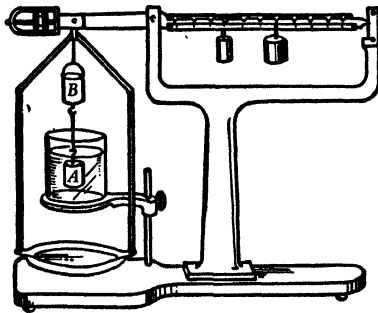


FIG. 5a. The solid cylinder *A* exactly fits the hollow cylinder *B*. The beam is first balanced with *A* and *B* in air. When *A* is submerged in water, balance is restored by filling *B* with water

b. Figure 5b. Show what becomes of the weight apparently lost.

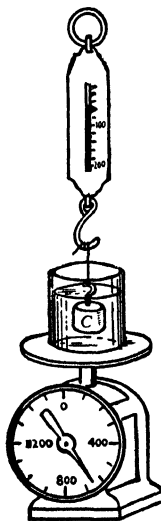


FIG. 5b. The vessel of water appears to gain as much weight as the metal cylinder appears to lose

c. Figure 5-4 in textbook. Have a student set up and demonstrate the Cartesian diver.

## CHAPTER 6. SPECIFIC GRAVITY AND DENSITY

a. Figure 6a. Demonstrate liquids and solids of different densities.

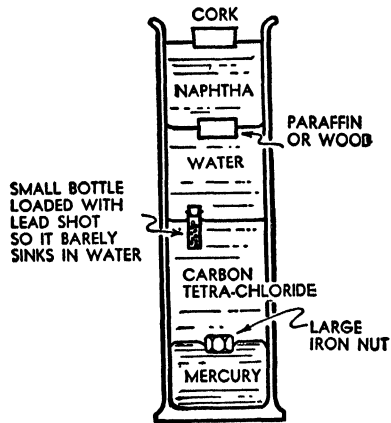


FIG. 6a. Liquids and solids of different densities

b. Figures 6-1 and 6-2. Demonstrate hydrometers.

c. Figure 6b. Demonstrate comparative densities of water and alcohol by the method of balancing columns (Hare's method).

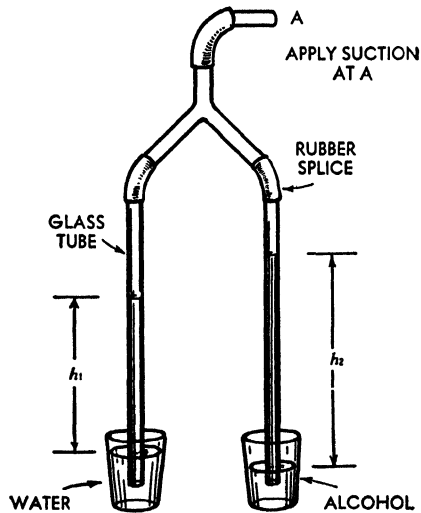


FIG. 6b. Specific gravity of alcohol =  $\frac{h_1}{h_2}$

## CHAPTER 7. MOLECULES AND THEIR ACTIONS

## 1. The Brownian Movement.

*a.* Demonstrate the Brownian movement as follows: Put about half a teaspoonful of gamboge into a test tube containing about 10 cc. of alcohol. Shake well and allow sediment to settle. Pour a few cubic centimeters of the clear, colored liquid into a second test tube and slowly add warm water, until the contents of the tube have a yellowish, milky appearance. Place two or three drops of the milky liquid on a clean microscope slide and cover with a clean cover glass. The cover glass should be sealed in place by melting paraffin around the edges with a hot wire or nail stuck in a cork handle. The Brownian movement may be viewed with a microscope having a magnification of three or four hundred diameters. The movement may be projected with suitable equipment.

## 2. Bombardment by Molecules.

*b.* Figure 7-2. Demonstrate bombardment by mercury molecules. Small bits of balsa wood may be used in place of glass.

## 3. Diffusion of Gases.

*c.* Figure 7a. Swab the inside of a glass jar or tumbler with a piece of cotton on the end of a glass tube, after having dipped the cotton in

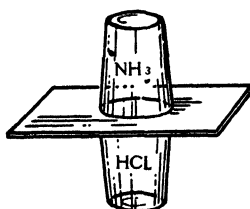


FIG. 7a. Diffusion of gases

hydrochloric acid. Cover the jar with a piece of window glass. Swab another jar or tumbler in the same way with cotton dipped in aqua ammonia. Invert this jar or tumbler over the one swabbed with hydrochloric acid. Hydrogen chloride (HCl) gas now fills the lower vessel and ammonia (NH<sub>3</sub>) gas fills the upper vessel. Although HCl is more

than twice as dense as  $\text{NH}_3$ , the two gases diffuse upon removal of the separating window glass, forming a visible cloud of ammonium chloride.

## CHAPTER 8. MOLECULAR FORCES IN LIQUIDS AND SOLIDS

### 1. Capillary Action.

*a.* Figures 8-5 and 8-6. Show capillary tubes in water and mercury.

### 2. Cohesion of Water.

*b.* Figure 8a. Measuring the cohesion of water. Balance the scales with glass disk *D* in air. Then bring it in contact with the water sur-

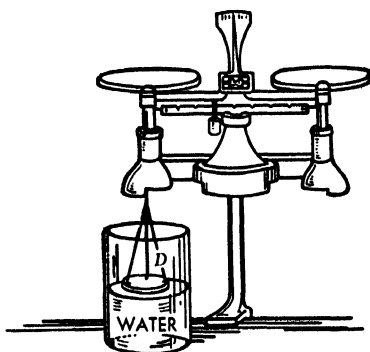


FIG. 8a. Cohesion of water

face. Several grams will be required to tear the film of water which sticks to the glass disk away from the water in the jar.

### 3. Reduction of Volume on Mixing Alcohol with Water.

*c.* Twenty-five cubic centimeters of water mixed with 25 cc. of alcohol make about 48 or 49 cc. of solution. Fill a specific gravity bottle (a small perfume bottle will do) with water and empty it into a small clean beaker. Fill the same bottle with alcohol and pour it into the water. Pour the solution back into the bottle and the reduction of volume will be evident. Enormous pressures would be required to produce this change of volume. The same demonstration may be made, of course, using graduated cylinders.

## 4. Surface Tension.

*d.* Figure 8b. A large mirror placed back of the dishes used in these demonstrations and inclined at about  $60^\circ$  with the table will help to make the effects easily seen.

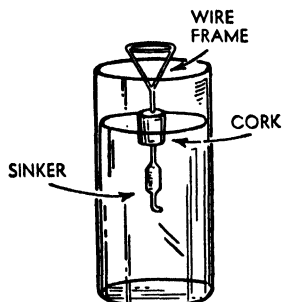


FIG. 8b. To demonstrate surface tension

A wire frame made as shown in Figure 8b will remain under the water when submerged. If it is thrust down so that it bobs up to the surface with considerable speed it may push a film of water a centimeter or two above the surface before it finally breaks through or is forced back down by the contracting film.

## 5. Elasticity.

*e.* Figure 8c. Drop glass marbles, steel bearing balls, rubber balls and various other balls, such as brass, wood, ivory, and lead, on an anvil

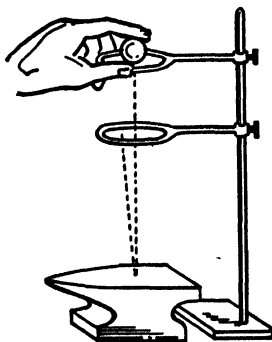


FIG. 8c. To demonstrate elasticity

from a height of a foot or so. Observe the height of rebound in each case.

*f.* Figure 8-10. Demonstrate Hooke's law.

### 6. Instability of Molecules under Strain.

*g.* Figure 8d. Use a Prince Rupert drop. Prince Rupert drops, made by dropping molten glass into water, are in a strained condition



FIG. 8d. A Prince Rupert drop

due to the sudden cooling of the outer surface of glass. When one of them is scratched with a diamond or when its "tail" is broken off, it flies to pieces with explosive violence. One should protect his eyes and face by breaking these drops under a glass jar.

### 7. Ductility of Glass.

*h.* Heat a glass tube in a Bunsen flame until it is soft and red. Remove it from the flame and quickly pull it out into a long slender thread.

## CHAPTER 9. THE WEIGHT AND THE PRESSURE OF AIR

### 1. Weight of Air.

*a.* Figure 9-1. Weigh a quantity of air.

### 2. Pressure of Air.

*b.* Figure 9-2. Perform the glass tumbler experiment over a sink for the paper may break loose as water soaks into it.

The student's project, page 64, may be performed by a student as a class experiment. Note carefully the precautions that must be observed.

*c.* With vaseline on the contact surfaces of the two parts of a Magdeburg hemisphere apparatus, pump out the air. Then let two strong boys try to pull the hemispheres apart. Now open the stopcock (unnoticed by the class if possible) and ask a small girl to separate the hemispheres.

### 3. Expansion of Air under Reduced Pressure.

*d.* Place a toy balloon, partly filled with air and with the neck tied tightly, under the belljar of air pump. Pump out the air surrounding the balloon and note the expansion of the air in the balloon.

### 4. The Torricelli Tube.

*e.* Figure 9-4. Demonstrate Torricelli's experiment.

*f.* Set up a Torricelli tube in a tall belljar and pump out the air. With a good air pump, the mercury in the tube can be made to drop almost to the level of the mercury in the dish in which the Torricelli tube stands.

## CHAPTER 10. THE BAROMETER AND ITS USES

*a.* Exhibit the mercury barometer and explain the method of reading.

*b.* Exhibit and explain the aneroid barometer. Mention the use of the aneroid barometer in determining the altitude of airplanes and the height of mountains.

## CHAPTER 11. COMPRESSION AND EXPANSION OF GASES

*a.* Figures 11-1 and 11-2. Demonstrate Boyle's law, J-tube method.

## CHAPTER 12. APPLICATIONS OF FLUID PRESSURE

### 1. Pumps.

*a.* Model pumps may be used here. The valve action can be shown with the glass models that can be obtained from scientific companies.

### 2. The Siphon.

*b.* Figures 12-4 and 12-5. Demonstrate the siphon using any jars that may be at hand and a rubber or glass tube.

c. Figure 12a. The fountain siphon is a rather spectacular experiment. It is a good exercise for student explanation. Put about half

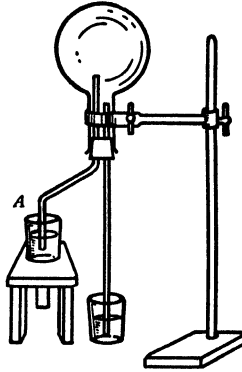


FIG. 12a. Fountain siphon

a glass of water in the flask, insert the rubber stopper fitted with the two open tubes, then invert, as shown in the figure, with the tube A dipping into a jar of water.

### 3. Bernoulli's Principle.

d. Tell the students to try the student's project Figure 12-3 (page 93) at home and report the result in class.

e. Figure 12b. Demonstrate Bernoulli's principle as shown in the figure. The ping pong ball tends to stay in the vertical air stream. Ask the students to explain.

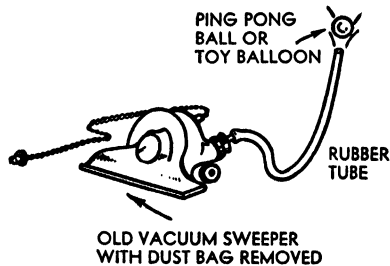


FIG. 12b. To demonstrate Bernoulli's principle

## CHAPTER 13. COMPOSITION OF FORCES

*a.* Figures 13-5 and 13-6 in textbook and 13a in Teacher's Guide. Demonstrate composition of forces by one of these methods.

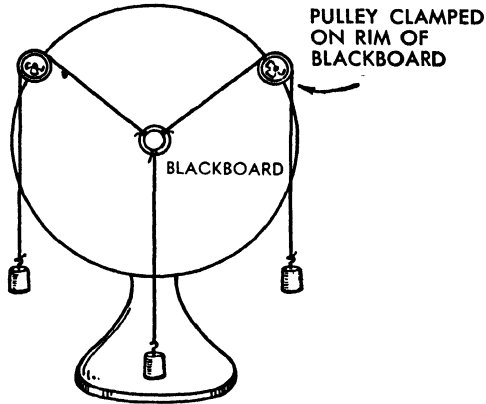


FIG. 13a. To demonstrate composition of forces

## CHAPTER 14. RESOLUTION OF FORCES

1. A Component May Exceed the Resultant.

*a.* Figure 14a. Show that the components may far exceed the weight.

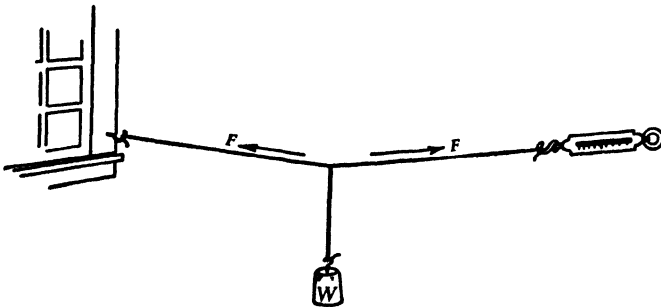


FIG. 14a. A component may far exceed the weight

2. Sailing into the Wind.

b. Figure 14b. When the sail is properly set, the ship moves as shown by the arrow.

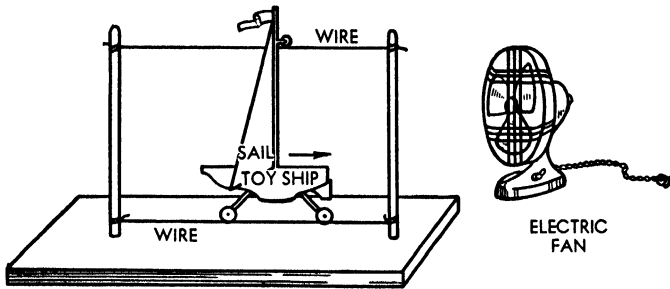


FIG. 14b. Sailing into the wind

CHAPTER 15. GALILEO AND THE LAWS OF FALLING BODIES

1. The Laws of Speed and Distance.

a. Figures 15a and 15b. Set the metronome for some convenient time interval (say, one second). Adjust the angle until a metal ball,

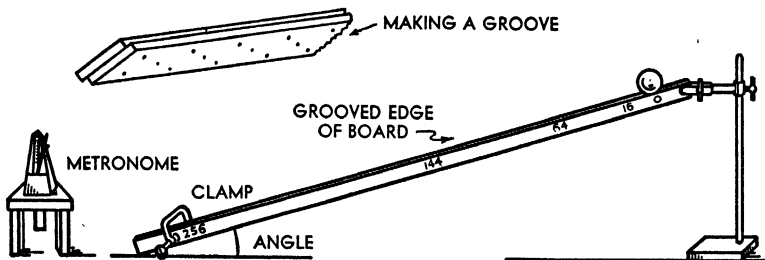


FIG. 15a. Laws of falling bodies

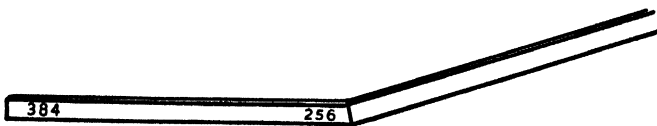


FIG. 15b. Laws of falling bodies

released at 0 at the instant the metronome "ticks," crosses the line marked 16 (16 cm. from 0) at the next tick. It will then cross the

64 mark at the third tick, the 144 line at the fourth tick and strike the clamp at the fifth tick.

Another grooved board placed in a horizontal position may be fitted on the end of the inclined board as shown in Figure 15b. If the clamp is placed at a distance of 128 cm. beyond the 256 mark (384 cm. from 0) the ball will strike it at the sixth tick of the metronome, showing speed at end of 4th time interval.

## 2. Effect of Air Resistance.

*b.* Drop simultaneously a piece of chalk and a sheet of paper. Repeat with the paper slightly crumpled.

Repeat with the paper still further crumpled and finally with the paper wadded tightly.

## 3. The Laws of Falling Bodies Applied to a Projectile.

*c.* Figures 15c and 15d. An object projected in a horizontal direction drops the same vertical distance in a given time as one permitted to fall vertically with zero initial velocity.

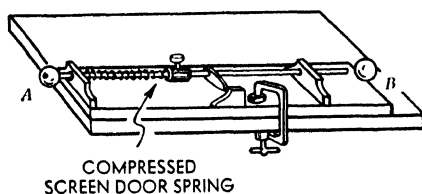


FIG. 15c. Projectiles

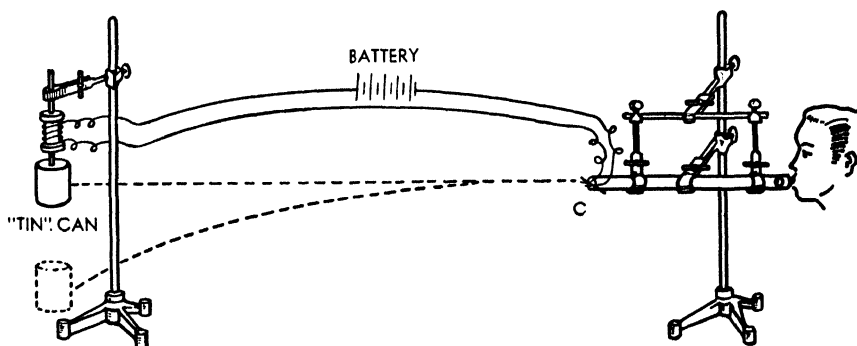


FIG. 15d. Projectiles

The balls *A* and *B* (Figure 15c) may be heard to strike the floor simultaneously.

Using the apparatus of Figure 15d, a marble or bearing ball blown from the glass tube breaks an electric circuit at *C* by knocking off a small piece of fine copper wire. This releases the "tin can" from the electromagnet. If the glass tube is aimed directly at the can in its fixed position, the marble or ball will collide with the can as they fall.

## CHAPTER 16. ACCELERATED MOTION

### 1. The Pendulum.

*a.* Figures 16-1 and 16a. Show that pendulums having bobs of different mass make one swing in the same time if their lengths are the same. Check by means of a metronome.

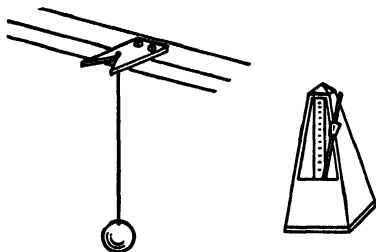


FIG. 16a. The pendulum

Show that the time of one swing is independent of the arc. Make the pendulum one fourth as long and show that it makes two swings for each tick of the metronome. Also make the pendulum one ninth as long and observe that it makes three swings for each tick of the metronome.

### 2. Streamlining.

*b.* Figure 16-3. Have the student's project (page 126) demonstrated by a student.

## CHAPTER 17. GRAVITATION

### 1. Center of Gravity.

*a.* Figure 17-2. The center of gravity experiment may be given as a demonstration or worked by the students individually.

b. Figure 17a. A double cone apparently rolls uphill. Let students discover the explanation.

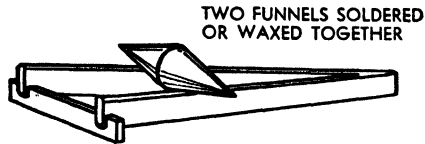


FIG. 17a. The double cone apparently rolls uphill

## 2. Equilibrium.

c. Figures 17-3, 17-4, 17-5. Show examples of stable, unstable, and neutral equilibrium.

## CHAPTER 18. NEWTON'S FIRST LAW OF MOTION

### 1. Inertia.

a. Place a coin on a card resting on a tumbler. Quickly jerk the card away. The coin drops into the tumbler.

b. Figure 18a. Pulling slowly breaks the string at *B*, but with a quick jerk the string breaks at *A* on account of the inertia of the mass *M*.

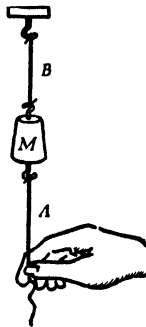


FIG. 18a. To demonstrate inertia

## 2. Centrifugal Force, a Special Case of Inertia.

c. Figures 18-2 and 18b. Spinning the flexible hoop causes it to assume the shape shown by the dotted lines. The detailed construction of the apparatus is shown in Figure 18b.

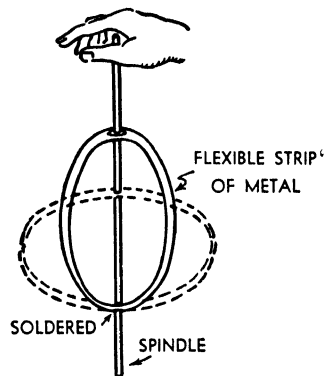


FIG. 18b. To demonstrate centrifugal force

d. Figure 18c. Spinning the liquids causes them to form layers as shown in the drawing.

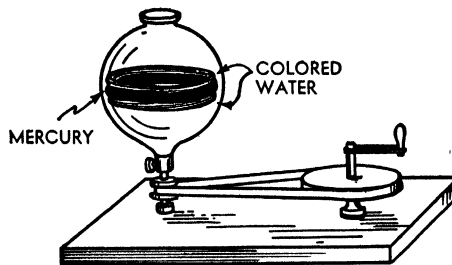


FIG. 18c. To demonstrate centrifugal force

e. Figure 18d. Spinning the ring causes its plane to make right angles with the axis of rotation as shown by the dotted lines.

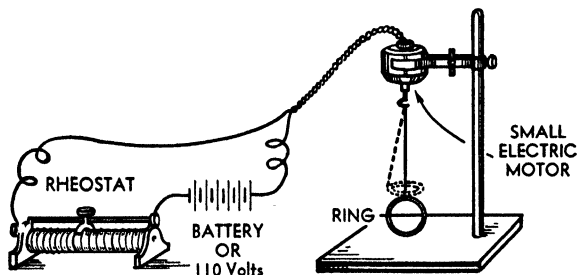


FIG. 18d. To demonstrate centrifugal force

f. Figure 18e. Whirling the weights (20 g. or so) by means of rotator shown in Figure 18c lifts the large weight of 100 grams.

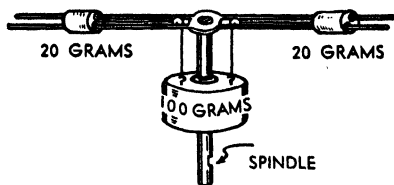


FIG. 18c. To demonstrate centrifugal force

g. Figure 18f. Marbles thrown into the megaphone come back toward the pitcher.

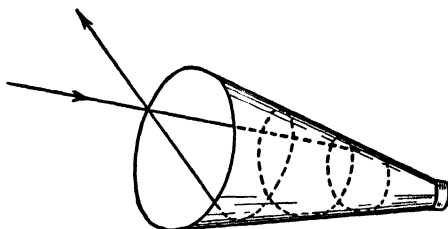


FIG. 18f. To demonstrate centrifugal force

h. Figure 18g. The spinning gyroscope maintains its plane of rotation. A gyroscope top may be used.

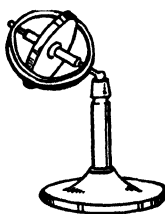


FIG. 18g. The gyroscope

## CHAPTER 19. NEWTON'S SECOND LAW OF MOTION

## 1. Acceleration Produced by an Unbalanced Force.

a. Figure 19a. Increasing the unbalanced weight increases the acceleration. This is done by removing successive 10-g. weights from one side and placing them on the other.

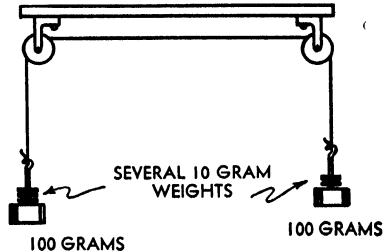


FIG. 19a. Acceleration

## 2. Conservation of Momentum.

b. Figure 19b. Float the blocks on water. Stretch the rubber band and let go. Compare speed and momentum of the two blocks. The small block moves more rapidly than the large one. Why?



FIG. 19b. Conservation of momentum

## CHAPTER 20. NEWTON'S THIRD LAW OF MOTION

## 1. Action Equals Reaction.

a. Figure 20-1. Demonstrate the law as applied to two static forces.

## 2. Transfer of Momentum.

b. Figure 20a. Demonstrate according to this figure.

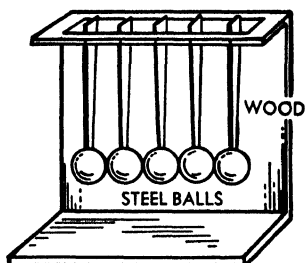


FIG. 20a. Transfer of momentum

## CHAPTER 21. INTRODUCTION TO AERODYNAMICS

## 1. Air Flow.

a. Figures 21-5 and 16-2. With a homemade wind tunnel and mist from dry ice on water, as explained in student's project (page 161), observe air flow about a model airplane wing and about objects of various shapes, such as those shown in Figure 16-2 in textbook.

## CHAPTER 22. WORK AND FRICTION

## 1. Force of Friction.

a. Figure 22a. Find the weight at *A* necessary to overcome friction. Now place a weight equal to that of the block upon the block and again find the weight at *A* necessary to overcome friction. The result will

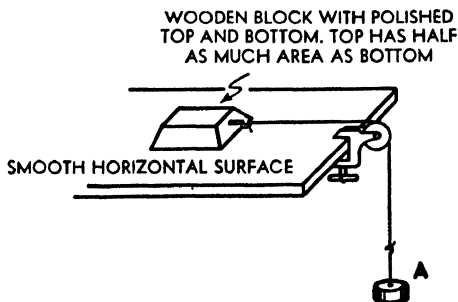


FIG. 22a. Force of friction

show that the force of friction is proportional to the force pressing the two surfaces together.

## 2. Coefficient of Friction.

b. Figure 22a. Find the coefficient of friction with the block placed as shown in the drawing, then turn the block over so that the smaller area is in contact with the table and again find the coefficient of friction. The coefficient of friction is independent of the area of the surfaces pressed together.

## 3. Coefficient of Friction of Rubber on Concrete.

c. Figure 22b. Measure force of friction and coefficient of friction with all wheels locked. Do the same with two wheels locked. With wheels all unlocked test the rolling friction.

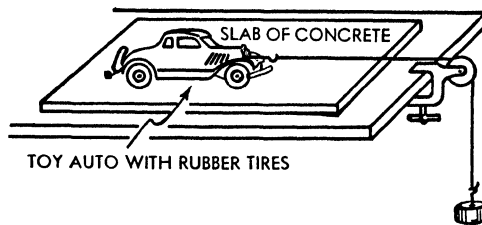


FIG. 22b. Coefficient of friction

## CHAPTER 23. THE PRINCIPLE OF WORK

a. Figures 23-1 and 23a. Show that  $Wd = fD$ . The friction will probably be negligible.

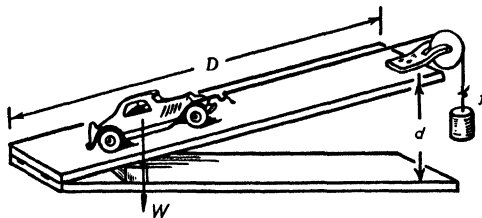


FIG. 23a. Principle of work

## CHAPTER 24. THE PRINCIPLE OF MOMENTS AND THE CONDITIONS FOR EQUILIBRIUM

### 1. Moments.

*a.* Figures 24-1 and 24a. Show that  $F_1D_1 = F_2D_2$ , in other words, that the moments are equal. Show that the principle of work applies

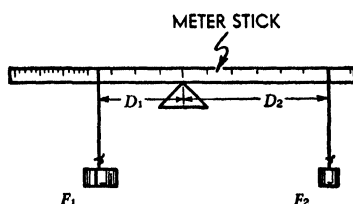


FIG. 24a. Principle of moments

to the lever as it does to all machines. Here, if the lever rotates about its point of support,  $F_2$  moves twice as far as  $F_1$ , so that the distance through which  $F_1$  moves times the larger weight equals the distance through which  $F_2$  moves times the smaller weight.

*b.* Figure 24b. Show that the sum of the clockwise moments equals the sum of the counterclockwise moments, in other words, that the algebraic sum of the moments equals zero.

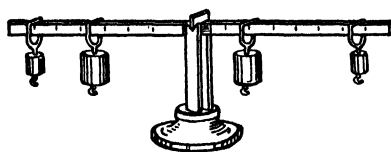


FIG. 24b. Equilibrium

## CHAPTER 25. SOME SIMPLE MACHINES

### 1. Efficiency of Pulleys.

*a.* Figure 25a. Finding the efficiency of a commercial block and tackle is an excellent demonstration. The friction losses are likely to be very high. The efficiency may be as low as 50 per cent. Ask the students, "What is the mechanical advantage of this arrangement?" "Is there any good reason for using a machine with such a low efficiency?"

Or put the questions in the reverse order. A weight of about 25 lbs. may be used in this experiment.

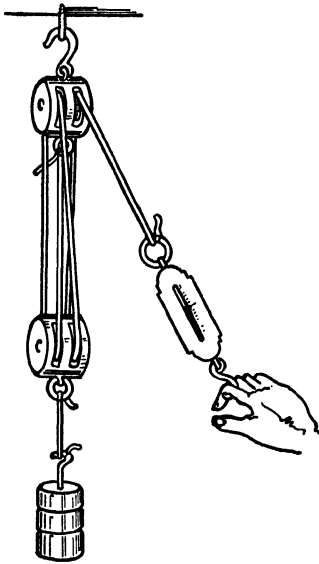


FIG. 25a. Efficiency of pulleys

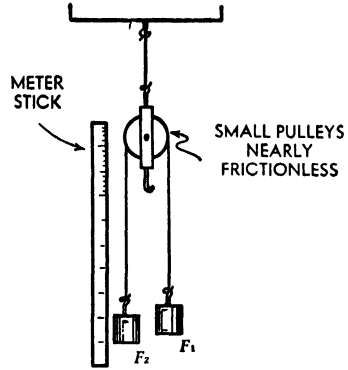


FIG. 25b. Efficiency of pulleys

b. Figures 25b, 25c, and 25d. Test other arrangements of pulleys, using small pulleys having very little friction. Ask the students to explain the high efficiency as compared with the commercial block and tackle.

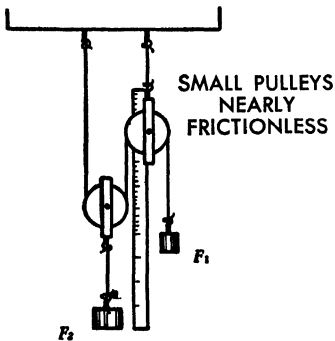


FIG. 25c. Efficiency of pulleys

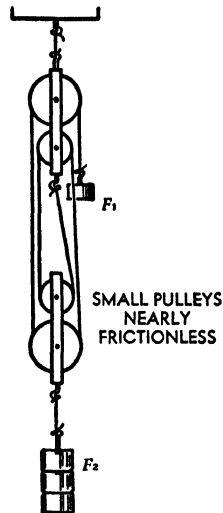


FIG. 25d. Efficiency of pulleys

## 2. Efficiency of Jackscrew.

c. Figure 25e. Find the efficiency of a small jackscrew. Find its mechanical advantage.

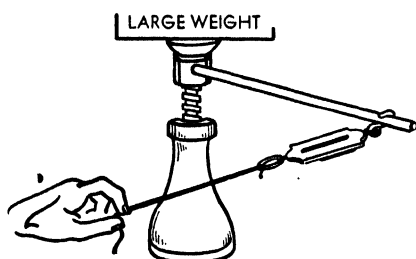


FIG. 25e. Efficiency of jackscrew

## 3. Wheel and Axle.

d. Figure 25f. Find the mechanical advantage and the efficiency of a wheel and axle.

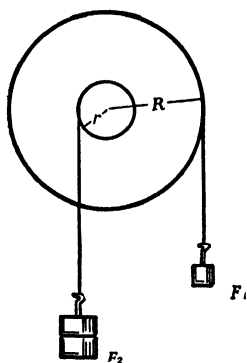


FIG. 25f. Efficiency of wheel and axle

## CHAPTER 26. ENERGY

a. Figure 26a. In the pile driver (about 3 ft. high), the potential energy of the steel block at the top is transformed, during its fall, into kinetic energy. At the bottom the kinetic energy is in turn changed into the work of driving a nail into soft wood. By measuring the initial potential energy and the distance the nail is forced into the wood, the resistance of the wood to the nail may be computed.  $Wh = Fd$ , where

$W$  is the weight of the steel block,  $h$  the height it falls,  $d$  the distance the nail moves into the wood, and  $F$  the average force with which the wood resists the nail.

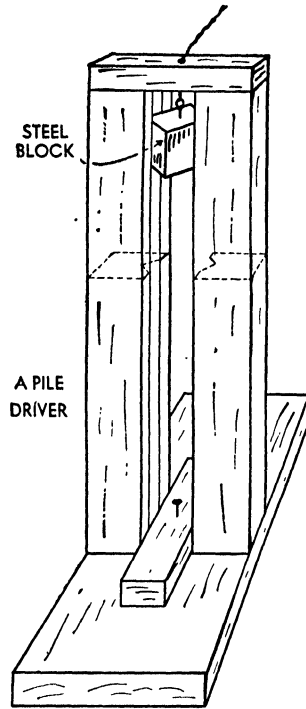


FIG. 26a. Transformation of energy

## CHAPTER 27. POWER

a. Figure 27a. Let a few students measure their own horsepower. Tighten belt over  $A$  until a favorable load is obtained. You are using the Prony brake method.

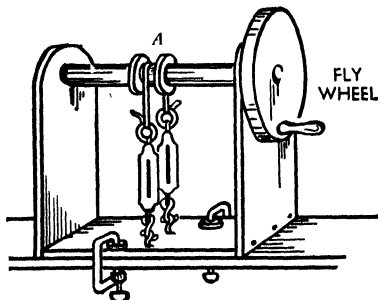


FIG. 27a. Measuring horsepower

## CHAPTER 28. THE NATURE OF HEAT

## 1. Heat from Motion.

- a. The student's project (page 222) may be used as a demonstration. Hammer a piece of lead on an anvil until it becomes hot.

## CHAPTER 29. TEMPERATURE AND THERMOMETERS

a. Figures 29-1 and 29-2. Set up a Galileo's air thermometer. A flask may be used having a one-hole rubber stopper through which a glass tube extends.

The same flask may be used for a water thermometer. Put a marker on the glass tube. This may be a strip of paper with an ink mark at the top of the water column. Place the flask on a wire gauze on a retort stand. Then play a Bunsen flame back and forth under the wire gauze. The water column will drop slightly at first on account of the expansion of the glass, then it will rise.

## CHAPTER 30. EXPANSION OF SOLIDS, LIQUIDS, AND GASES

## 1. The Pulse Glass.

a. Figure 30a. Demonstrate Franklin's pulse glass. Warming one of the bulbs with the hand causes the vapor to expand, pushing the liquid into the other bulb.



FIG. 30a. The pulse glass

## 2. The "Palm Glass."

b. Place a piece of cellophane on the palm of the hand. It curls up because the portions next to the hand expand as they become warmer.

## 3. The Compound Bar.

c. Figure 30-2. Demonstrate the compound bar.

## 4. The Thermostat.

*d.* Figure 30b. Demonstrate a simple thermostat. A simple thermostat may be constructed as suggested in the drawing. The strips of

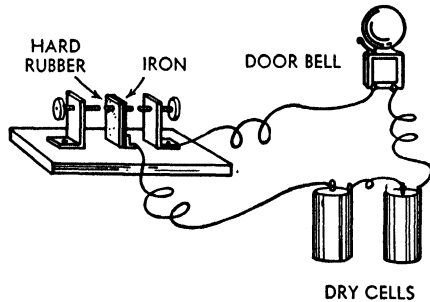


FIG. 30b. To demonstrate the action of a thermostat

iron and hard rubber are riveted together and mounted on a base as shown. The screw making adjustable contact is set so that the contact point on the rubber-iron compound bar almost touches it when the compound bar is not heated. Set a Bunsen burner or an electric heater a short distance from the compound bar. Contact will be closed by the bending of the bar due to greater expansion of the hard rubber. Two dry cells and a door bell may be connected as shown to complete the demonstration. Interpose a sheet of metal between the source of heat and the compound bar to stop the ringing of the bell. Remove the shielding sheet to start the ringing again.

## CHAPTER 31. HOW HEAT TRAVELS

## 1. Conduction.

*a.* Figure 31a. Support a rod of iron and one of copper so that the ends reach the flame of a Bunsen burner. Have nails fastened to the

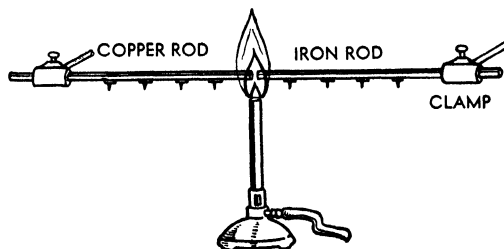


FIG. 31a. Heat by conduction

rods by means of bits of beeswax and uniformly spaced from the flame. The nails will drop first from the better conductor.

## 2. Convection in Liquids.

*b.* Figure 31-3. Place some coloring matter, such as potassium permanganate or aniline dye, in a beaker of water. A Bunsen flame placed under one side of the beaker causes visible convection currents.

## 3. Convection in Air.

*c.* Figure 31b. A metal or wood box with a glass window on one side and a chimney on top of each end can be easily constructed as sug-

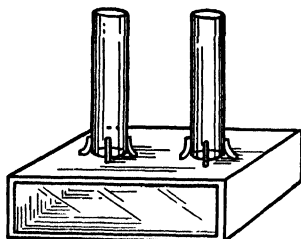


FIG. 31b. Heat by convection

gested in the drawing. Metal strips to hold the chimneys are riveted (or soldered if the box is of metal) around the holes cut for the chimneys. Glass tubes of large diameter are used as chimneys. Clips should be designed to hold the window in place during the experiment.

When a lighted candle is placed under one chimney convection currents in the air are produced. They may be made discernible by holding a bit of burning touch paper over the chimneys. Touch paper can be made by soaking blotting paper or filter paper in a solution of potassium nitrate and allowing it to dry. It burns without flame and gives a white smoke.

## 4. Radiation.

*d.* Figure 31c. Any source of radiant heat, such as an electric lamp, a flame, or even a hot iron, causes the vanes of the radiometer to rotate. There is a rather high vacuum in the radiometer, only a comparatively

few of the original molecules being left. It is the rebound of these molecules from the black surface of the vanes that causes the rotation.



FIG. 31c. Heat by radiation

#### 5. Radiation from Different Surfaces.

*e.* One can easily show the surprising fact that a layer of asbestos paper, such as is used for wrapping pipes of warm air furnaces, increases the radiation of heat as compared with the bright uncovered metal pipes.

Choose two bright "tin" cans of the same size and shape. Wrap one with a layer of asbestos paper. Pour boiling water in each can, then place a thermometer in each. Observe which can cools faster. Another can may be covered with black paint or lamp black to compare radiation from black and bright surfaces at the same initial temperature.

#### 6. Reflection of Radiant Heat.

*f.* Figure 31d. Two parabolic reflectors, such as automobile head-light reflectors, are placed several feet apart, facing each other and with

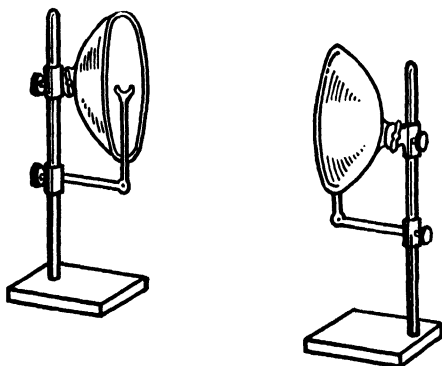


FIG. 31d. Reflection of radiant heat

their axes coincident. An iron ball heated until it begins to glow is placed at the focus of one reflector. A radiometer placed at the focus of the other reflector spins rapidly. The back of one's hand put in place of the radiometer can be sensibly burned by the reflected heat waves.

## CHAPTER 32. HEAT UNITS

### 1. Specific Heat.

*a.* Heat equal weights of aluminum and lead in boiling water so that they are at the same temperature. It is best to have the two weights of the same shape. Balls or cylinders may be used. Place the hot weights on a cake of paraffin. The aluminum will melt much more of the paraffin than the lead. One or both of the weights may melt its way entirely through the paraffin, depending upon the thickness of the paraffin. The great difference in heat absorbed by the two metals in the same change of temperature is easily seen.

## CHAPTER 33. MELTING AND FREEZING

### 1. Bursting an Iron Pipe.

*a.* A short section of iron pipe threaded at both ends and with iron caps to fit can be obtained from a plumber. *Fill* the pipe with water and screw the caps on tight. Place the pipe in a freezing mixture of salt and ice or use "dry ice" to freeze the water in the pipe.

### 2. Regelation.

*b.* Demonstrate regelation using the method of the student's project (page 263), but with a rather large cake of ice. If the experiment is started at the beginning of the class period, the wire will have cut its way for a considerable distance into the ice by the end of the period. If you can select a cake of ice of such a thickness that the wire cuts its way through shortly before the end of the period, the students can see that the ice has not been cut in two. The effect is very striking.

### 3. Freezing Mercury.

*c.* Fill a small match box or a test tube with mercury. Insert a small stick (a pencil will do) in the mercury, to be used later as a handle. Surround the mercury and its container with a solution of "dry ice"

(solid carbon dioxide) and ether or alcohol. When the mercury has frozen, its container can be broken away leaving a little hammer of frozen mercury on the end of a stick. The mercury hammer can be used to drive small nails. Dry ice alone will freeze mercury but ether hastens the action.

#### 4. Effects of Low Temperature.

d. This experiment and the preceding one on freezing mercury are spectacular, suitable for demonstration before a large group. A rubber ball or a banana peel frozen as described in number 3 becomes exceedingly brittle. If thrown on the floor it breaks like chinaware. Fruits and flowers can be treated in the same way. *Caution: When using ether be sure to have good ventilation and have no flame in the room.*

If about a liter of liquid air can be obtained, still more striking effects can be shown. Alcohol can be frozen. A spiral of lead wire (such as fuse wire) held in liquid air for a short time, say two or three minutes, becomes elastic. A small weight suspended from such a spiral will bob up and down as if it were hanging on a brass or steel spring. *Caution: If liquid air is used, do not put a cork in the bottle but use absorbent cotton instead. Put the cap on loosely. Failure to observe this precaution will result in an explosion.*

## CHAPTER 34. EVAPORATION

### 1. Cooling Effect of Evaporation.

a. Figure 29-1. Set up an air thermometer. Place a few drops of alcohol on the bulb. After noting the effect of the evaporation of the alcohol, place a few drops of ether on the bulb. Compare the effects produced. Fan the bulb and note the effect.

### 2. Freezing Water by Evaporation.

b. Place a drop or two of water on a large cork. Set a watch crystal or other shallow container on the cork so that a film of water separates the cork and the shallow container. Put a little ether in the watch crystal and fan it gently, being careful that none of the ether trickles down the outside of the crystal into the water. In a few minutes the water freezes, fastening the crystal to the cork.

c. Figure 34a. Water may be frozen by its own evaporation. By reducing the pressure on the surface of water the rate of evaporation

of the water may be so rapid as to cause it to freeze. Apparatus is arranged as shown. The sulfuric acid (concentrated) in the flask absorbs the water vapor. The water boils before it freezes. With a good

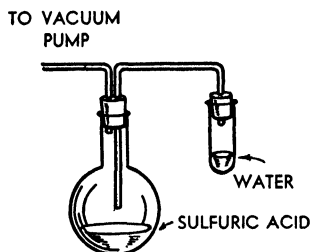


FIG. 34a. Cooling by evaporation

motor-driven vacuum pump one or two cubic centimeters of water can be frozen in a few minutes. *Caution: Choose a fairly large test tube so that water will not be forced into the flask containing sulfuric acid.*

A test tube containing dry calcium chloride may be connected in the rubber hose line between the flask and the pump to prevent water vapor from reaching the pump. The test tube fittings are shown in Figure 34b.

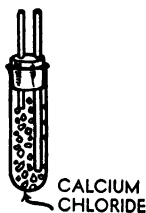


FIG. 34b. Drying air

### 3. Effect of Pressure on Boiling Point.

*d.* Fill a pyrex flask about half full of water and bring the water to the boiling point over a Bunsen flame. Remove the flame. When the water has stopped boiling close the flask with a rubber stopper and invert it in the ring of a retort stand or support it in a vertical position by means of a clamp. Put ice cubes on the flask or pour cold water over it. The water in the flask will boil vigorously. Using a one-hole rubber stopper, with a thermometer passing through it, makes it possible to show the low temperature at which the water is boiling.

### 4. Distillation.

*e.* Figure 34-3. Add coloring matter (ink will do) to the water in the flask. The distilled water comes out clear.

### CHAPTER 35. SOME EFFECTS OF EVAPORATION AND CONDENSATION

*a.* The student's project (page 281) may be worked out by all the members of the class in the laboratory.

*b.* This experiment can be carried farther as a demonstration. Use dry ice or dry ice and ether, as in demonstration to accompany Chapter 34. A large test tube or a beaker can be cooled to such a temperature that frost will be formed on it.

### CHAPTER 36. HEAT AND WORK

#### 1. Starting Fire by Friction.

*a.* If there is a boy scout in the class have him demonstrate starting fire by friction and with flint and steel.

*b.* Figure 36a. Use a Tyndall's heat-by-friction cylinder. Put a little ether or alcohol in the tube and push the cork in tight. Rotate the

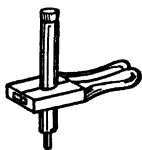


FIG. 36a. Heat from friction

tube while pressing the wooden friction clamp against it. Heat by friction will cause the liquid to boil and blow out the cork.

#### 2. Heat by Compression.

*c.* Figure 36b. A fire syringe is made like a tire pump but has a small piston and a cylinder with comparatively thick walls. Fasten a

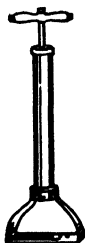


FIG. 36b. Heat by compression

Try the effect of each of these substances on one pole of a large demonstration compass. A demonstration compass can be made by fastening a strongly magnetized hacksaw blade to a cardboard tube of

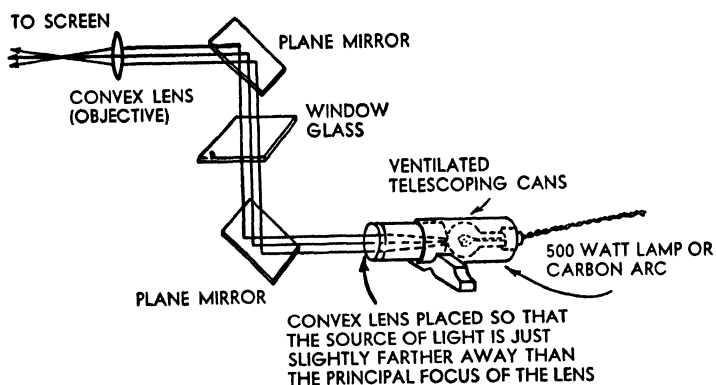


FIG. 55c. Demonstration projection apparatus

small diameter (1 in. or less) as shown in the drawing. Drill a small hole through the center of the cardboard tube. Paint one end of the tube red and the other blue. Set a large needle in an upright position in a supporting stand and use this as a pivot for suspending the tube and hacksaw blade. Let the blade rest on the point of the needle. This makes a light yet strongly magnetic compass which can be seen by a large class, Figure 55b.

A substitute for large demonstration equipment in magnetism is to arrange a projection apparatus as in Figure 55c.

With this apparatus, objects which one wishes to project on the screen can be placed on the window glass. Images of such objects are formed on the screen by the convex lens. In order to avoid distortion, good lenses should be used. The convex lens used as the objective should be a good objective lens from a projection lantern. An old projection lantern, if one is available, can be made over as suggested in the drawing to suit the needs of the demonstrator.

A small compass for use with this projection equipment is made by carefully removing from the enclosing case an ordinary small compass with its supporting pivot. The pivot should be waxed to a small piece of clear glass so that it can be set on the window glass of the projection equipment described above.

### 5. Magnetic Field and Lines of Force.

*e.* Place a small bar magnet on the horizontal window glass of the projection equipment described in 4. Cover it with a piece of thin glass. Sprinkle iron filings on the covering glass and tap it gently with a pencil. Focus the image of the iron filings on the screen. Repeat with a small U magnet. Also use two bar magnets first with unlike poles about 2 or 3 cm. apart, then with like poles placed the same distance apart.

### 6. The Nature of Magnetism.

*f.* Nearly fill a large glass test tube with iron filings. Close the open end with a cork. Stroke the tube of filings with one pole of a strong magnet. Stroke the tube in the same direction each time. Bring one end of the tube near one pole of a compass, either the small projection form or a large (but light) demonstration form. The tube of filings shows magnetic polarity. Now shake the filings vigorously and test again.

Unwind a long piece of clock spring. Magnetize it by stroking with a magnet as described for the tube of filings. Test each end for polarity with a compass. Break the magnetized clock spring in the middle. Test all ends for magnetic polarity. Break each half and test again. Holding a short piece of magnetized clock spring in the jaws of a pair of tongs, heat it to a bright red in a Bunsen flame. Keep it away from magnets until it is cooled (it can be dropped in a jar of water). Test both ends for magnetic polarity. Heat it again and let it cool in a strong magnetic field. Retest for polarity.

## CHAPTER 56. THE EARTH AS A MAGNET

### 1. Angle of Dip.

*a.* Exhibit a dipping needle.

### 2. Magnetism Induced by the Earth's Field.

*b.* Hold a long steel rod parallel with the earth's magnetic field and hammer the upper end vigorously. Test both the lower and upper ends for magnetic polarity, using the demonstration compass. Reversing ends (one end should be marked), place the rod back in the earth's field and hammer it again. Show the reversed polarity.

If a rod or strip of permalloy is available, this demonstration can be made very effectively without hammering. Using the projection compass, bring one end of the strip near the north pole of the compass, keeping the strip in a horizontal position. Slowly raise the permalloy strip to a vertical position, keeping the lower end near the north pole of the compass. Note the repulsion as the permalloy strip becomes magnetized in the earth's field.

## CHAPTER 57. ELECTRIC CHARGES

### 1. Action of Electric Charges.

*a.* Balance a meter stick on a watch crystal. Rub a hard rubber rod with wool and bring the rod near one end of the stick. Hold the rod parallel with the stick but not touching it. Show that the rubber rod attracts each end of the stick.

Repeat the demonstration, using a glass rod rubbed with silk instead of the rubber rod.

A large pith ball or a ping pong ball coated with aluminum paint or graphite may be used instead of the balanced meter stick.

### 2. Attraction and Repulsion of Charges.

*b.* Figure 57-1. Suspend a ping pong ball between two metal plates placed parallel and about 3 or 4 in. apart. The ping pong ball should be one which has been coated with aluminum paint or graphite. Connect one plate to a knob of an electrostatic machine. Connect the other plate to a water pipe. Operate the electrostatic machine and observe the vibration of the ball.

### 3. An Electrified Stream of Water.

*c.* Draw out a short piece of glass tubing to a small nozzle at one end. The opening should be about 1 mm. in diameter. Connect the nozzle to a water faucet by means of rubber tubing. Mount the nozzle in a nearly vertical position near a sink. Turn on the water until a fine stream of water rises 3 or 4 ft. in the air.

When a charged rubber rod is brought near the stream of water, the stream will be deflected. The surface tension forces of the water will also be affected so that the stream does not break into droplets. In fact, it is possible that a rather broad spray may be converted into a narrow stream.

## 4. An Electroscope.

*d.* Figure 57a. Feeble charges can be readily detected and their sign determined by a homemade electroscope. Cut the top and bottom

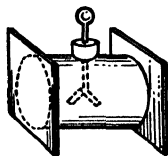


FIG. 57a. An electroscope

out of a tin can. Drill a hole in the side of the can at the center. Fit this hole with a one-hole rubber stopper. Flatten one end of a short metal tube or rod and insert it in the hole through the rubber stopper. Solder or screw a metal knob (either solid or hollow) on the other end of the rod which should project an inch or so outside the can. Fasten the can to a suitable base, or let one edge of the glass windows waxed to the ends serve as a base. Stick two small leaves of aluminum foil on the flattened end of the metal tube which extends to the center of the inside of the can. Use a little shellac to stick the leaves. Place a source of light (the one described in the experiment on reflection of light, Figure 46a, is well adapted to this need) near one window of the can. Place a convex lens a short distance from the other window so that it forms an image of the leaves on the screen. A large class can now follow various demonstrations with this electroscope.

## 5. Charging by Contact.

*e.* Bring a charged rubber rod slowly toward the knob of the electroscope. Observe the effect on the leaves. Remove the charged rod without touching the knob. Observe that the leaves collapse. Note: If the leaves do not collapse, connect the "tin can" to a water pipe by means of a copper wire. Repeat the demonstration. Unless one's shoe soles are good insulators, he can easily discharge the electroscope by touching the knob with his hand.

Now charge the electroscope by touching the knob with the charged rubber rod. Remove the rod. Observe the effect of bringing the charged rubber rod near the knob of the charged electroscope. Also observe the effect of bringing a charged glass rod (one rubbed with silk) near the knob. Note: Glass rods frequently cause trouble in electrostatics because of a film of moisture which collects on the surface. This should be completely evaporated by heating it carefully in a Bunsen flame.

Move the rod back and forth in the flame—never let it come to rest in the flame—until the rod is quite hot.

## 6. Charging by Induction.

*f.* Demonstrate charging by induction as illustrated in Figures 57-4, 57-5, and 57-6 in textbook.

## 7. Opposite Charges Appear Simultaneously and in Equal Amounts.

*g.* Make a little woolen hood to fit over the end of a hard rubber rod. Attach a strong silk thread to the end of the hood. Making sure that both hood and rod are neutral to start with, place the hood on the rod and rub it back and forth. Do not touch any more of the hood with your hand than is absolutely necessary. Now bring the rod with the hood on it near an electroscope. Note that there is no deflection. Remove the hood by pulling on the silk thread. Show that both hood and rod are charged and that they have opposite signs.

# CHAPTER 58. ATMOSPHERIC ELECTRICITY AND ELECTROSTATIC MACHINES

## 1. A Static Charge Rests on the Surface of a Conductor.

*a.* Set a metal can (the inner part of a calorimeter may be suggested) on a cake of paraffin to insulate it. Charge it by contact with a charged hard rubber rod. Fasten a penny on an insulating handle with a little sealing wax to make a proof plane for transporting charges. Touch the penny to the inner surface of the charged cup being careful not to drag the penny over the rim of the cup as it is removed. Bring the proof plane near the electroscope and observe that it is not charged. If it shows a charge look for faulty insulation in the handle of the proof plane. A hard rubber handle is better than one of glass. Touch the penny to the outer surface of the charged can and test again.

## 2. Discharging Effect of Points.

*b.* Figures 58-2 and 58a. Demonstrate according to Figure 58-2. An electric whirl also demonstrates the discharging effect of points, Figure 58a. Cross two short pieces (3 or 4 in. long) of wire at right angles and solder them together at the junction. Drill a small hole into the solder. Balance the crossed wires over a needle stuck in a large cork. Bend the four ends of the cross at right angles to the wires,

making all the bends in the same direction; i.e., either clockwise or counterclockwise looking down on the cross. File sharp points on the

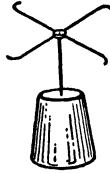


FIG. 58a. Demonstrating discharging effect of points

ends of the wire cross. Connect the needle with an electrostatic machine and observe the rotation of the wire cross.

### 3. How a Lightning Rod Protects a House.

*c.* First construct a small model house. Convenient dimensions are 6 by 10 by 8 in. high. Make the roof of asbestos paper. Solder a metal ball on the end of a stiff wire and let the wire project through the base of the house so that the knob nearly reaches the roof inside the house. Connect one knob of a large electrostatic machine to the stiff wire under the base of the house and adjust the other knob of the electrostatic machine over the house until a spark jumps. Put a little ether on the roof with a medicine dropper. The spark will now set fire to the roof.

Bend a narrow strip of thin metal parallel to the length of the strip so as to make a ridge roll for the roof of the model house. Solder several pins or half pins to this strip so the points project upward when the strip is placed on the roof. Connect this strip to the stiff wire which runs up inside the house. This makes a lightning rod with several discharging points. Operate the electrostatic machine again. No large spark occurs.

### 4. Electric Condensers.

*d.* Figures 58b and 58-4. Tack a small piece of sheet metal on a wooden base to make one plate of a condenser, Figure 58b. Make an-

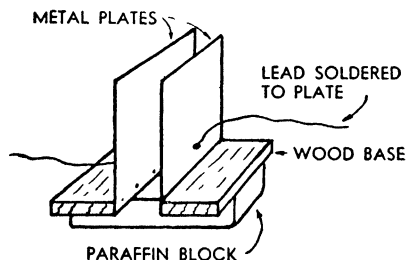


FIG. 58b. An experimental condenser

other plate in the same way. Set one plate on a cake of paraffin and connect it by means of a wire to the knob of an electroscope. Charge the metal plate. Observe the deflection of the leaves of the electroscope. Connect the other condenser plate to a water pipe by means of a long flexible wire. Slowly bring the grounded plate near the charged plate and observe the reduced deflection of the electroscope. Remove the grounded plate without touching the plate connected to the electroscope. Note that the deflection returns to its former value.

e. Charge and discharge a Leyden jar, Figure 58-4.

### 5. An Electrophorus.

f. Figures 58-5, 58-6, 58-7, and 58-8. See A. L. Foley: *An Efficient and Inexpensive Electrophorus*, *School Science and Mathematics*, October, 1936. This magazine is on file in many public libraries.

Melt some stick sulfur by heating it *very slowly* in a metal pan with a metal plate between the containing pan and a Bunsen burner. Pour the melted sulfur into an aluminum pie pan. The sulfur need not be more than a half inch deep. Break out the central portion of the sulfur where there are numerous empty spaces left between the crystals because of contraction on solidification. Then fill with melted sulfur.

To charge the electrophorus strike it glancing blows with a heavy piece of wool. Let the wool drag over the rim of the pan with each blow.

## CHAPTER 59. ELECTRIC CELLS

### 1. The Plates of a Battery Are Charged.

a. Figure 59-2. Demonstrate as shown in this figure.

### 2. A Projection Cell.

b. Figure 59a. This figure illustrates the construction of a cell which is suitable for use with a projection lantern.

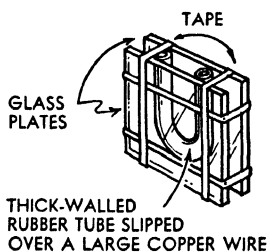


Fig. 59a. Cell for use with projection lantern

Cut two narrow strips: one of copper, one of zinc. Tack these to small blocks of wood and slip them into the cell. A binding post can be soldered to each strip if it is desired.

Put a dilute solution of sulfuric acid in the cell. Observe hydrogen bubbles rising from the zinc due to local action. Connect the zinc and copper strips together with a wire. Observe hydrogen bubbles rising from the copper strip as well as from the zinc. Also observe the collection of hydrogen bubbles on the surface of the copper (polarization). Amalgamate the zinc by coating it with mercury and demonstrate that local action is thereby prevented.

### 3. The Dry Cell.

*c.* Saw an old dry cell through the center and parallel to the carbon. Exhibit the two halves.

### 4. Voltage of Various Cells.

*d.* A demonstration voltmeter-ammeter may be used to measure the voltage of the electric cell used with a projection lantern, a dry cell and any other cells that may be at hand.

A demonstration voltmeter-ammeter may be improvised by using a sensitive galvanometer with a large mirror supported at such an angle that the class can see the image of the instrument. A high resistance of the proper value must be used in series with the galvanometer to make a voltmeter, and a low resistance of the proper value must be shunted across the galvanometer to make an ammeter.

## CHAPTER 60. THE CHEMICAL EFFECTS OF AN ELECTRIC CURRENT

### 1. Water, a Poor Conductor of Electricity.

*a.* Figure 60-1. Demonstrate as in textbook.

### 2. Electrolysis of Water.

*b.* Figure 60-2. Demonstrate as in textbook. For chemical effects of electricity it is essential to have a source of direct current available in the laboratory. If the laboratory is supplied with alternating current, a motor generator set or a rectifier, either of the vacuum tube or mercury vapor type, may be installed. Current, voltage and power demands must be considered in selecting a rectifier.

If a 115-volt source is used for electrolysis of water, a lamp of suitable wattage should be connected in series to limit the current.

### 3. Electroplating.

c. The pupils singly, or in small groups, should work an experiment in copper plating.

d. Figure 60a. An interesting demonstration of lead plating is quite suitable for projection with the apparatus described in Figure 55c, page

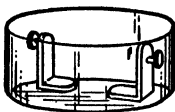


FIG. 60a. To demonstrate lead plating

63. Place two strips of lead 3 or 4 cm. square in a shallow, flat-bottomed glass vessel as shown in the sketch of Figure 60a. Place the strips 2 or 3 cm. apart. The corners should be rounded off and the ends farthest apart should be bent upward so that binding posts or copper wires attached there will not be in the solution used.

A saturated solution of lead acetate into which a few drops of acetic acid have been dropped is used as the electrolyte. After freshly sandpapering the edges of the lead electrodes, pour in enough of the electrolyte to cover the horizontal portions of the lead electrodes. Mount the glass container on the horizontal stage of the projection lantern and get a sharp image of the lead electrodes on the screen. Connect the electrodes in series with a  $7\frac{1}{2}$ -watt lamp to a 110-volt D.C. source. The cathode will appear to grow in a fern-like structure ("lead tree") as metal is deposited. Reverse the polarity to make the "tree" grow on the other electrode.

### 4. Storage Cell.

e. Hang two rather thick sheets of lead in a glass vessel containing a solution of sulfuric acid (approximately 10 parts of water and 1 part concentrated sulfuric acid). Connect the two lead plates to an electric doorbell. Note that the bell does not ring. Send direct current through the cell for a few minutes. A 6-volt storage battery, a battery charger, or a D.C. motor generator set can be used. If a 110-volt D.C. source is used, connect a 25-watt lamp in series with the storage cell.

Hydrogen is liberated at the cathode and oxygen at the anode. In a few minutes the anode becomes coated with a reddish brown layer of

lead peroxide. Disconnect the charging current and connect the doorbell to the demonstration storage cell again.

f. Exhibit electrodes and separators of a commercial storage battery.

## CHAPTER 61. THE MAGNETIC EFFECTS OF AN ELECTRIC CURRENT

### 1. Oersted's Discovery.

a. Hold a demonstration compass under a wire running north and south. Send direct current through the wire. Repeat with the compass above the wire.

### 2. Magnetic Field around an Electric Current.

b. Figure 61-1 and Figures 55c and 61a. With the projection apparatus illustrated in Figure 55c, page 63, one can readily show the circu-

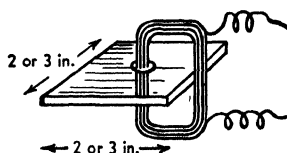


FIG. 61a. To demonstrate magnetic field around a current

lar shape of magnetic line of force around a wire carrying a current. Drill a small hole in the center of a small piece of clear glass. Choose a rather thin piece, because drilling through glass is not easy. The drilling can be done with a small short piece of glass tubing used as a bit in a hand drill. Use emery powder and turpentine as an abrasive. To start the hole clamp the glass between two blocks of wood. Select blocks with plane surface faces so the glass will not be broken when they are clamped together. A hole through which the glass tube will fit and turn easily should be made in one of the blocks before they are clamped on the glass. Dip the end of the glass tube in turpentine, then in emery powder, before inserting it in the hole. Press the end of the glass tube firmly against the glass plate and turn the drill. Frequently renew the turpentine and emery powder as the drilling is continued. After the hole is started the guide block can be removed, thus making it easier to replenish the abrasive.

Wind 30 or more turns of enameled magnet wire (size 26 or 28 is convenient) in a rectangular form through the hole in the glass, as sug-

gested in Figure 61a. Tie the wires together in a tight compact bundle. Fasten the bundle to the glass with glue or sealing wax, both at the hole and at the edge of the plate. Support this apparatus in the proper position for projection with the glass plate horizontal.

Make some fine iron filings by filing an iron nail. Sprinkle some of these filings on the glass plate around the wire. Connect the ends of the wire momentarily to a dry cell while the glass plate is tapped gently with a pencil. Do not leave the current on long enough to overheat the wire.

### 3. Ampere's Right-hand Rule for a Coil.

*c.* Figure 61-3. Wind a dozen turns of fairly large copper magnet wire on a broomstick or other convenient form of approximately 1 or 2 in. diameter. Remove the coil and spread the turns slightly so that the class can see the individual turns. Connect one end of the coil to a terminal of a dry cell. Bring one end of the coil near a pole of a demonstration compass. Touch the other end of the coil to the second terminal of the dry cell. Observe the deflection. Test the polarity of each end of the coil. Note the connections to the dry cell. Apply the right-hand rule.

### 4. Lifting Magnet.

*d.* Use a properly designed electromagnet and a storage battery. The electromagnet may be of the simple U form for demonstration purposes. Pick up an anvil or an iron bar with the magnet.

### 5. Telegraph Circuit.

*e.* Figure 61-4. Set up two sounders, two relays, two keys, and batteries connected as shown in Figure 61-4 in textbook.

### 6. Galvanometer.

*f.* Suspend a coil of magnet wire between the poles of a large U magnet. Either a permanent magnet or an electromagnet can be used. The apparatus should be large enough for the entire class to see the coil clearly. Send current from a dry cell through the coil and note its deflection.

## CHAPTER 62. ELECTRICAL RESISTANCE

*a.* Connect a wire wound rheostat in series with a lamp and source of electric power. Dim the lamp by varying the resistance. If 110-volt lines are used, the rheostat should have a high resistance, unless high wattage lamps are used. In the latter case the rheostat should have a high current-carrying capacity. Low resistance rheostats can be used, of course, with batteries and lamps for low voltage operation (lamps for flashlights or automobiles or Christmas tree decorations).

## CHAPTER 63. OHM'S LAW

*a.* Measure the voltage of each of two or three fresh dry cells.

Connect a single cell in series with a known resistance (1 or 2 ohms of a standard resistance box) and a demonstration ammeter. Compare the reading of the ammeter with the current calculated by means of Ohm's law. Call attention to the fact that the internal resistance of the cell and the resistance of the connecting wires are very small in comparison with a few ohms. Double the resistance and recheck the current. Connect two dry cells in series and measure their voltage as a battery. Connect this battery in series with a known resistance of 4 or 5 ohms and the demonstration ammeter. Recheck the current.

## CHAPTER 64. SERIES AND PARALLEL CIRCUITS

1. Ohm's Law Applied to a Circuit.

*a.* Figure 64a. Connect in series an iron wire and a copper wire of the same diameter and length (2 ft. of 22 gauge is a suggestion), an iron

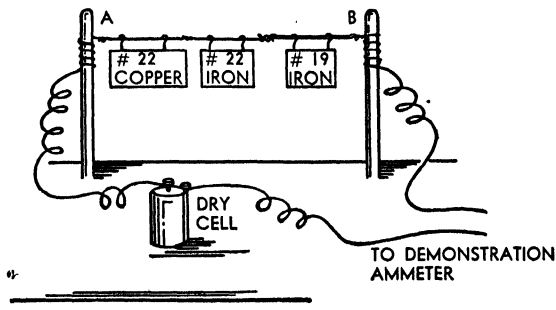


FIG. 64a. To demonstrate Ohm's law

wire of the same length but larger diameter (preferably one having twice the cross section; i.e., one of 19 if 22 gauge is used for the first iron wire as suggested above).

Stretch this wire above the demonstration table. Tag each section of the wire with an appropriately labeled card. Connect the circuit to a dry cell in series with a demonstration ammeter as shown in the drawing. Measure the resulting current. Connect a demonstration voltmeter (the ammeter may be converted into a voltmeter by replacing the low shunt resistance with a high series resistance) across the points *AB*. Using these measured values of current and voltage, calculate the resistance between *A* and *B*. Connect the voltmeter successively across the three sections of wire between *A* and *B*. Use these values to compute the resistance of each section. Connect two dry cells in series with the circuit described. Compare the resulting current with the former value. Compare the various voltages with their former values. Measure the voltage across half of the #22 iron wire. Calculate its resistance and compare with the full value. Compare the resistances of the two sections of iron wire having the same length but different diameters.

## CHAPTER 65, HOW A MAGNETIC FIELD PRODUCES AN ELECTRIC CURRENT

### 1. Induced Currents.

*a.* Wind 20 or 30 turns of magnet wire on the bottom of a glass tumbler. Allow an extra length of a foot or two at each end for making connections to a demonstration galvanometer. Pull the windings of the coil far enough apart for the class to trace the direction of winding.

Test the polarity of a strong permanent magnet by means of a demonstration compass. Mark the north pole so that the class can identify it.

With the coil connected to a demonstration galvanometer thrust it (the coil) quickly over the north pole of the magnet. Observe the deflection. Thrust the coil slowly over the same pole. Divide the coil so that about half of it is used and thrust one half over the magnet. Move the coil to and fro parallel to the magnetic lines of force. Thrust the coil over a weaker north pole.

### 2. Lenz's Law.

*b.* Connect a dry cell to the galvanometer through the body of the demonstrator as a high resistance. Point out the polarity of the dry

cell, the direction of current through the galvanometer, and the direction of the consequent deflection. Connect the coil back to the galvanometer as in the preceding demonstration. Pull the turns apart slightly so that the class can see the direction of winding. Thrust the coil over the tested and marked north pole of a strong magnet. Observe the direction of deflection. Pull the coil back over the north pole and note the direction of deflection. Thrust the coil over the south pole of the magnet. Turn the coil over and thrust it over the north pole. In each case above trace the direction of deflection produced in the galvanometer. Apply the right-hand rule and note how Lenz's law is followed in each case. Note: If the class is very large, increase the size of the coil and magnet used.

### 3. Induction from the Earth's Magnetic Field.

*c.* An earth inductor consists of a coil having a sufficient number of turns of wire to cause a deflection of a galvanometer by turning it in the earth's magnetic field. Use a sensitive demonstration galvanometer. Point out the application to the earth inductor compass.

## CHAPTER 66. ELECTRIC DYNAMOS OR GENERATORS

### 1. A.C. Magneto.

*a.* Connect a  $7\frac{1}{2}$ -watt lamp or a small neon lamp to a telephone magneto turned by hand. If the class is not too large, let each one note the increased difficulty of turning the generator when the  $7\frac{1}{2}$ -watt lamp is connected.

### 2. A.C. Dynamo.

*b.* If a small A.C. dynamo is available, drive it by means of an electric motor. Use a battery to excite the field. Christmas tree lamps are suitable for operation by small machines giving 6 to 10 volts.

### 3. Commutator.

*c.* Exhibit wooden or cardboard models of commutators. Models of armatures and fields can also be used advantageously. If the teacher can make good blackboard drawings, however, that procedure is simplest.

#### 4. D.C. Generator.

*d.* Procure a small D.C. generator having an output voltage of 6 to 10 and a wattage of 25 to 100. Drive it with an electric motor or a small gasoline engine. Operate a bank of Christmas tree lamps.

If the generator is shunt wound, connect more lamps in parallel in the load until the machine fails on account of the weakened field. If the generator is series wound, demonstrate the failure of the machine with a load of high resistance.

*e.* A student might be encouraged to construct a model house lighting circuit for use with a small generator. The wiring can be put on a wooden panel for demonstration. Switches, fuses, etc., can easily be included. Use 1-ampere fuse wire to make special fuses or get fuses designed for protecting the lighting circuit of an automobile. Blow a fuse by short circuiting a lamp. Replace the fuse.

*f.* If it is desired to include transformers in the model lighting circuit, choose a small A.C. generator and use it with radio filament transformers.

### CHAPTER 67. THE INDUCTION COIL AND THE TRANSFORMER

#### 1. Inductance.

*a.* Pick out the ends of a ½-pound spool of #28 magnet wire. Solder flexible lead wires to these ends and carefully tape the coil so the small wires are not placed under tension or bent back and forth. This makes a good coil for general laboratory use.

Connect such a coil with a few dry cells in series. Include a switch in the circuit. Connect a small neon lamp in parallel with the switch. When the switch is opened the neon lamp flashes. Insert a soft iron core in the coil and observe the increased flash when the switch is opened.

#### 2. Induction Coil.

*b.* An induction coil from the ignition system of an automobile may be bought for a small price. One of these makes a satisfactory demonstration. Of course a large and more expensive coil makes a more spectacular demonstration.

Connect a Leyden jar across the secondary terminals and note the intensifying effect on the spark.

### 3. Transformer.

c. Carefully take apart a small transformer, such as a power transformer for a radio set. Retain only the primary winding and one low voltage secondary winding. Remove several sheets of the laminated core so the windings can be moved on the core. Tape the windings and lead wires securely. Operate a few pilot lamps or flash lamps with this transformer. Point out that the primary and secondary circuits are separated electrically but linked magnetically.

## CHAPTER 68. THE TELEPHONE

### 1. Carbon Microphone.

a. Cut two holes 2 or 3 in. apart in the lid of a cigar box and push a small carbon rod into each hole, making a tight fit. Carbons from an old flashlight battery work nicely. Make a small cone-shaped hole in each upright carbon rod. This can be done with a pocket knife. Make the holes facing each other. Each end of another carbon rod is sharpened to fit loosely into the cone-shaped holes. This makes a crude carbon microphone.

Connect wires to the two upright carbon rods, placing the microphone in series with a dry cell and the primary winding of a microphone transformer. The secondary of the transformer is connected to the input terminals of an audio amplifier. The output of the amplifier is connected to a loud-speaker. A paper funnel can be fitted into a large hole in one end of the cigar box. An alarm clock placed on the cigar box can be heard by a large class. Talk into the funnel. Keep the microphone as far as possible from the loud-speaker and behind it.

Note: A microphone transformer can be made by winding a layer or two of #28 magnet wire over the core of an audio transformer. Use the home-wound layer as the primary.

b. Have a pupil set up the circuit of Figure 68-5 in textbook.

## CHAPTER 69. ELECTRIC MOTORS

### 1. Principle of Electric Motor.

a. Figure 69a. Make a hook or loop in one end of a piece of thick copper or aluminum wire. The wire should be about 2 ft. long. Sus-

pend the wire in a vertical position with the hook or loop over a supporting horizontal brass rod. Let the lower end of the wire dip in a dish of mercury.

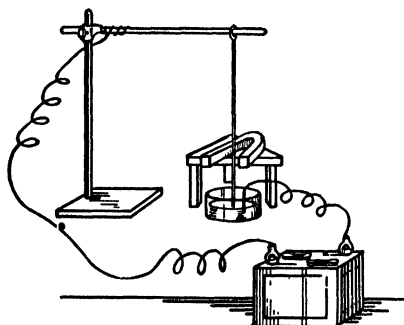


FIG. 69a. The principle of the electric motor

Place a strong U magnet as shown in the drawing. Connect a storage battery as shown. Note the motion of the wire as the circuit is closed. Turn the magnet over and repeat. Reverse the battery connections and observe the motion.

## 2. D.C. Motor.

*b.* Connect the D.C. generator described in demonstration 66-4 to the terminals of a storage battery or other source of D.C. having the same voltage which the machine is designed to generate. Reset the brushes for minimum sparking when the machine is used as a motor.

## 3. Series Wound Motor.

*c.* Connect a small series wound motor, such as is frequently used for running small fans, to 110 volts A.C. If a D.C. source at 110 volts is available, connect the series wound motor to this source.

# CHAPTER 70. THE HEATING EFFECT OF AN ELECTRIC CURRENT

## 1. Electric Arc.

*a.* Figure 70-2. Demonstrate the carbon arc as shown in this figure. Note that a rheostat must be used in series with the arc.

*b.* The principle of the electric furnace can be demonstrated as follows: Chisel a groove in the larger face of a brick. The groove should be large enough to permit one of the carbons of the arc to be laid in it.

Halfway between the ends of the brick chisel a depression about 1 in. deep. Place the two carbons in the groove with their ends over the depression but not quite meeting. In the depression place iron filings or small bits of some other metal. Place another brick on the lower brick and the carbons. Then make the connections for an electric arc. The intense heat will melt the metal in the depression.

## 2. Heating Effect of a Current.

*c.* Connect 6 or 8 ft. of 24 or 26 gauge iron wire in series with an equal length of copper wire of the same gauge. Stretch this wire above the demonstration table and connect it in series with a bank of lamps and the commercial 110-volt A.C. mains. Vary the current through the circuit by changing the number or wattage of the lamps used. Adjust the current so that the iron begins to glow. The copper wire, which carries the same current, is comparatively cool.

Connect the same two wires, one of copper, the other of iron, in parallel and stretch the circuit above the demonstration table again. Connect the circuit in series with an electric toaster or some other device using a rather large current. The bank of lamps may be connected in parallel with the toaster to increase further the total current and to provide a means of controlling the current. Increase the current through the parallel circuit of iron and copper wire until the copper wire begins to glow. The iron wire will be comparatively cool.

Both copper and iron wires should be properly tagged so that the class can identify them.

## 3. Expansion of Iron.

*d.* Stretch an iron wire above the demonstration table. For operating on 110 to 120 volts, a convenient size and length of wire is 20 or 22 gauge and a length of approximately 8 or 10 ft. Hang a suitable marker on the wire. Connect the wire to a 110- to 120-volt supply through a rheostat of large current-carrying capacity. As the current is increased the wire expands. If the wire is heated sufficiently, it contracts momentarily, after which it expands again.

It is interesting to observe wire as current is reduced. The wire first contracts, then momentarily expands, and finally contracts again. This expansion is due to heat liberated while the iron undergoes a change of its crystalline arrangement. The momentary contraction while the current is increasing is due to an absorption of heat during the crystalline rearrangement.

## CHAPTER 71. ELECTRIC POWER AND ENERGY

## 1. Watt-hour Meter.

*a.* Exhibit a watt-hour meter or kilowatt-hour meter. Connect it to a circuit in which the load is varied from a small lamp to a laundry iron or electric heater. Such a meter can usually be borrowed from an electric power company. Use it to measure the electrical energy consumed by some electrical device, say an electric iron, a toaster, or a bank of lamps. Have pupils compute cost of operation per hour at the rate prevailing in your community.

## CHAPTER 72. ALTERNATING CURRENT

## 1. Wave Form.

*a.* If a cathode ray oscillograph is available, show the sinusoidal form of commercial A.C. generators. Connect the 60-cycle A.C. lines to a step-down transformer (small bell transformer, a toy train transformer, or a radio filament transformer). Connect the low voltage output of the transformer to the input terminals of the oscillograph.

## 2. A.C. Ammeters and Voltmeters.

*b.* Show various A.C. measuring instruments to the class.

## CHAPTER 73. INDUCTANCE AND CAPACITANCE

## 1. Choke Coil.

*a.* Figure 73-8. Using the coil described in the student's project, page 576, place in series an electric lamp of 25 or 100 watts or a bank of lamps. Operate on 110-volt A.C. line. Insert a soft iron core in the coil and note the dimming effect. A laminated iron core can be made by tying together a bundle of soft iron wires of suitable length.

## 2. Action of a Condenser.

*b.* Connect a paper condenser (not an electrolytic) of large capacitance (5 to 10 or more microfarads, telephone condensers are good) in series with a lamp of low wattage ( $7\frac{1}{2}$  to 25 watts) and the 110-volt

A.C. lines. If a single condenser of such large capacitance is not available, connect two or more condensers of small capacitance in parallel.

### 3. Electrical Resonance.

c. Figure 73a. Connect the choke coil and the condenser described above in series with the 110-volt lines. Note that the lamp grows

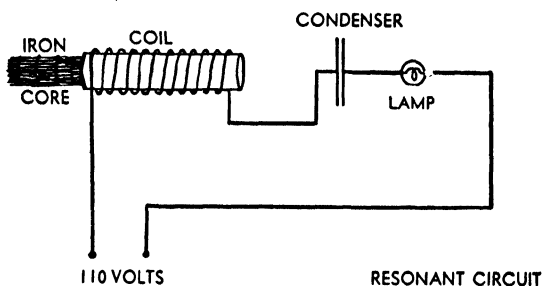


Fig. 73a. To demonstrate resonance

brighter as the iron core is inserted slowly, reaches a peak, then diminishes in brightness.

## CHAPTER 74. POWER IN AN ALTERNATING CURRENT CIRCUIT

a. Arrange a circuit in which the voltage, the current, and the power of a coil containing an iron core are measured respectively with a voltmeter, an ammeter, and a wattmeter. The primary of a step-down transformer is suitable as a coil. The product of the volts times the amperes will not be equal to the watts at no load. As a resistance load is put on the secondary, the product of volts times amperes becomes more nearly equal to the number of watts recorded by the wattmeter.

## CHAPTER 75. ELECTRIC OSCILLATIONS AND WAVES

### 1. Resonant Leyden Jar Circuits

a. Figure 75a. Choose two Leyden jars of the same capacity. Connect a rectangular frame consisting of a metal rod or tube to one of the jars. Place a spark gap in the circuit as shown in the drawing and connect the secondary winding of an induction coil across the gap. When

the coil is in operation, a spark of several millimeters in length should be produced at *A*. Six or eight inches from this circuit, and parallel with it, set up the other Leyden jar with a rectangular loop of adjustable dimensions connected to it as shown.\* The end *B* of the loop is made to move along the horizontal portions of the loop so that the area of of

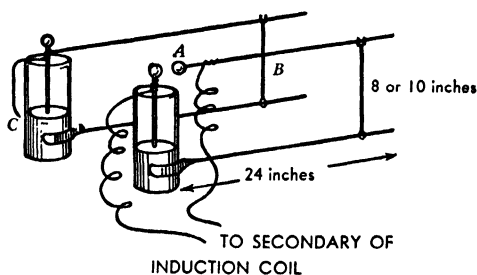


FIG. 75a. An experimental oscillator

the loop can be made either equal to that of the other circuit, or very different (both larger and smaller). Connect a copper wire or strip *C* to the inner conducting layer of the Leyden jar and let it come within 2 or 3 mm. of the outer conducting layer of the jar. The distance for best results will depend upon the dimensions of the circuits and upon the voltage applied across *A*.

When *B* is moved to the position which makes the areas of the two loops equal, sparks will occur at *C* due to sympathetic vibrations with the sparks at *A*. Detuning the circuits stops the sympathetic sparks. This experiment represents the Hertz oscillator.

## CHAPTER 76. CONDUCTION OF ELECTRICITY THROUGH GASES†

### 1. Conduction of Air.

*a.* Figures 76-1 and 76-2. Demonstrate that hot air is a non-conductor of electricity but ionized air is a conductor.

### 2. Conduction of Rarefied Air.

*b.* Figures 76-3 and 76a. Use a good motor-driven vacuum pump. Place a spark gap 3 or 4 in. in length in parallel with the connections to the glass tube which is to be exhausted. The glass tube should be

\*These loops should be supported by wooden frames.

at least 2 or 3 ft. long. Before the tube is exhausted the discharge occurs across the spark gap in parallel with the tube. As the evacuation pro-

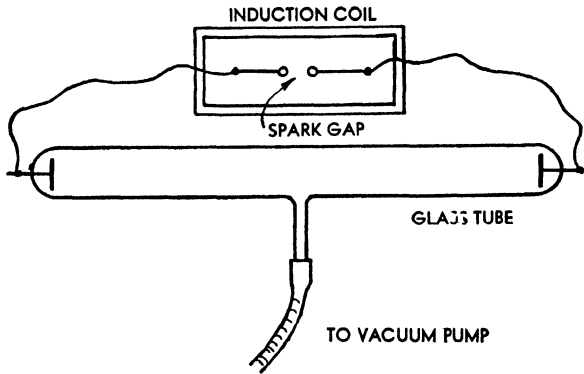


FIG. 76a. To demonstrate conduction of rarefied air

ceeds, the discharge goes through the rarefied air. Note the changing appearance of the conducting air as the evacuation proceeds.

### 3. Heating Effect of Cathode Rays.

*c.* Figure 76-4. Connect to an induction coil. Note: In these discharges of electricity through rarefied gases, it is a wise precaution to insert a spark gap in series with the secondary winding of the induction coil and the discharge tube to be operated. This will protect both the secondary winding and the discharge tube against excessive currents. Adjust the length of the spark gap (from a few millimeters to a few centimeters) to give sufficient current for the demonstrations.

### 4. Cathode Rays Travel in Straight Lines.

*d.* Figure 76-5. Demonstrate according to this figure if the apparatus is available.

### 5. Mechanical Effect of Cathode Rays.

*e.* Demonstrate with a Crookes rolling wheel tube.

### 6. Fluorescence Caused by Cathode Rays.

*f.* Exhibit a Geissler fluorescent tube.







