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ABSTRACT

Presented are descriptions (with photographs) of demonstration equipment purchased, assembled, developed, and used at William Jewell College (Missouri) during the past 25 years. The descriptions are organized into the following topic areas: (1) mechanics; (2) heat; (3) waves, sound, and acoustics; (4) electricity; (5) optics; and (6) atomic and nuclear physics. This arrangement follows closely the freshmen-level text by Harvey E. White ("Modern College Physics") and is related to the sophomore-level text by F. W. Sears and M. W. Zemansky ("University Physics"). However, many of the demonstrations presented may be used with any one of the good freshmen/sophomore-level college physics textbooks currently available. (JN)

PHYSICS DEMONSTRATION EXPERIMENTS

at WILLIAM JEWELL COLLEGE

by
Wallace A. Hilton

Revised Edition

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PREFACE

PHYSICS DEMONSTRATION EXPERIMENTS at William Jewell College is an attempt to bring together in one volume a brief description, with photographs, of demonstration equipment that has been purchased, assembled, developed and used at William Jewell College during the past twenty-five years.

The arrangement of the materials follows closely the freshman-level text by Harvey E. White, MODERN COLLEGE PHYSICS, 5th Edition, 1966, Van Nostrand, and is related to the sophomore-level text by F. M. Sears and M. W. Zemansky, UNIVERSITY PHYSICS, 4th Edition, 1970, Addison-Wesley. However, many of the demonstrations presented may be used with any one of the good freshman-sophomore-level college physics texts available in this country.

Appreciation is expressed to the Administration and Trustees of William Jewell College, who through the years have provided an adequate yearly budget which has made available a continuing supply of physics demonstration equipment. The generous gifts from the E. S. Pillsbury family are acknowledged and appreciated.

Appreciation is also expressed to Professors Glen T. Clayton and Roger C. Crawford, who have served as co-workers in the department of physics; and to Professors John L. Philpot and Charles Don Geilker, who have served as associates in the teaching of physics to students at William Jewell College.

To the editors of the AMERICAN JOURNAL OF PHYSICS, THE PHYSICS TEACHER, and SCHOOL SCIENCE AND MATHEMATICS, appreciation is expressed for their permission to reprint selected papers from their journals. To the author and co-authors of these papers: L. B. Ham, Glen T. Clayton, Roger C. Crawford, Janet M. Whan, John W. Hilton, Robert Sandquist, Joseph W. Chasteen, and Wesley E. Moore, deep appreciation is expressed.

Deepest appreciation is expressed to John and Robert, who through the years with great enthusiasm for physics demonstrations, have inspired and helped in developing and presenting physics demonstration experiments to interested individuals and groups in the midwest. My deepest appreciation goes to Ruth, who for thirty years has shared in this work with her time, patience, encouragement, interest, and deep concern.

Wallace A. Hilton
August 25, 1970

ACKNOWLEDGMENT

The preparation and publication of this book was partially supported by a grant from the U.S. Office of Education, Department of Health, Education and Welfare, through a faculty development grant from the Kansas City Regional Council on Higher Education (KCRCHE) and William Jewell College.

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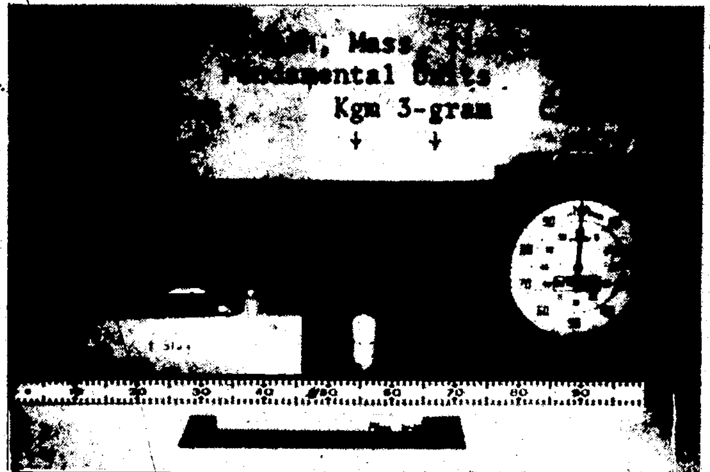
M-1 FUNDAMENTAL UNITS: LENGTH, MASS, TIME

M-1a Length, Mass, Time

Fig M-1a shows models of these three fundamental units: Lengths shown are a meter stick and a one-foot length. Masses shown are a slug, a kilogram, and a 3-gram piece. The lecture room clock reads to 1/100 second.



M-1b Micrometer and Vernier Calipers

Demonstration micrometer caliper and a vernier caliper are shown in Fig M-1b.


Fig M-1b

M-1c Slide Rule and a Vernier Scale

These two demonstration pieces are for use with the overhead projector. This makes it possible for the entire class to see the instructor operate the slide rule. The apparatus for teaching the correct reading of a vernier scale is also shown in Fig M-1c.


Fig M-1c Slide Rule & Vernier Scale

M-1d Time Signals

Time signals from the National Bureau of Standards Radio Station, WWV, Fort Collins, Colorado, are received on the Physics Department's amateur radio receiver (Fig M-1d) and then sent to a speaker in the lecture room (Fig M-1d*) where the entire class may hear the time signals and observe the various wave forms on an oscilloscope.

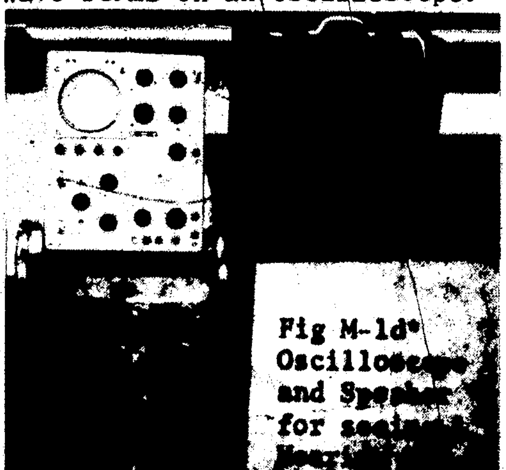
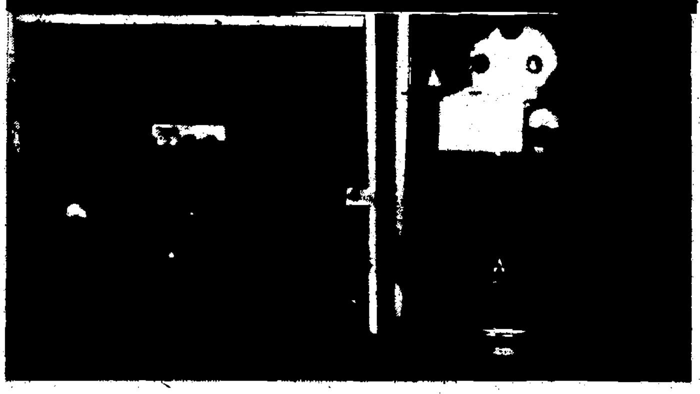
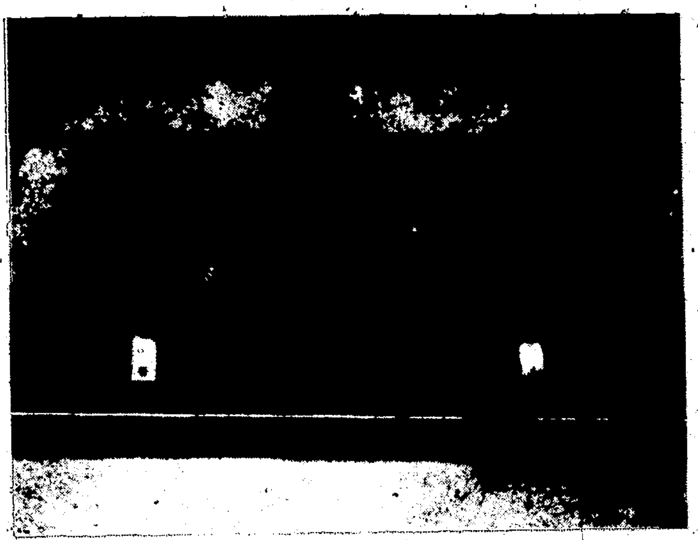


Fig M-1d*



M-1e Greenwich and Sidereal Times

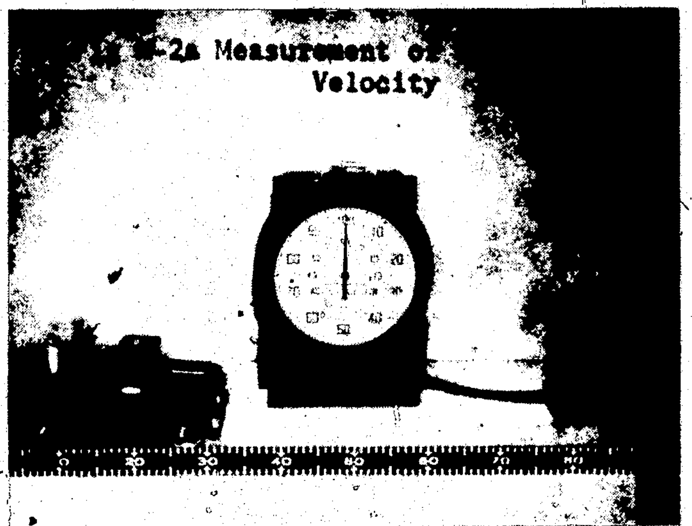
Professor C. D. Geilker has placed two clocks at the front of the lecture room, of which one reads Greenwich time and the other reads sidereal time. These are on permanent display, and are shown in Fig M-1e.



M-2 CONSTANT VELOCITY

M-2a Measurement of Constant Velocity

The apparatus consists of a constant speed motor with a wheel and axle attached by a light string to a small toy truck, which is pulled across the table at a constant velocity. The distance is measured with a meter stick and a student starts and stops the large clock. The students then calculate the average velocity of the truck.

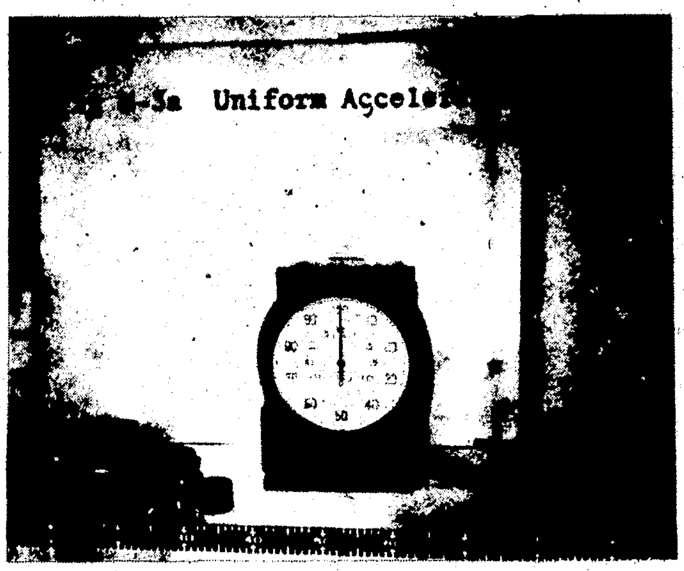


M-3 UNIFORM ACCELERATION

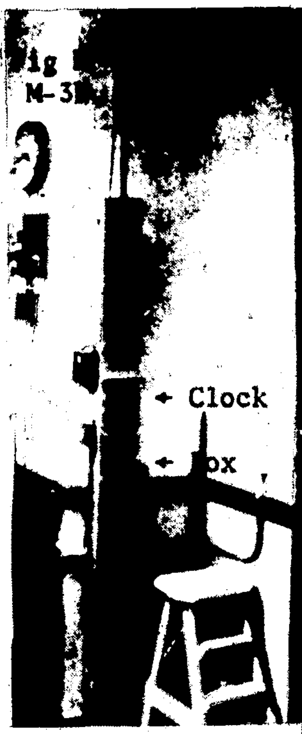
M-3a The truck shown in Fig M-3a is accelerated by the gravitational force on a 50-100 gram mass with the aid of two pulleys. The distance and the time are read and the acceleration is calculated by the equation: $x = 0.5\ at^2$.

M-3b Acceleration Due to Gravity

This apparatus is a permanent setup in one corner of the lecture room. An electromagnet holds a small steel ball near the ceiling of the room. A switch turns off the magnet and starts the clock at the same time. When the ball hits a small box, which may be set at several different levels, the clock stops. The distance that the ball falls is measured with a meter stick and the time is read to the nearest 1/100 second. The acceleration due to gravity is then calculated by the equation: $y = 0.5\ g\ t^2$.



M-3c Duff's Plane



A steel ball has a period of about 0.6 seconds in the Duff's plane shown in Fig M-3c. The plane is covered with chalk dust. Then one end of the plane is raised about 2-3 inches and the steel ball is allowed to roll down the plane with the vibrating period of about 0.6 second. The acceleration of the ball down the plane may be calculated from measurements of the distance traveled by the ball during each oscillation.

M-3d Wire and Car

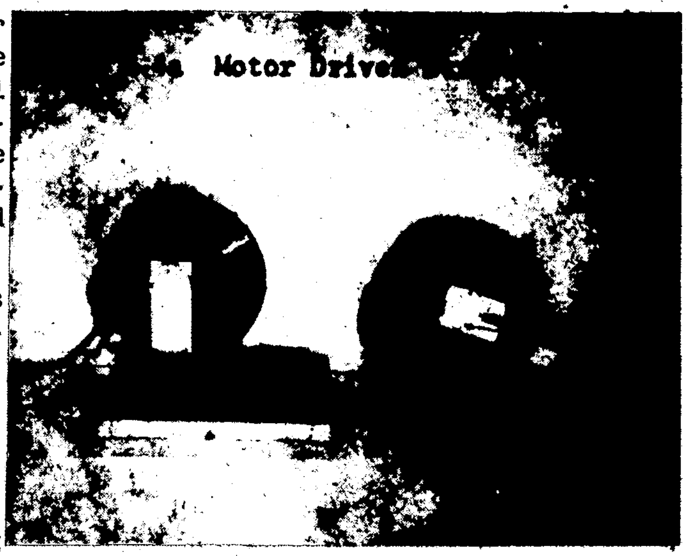
A wire about 6 meters in length is stretched tightly across the blackboard as shown in Fig M-3d. A small car with low friction wheels is allowed to roll down the wire. Marks one meter apart along the wire are made on the board.

A student operates the lecture room clock and observes the time for the car to accelerate through one meter. This is repeated for 2 meters, 3 meters, 4 meters, and 5 meters. The acceleration is then calculated and the results compared with the theoretical value: $a = g \sin \Theta$, where Θ is the angle the wire makes with the horizontal.

M-3e The Air Track

The method of obtaining the acceleration of a car moving down an inclined plane may also be done with an air track as shown in Fig M-3e. A 0.01 second clock and a scaler are available for the meas-

urement of the time. A meter stick is used to measure the distances. The experimental value of the acceleration obtained is compared with the value obtained from the formula: $a = g \sin \Theta$ as explained in the previous demonstration.

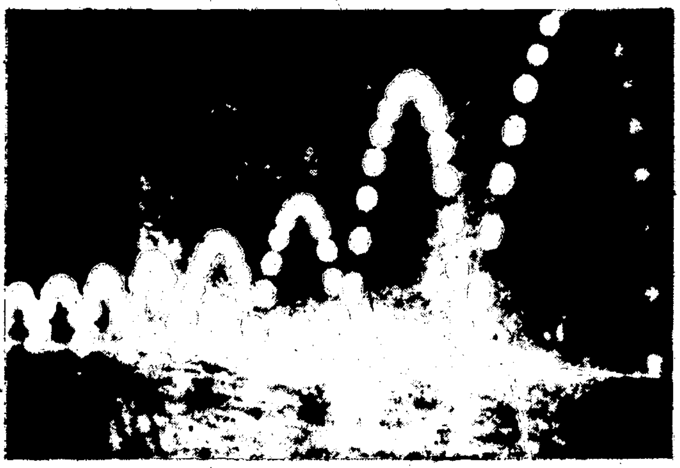


The technique involved in this and the previous two experiments has been described as diluting gravity.

M-4 STROBOSCOPES

M-4a Motor Driven Stroboscopes

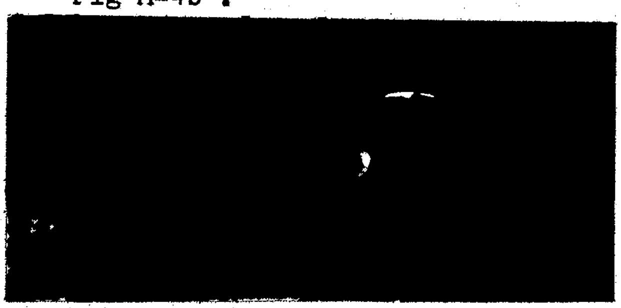
Another method of measuring time and motion in velocity and acceleration experiments is to use a stroboscope. Two motor driven units are shown in Fig M-4a. They run at a constant angular velocity; however, the number of slots in the wheel may be varied.



A photograph of a bouncing ping-pong ball taken with a Polaroid camera through one of the motor driven stroboscopes is shown in Fig M-4a*. Sharper images of the ball may be obtained when using the stroboscope shown in Fig M-4b.

M-4b Electronic Strobe Light

The General Radio Strobe shown in Fig M-4b is useful for the experiments already presented on the measurement of velocity and acceleration. It has value in experiments with the air table and air track. It is also useful when measuring angular velocities as shown in Fig M-4b*.



M-5a The Feather and the Coin

Fig M-5a Feather and the Coin

In air, the acceleration due to gravity appears to be less for a feather than for a coin; however, in a vacuum the acceleration due to gravity appears to be the same for both objects and they will be seen to fall together. This is a familiar demonstration and may be presented with the long glass tube shown in Fig M-5a. The vacuum pump is a permanent installation under the lecture table.

M-6 NEWTON'S FIRST LAW OF MOTION

M-6a The Tablecloth Experiment

Most students have tried to pull a cloth from a table without moving a plate or dish. This procedure may be demonstrated by pulling back on a spring, then releasing it so as to hit a piece of cardboard upon which is a steel ball. The force of the spring on the card moves it quickly, but the ball remains in place.

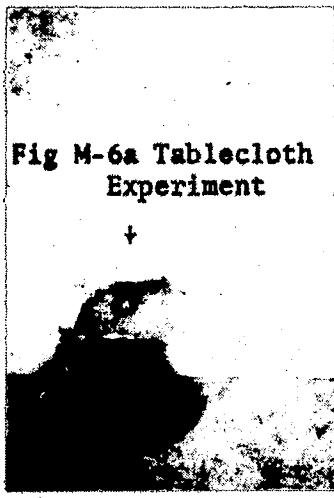


Fig M-6a Tablecloth Experiment

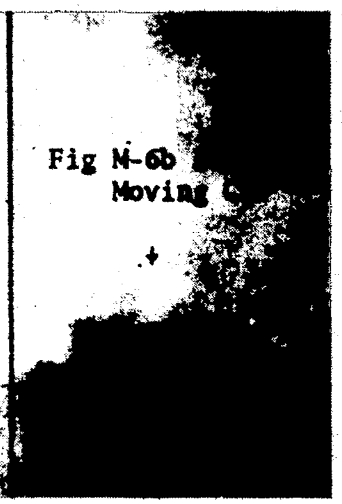


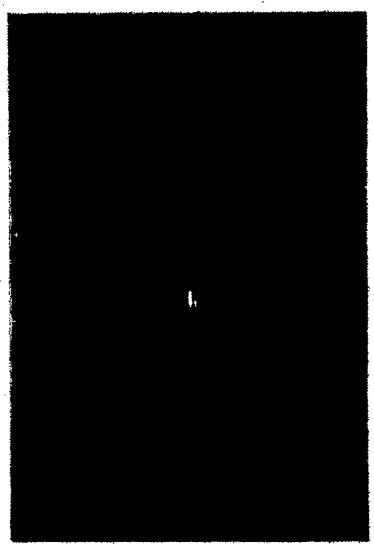
Fig M-6b Moving

M-6b Ball and Moving Car

A steel ball in a car moving at constant velocity is projected upward while in motion. The ball follows a path above the car and then returns to the car as shown in Fig M-6b.

M-6c Water Hammer

Water is enclosed in a vacuum bulb. When the bulb is lowered rather fast, the falling water strikes the bottom with a click, and sounds as if hit with a solid.



M-6d A Body at Rest

This figure shows two small masses suspended by a small string. The string both above and below the 100-gram mass is the same. When a sharp jerk is given the lower mass, which string breaks? This is another demonstration of Newton's First Law of Motion.

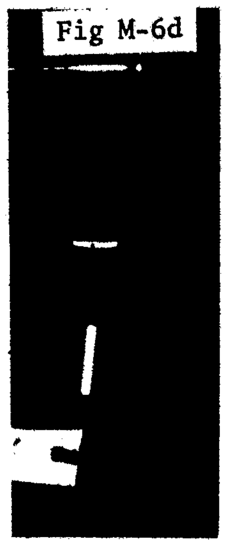


Fig M-6d

M-6e Hit the Nail on the "Head"

Another demonstration of the First Law is to have a student hold a large book on his head. Then have another student place a 2-inch board on top of the book and drive a nail into the board.

M-7 NEWTON'S SECOND LAW OF MOTION

M-7a An Acceleration Experiment

The apparatus shown in Fig M-7a consists of a toy truck with the original wheels removed and replaced with two front axles from a bicycle. This reduces the friction. A string is attached to the truck, through two pulleys to a small mass. This force accelerates the truck across the laboratory table for about 150 cms. The time is observed and the acceleration is calculated.

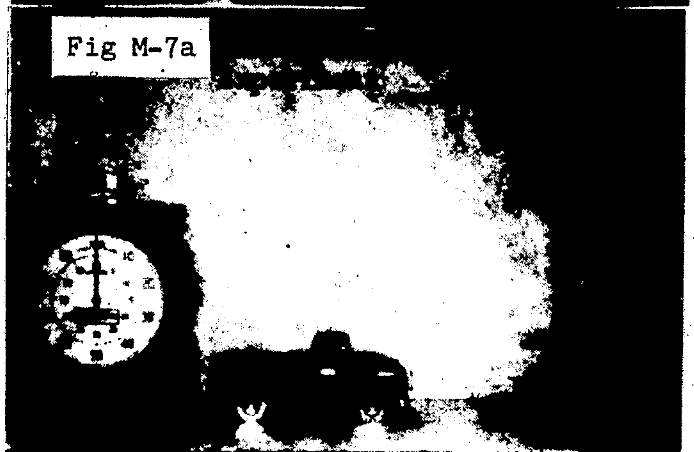
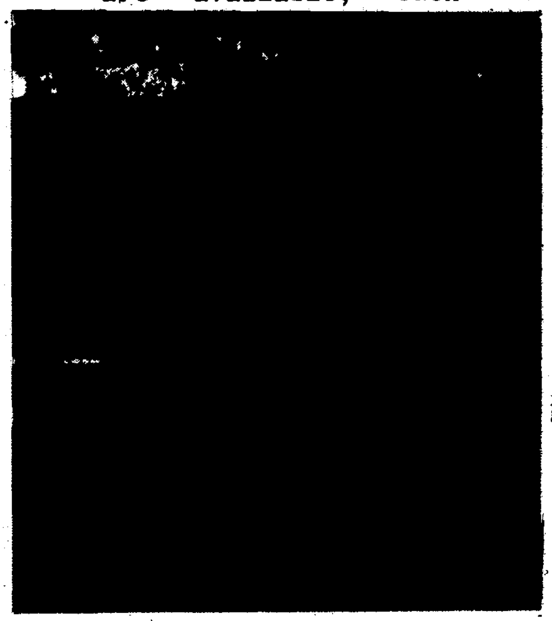


Fig M-7a

M-7b Another Acceleration Experiment

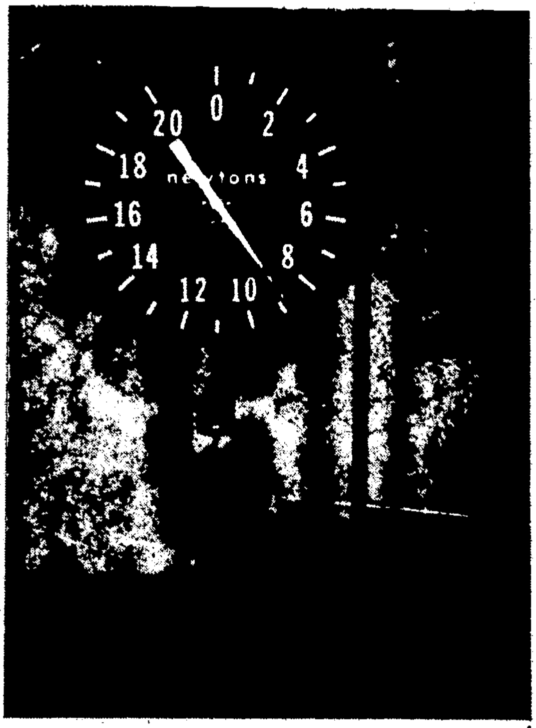
A similar experiment to M-7a may be done using an air track. This is shown in Fig M-7b. Better results may be obtained since friction is less and more accurate timing devices are available, such as a scaler with photo-detectors or a special circuit for starting and stopping the 1/100 second clock.



M-7c The Atwood Machine

The Atwood machine demonstrates an application of Newton's Second Law. An "air" pulley with low friction is mounted about 6 feet above the floor. Two 500-gram masses are attached to the ends

of a long string which pass over the "air" pulley. A small mass (about 50 grams) is added to one of the 500-gram masses, and the acceleration is observed over a distance of 2 meters. The time for the 2-meter trip is measured by the clock, and the theoretical value of the acceleration is compared with the experimental value obtained.



M-8 NEWTON'S THIRD LAW OF MOTION

M-8a Forces Exist in Pairs

Fig M-8a llustrates Newton's Third Law. The 900 grams of mass is equal to 8.82 newtons as indicated on the scale.

M-8b Train on a Circular Track

An electric train on a circular track illustrates Newton's Third Law. The train is moving counter clockwise and the track is moving clockwise as seen in Fig M-8b.

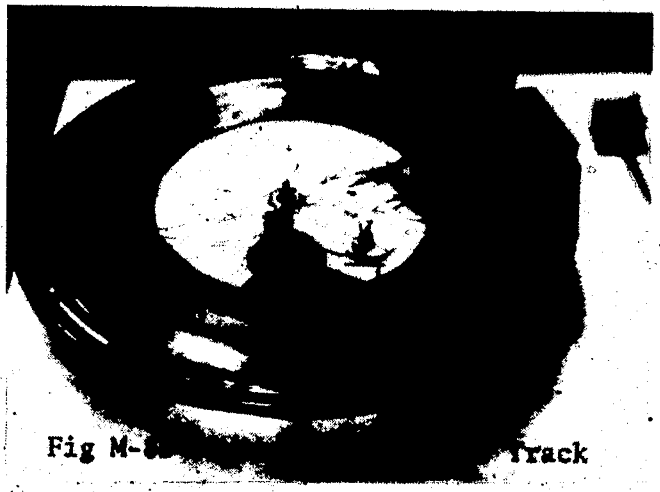


Fig M- Track

M-8c Mass Under Spring Tension

Fig M-8c shows a small mass attached to a spring and supported on a balance. The mass is pulled down and tied to the base with a string. A lighted match burns the string and releases the mass. What happens to the reading on the balance?

M-8d Falling Water

Fig M-8d shows a funnel above a beaker on a balance. The bottom of the funnel is closed by a rubber washer which is spring-loaded and attached to the upper support with a light string. The funnel is filled with water and the balance is adjusted for equilibrium. A lighted match burns the string. The water pours into the beaker. What happens to the left side of the balance? Does it go up? Down? Stay the same? Watch closely. Explain.

M-8e The Monkey and the Coconut

The brief article below describes this experiment.

Reprinted from AMERICAN JOURNAL OF PHYSICS, Vol. 33, No. 8, 662, August 1965
Printed in U. S. A.

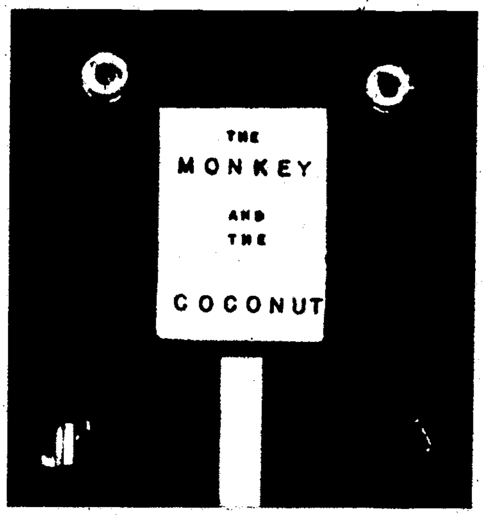


FIG. 1. The monkey and the coconut.

The Monkey and the Coconut: A Demonstration

THE demonstration, The Monkey and the Banana,[1] is similar to the Monkey and Coconut demonstration shown in Fig. 1. Here the yo-yo also represents the monkey, but it is made of steel and was turned on a lathe. The coconut is represented by a piece of steel with a mass equal to that of the yo-yo. The two ball-bearing pulleys[2] have low friction which aid in making an interesting and worthwhile demonstration.

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Liberty, Missouri 64068

[1] R. C. Johnson, Am. J. Phys. 33, 348 (1965).
[2] Central Scientific Company, Catalog J-300, Item 75762.

M-9 NEWTON'S LAW OF UNIVERSAL GRAVITATION

M-9a The Cavendish Experiment may also be done as a class demonstration. The equipment shown in Fig M-9a is permanently located in the lecture room. The beam of light is reflected across the room to a screen which is marked off in 10-cm lengths. The apparatus must be adjusted several hours before attempting to do the experiment.

Fig M-9a The Cavendish Experiment

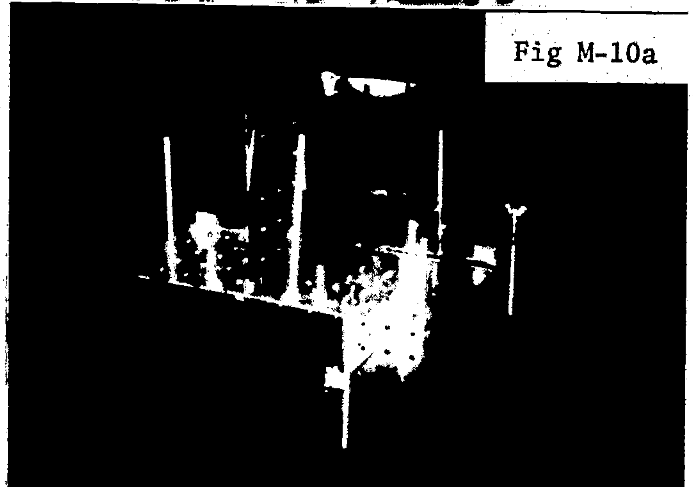


Fig M-10a

M-10 VECTORS

M-10a Vector Model

A three-dimensional vector model is shown in Fig M-10a and is useful as an introduction to the study of vectors.

M-10b Blackboard Vectors

The Chalk-board drafting machine shown in Fig M-10b is very useful in the drawing of large scale vector diagrams on the blackboard. This machine is also very helpful in the teaching of geometrical optics.

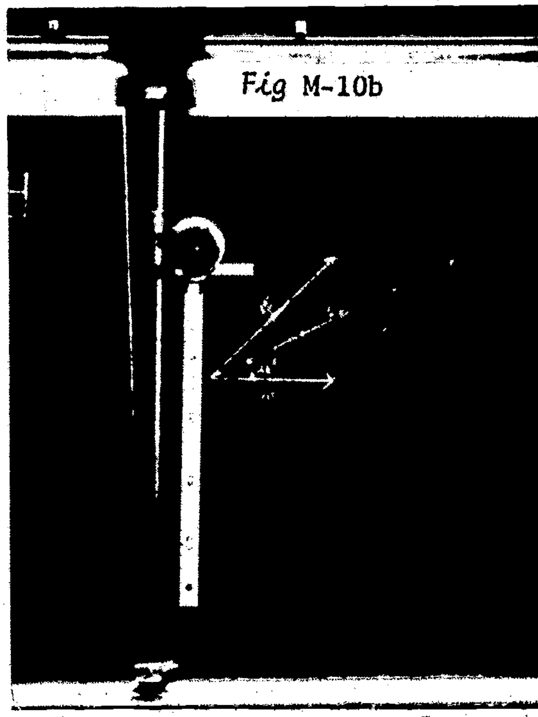


Fig M-10b

M-10c Force Tables and a Torque-Vector Apparatus

Fig M-10c shows three types of apparatus for teaching and demonstrating vectors. The first is the conventional force table, which illustrates that the sum of three (or more) forces in a plane is equal to zero. The second demonstrates that the sum of the forces in three-dimensional space (x-y-z axes) is equal to zero. The third shows that the sum of the torques of a system is equal to zero.

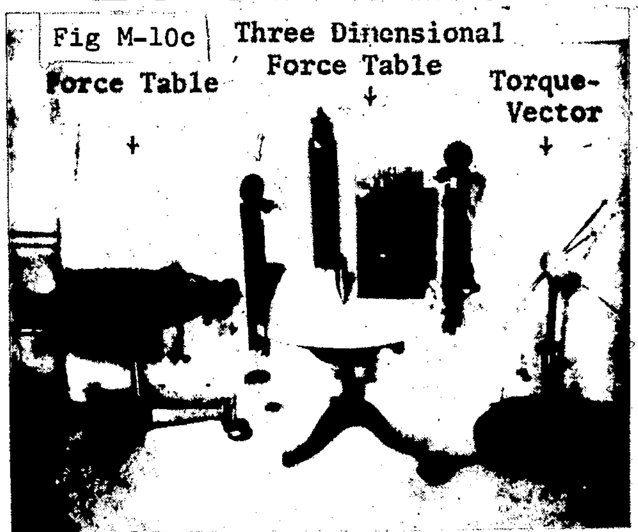


Fig M-10c

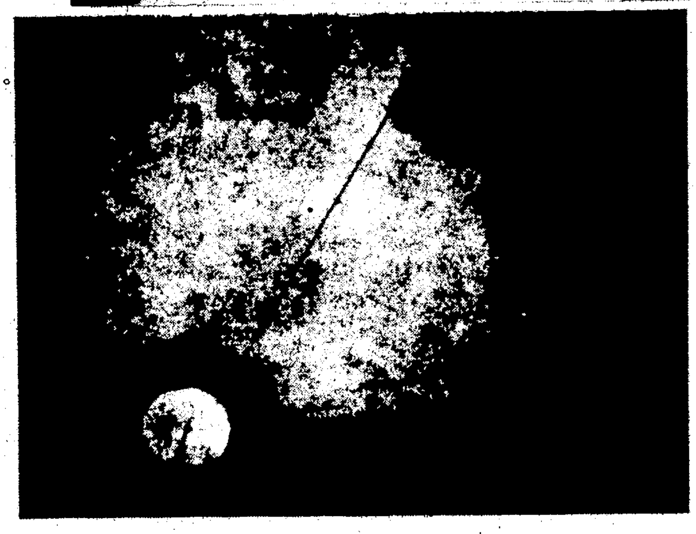
M-10d A Spool That Obeys Orders

A spool that obeys orders is shown in Fig M-10d. A brief paper describing this spool is reprinted below from THE PHYSICS TEACHER, Vol 2, p. 139 (March 1964).

A Spool That Obeys Orders

Wallace A. Hilton
William Jewell College
Liberty, Missouri

A demonstration with a large spool that creates interest in the "physics" involved can be performed as follows. A spool (Fig. 1) with a length of 4″ to 6″ and with diameters d and D that are approximately 3″ and 6″ may be turned on a lathe or made up with wooden cylinders. The dimensions are not critical. If now a ribbon is wrapped around the smaller cylindrical section and pulled in the proper manner (appropriate value of θ) the spool will roll forward, or backward or slide along a table top. While innocently pulling the ribbon at the proper angle one



can give verbal instructions which the spool obeys!

A problem for a class is, "What are the conditions for each behavior of the spool?".

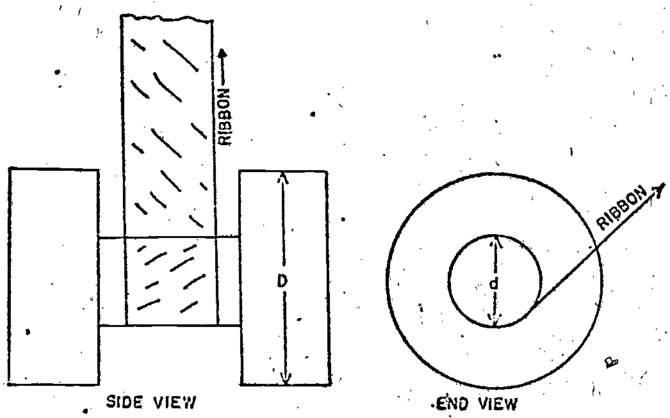


Figure 1. A spool that obeys orders.

The condition for sliding is explained as follows:

$\Sigma F_x = F \cos\theta - \mu N = 0$ (Eq 1)

$\Sigma\Gamma = Fr - \mu NR = 0$ (Eq 2)

Equations 1 and 2 are based on Fig 2 and state that the sum of the forces in the x-direction is equal to zero, and that the sum of the torques is equal to zero.

Now substitute the value of μ from Eq 1 in Eq 2 as follows:

$Fr = (F\cos\theta)R$ (Eq 3)

and $\cos\theta = r/R$ (Eq 4)

Thus for the sliding condition, the cosine of the angle between the string and the horizontal is equal to the ratio of the radius of the axle to the larger radius: r/R.

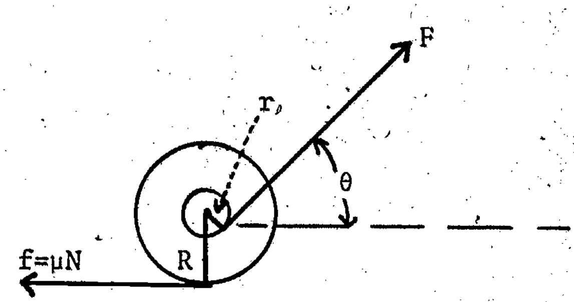


Fig 2 The Spool that Obeys Orders

M-11 FRICTION

M-11a Coefficient of Friction

The apparatus shown in Fig M-11a is useful for the conventional demonstration on the various types of friction: starting, sliding, rolling, etc.

Its best use is for showing the angle of uniform slip and then obtaining the coefficient of either starting or sliding friction by the formula:

$$\mu = \tan\theta$$

where μ is the coefficient of friction and Θ is the angle of uniform slip.

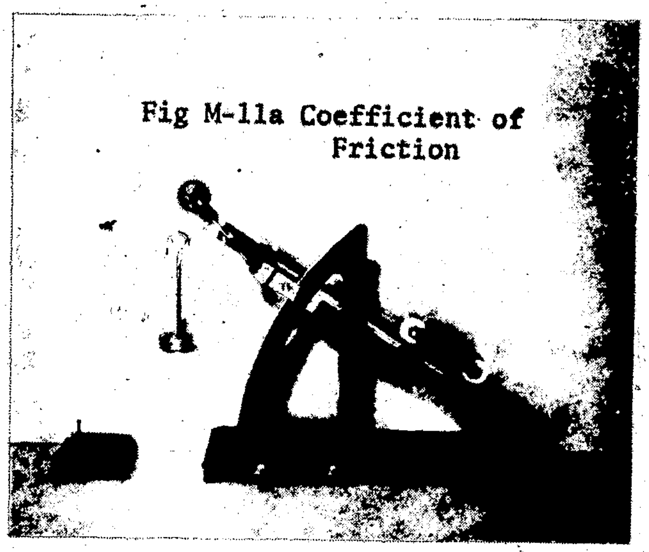


Fig M-11a Coefficient of Friction

M12 FLUID FLOW AND STREAMLINING

M-12a Ball in an Air Jet

One method of demonstrating the Bernoulli principle is to place a ping-pong ball in a jet of air as shown in Fig M-12a.

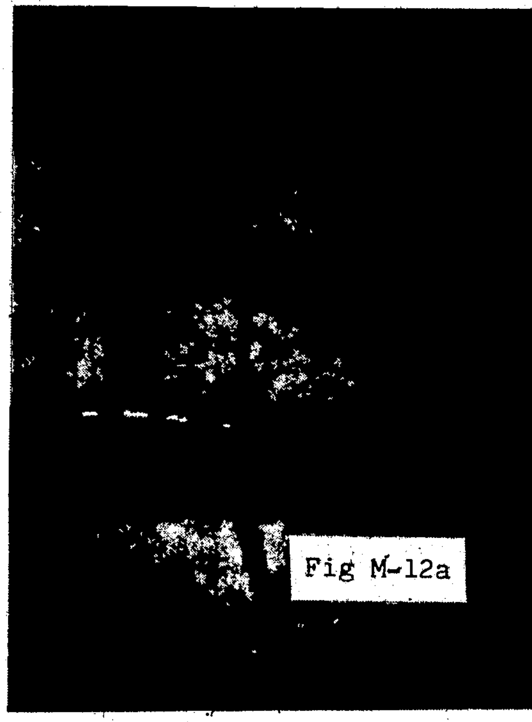


Fig M-12a

M-12b The Blow Tube

Another way to demonstrate Bernoulli's principle is to construct a blow tube with a small spool and a short tube as shown in Fig M-12b. A pin is punched through a small sheet of paper and inserted into the bottom (open) end of the spool. Blowing on the pipe will produce the Bernoulli effect on the top side of the paper, thus holding the paper to the spool. You may have to prove to some students that you are blowing and not sucking.

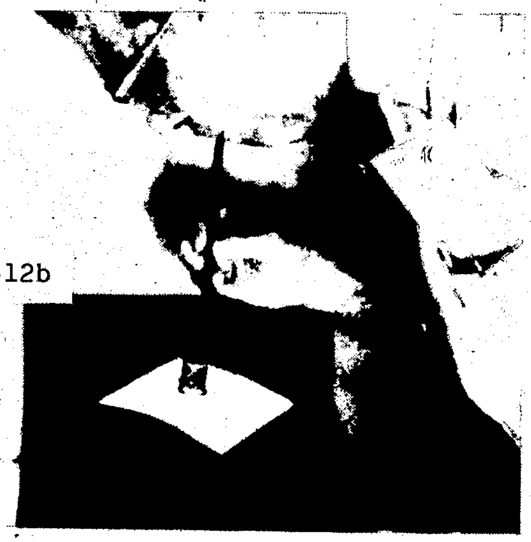


Fig M-12b

M-12c Bernoulli's Principle Apparatus

This apparatus demonstrates the relationship between velocity and pressure in a stream of air. Manometers are located at 4 different places along the tube and the pressure is compared with the velocity of the air stream at these points.

Compressed air from the outlet on the lecture desk is used for the demonstration.

Care must be used in adjusting the air pressure in order to keep the liquid in the manometers.

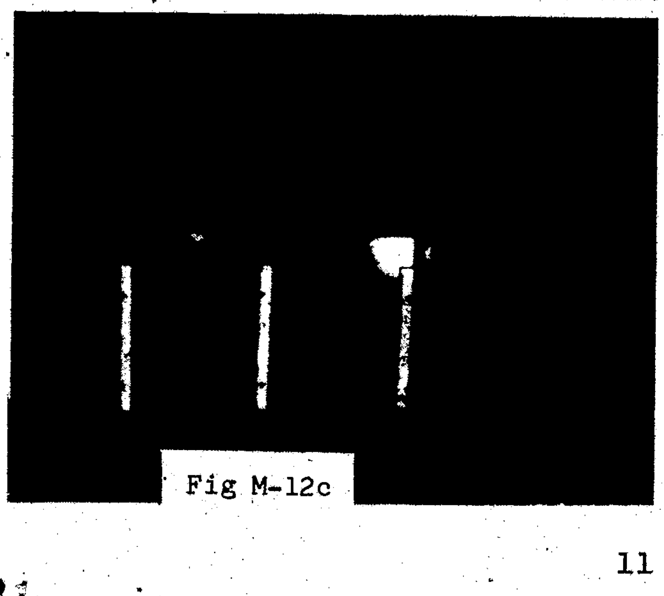
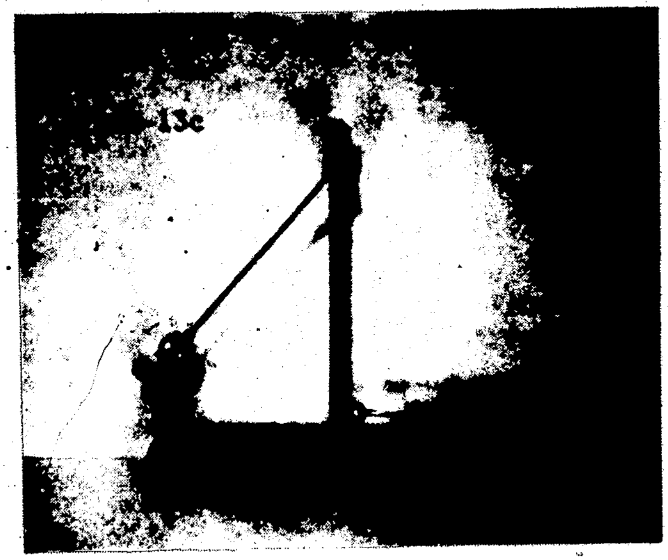


Fig M-12c

M-13 PROJECTILE MOTION

M-13a Shooting the Monkey

The familiar "Monkey and Hunter" experiment may be demonstrated with the items shown in Fig M-13a. The tin can represents the monkey, and the tube with ball bearing is the blow-gun. The can is held by an electromagnet which is about 7 ft. above the floor. The gun is pointed at the can. An electrical switch turns off the electromagnet as the ball leaves the gun. The ball hits the can. The required 6 volts is on the lecture desk and the electromagnet and wire are permanently installed in the room. It is a "must" demonstration and is easily set up.

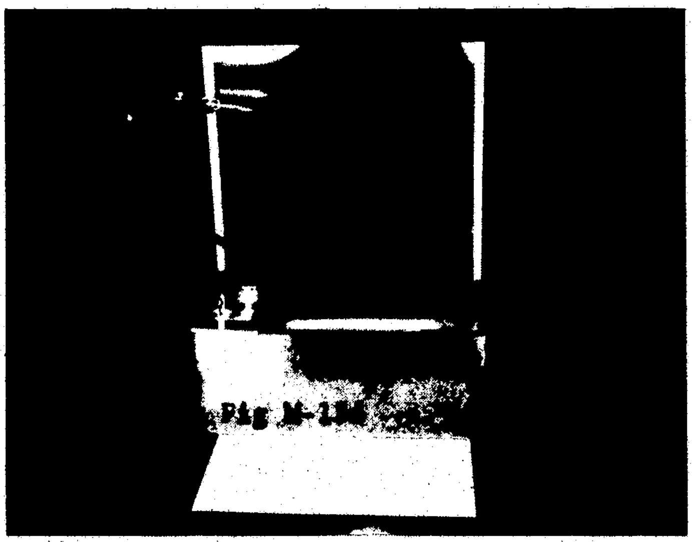


M-13b Falling Ball and a Horizontally Projected Ball

Fig M-13b shows apparatus to project a ball horizontally at the same instant that another ball falls vertically. Both hit the floor simultaneously.

M-13c Spring-Gun Ballistic Pendulum

The apparatus shown in Fig M-13c is useful for determining the initial velocity of a projectile by use of a ballistic pendulum.



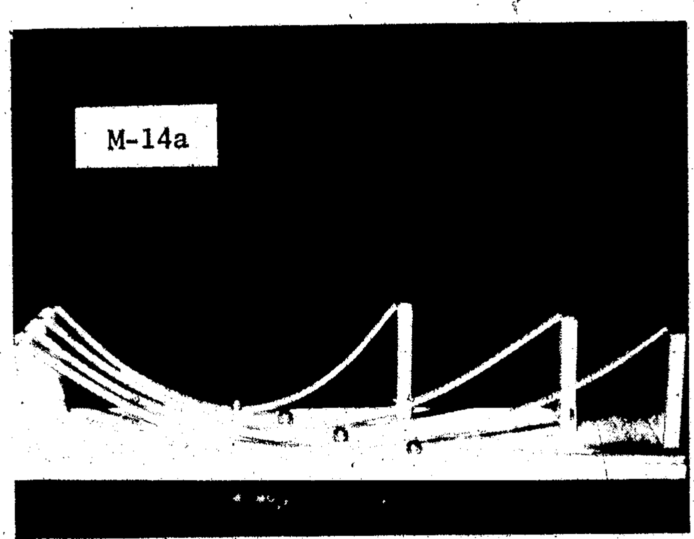
M-13d Water Drop Parabola Demonstrator

This apparatus demonstrates the parabolic path of a water jet. The individual drops will appear to stand still when using the GR stroboscope shown in Fig M-4b. Proper adjustment of the stroboscope may also cause the drops to appear to move slowly in either direction.

M-14 CONSERVATION OF ENERGY: WORK AND POWER

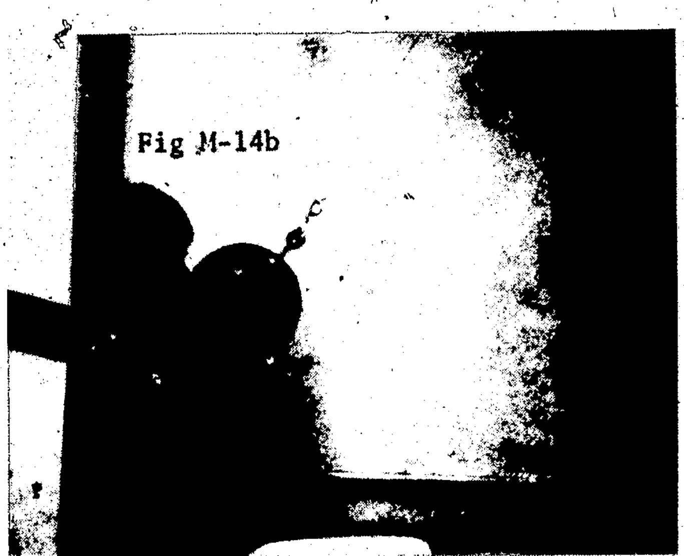
M-14a Conservation of Energy (1)

Three curved tracks are shown in Fig M-14a. A steel ball is placed at the top of each track and each rises to about the same height at the other end of the track (neglecting friction and rotational energy). On the fourth track, the ball has all kinetic energy as it continues to roll on the level track.



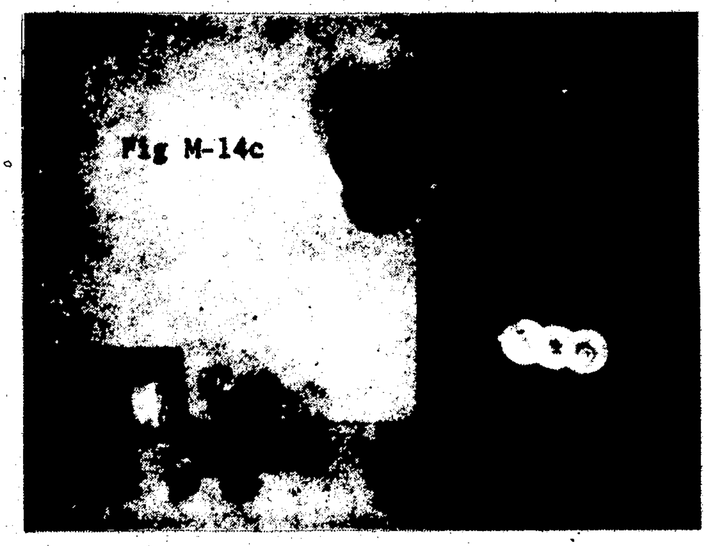
M-14b Conservation of Energy (2)

A similar experiment is to hang a heavy bowling ball by a heavy string to the ceiling. Have a student hold the ball at the tip of the nose and then let it swing. This is a test of the student's belief in the law of conservation of energy. The student should be advised not to push the ball, but just to let it go.



M-14c Gears, Wheel, and Axle

Fig M-14c shows the PIC-Kit (M304A) for demonstrating torque, gear trains, etc., and a wheel-and-axle.



M-14d Pendulums

Fig M-14d shows three pendulums: one a 66-cm rod, the second a 99-cm stick pivoted at 66 cms from the lower end, and the third a steel ball supported by a string, with the length of the string plus the radius of the ball equal to 66 cms. The period of the first and second pendula are compared to the third. Then the 99-cm stick is pivoted at one end and its period compared to the period of the simple pendulum. The experimental values may be compared to the theoretical values.

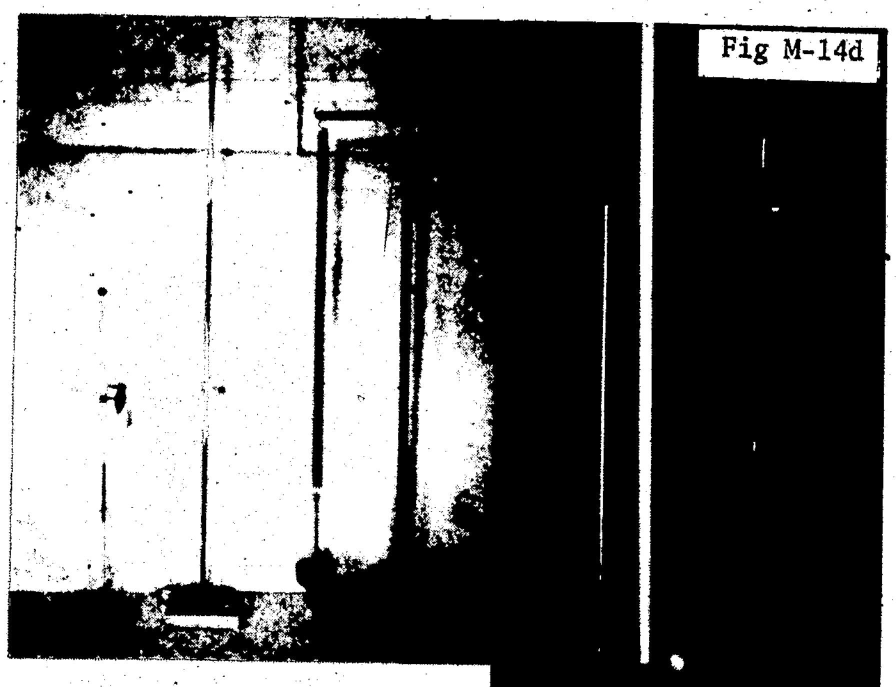
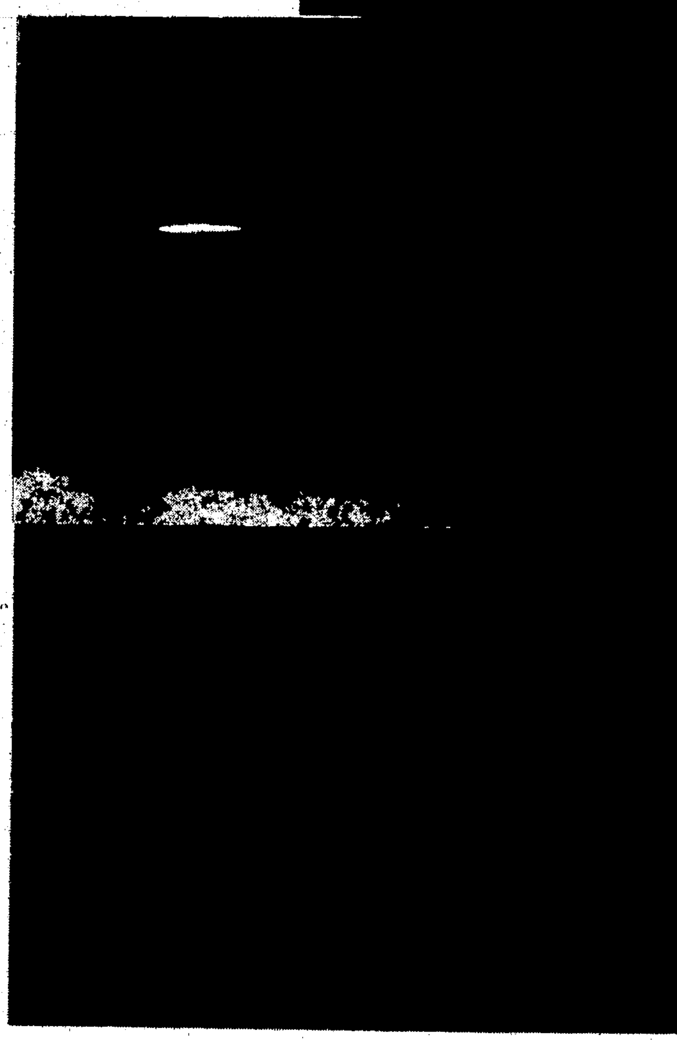


Fig M-14d



M-14e Conservation of Energy Toy and an Oscillating Mass on End of Spring

Fig M-14e shows a toy bird that has been lifted to the top of a smooth rod and thus given potential energy = mgh. The toy is made so that the bird slowly slides down the rod, giving up energy to friction and to sound energy as the bird pecks on the rod. The bird also picks up kinetic energy. It's an instructive toy. Also shown in this Figure is a student-made unit, except that the bird is replaced by a loaded spring which slowly slides down a taller rod.

This figure also shows a mass on the end of a spring which is useful for demonstrating conservation of energy, transfer of energy (kinetic to potential, etc), and simple harmonic motion.

M-14f Other Types of Pendulums

Shown in Fig M-14f is a "Variable G Pendulum" which demonstrates the change in period with change in the acceleration due to gravity. The effective value of g changes as the plane of vibration moves through an angle μ. Also shown in the figure are two Wilberforce's pendulums, one of which is much larger than the other.

M-14g Rotational Harmonic Motion (Welch)

In this experiment the potential energy stored in a spring is used to produce rotational harmonic motion and to study angular momentum and moment of inertia.

M-15 MOMENTUM

M-15a Introductory Demonstrations

Fig M-15a presents five pieces of equipment for demonstrating the conservation of momentum: (1) Two steel balls of equal mass supported by two strings; (2) five steel balls; (3) six pool balls held by strings; (4) V-trough with six steel balls in arrangement to roll balls down an inclined plane; and (5) air-gun with wooden block (with paraffin center) for determining the velocity of a bullet from the gun.

M-15b Bowling Balls

This demonstration consists of two bowling balls for a momentum demonstration.

M-15c Conservation of Momentum

This experiment consists of a long board (with stops on each end) which is balanced near the center on two small 1" x 1" x 12" boards. Two spring-loaded cars, each holding one or more bricks, are placed at the center of the board. The springs are released, the cars move in opposite directions, and the board stays balanced, thus demonstrating the conservation of momentum. The experiment may be repeated with 2 bricks on one car and one brick on the other.

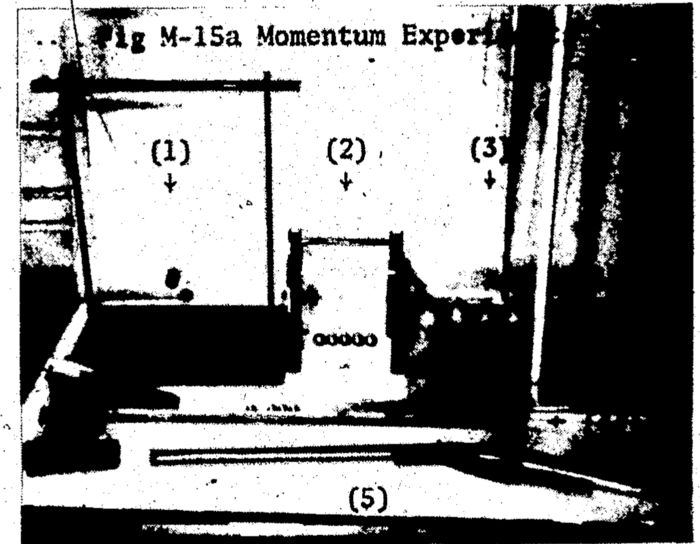
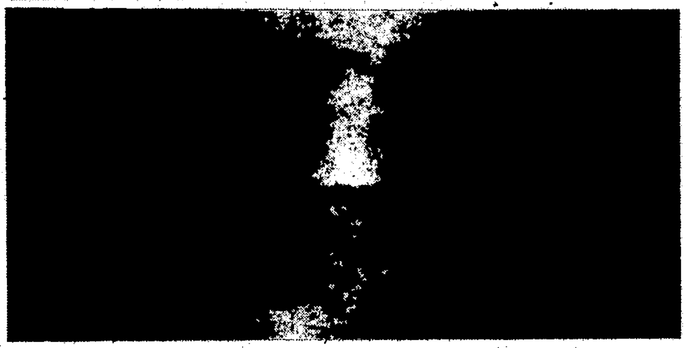
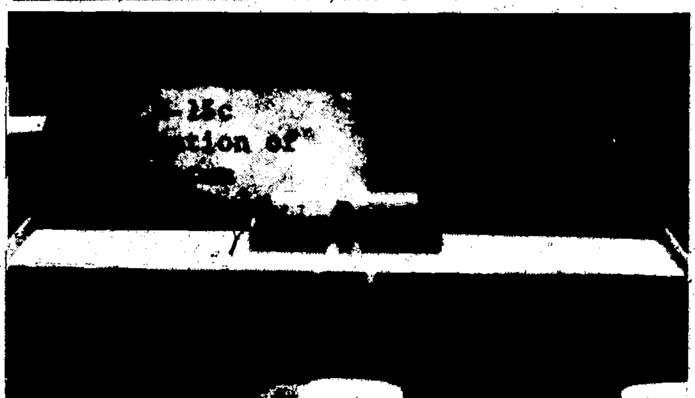
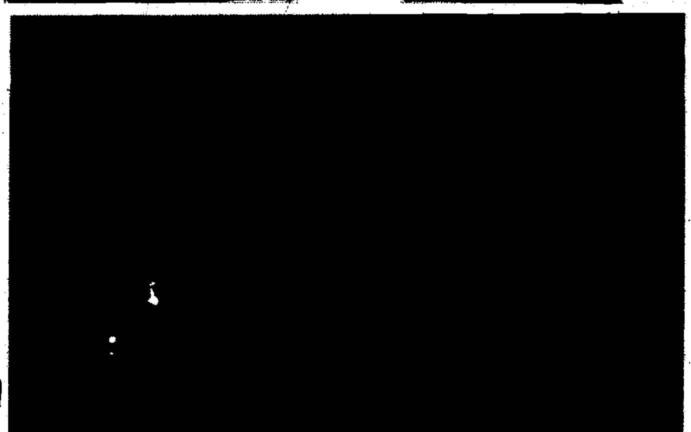


Fig M-15a Momentum Experi







M-15d "Dry-Ice" Pucks

Three "dry-ice" pucks to be used on a plate-glass-covered table in the lecture room are available for collision demonstrations.

M-15e Air Track Experiments

1. Fig M-15ea shows an air track with two cars of equal mass. The one on the right is approaching the one on the left, which is stationary. After impact, Car 2 moves at about the same velocity as Car 1 did before impact, thus demonstrating the conservation of momentum. The Ealing xenon strobe was used at a frequency of 10 Hz.

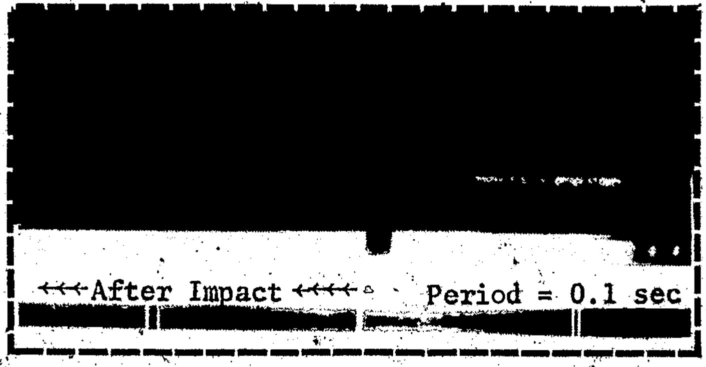
2. Fig M-15eb shows the acceleration of a car down an inclined air track. The strobe frequency was 10 Hz. The acceleration of the car may be calculated. A meter stick may be seen below the strobe data. (Ealing Air Track & Strobe).

M-15f Air Table Experiments

Two experiments are shown using an Ealing Air Table and Strobe. A Polaroid camera is also shown (Fig M-15f)

1. A conservation of momentum experiment is shown in Fig M-15fa. Here an air puck with reflector moves across the table and strikes another puck. From the record it is possible for the student to calculate the momentum before and after impact.

2. Angular acceleration may be calculated from the data shown in Fig M-15fb. A mass of 100 grams is attached by a string (over a pulley) to a 1630-gram solid disk of 15 cm radius. The theoretical angular acceleration may be calculated and compared to the experimental value. The strobe frequency was 10 Hz.



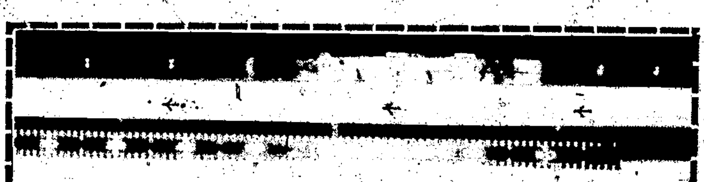
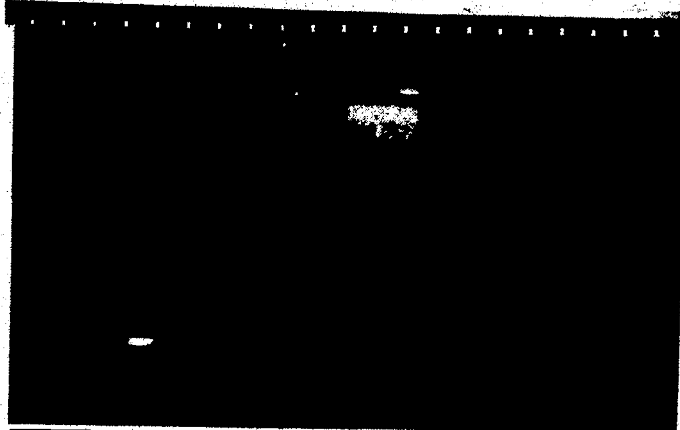


Fig M-15eb Acceleration Down an Air Track



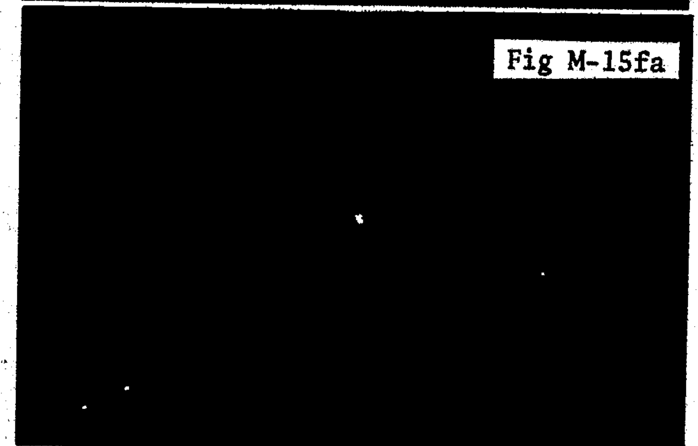


Fig M-15fa

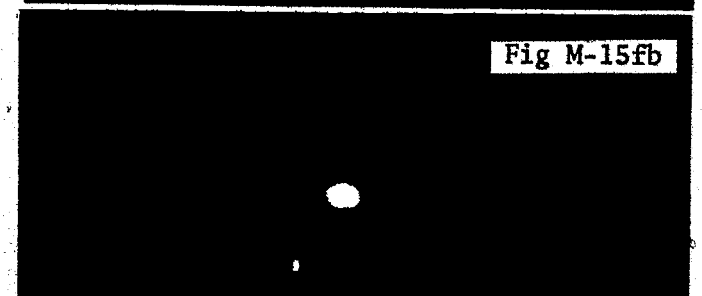


Fig M-15fb

M-15g Moving the Air Track and the Air Table

Our air track and air table are usually kept in a laboratory but are easily moved to the lecture room as described in the following brief article reprinted from the AMERICAN JOURNAL OF PHYSICS, Vol 36, March 1968.

Moving the Air Track

AN air track[1-2] with its many attachments is a useful, but bulky, piece of equipment to move around the laboratory and from classroom to laboratory. This transportation problem can be made much easier by the construction of a table with space for the air source and open shelves for the attachments. The table is then mounted on four large rubber swivel castors.[3] Such a table with air track and various attachments is shown in Fig. 3. One of the values of

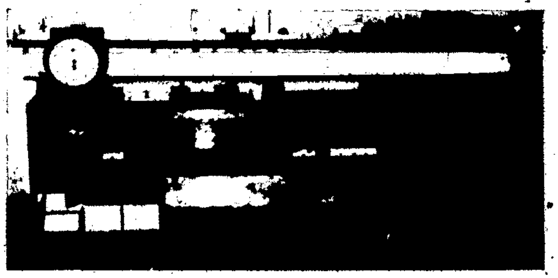


FIG. 3. Air-track table.

such an arrangement is that the air track, blower, and attachments for doing various experiments and demonstrations are kept together and easily moved from the laboratory to the classroom.

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[1] The Ealing Corporation, Cambridge, Mass. 02140. Item No. 33-000.

[2] Macalaster Scientific Co., Waltham, Mass. 02154. Item No. 11000.

[3] Direct Systems Corporation, 539 Ellicott Street, Buffalo, N. Y. 14203. Item No. 3-046.

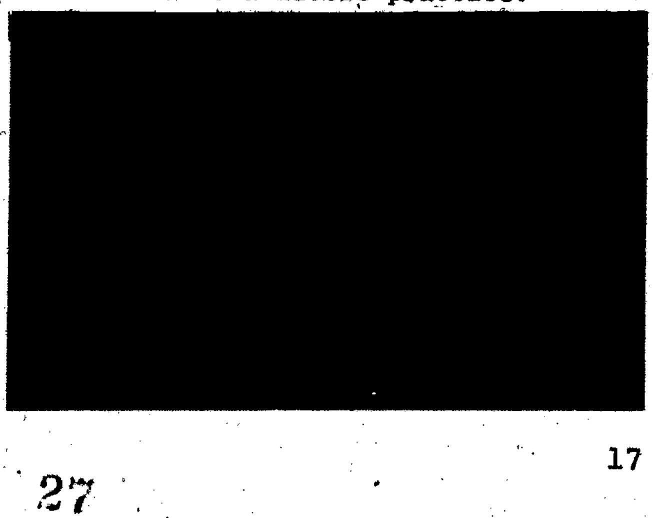
M-16 CIRCULAR MOTION

M-16a Demonstration of the Radian

A large wheel about 3 feet in diameter is carefully divided into 6 60° angles, shown in Fig M-16a. It is mounted on a ball-bearing axle and attached to a stand. A string is used to mark off radii along the circumference, thus demonstrating that there are 2π radians in a circle.

M-16b Circular Motion

Three devices are shown which may help to demonstrate circular motion: (1) The rotation of a small chain causes it to form a circle; (2) A loop-the-loop; and (3) A coat hanger. For (3), place a dime on the base and rotate the hanger about your first finger. It takes a little practice.



M-16c Circular Motion (1)

Fig M-16c shows three demonstrations on circular motion: (1) Two jars filled with water have two corks tied by strings to the base. The jars are connected by a metal bar and set on a small car. When the car is given a quick push, the balls move forward. (2) The jars are now moved to another stand and rotated about their center of mass. The balls now move toward the center. (3) A small circular chain is placed around a wheel which is attached to a motor drive. At full speed the chain is forced off the wheel and moves across the table (or floor) in a circle for several feet before collapsing.

M-16d Circular Motion (2)

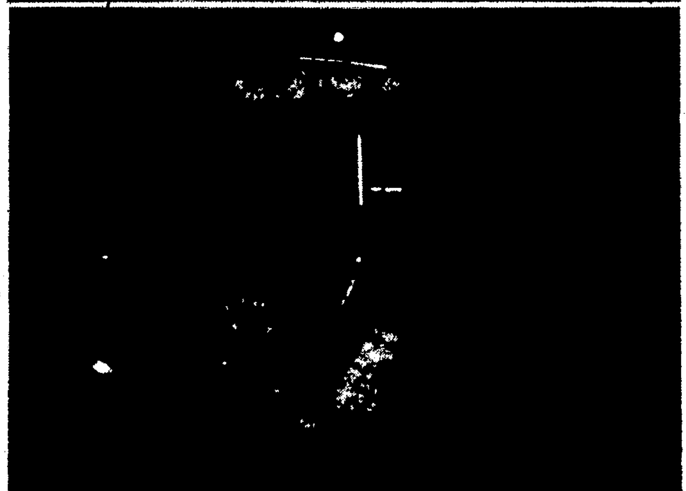
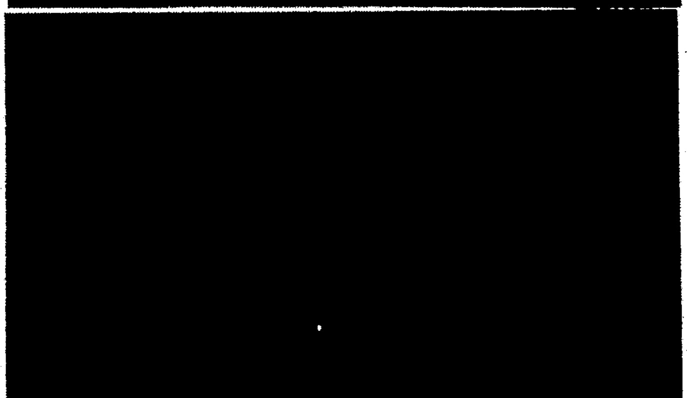


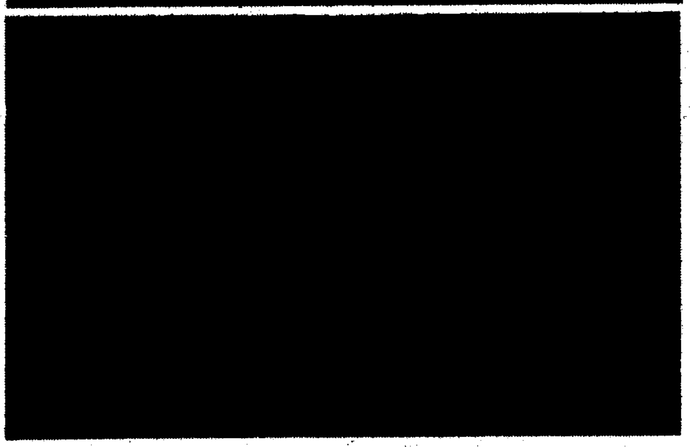
Fig M-16d also shows three demonstrations on circular motion: (1) The semicircular tube is filled with water with a spherical cork floating at each end. When rotated, the corks move down the tube. (2) Lighted candles in plastic cylinders are rotated about their center of mass. The flame moves toward the center. (3) Water, a cork, and a steel ball are placed in a circular dish and rotated. The student is asked to predict what happens.

M-16e Circular Motion (3)



Centripetal force apparatus, which is usually used as a laboratory experiment, is shown in Fig M-16e.

M-16f Circular Motion (4)



A Cenco Watt's governor is shown with valve regulating gear. This illustrates an application of centripetal force. As the angular speed increases, the valve closes.

M-17 KEPLER'S LAWS

M-17a Construction of an Ellipse

An ellipse may be constructed by using two nails, a string, and a pencil as shown in Fig M-17a.

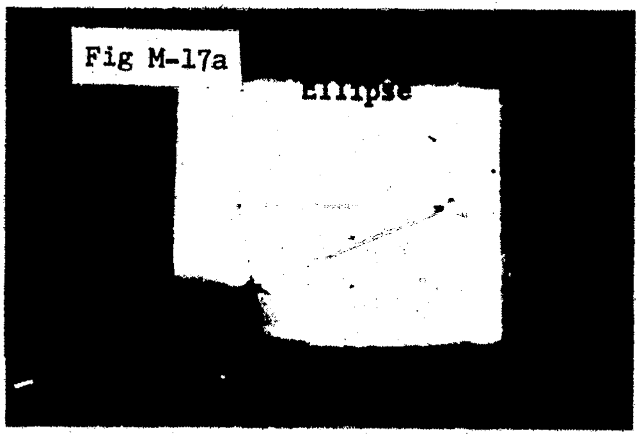


Fig M-17a

M-17b Elliptical Path from Air Table Puck (1)

A strong magnet is placed under the air table and a magnetic air puck with pin-point source of light traces an elliptical path as shown in Fig M-17b.

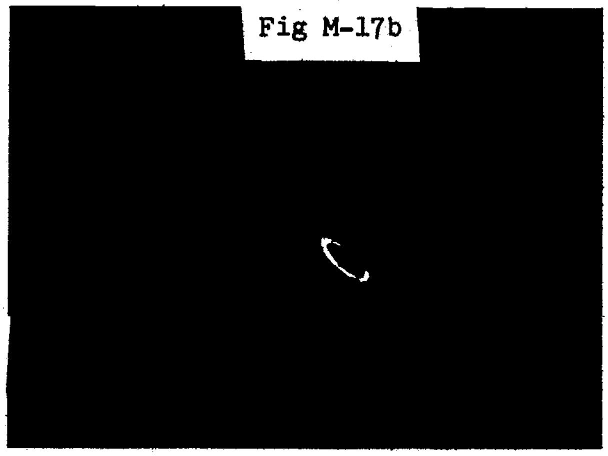


Fig M-17b

M-17c Elliptical Path from Air Table Puck (2)

With a stroboscope the distance traveled during each time interval is recorded on film. This demonstrates that equal areas are swept out in equal time intervals, as shown in Fig M-17c. (See THE PHYSICS TEACHER, Vol 8, pp 244-48.)

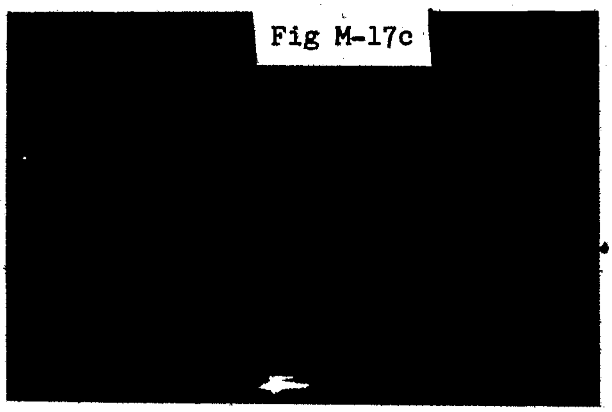


Fig M-17c

M-17d Escape Velocity

After presenting the derivation of the equation for "escape velocity," some teachers and some classes may find it amusing to see a demonstration on "Escape Velocity." The apparatus, shown in Fig M-17d, is placed on he lecture room table before the class enters. The water is poured into the can. THE CAN HAS A SMALL HOLE IN IT AND THE WATER IMMEDIATELY FLOWS INTO A SHALLOW PAN UNDER THE BLACK BOX. The instructor carefully picks up the tin can by the heavy strings attached to it, then carefully starts it swinging in a vertical circle and increases its angular speed to a maximum, then announces to the class that the can (AND WATER) has reached "escape velocity." He then carefully lets it come to rest. Then he turns the can over and no water pours

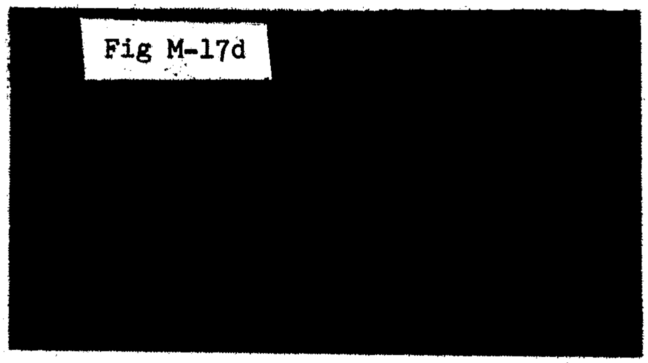


Fig M-17d

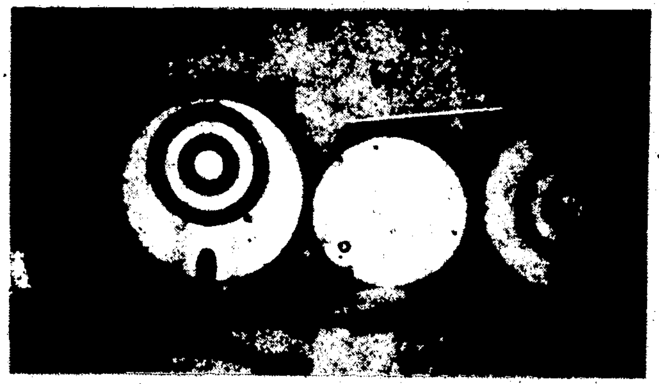
out, THUS DEMONSTRATING THAT ESCAPE VELOCITY WAS ATTAINED. It's a joke but students seem to enjoy this change of pace.

M-18 CENTER OF MASS

M-18a Center of Mass Apparatus (1)

Three pieces of equipment are shown in Fig M-18a: (1) A 50-gram and a 100-gram mass are supported on a meter stick with the fulcrum at the center of mass; (2) A toy horse with rider and lead weight are supported at the center of mass; and (3) A small double-cone-shaped piece of wood appears to roll uphill (however, its center of mass is moving downhill).

M-18b Center of Mass Apparatus (2)



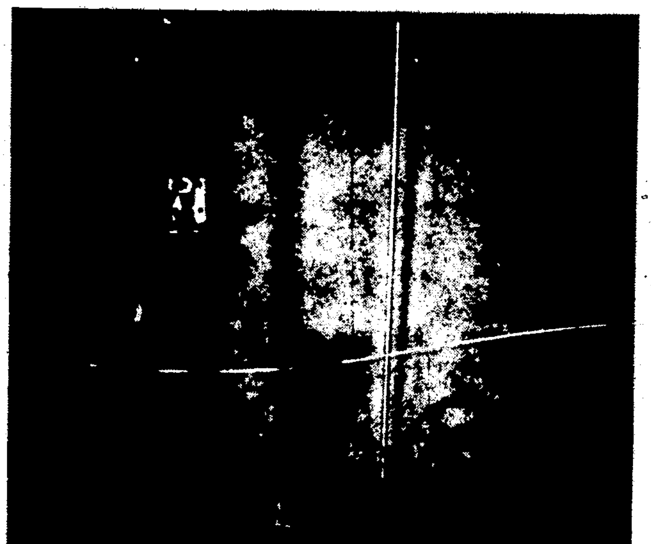
Several pieces of equipment for demonstrating center of mass are shown in Fig M-18b: (1) Leaning Tower of Pisa, (2) three disks with movable and stationary centers of mass, and (3) various smaller items.

M-19 MOMENT OF INERTIA; ROTATION

M-19a Gyroscopes

Six types of gyroscopes are shown in Fig M-19a. They may be used in various ways to demonstrate principles of the gyroscope, including precession and rigidity in space.

M-19b Gyroscopes; Moment of Inertia



Shown in Fig M-19b are (1) two magnetic gyroscopes, (2) Maxwell's Wheel, and (3) ring and disk moment-of-inertia apparatus.

M-19c Moment of Inertia: Ring and Disk

The ring and disk shown in Fig M-19b are placed at the top of an inclined plane. Each has the same mass and, being at the same level, each has the same potential energy. When released, the disk rolls down the inclined plane faster than the ring. Students are asked to predict which will go faster. Their decision should be based on their understanding moment of inertia and the conservation of energy. The result is shown in Fig M-19c.

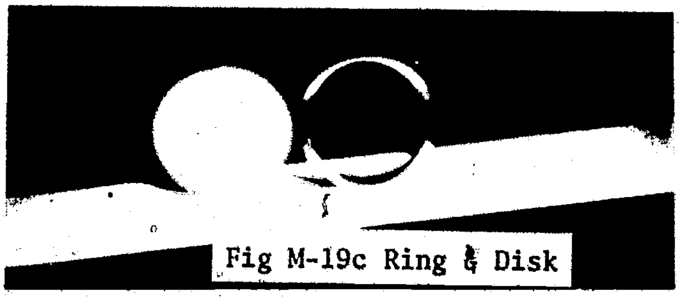


Fig M-19c Ring & Disk

M-19d Simple Foucault Pendulum

Fig M-19d shows a simple Foucault pendulum. When the pendulum is set into vibration and the support is rotated, the pendulum swings in the original plane.

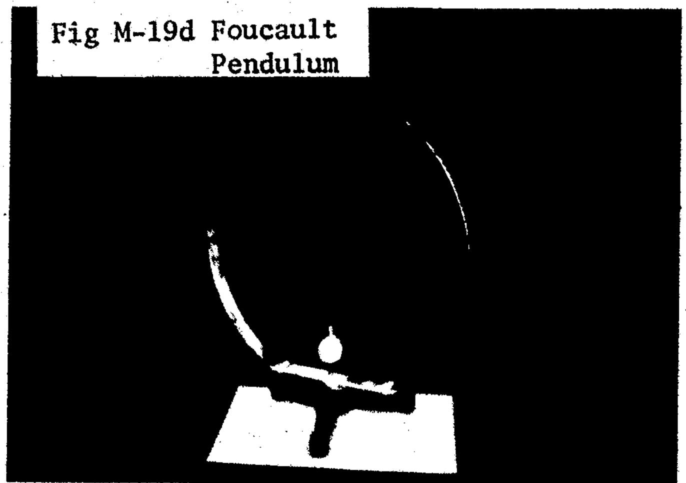


Fig M-19d Foucault Pendulum

M-19e Magnetic-driven Foucault Pendulum

This pendulum is on permanent exhibit as a corridor demonstration and is described by C. L. Strong in SCIENTIFIC AMERICAN, Vol. 210, Feb. 1964, pp 132-139.

Fig M-19e

M-19f Precession (1)

A bicycle wheel wrapped with No. 9 iron wire serves as a gyroscope for a student on a pivoted stool. When the gyroscope is raised overhead, the student rotates through 90°. Lowering the gyroscope to its original position causes rotation in the other direction. This is an example of precession. See Fig M-19f.

M-19g Precession (2)

The gyroscope, made from the front wheel of a bicycle, is placed on a ball-bearing

pivot at the top of a ring stand. The gyroscope then precesses about the vertical axis.

M-19h Precession (3)

Probably the cheapest way to demonstrate precession is to cut a circle from a piece of cardboard, then drive a nail through its center and into the end of a small stick. Placing a finger (or light force) at any point on the rotating disk will cause it to precess. (See Fig M-19a [-2])

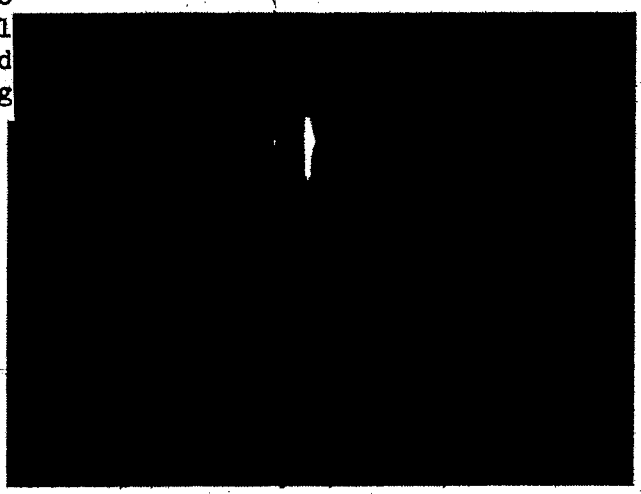
M-19i Conservation of Angular Momentum

The conservation of angular momentum may be demonstrated by having a student sit on a stool pivoted on ball bearings and hold weights in the outstretched hands. While rotating slowly, bring the hands (with weights) in toward the body. The angular velocity increases, consistent with the equation

$$I_1\omega_1 = I_2\omega_2.$$

M-19j Elasticity and the Coefficient of Restitution

Fig M-19j shows these items: (1) three rubber balls of various degrees of elasticity, (2) "silly" or "bouncing" putty, (3) coefficient of restitution apparatus, (4) carborundum and two Bologna bottles, and (5) several Prince Rupert Drops. Items 4 and 5 are helpful in demonstrating the surface tension of glass.



M-19k Free Fall Paradox

The apparatus for demonstrating a free fall paradox is shown in Fig M-19k. Its explanation involves several principles from mechanics and is described in the following brief paper which is reprinted from THE PHYSICS TEACHER, Vol 3, Oct. 1965, pp. 323-324.

M-19k, Free Fall Paradox, continued

Free Fall Paradox

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THE "Falling Chimney"—Free Fall Paradox[1] in which a ball is placed at one end of a uniform stick which is pivoted at the other end and making an angle of about 30° with the horizontal may serve as an interesting demonstration on torque, angular acceleration and moment of inertia.[2] In the demonstration, the elevated end of the stick is released and the ball drops into the cup which is located as shown in Fig. 1.

If the stick is uniform and one may neglect the mass of the cup, the moment of inertia of the stick about the lower end is

$$I = 1/3\,mL^2 \qquad (1)$$

where m is the mass of the stick, and L is its length. The acceleration of the moving end of the stick is given by

$$a = L\alpha \qquad (2)$$

where α is the angular acceleration. The torque, T, on the stick is

$$T = I\alpha = \frac{L}{2} mg\cos\theta \qquad (3)$$

where g is the acceleration due to gravity and θ is the angle the stick makes with the horizontal. This decreases as the stick falls.

Substituting the value of I from Eq. 1, and α from Eq. 2 into Eq. 3, one finds that the acceleration of the *falling end* of the stick along the tangent of its path is given by

$$a = \frac{3}{2} g\cos\theta \qquad (4)$$

and the *vertical component* of this acceleration is

$$a_v = 3/2\,g\cos^2\theta. \qquad (5)$$

Thus the end of the stick has a greater acceleration downward than the ball only when $\cos\theta$ is greater than $\sqrt{(2/3)}$ or when θ is about 35° or less.

[1] R. M. Sutton, *Demonstration Experiments in Physics*, McGraw-Hill, 1938, page 89.

[2] P. A. Constantinides, *Experiments on Torque, Angular Acceleration, and Moment of Inertia*, Am. Jour. Phys., Vol. 7, 254-57.

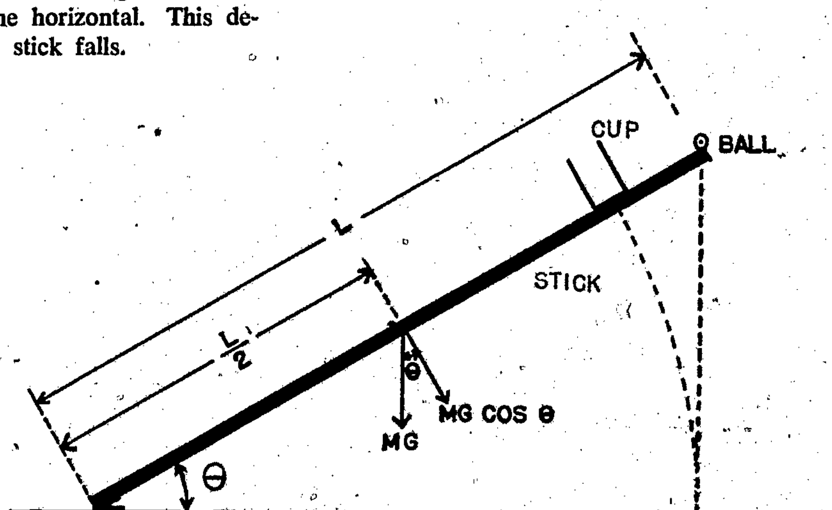

Figure 1. Arrangement of ball, cup and stick in order to demonstrate the free fall paradox.

M-191 The Conical Pendulum

The following paper is reprinted from AMERICAN JOURNAL OF PHYSICS, Vol 31, p 58, January 1963.

Another Version of the Conical Pendulum

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THE construction and use of a conical pendulum has been presented in a recent AAPT Apparatus Committee report.[1] Less shop time is required to construct the conical pendulum shown in Fig. 1. Here the main bearing is made from a front axle of a bicycle wheel. The bearings are placed at each end of a 2-in.-diam aluminum rod, which is 2 in. long. A hole is bored through the center of the axle, through which a vertical string passes to an attached mass.

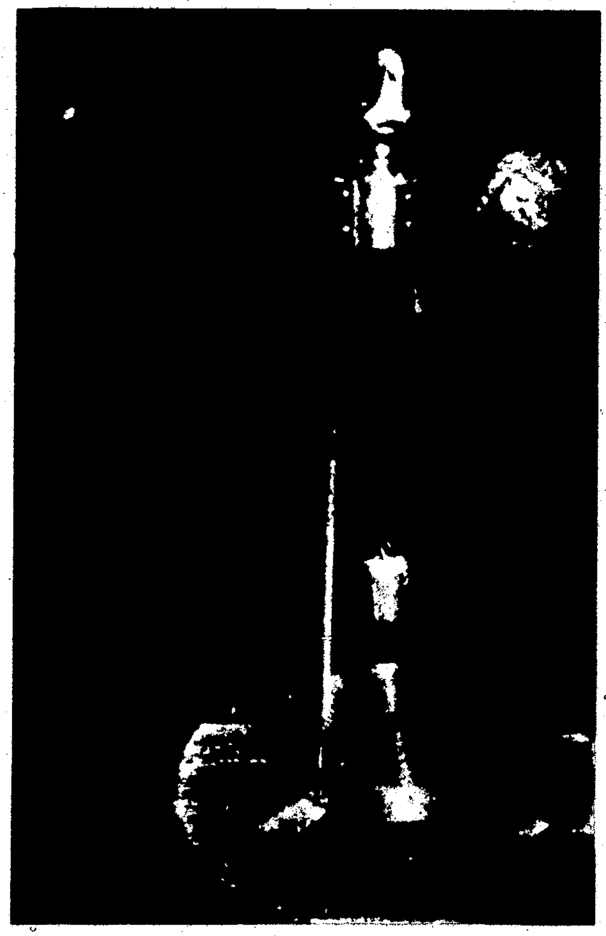


FIG. 1. A conical pendulum with the bearings made from a front axle of a bicycle wheel.

This design of a conical pendulum has proved to be a satisfactory and useful demonstration and laboratory piece for the introductory courses.

[1] R. G. Marcley, Am. J. Phys. 30, 221 (1962).

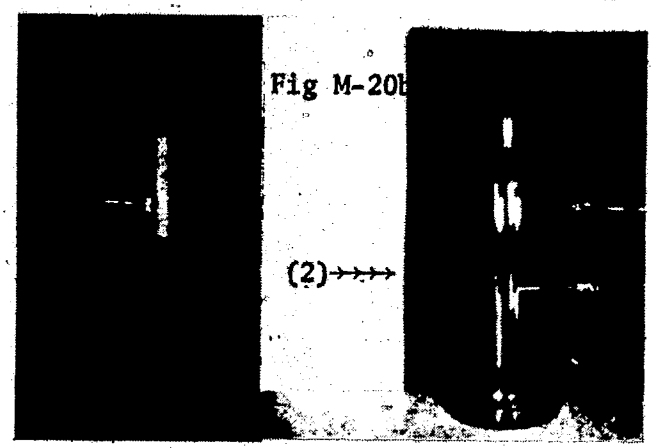
M-20 LIQUIDS AND SOLIDS

M-20a Density

Fig M-20a presents several small pieces of demonstration equipment which are helpful in presenting this topic to beginning students. They are: (1) a siphon, (2) Cartesian diver, (3) demonstration of wood density, (4) salt, two density balls and beaker, (5) frozen paraffin, and (6) a 1-liter cube.

M-20b Pressure

The devices shown in Fig M-20b show that the pressure in a liquid varies with depth: (1) Here a small funnel covered with rubber is lowered into a container of water and the pressure is detected on the manometer which is



connected by a rubber tube. (2) The bottle is filled with water and the change in pressure with depth is observed by the horizontal distances that the three streams are projected in a horizontal direction.

M-20c Archimedes' Principle

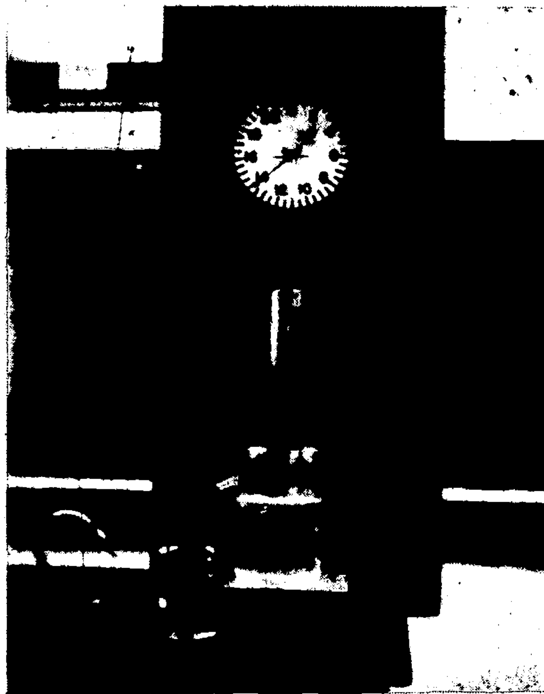
In this demonstration the buoyant force of the water is used to determine the density of a metal cylinder. The volume of the water which overflows is equal to the volume of the cylinder. The four steps in the experiment for demonstrating Archimedes' principle are as follows:

1. The metal cylinder is placed in a cup; the fit is a tight one. The vertical depth of the cylinder is noted. The cup is suspended from one arm of an equal arm balance and weights are added to the other arm until balance is achieved.

2. The metal cylinder is removed from inside the cup and is hung from a hook on the bottom of the cup. The balance is preserved.

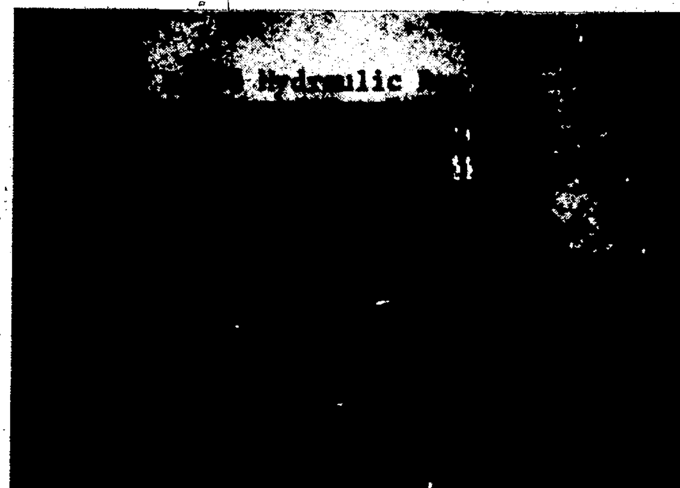
3. A beaker of water is raised until the metal cylinder (not the cup) is immersed. The balance is destroyed.

4. Water is poured into the cup to the same depth as had been occupied by the cylinder. The balance is now restored.



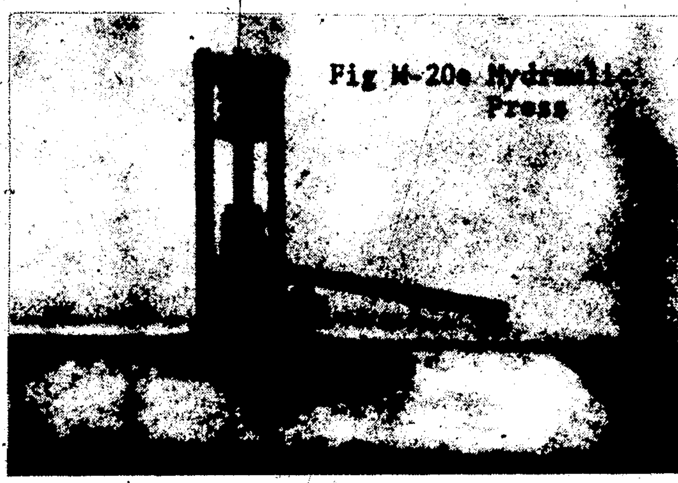
M-20d The Hydraulic Ram

This model of a hydraulic ram shows how water may be caused to rise to a level higher than its source of supply. The apparatus is a little difficult to operate, but with the right touch, it will work.



M-20e Hydraulic Press (Welch)

This hydraulic press develops a 5000-pound force to measure the breaking force on a small board or the compressional force on a large spring as shown in Fig. M-20e.



M-21 SOAP BUBBLES, THIN FILMS, SURFACE TENSION

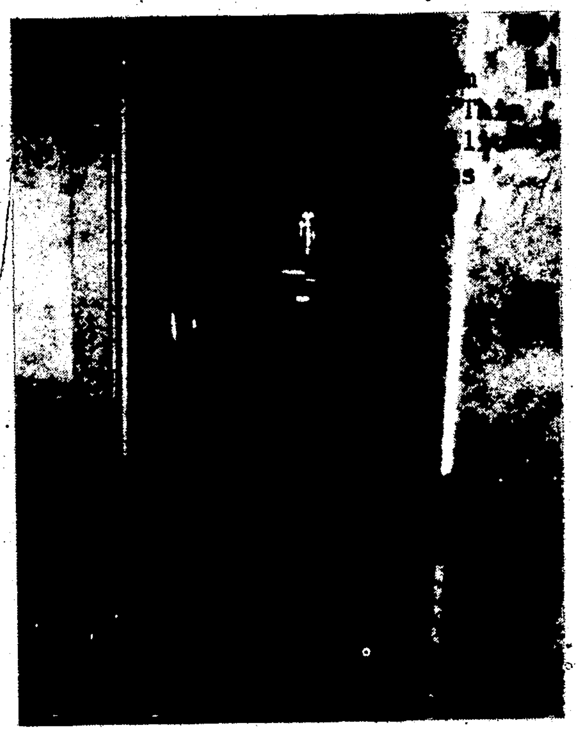
M-21a Surface Tension and Soap Films

The demonstration items in Fig M-21a include a beaker of liquid soap and 8 wire devices for exhibiting thin soap films.

A funnel and two pipes for blowing soap bubbles are also shown. (See C. V. Boys, SOAP BUBBLES, Doubleday)

M-21b Vacuum Deposition of Thin Metallic Films

Those students who plan to major in physics may want to see the vacuum system that is used in the independent study and research program for the deposition of thin metallic films. The system is shown in Fig M-21b.



M-22 GASES AND FLUIDS

M-22a Density of Air

A spherical container is weighed on a balance. The air is then pumped out of the container and it is weighed again. The balance shows a loss of weight of about one gram. The optical system shown makes it possible to project an image of the pointer of the balance on the classroom screen, so the entire class may see that there is a loss of weight when the air is removed.

M-22b Barometers and Magdeburg Hemispheres

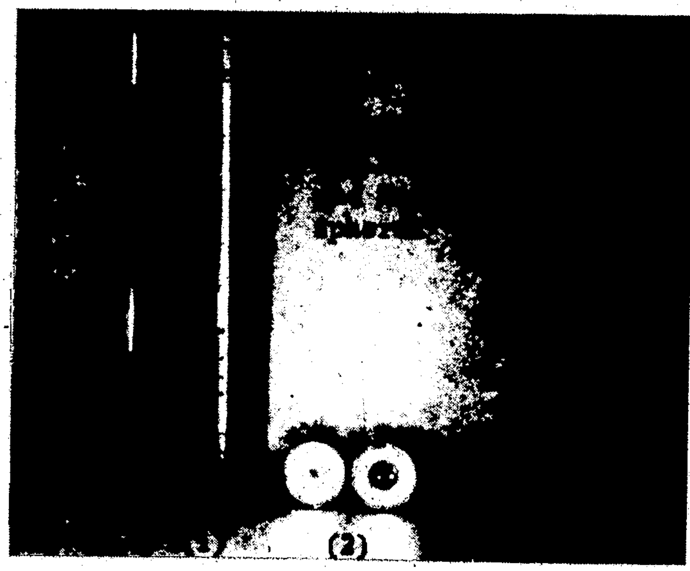
Fig M-22b shows three pressure sensing devices: (1) a mercury barometer with a tall bell jar for reducing the pressure surrounding the barometer, (2) two aneroid barometers, and (3) two sets of Magdeburg hemispheres.

M-22c Buoyant Force of Air (Leybold)

A small mass and a large bulb are suspended in air on a balance. The balance reads zero. The mass and the bulb are placed under a bell jar and the air is removed. The bulb "drops" since there is now no buoyant force due to the air. So, which has the greater mass: a pound of feathers or a pound of rocks? See Fig M-22c.

M-22d Force on an Evacuated Can

Air may be pumped out of a one-gallon paint can and the class will see the can collapse; or the can may be evacuated by putting a small amount of water in the can and heating it to the boiling point as shown in Fig M-22d. A stopper closes the opening. Water is then poured on the can, condensing the steam, and the pressure of the air collapses the can.



M-22e Density of Air and Pascal's Vases

The relative density of hot and cold air is demonstrated by heating one of the cans shown in Fig M-22e, causing the air to expand. Thus some of the air leaves the can and the scale no longer reads zero. Pascal's vases demonstrate that pressure is proportional to the depth of

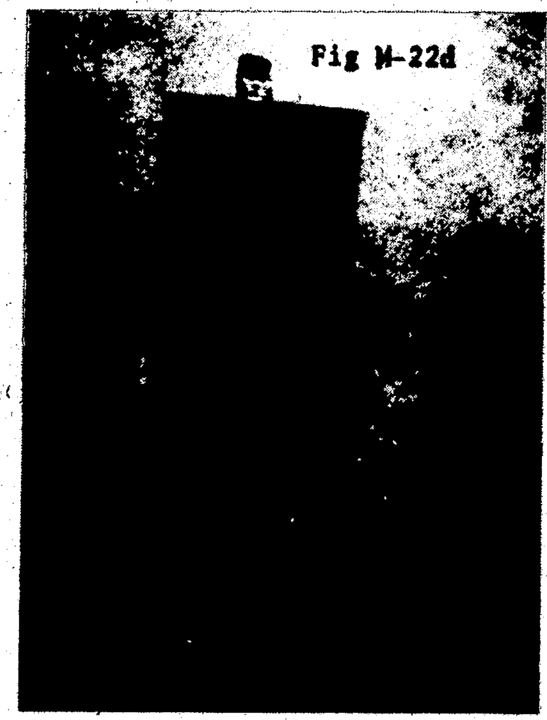


Fig M-22d

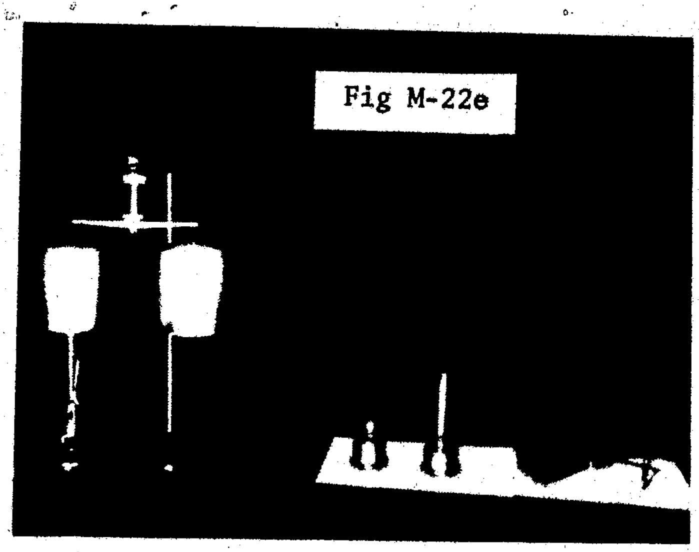


Fig M-22e

the liquid and independent of the volume and area of the surface of the liquid.

M-22f Pumps, Hydraulic Lift

Fig M-22f shows five demonstration pieces: (1) equilibrium tubes, (2) spiral pump, (3) lift pump, (4) force pump, and (5) hydraulic lift.

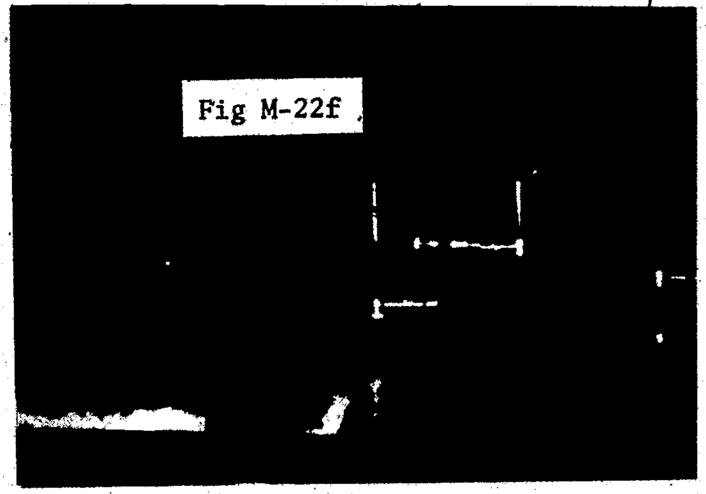


Fig M-22f

M-22g Capillary Apparatus

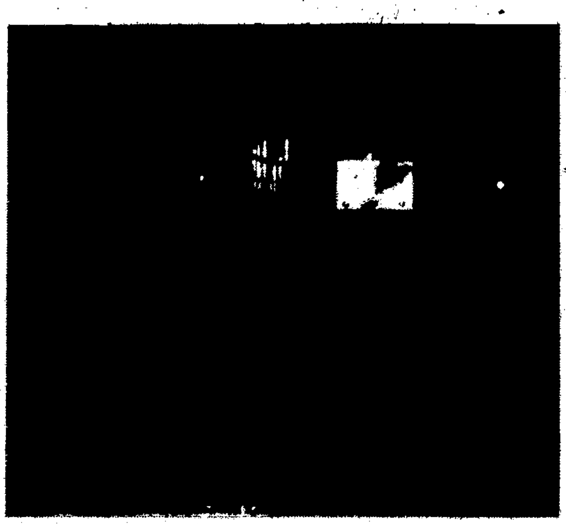
Two pieces of capillary apparatus and a set of capillary tubes are shown in Fig M-22g.

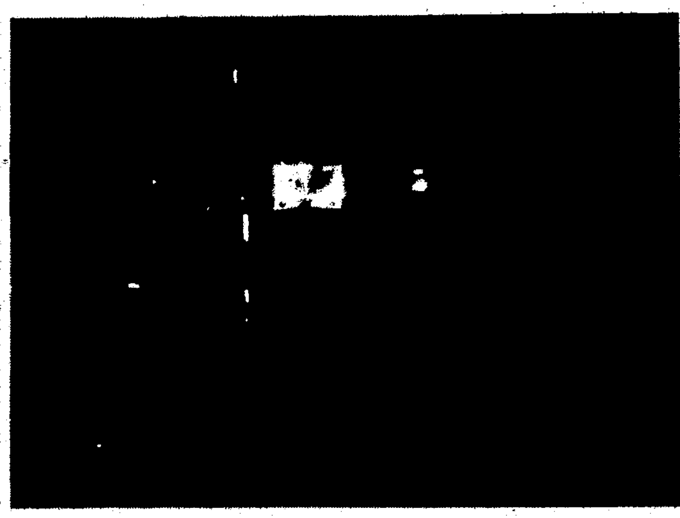
M-22h Capillary Tubes

A set of seven capillary tubes is used with an optical system to project an image of the tubes on the classroom screen.

M-22i Molecules in Motion

An evacuated glass tube contains a small amount of mercury and some small colored glass chips. When the mercury is heated, some of it goes into the vapor state. The molecules of mercury have rather high speeds as indicated by the rapid movement of the colored glass chips. The optical system shown in Fig M-22i makes it possible to project this molecular motion on the classroom screen and it is then easily visible to the entire class.





M-22j Brownian Motion

A small smoke chamber is placed under a microscope. The bombardment of the smoke particles by air molecules is indicated by the random movement of the smoke particles. The apparatus is shown in Fig M-22j.

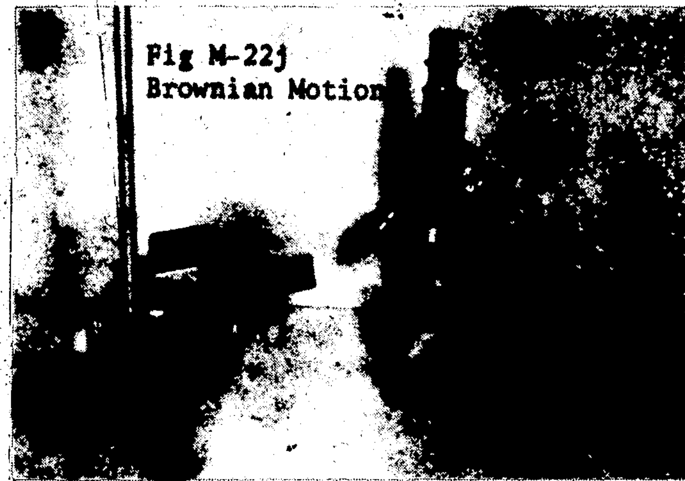
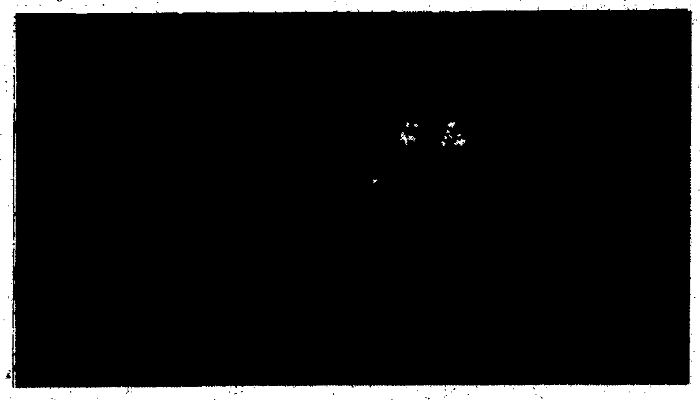


Fig M-22j
Brownian Motion

M-23 WEATHER (Meteorology)

M-23a Relative Humidity

Three types of hygrometers are shown in Fig M-23a: (1) sling psychrometer, (2) wet-and-dry bulb hygrometer, and (3) a dial-thermometer-type hygrometer.



M-23b Mechanical Gas Model and Cloud Chambers

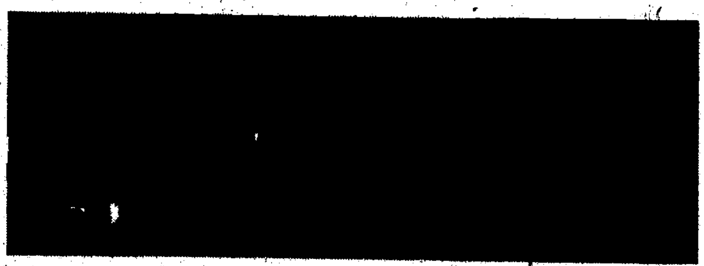
Fig M-23b shows a mechanical gas model (H54C) and two cloud chambers. The larger one consists of a gallon jug with a small amount of water and methyl alcohol in it. In order to have condensation nuclei, a small amount of smoke is introduced into the bottle. A rubber stopper is inserted in the bottle as shown in Fig M-23b. Air is forced into the bottle until the stopper jumps out and a white cloud appears in the bottle due to the cooling by expansion of the air in the bottle.

M-23c Weather Maps

The United States Department of Commerce's Daily Weather Maps are received each week by the physics department and are available to staff and students for use in the classroom and laboratory.

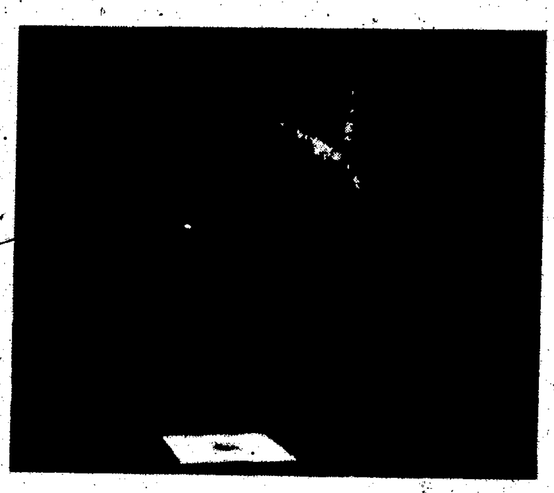
Several large-scale weather maps are available for classroom use. See Fig M-23c.

H-1 TEMPERATURE



H-1a Thermocouples

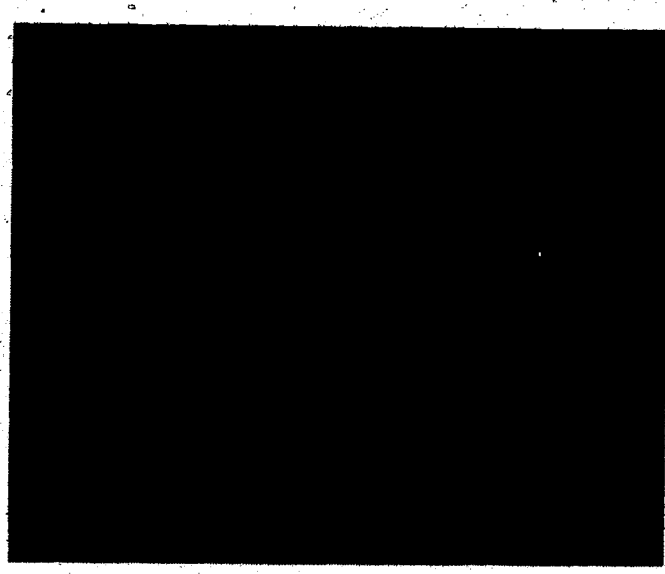
A chromel-alumel pyrometer is the basis for this thermometer which is calibrated from 0°F to 2000°F, and may be used to measure the temperature of the flame from a laboratory burner. Also shown are several iron-constant and chromel-alumel thermocouples which are connected to a galvanometer. Heating the junction of the two metals will cause a deflection on the galvanometer.



H-1b Thermocouple Magnet

A Bunsen burner is used to heat one junction of a thermocouple as shown in Fig H-1b. The thermocouple magnet at the time the photograph was taken was holding a mass of 13 kilograms or about 29 pounds.

H-2 EXPANSION IN METALS AND LIQUIDS



H-2a Equipment shown in Fig H-2a includes: (1) ice bomb, (2) a pulse glass, (3) air thermometer, (4) ball and ring for demonstrating thermal expansion, (5) bimetallic strip, (6) ball and ring, and (7) water thermometer.

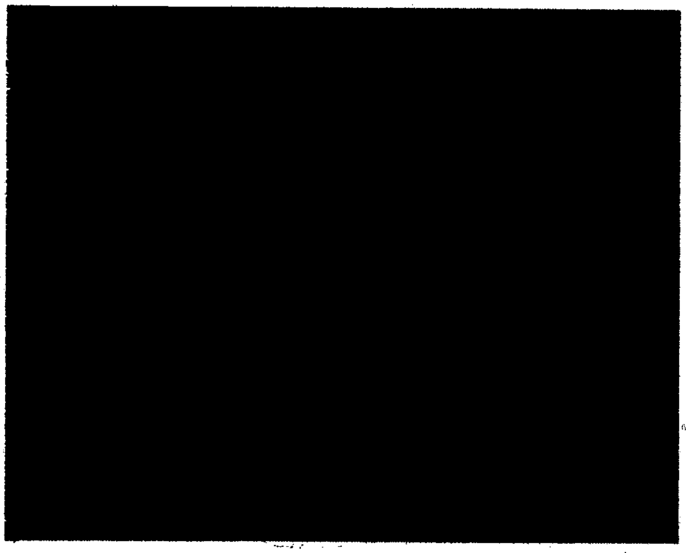
H-2b Linear Expansion

A wire heated by an electric current will expand. In the wire used with the equipment shown in Fig H-2b, a Powerstat varied from 0 to 30 volts A.C. through a 3-ohm resistor will cause a significant change in the length of the wire. If about 26-gauge iron wire is used the recalescence of iron which occurs at the Curie temperature may be observed. (LeRoy Weld, A TEXTBOOK OF HEAT, Macmillan, 1948, pp 378-79.)

H-3 HEAT TRANSFER

H-3a Conduction, Convection, and Radiation

Three simple devices are shown in Fig H-31 to demonstrate conduction, convection and radiation. In the conduction experiment, each of the six cups at the end of the six rods are filled with paraffin. Heat is applied at the center and the melting of the paraffin is a measure of the conductivity of heat. For convection, a candle is lighted under one chimney. Use smoke to demonstrate the convection currents. For radiation effects, a heat lamp is pointed toward the two thermometers. One will show a greater increase in temperature than the other.



H-3b Radiation (1)

At the left in Fig H-3b is a Leybold Radiation screen. On one side is polished metal with a black letter L. The other side is coated with thermochrome paint. The apparatus demonstrates the absorption of thermal radiation. The apparatus on the right in the photograph consists of a radiometer and two pieces of glass, one opaque and the other clear and heat-absorbing. A source of infrared is to the right. The absorption of heat by the clear glass and the transmission of heat by the opaque glass is demonstrated.

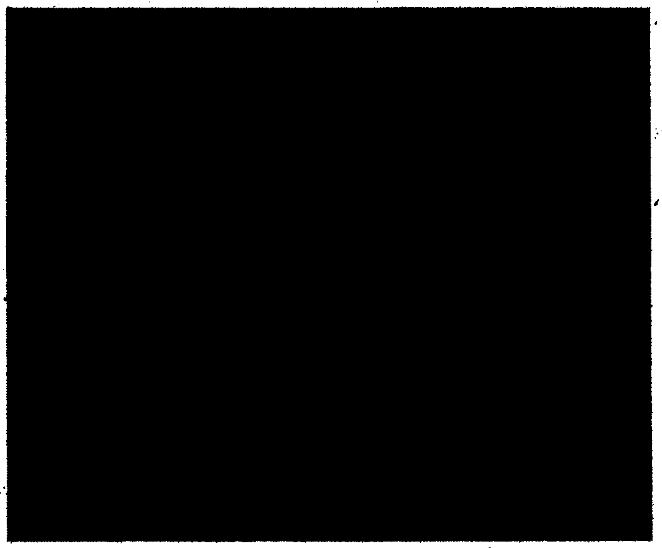
H-3c Radiation (2)

A heat source near the focal point of a reflector reflects thermal radiation across the table to another concave reflector where it is focused on a radiometer which is used as a detector of the radiation.

H-4 KINETIC THEORY OF GASES

H-4a Avogadro's Number

When deriving equations for the kinetic theory of gases, it is useful to have a box of gas. A convenient size is 22.4 liters which at normal temperature and pressure contains Avogadro's number of molecules. Such a box is shown in Fig M-4a.



H-5 THERMODYNAMICS AND HEAT ENGINES

H-5a Heat Engines (1)

Shown in Fig M-5a are three types of heat engines: (1) Hero's engine, (2) steam gun, and (3) friction gun. The steam gun requires water and the friction gun requires ether.

H-5b Heat Engines (2)

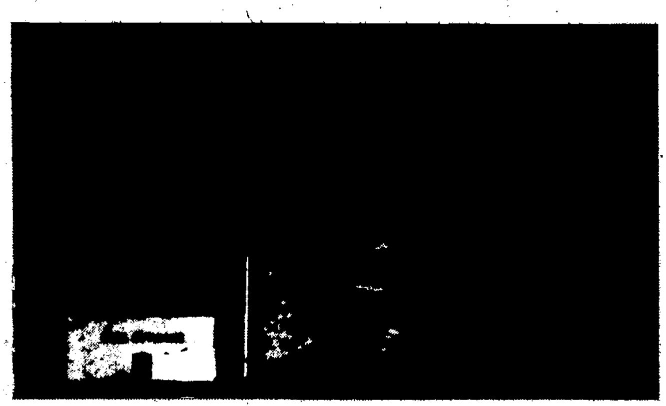
Fig M-5b shows (1) a model of a steam locomotive, (2) a model of a gasoline engine, and (3) a working model of a steam engine which furnishes power for a small electric generator.

H-5c Fire Syringe

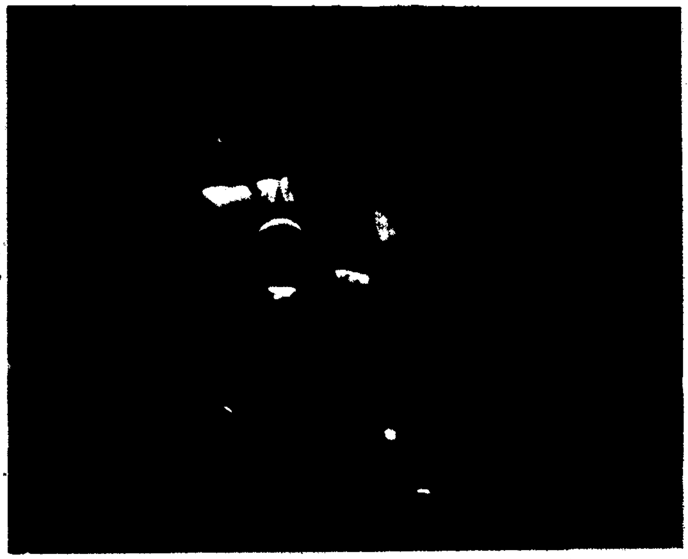
Three fire syringes are shown in Fig M-5c. This equipment demonstrates the heat generated by air compression, in that a small piece of cotton will be ignited when the air is compressed very rapidly. It is difficult to get it to work, but it can be done.

H-5d Boiling Water at Reduced Pressures and at 50°C

This is a dangerous demonstration and much care must be taken as there is danger of an implosion. Take a ROUND bottom flask and fill it about one-third full with water and then heat to boiling. Insert a thermometer in a rubber stopper,

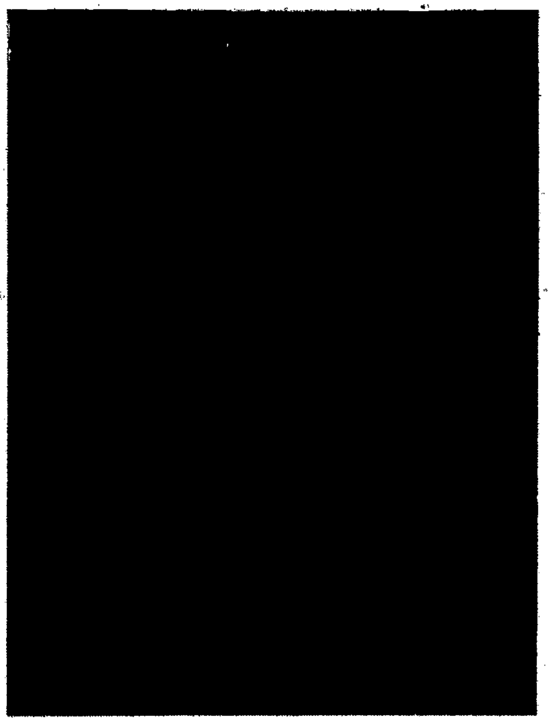


and insert it in the mouth of the flask, then rotate it 180° and place in a ring stand as shown in Fig M-5d. When cold water is poured over it, the vapor condenses and forms a partial vacuum causing the water to boil. This will continue until the temperature of the water has been reduced to 45 - 50 degrees C. DO NOT USE A FLAT BOTTOM FLASK AS IT IS SURE TO BREAK.



H-5e Geyser Demonstration

A geyser consists of intermittent jets of heated water and steam.



Natural geysers, such as Old Faithful at Yellowstone National Park, are caused by subterranean water coming in contact with very hot rocks, and then generating steam in such a rapid way that free circulation of the water is prevented.

The demonstration equipment is shown in Fig H-5e. It requires much heat and a large burner.

It is a rather messy experiment and is not recommended unless help is available to clean up the mess; however, it does work, and students like it.

H-5f Thermodynamic Surfaces

The two thermodynamic surfaces shown in Fig H-5f will be helpful when teaching this part of thermodynamics. They are also helpful in explaining P-V-T diagrams.

S-1 SIMPLE HARMONIC MOTION

S-1a Mass on End of a Spring

See Experiment M-14e.

S-1b Simple Pendulum

See Experiment M-14d.

S-1c Foucault Pendulum

See Experiment M-19d and M-19e.

Fig S-1d

S-1d Lissajous Figures

Lissajous figures may be produced when two vibrating motions are at right angles to each other. The equipment in Fig S-1d projects a beam of light through two slits, each of which is moving at 90° with respect to the other. This motion produces Lissajous figures on the classroom screen.

Lissajous figures may also be produced on a cathode ray oscilloscope.

The following paper on Lissajous Figures gives other examples. It is reprinted from SCHOOL SCIENCE AND MATHEMATICS, January 1957, pp 7-8.

LISSAJOUS FIGURES[1]

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William Jewell College, Liberty, Missouri

About 100 years ago the French scientist, Lissajous attached a mirror to each of two tuning forks. These were placed at right angles to each other so that a light ray directed toward one mirror would be reflected to the other and then to a screen. When the forks were set into vibration the now-familiar Lissajous figures were observed.

In order to explain these patterns which so often are demonstrated on cathode ray oscilloscopes; four methods using the equipment shown in Fig. 1 are used.

FIG. 1. Apparatus for demonstrating Lissajous figures.

[1] A prize winning exhibit at the 18th Annual Colloquium of College Physicists, State University of Iowa, June 13-16, 1956.

First the patterns are presented on an oscilloscope by applying a 60 cycle per second AC voltage across the horizontal plates of the tube and then connecting the output voltage from a variable frequency audio oscillator to the vertical plates. A large number of different patterns may be obtained in this manner.

A second method is to attach a small penlight flashlight with a focusing lens to the end of a compound pendulum. Arrange so that a small beam of light will focus on a piece of 8×10 inch photographic paper located just under the pendulum. With the room completely dark, turn on the penlight, and start the pendulum swinging above the photographic paper. After some 25 to 100 oscillations, stop the pendulum and develop the photographic paper in the usual manner. Interesting Lissajous patterns will be observed. The pendulum light is shown at the lower-center of Fig 1 and some patterns obtained by this method are shown in the upper-center of Fig 1.

Another method makes use of two small electric motors which are geared to rotate at a slow speed. One motor moves a ball-point pen back and forth and causes it to under-go simple harmonic motion in a straight line. The other motor moves a small two wheeled cart in simple harmonic motion and at right angles to the motion of the pen. The pen then traces out Lissajous figures on a piece of paper attached to the moving cart. The speed of each motor may be varied by a rheostat, thus producing various types of curves.

One of the simplest methods of demonstrating these patterns is to use "curb feelers" which are intended to be attached at curb level to an automobile and may be purchase at any auto store. Due to the fact that the frequency of vibration of these "feelers" vary at different angles, the small ball at the end of the "feeler" will produce interesting Lissajous patterns when set into vibration. The young man in the lower-right of Fig 1 is about to set such a "feeler" in motion.

S-1e Turntable Oscillator

The Welch Turntable Oscillator set produces many types of curves in slow motion. It consists of two turntables and a tape recording attachment and is shown in Fig S-1e. It will produce ellipses, Lissajous figures, and sine curves of several frequencies. An accelerometer attachment is also available.

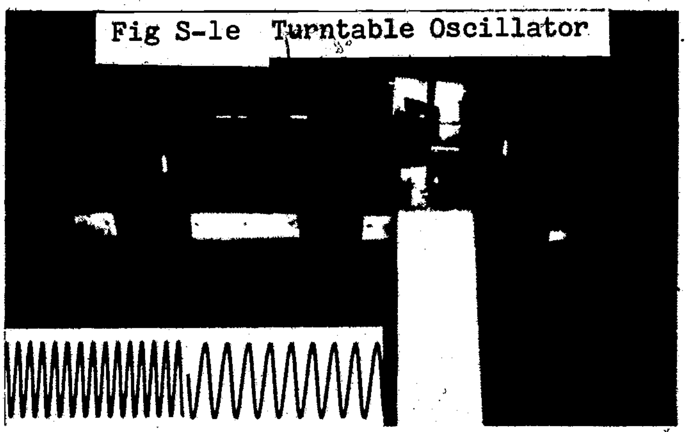


Fig S-1e Turntable Oscillator

S-1f SHM with a Mass and Two Springs

An interesting problem is to calculate the frequency of a mass oscillating between two springs. It may be demonstrated with the air-track equipment shown in Fig S-1f. Experimental results may then be compared with theoretical values.

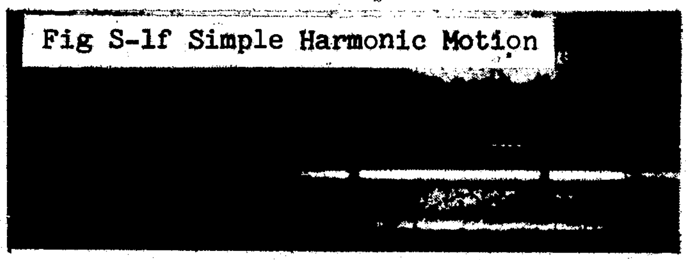


Fig S-1f Simple Harmonic Motion

S-1g Spherical Dish and Balls

The spherical dishes and balls shown in Fig S-1g may be used to present another demonstration on simple harmonic motion.

The ball (or balls) may be placed at one edge of the dish and permitted to roll back and forth and undergo simple harmonic motion.

They may also be set in motion so as to produce ellipses.

One of the dishes

S-1g (Continued)

is made of clear plastic and may be used with the overhead projector to project the motions of the balls on the classroom screen.

S-2 WAVES

S-2a Transverse and Longitudinal Waves

(1) Have two students stretch a long spring across the front of the lecture room at a height of about four feet. Ask one of the students to hit the spring (at 90°) with their right hand, at a distance of about one foot from the left hand, which is holding one end of the spring. A transverse pulse will move down the spring and reflect 180° out of phase from the other student's hand. Standing transverse waves may also be set up in the spring.

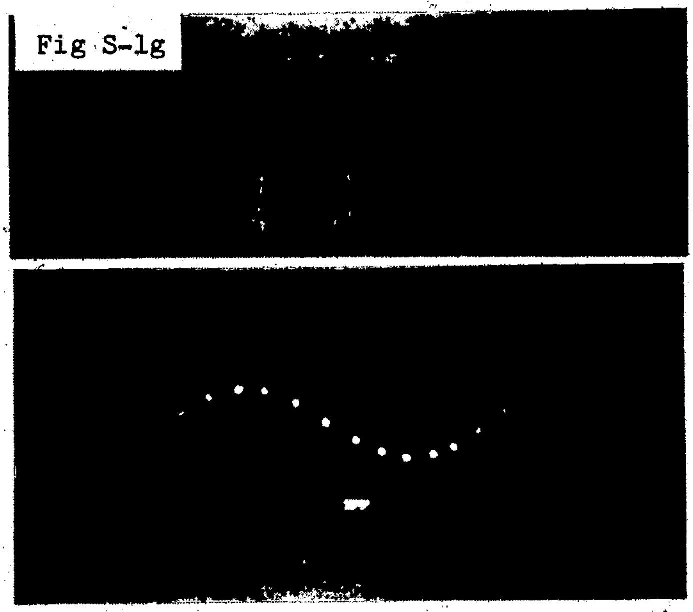
(2) A "slinky" spring may be stretched across the lecture room table and longitudinal waves sent down the spring. Standing waves may also be set up in the "slinky" spring.

(3) In the center of Fig S-2a is a Russian-built wave apparatus which is capable of producing traveling transverse and longitudinal waves. It will also demonstrate standing waves, both transverse and longitudinal.

S-2b The Melde Experiment

Apparatus for demonstrating standing transverse waves is described in the following brief paper reprinted from the AMERICAN JOURNAL OF PHYSICS, Vol 20, p 310, May 1952.

Fig S-1g



The Melde Experiment

IN the laboratory and particularly in the lecture room, it is sometimes desirable to have larger equipment than that usually available for the Melde experiment.

Figure 1 shows apparatus that is capable of setting up standing waves on a rope or heavy cord that will reach across the lecture room. Except for the motor and variable transformer, the apparatus may be constructed for little or no cost with materials usually found in the laboratory or shop.

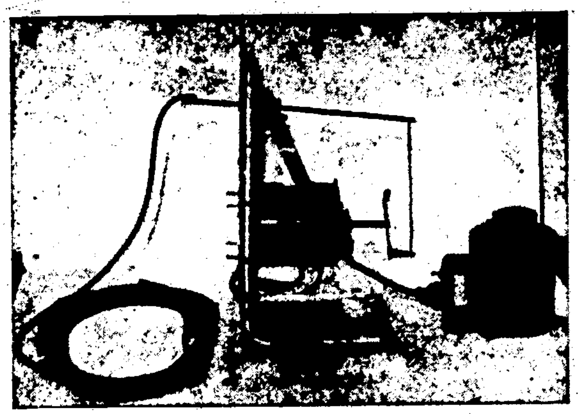


FIG. 1. Motor-driven device for generating standing waves in a rope.

The rope is attached to a rocker arm which is set into oscillation by the crank and rod which are in turn attached to the motor shaft. The speed of the motor is controlled by a Powerstat-type transformer. By varying the tension on the rope and the speed of the motor, standing waves of various length may be demonstrated.

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Liberty, Missouri

S-2c Transverse Waves

The electrical-driven tuning fork shown in Fig S-2c will set up standing transverse waves on a string that is attached to one of the prongs of the fork.

S-2d Longitudinal Waves

Another demonstration of longitudinal (or compressional) waves makes use of the apparatus shown in Fig S-2d. It consists of 18 small magnets attached at each end by a string. Like poles are all in the same direction, so that when the magnet at one end is given a small push, the energy is transmitted to each of the magnets.

S-2e Gas Flames as a Detector of Pressure Standing Waves

This device consists of a long tube with a line of very small holes bored along the top. One end is connected to a gas supply and the other has a 20-watt horn driver unit which is connected to an audio-oscillator and amplifier. When resonance is obtained, standing waves are set up in the tube and are detected by the change in heights of the various gas jets. It is a rather dramatic type of demonstration.

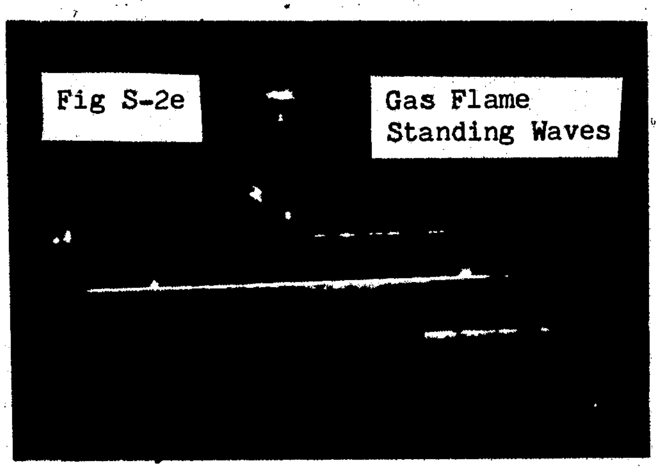

Fig S-2e Gas Flame Standing Waves

S-2f Group and Phase Velocities

Group and phase velocity may be demonstrated with the unit shown in Fig S-2f. There is some advantage in using it with an overhead projector.

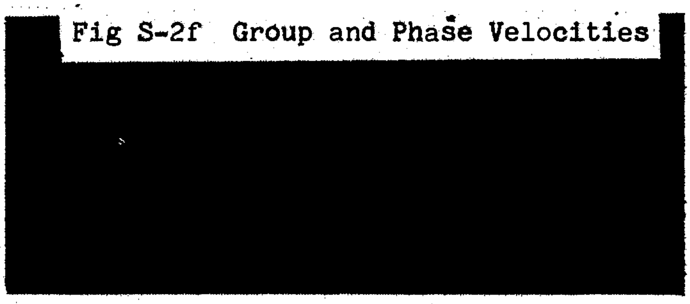

Fig S-2f Group and Phase Velocities

Reprinted from
School Science and Mathematics
June, 1952

S-2g Standing Wave Demonstrations

The apparatus described in the paper to the right is located in the physics lecture room; it is useful for demonstrating three types of standing waves: mechanical transverse, longitudinal, and electromagnetic.

Also stored with this unit is some 420 mHz microwave equipment.

STANDING WAVE DEMONSTRATIONS

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When discussing the various types of standing waves in a physics class, it is often helpful to use various types of demonstration equipment. As an aid in the teaching of transverse, longitudinal, and electromagnetic waves, the apparatus shown in Fig. 1 has proved helpful at William Jewell College.

FIG. 1. Apparatus for the demonstration of transverse, longitudinal, and electromagnetic standing waves.

Transverse waves are demonstrated by using a mechanical oscillator[1] attached to a small motor. Three strings are attached to the oscillator with weights of 50 grams and 200 grams on the two horizontal strings respectively. On the vertical cord a 50 gram weight is attached after the string has been looped over a pulley. All three strings are of the same length. The speed of the motor is controlled by a variable transformer and is usually adjusted so that the 50 gram vertical string (only lower part is shown in Fig. 1) vibrates in one segment. Then the 50 gram horizontal string vibrates in two segments and the 200 gram horizontal string vibrates in one segment. The ratio of the frequencies of the horizontal and vertical 50 gram strings may then be studied as well as the ratio of the weights of the two horizontal cords.

The apparatus for showing compressional or longitudinal waves has been suggested by Rogers[2] at the Iowa State Teachers College. A tumbling spring[3] is suspended horizontally in a box made of plywood. A laboratory mechanical vibrator or rotator is connected to

[1] Central Scientific Company, Catalog J-150, Item 74565, p. 1068.
[2] R. A. Rogers, Colloquium of College Physicists, State University of Iowa, June 15, 1950.
W. J. Cunningham, *American Journal of Physics*, Vol. 15, pp. 348–52.

one end of the spring and by careful adjustment of the frequency, standing compressional waves may be observed. By removing the small box at the other end of the coiled spring, standing waves reflected at a free end may be observed.

Electromagnetic waves are demonstrated by using a very high frequency oscillator, which in this case is a 200–500 megacycle oscillator. A Lecher-wire system, made out of iron rods about six feet in length is used. An ordinary fluorescent lamp is used as a detector of the standing waves. The distance between points of maximum intensity is the half wavelength.

S-2h Demonstration Experiments in Physics

Reprinted from *School Science and Mathematics* March, 1951

The article reprinted here describes three demonstration experiments: (1) a transverse-wave apparatus, (2) the climbing monkey demonstration (which has been described already in Experiment M-8e), and (3) a "falling body apparatus" which is described in Experiment M-3b.

DEMONSTRATION EXPERIMENTS IN PHYSICS

WALLACE A. HILTON
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Three demonstration experiments in physics that have been suggested by Roberds,[1] Christensen,[2] and Mackay[3] are of such a nature that they can all be assembled as one piece of equipment that will take up less than a two-foot square of floor space as shown in Fig. 1.

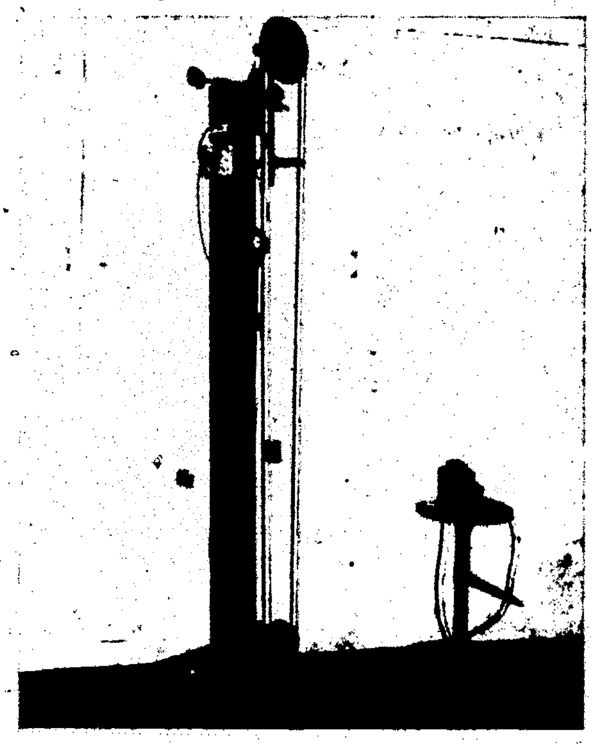


FIG. 1

The falling body apparatus as proposed by Roberds[1] makes use of a Cenco impulse counter which records the time for a steel ball to fall through a certain distance. In Fig. 2, the counter (C) is operated from the transformer (T) and reads to 1/120 of a second when used on 60-cycle current. When the key (K) is closed the voltage drops below the value necessary to operate the clock. When the spring (S) is released, the ball (B) begins to fall and the counter starts. It continues until the circuit is broken by the ball when it strikes the

[1] W. M. Roberds, *American Physics Teacher*, Vol. 5, p. 228.
[2] F. E. Christensen, *American Journal of Physics*, Vol. 16, p. 248–249.
[3] R. S. Mackay, *American Journal of Physics*, Vol. 16, p. 248.

spring (S′). In our case the distance is 170 cm. and the error is less than 3%.

The transverse-wave apparatus as developed by Christensen[2] consists of an endless belt running over two pulleys, the belt in this case consisting of rubber tubing filled with sand. The lower pulley

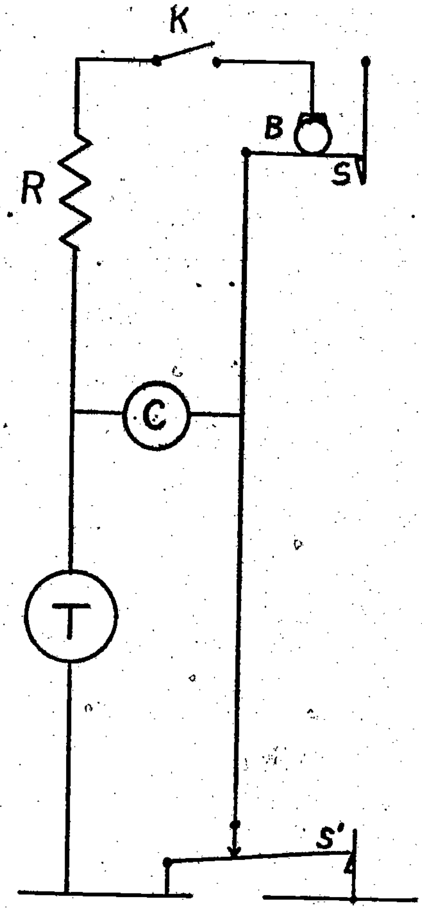


FIG. 2

is attached to an electric motor and the speed is controlled by varying the applied voltage. The other pulley is placed about 7 feet above the lower one. The speed of the motor is adjusted so that when the slack side of the belt is given a quick tap just below the upper pulley, the wave form moves slowly down the belt. This demonstration proves helpful when developing the formula for the velocity of a wave on a stretched string.[4]

Mackay[3] has proposed a solution for the "climbing monkey" problem which is used as the third experiment for this piece of equipment. The problem involves a monkey hanging from a rope that passes over a frictionless pulley to a coconut that has the same mass as the monkey. The problem is to determine what happens when the monkey starts to climb the rope. In this apparatus, a steel yo-yo represents the monkey and a tin can filled with paraffin and lead shot symbolizes the coconut. Two ball-bearing pulleys approach a frictionless pulley, and a light string is used for the rope. Part of the string is wound around the yo-yo and the remaining part is placed over the pulleys with the remaining mass on the other side. With both masses

at the same height, the system is released and both the "monkey" and the "coconut" fall and rise together.

In Fig. 1, the falling body experiment is shown at the center of the picture, the standing wave apparatus is to the right and front; while the "climbing monkey" experiment is to the rear and to the left.

[4] M. Y. Colby, *Sound Waves and Acoustics*, Henry Holt, 1938, p. 81.

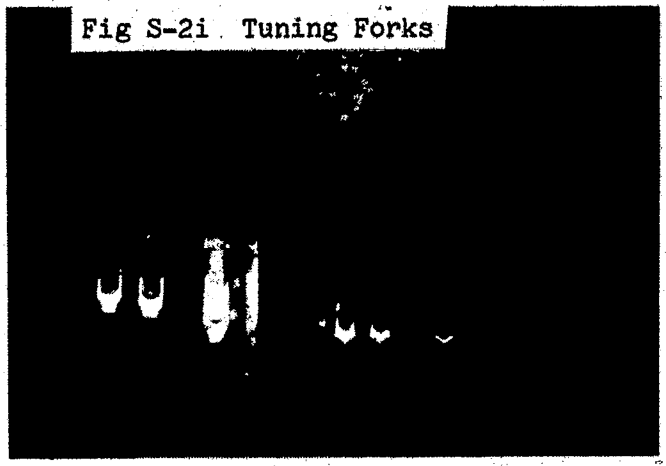
S-2i Tuning Forks

Shown in Fig S-2i are three sets of tuning forks: (1) This set consists of four very high quality tuning forks which are primarily for use in an advanced laboratory to determine the intensity of sound.

(2) This set consists of a 125 Hz, a 250 Hz, and 500 Hz, and a 1000 Hz tuning fork.

(3) This set of tuning forks includes the following forks: 256 Hz, 320 Hz, 384 Hz, and 512 Hz.

Fig S-2i Tuning Forks

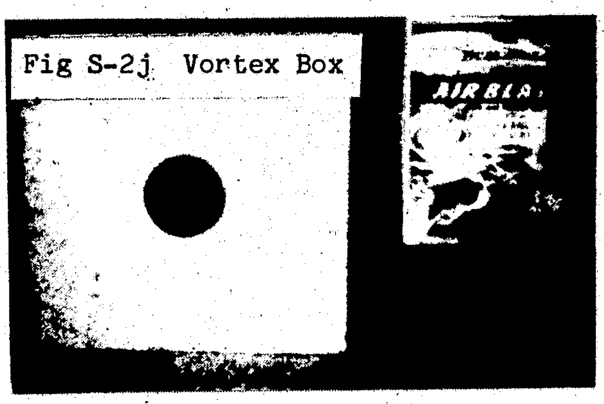


S-2j Vortex Box

The vortex box shown in Fig S-2j is about 15 inches square and 4 inches deep. The back is covered with sheet rubber from an old inner-tube. When filled with smoke, a quick hit on the back will produce smoke rings that travel across the classroom. If smoke is not available, it can be aimed at the class, and some students will feel and "see" the compressional wave.

Also shown is a toy "Air Blaster" which will produce a similar effect.

Fig S-2j Vortex Box



S-2k Seismograph

Two demonstration seismographs, similar to those used in industry, are shown in Fig S-2j. The smaller one is shown connected to the input of a high-gain cathode ray oscilloscope. The vibrations caused by a slight tap on the table will be shown on the cathode ray tube.

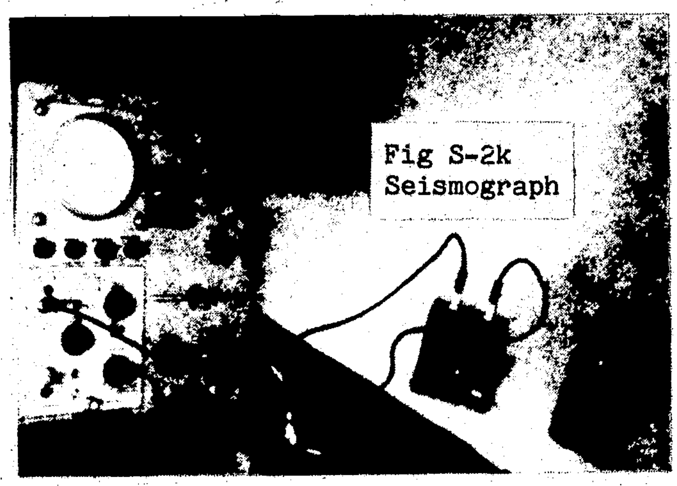


Fig S-2k Seismograph

S-3 SOUND

S-3a Bell in a Vacuum

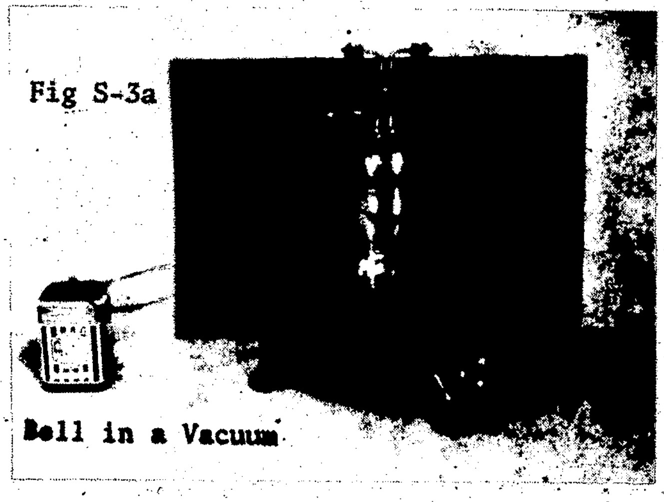


Fig S-3a

Bell in a Vacuum

Fig S-3a shows a small bell in a vacuum jar. When connected to a 6-volt battery, it rings. As the air is pumped from the jar, the sound from the bell gradually decreases until it is just audible.

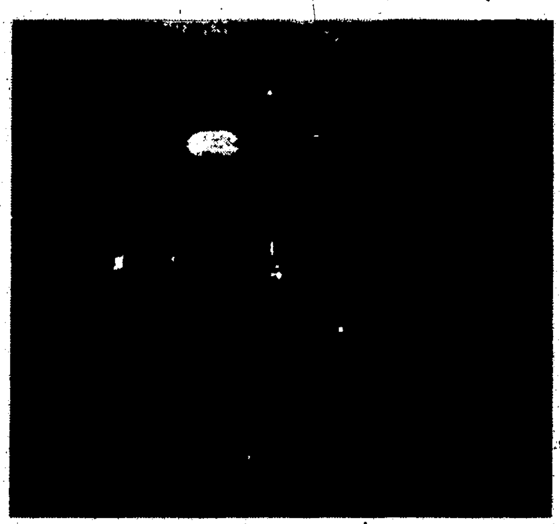
S-3b Savart's Wheels

The Savart's wheel shown in Fig S-3b is attached to a motor drive. The ratio of the number of teeth on the four wheels is: 3, 4, 5, and 6. When a piece of cardboard is touched to all four of the rotating wheels, a major chord is heard.

S-3c Intensity of Sound

The sound level in a room may be measured with the General Radio Sound Level meter shown in Fig S-3c.

With the instructor speaking, a typical sound level might be 65-75 decibels, with the reference level being 10^{-16} watts/cm^2. The primary use of this instrument is for determining the acoustical impedance and absorption coefficients for acoustical tile.



S-3d Manometric Capsule

(see photo on following page)

An historic experiment is a manometric capsule and flame devised by Koenig. Before the development of the oscilloscope, it was a laboratory method for studying sound waves. Talking into the microphone caused the flame to vary. This change could be observed in a

rotating mirror. This demonstration will help the student to better appreciate the use and value of a cathode ray oscilloscope. More information may be found in J. O. Reed and K. E. Guthe, COLLEGE PHYSICS, 1913, Macmillan, pp 174-175.

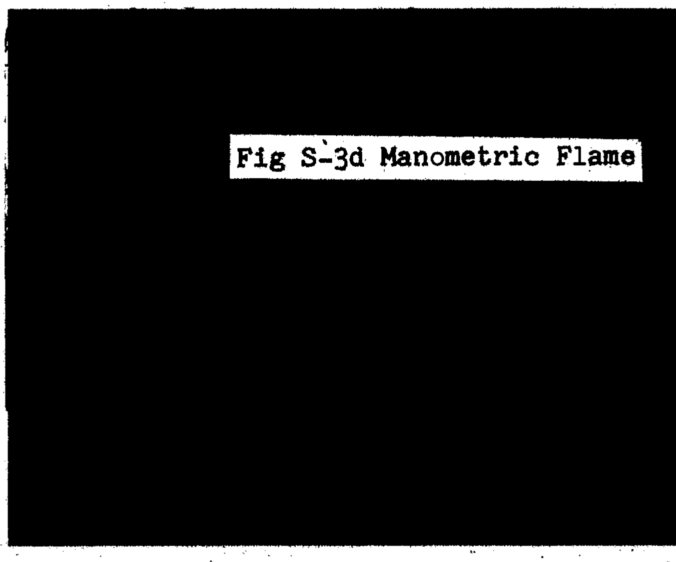


Fig S-3d Manometric Flame

S-3e Measuring the Velocity of Sound (1)

Shown in Fig S-3e is an audio oscillator and amplifier connected to a 20-watt driver at the end of a glass tube. The tube contains cork dust; standing waves are observed by the movement of the cork dust when the oscillator is tuned to a resonant frequency of the tube. Measuring the wave-length of the standing waves in the tube and observing the frequency of the oscillator, the velocity of sound in air may be quickly calculated from the equation:

$$V = f\lambda.$$

A similar experiment may be done with a glass tube and a tuning fork.

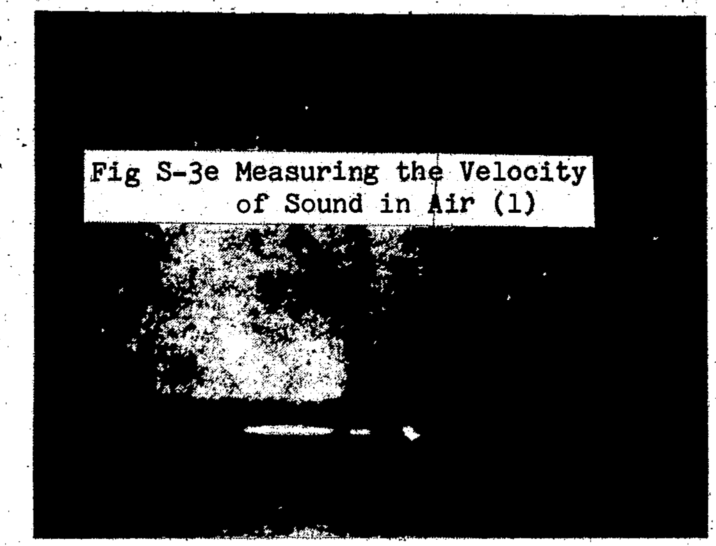


Fig S-3e Measuring the Velocity of Sound in Air (1)

S-3f Measuring the Velocity of Sound (2)

A rather unique method for measuring the velocity of sound has been described by C. K. Manka in AMERICAN JOURNAL OF PHYSICS, vol 37, p 229, Feb 1969. C. D. Geilker has assembled the equipment shown in Fig S-3f for measuring the velocity, using the method described by Manka. Several students have used the equipment for an experiment, and it could serve as a good classroom demonstration.

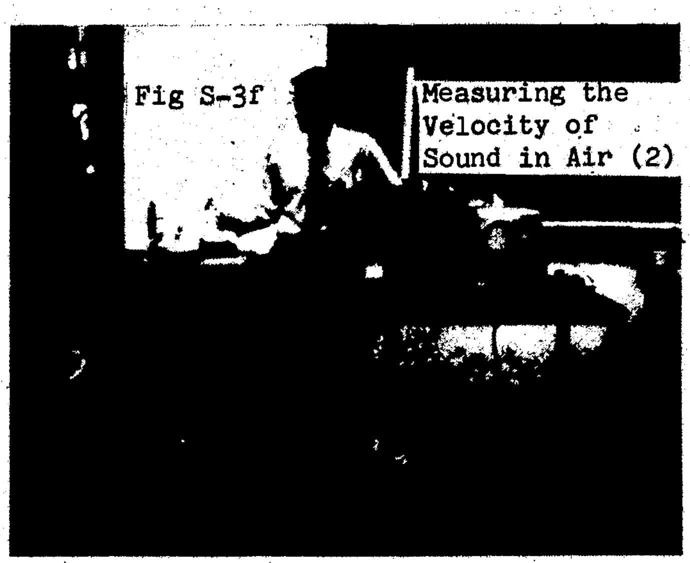


Fig S-3f Measuring the Velocity of Sound in Air (2)

S-3g Simple Glass Tube Cutter

For demonstrations and experiments such as S-3e which involve the use of large glass tubing, it is often necessary to cut this size tubing.

Simple equipment which will do the job is described in the paper to the right. A variable a.c. voltage source adjusted so as to make the wire red hot may be used in place of the batteries shown in the article.

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April, 1953

A SIMPLE GLASS TUBE CUTTER

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A simple device for cutting glass tubing of diameter greater than ¼ inch is shown in Fig. 1. The apparatus consists of a small wire suspended between two points and looped around the piece of glass

FIG. 1. Simple apparatus for cutting glass tubing.

to be cut. The wire is heated by an electric current until it becomes red-hot. A small amount of water is then poured over the wire and glass. The glass immediately breaks at the desired point.

Batteries may be used as the source of power to heat the wire; however, a more satisfactory method is to use a variable type transformer capable of delivering the necessary power. In the apparatus shown, about 6 amperes of current is sufficient to heat the wire to be red-hot. The voltage needed will depend upon the resistance of the wire used.

S-4 RESONANCE

S-4a Mechanical Resonance

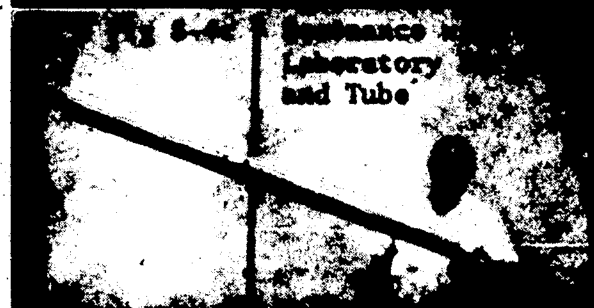
Four demonstration pieces for illustrating mechanical resonance are shown in Fig S-4a (on the following page). They are: (1) coupled ball-and-string pendulums (start one swinging and the energy is soon transferred to the other); (2) gyroscope and four vibrating reeds (the gyroscope is slightly out of balance, which sets the various reeds into vibration at their natural frequency); (3) coupled pendulum oscillator (similar to No. 1, except rods and spring steel are used in place of the string); and (4) a small Wilberforce's pendulum. Some of these may be used in the study of mechanics; however, they are also useful in the study of sound and acoustics.

S-4b Vibrating Strings

When a wire on a sonometer is tuned to the frequency of a tuning fork, resonance may be observed by the motion of a small piece of paper which is folded and placed over the wire at its center, if the vibrating tuning fork is placed on the bridge of the sonometer as shown in Fig S-4b.

S-4c Resonance with a Laboratory Burner

In this demonstration a long aluminum tube (about 5 feet in length and 4 inches in diameter) is mounted as shown in Fig S-4c. When a Fisher burner is inserted in the lower end of the tube, resonance occurs and a loud tone is heard. Moving the burner causes a change in length of the standing waves, and thus changes the frequency of the tone.



S-4d Acoustical resonators

Fig S-4d shows four types of equipment that may be used for demonstrations of acoustical resonance. They are:

(1) The Acoustic Resonator.

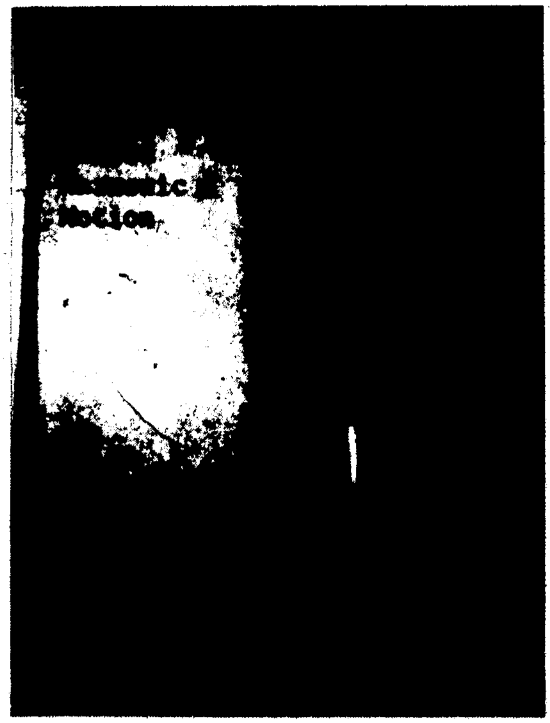
(2) Vibrating Bars. When one is hit by a rubber hammer, the other one starts vibrating. Beats may be obtained by placing a small weight on one and then striking both at about the same time.

(3) Variable-length open and closed tubes.

(4) Tuning forks with resonance boxes: 256 Hz, 320 Hz, 384 Hz, and 512 Hz.

S-4e Forced Harmonic Motion

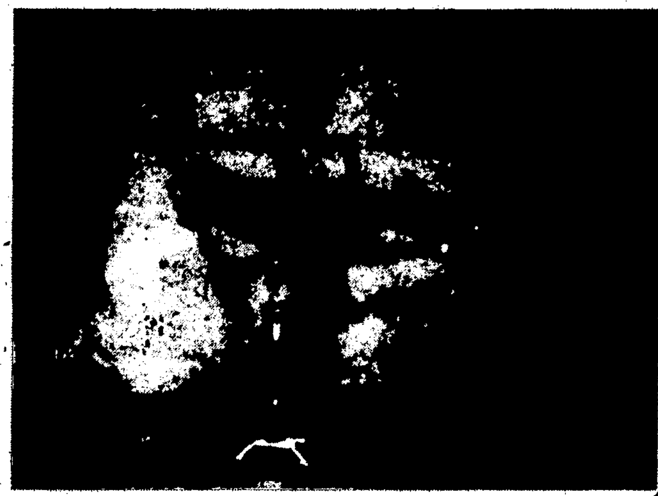
The apparatus shown in Fig S-4e is a Macalaster-PSSC forced harmonic oscillator. The apparatus may be used for demonstrations in mechanical resonance; relationships among frequency, phase, and amplitude; damping effects, etc.



S-5 BEATS

S-5a Demonstrations of Beats

Two tuning forks are shown in Fig S-5a. The difference in frequency of the two forks is about 1 Hz; thus when both are vibrating, beats are easily heard.



Also shown in Fig S-5a are two Knipp singing tubes, one of which may be tuned to produce beats with the tone from the other tube.

On the right in Fig S-5a is an adjustable pitch Galton whistle which ranges from the audible to the ultrasonic.

S-6 DOPPLER EFFECT

S-6a Doppler Sound

The apparatus shown in Fig S-6a when rotated at a rather slow speed emits a sound which produces the doppler effect as the source moves toward and away from the listener. CAREFUL ADJUSTMENT OF THE ANGULAR SPEED OF THE ROTATOR IS IMPORTANT. KEEP THE SPEED LOW.

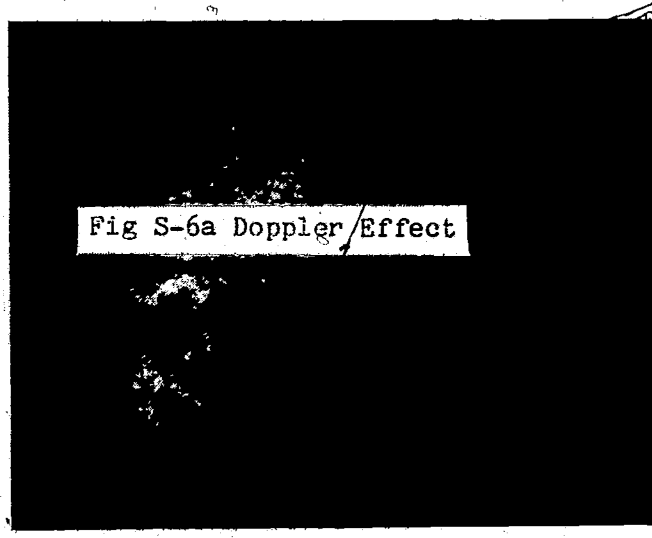


Fig S-6a Doppler Effect

S-7 MUSICAL ACOUSTICS

S-7a Musical Sounds

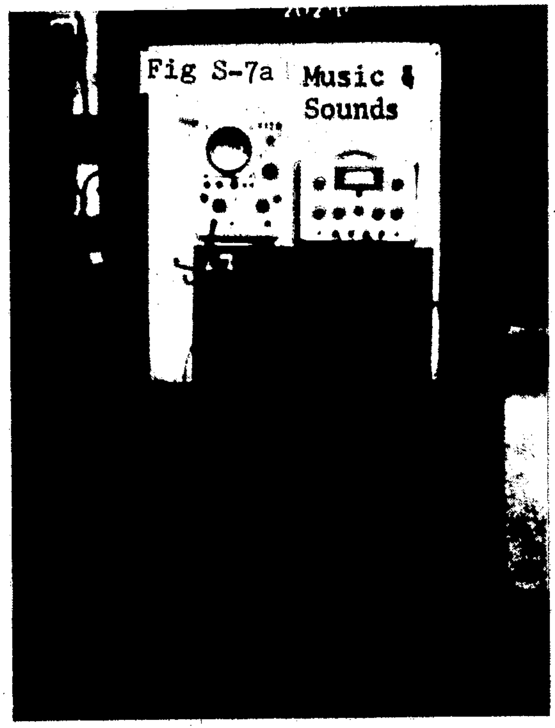
The Physics Department has the following record albums which may be played on the turntable which is part of the equipment shown in Fig S-7a:

1. The Science of Sound (33 rpm)
   Bell Telephone Laboratories
2. Energy and Motion (33 rpm)
   Zaret and Singer
3. Experiment Songs (33 rpm)
   Dorothy Collins
4. Space Songs (33 rpm)
   Tom Glazer and Dottie Evans
5. Physics Songs (78 rpm)
   State University of Iowa

An oscilloscope shows the wave forms of the musical sounds.

A flip of a switch puts a microphone on the input of the amplifier. Then speech signals may be observed on the oscilloscope.

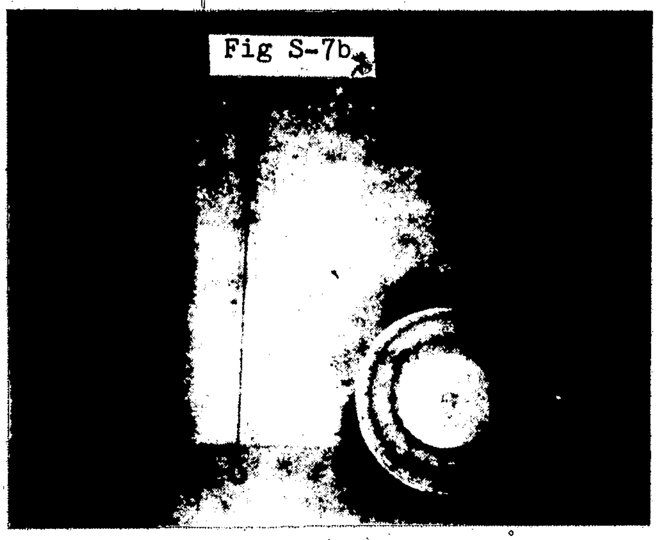
An audio oscillator may be connected into the input of the amplifier and signals from 20 Hz to 17,000 Hz may be seen on the oscilloscope and heard by the students, if in the range of their hearing.



S-7b Organ Pipe and Model of Wave

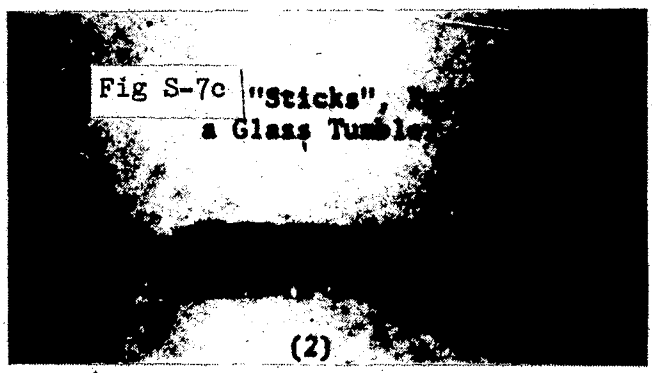
(1) An organ pipe which may be connected to the air outlet on the lecture room desk is shown in Fig S-7b. The pitch of the sound may be changed by moving the plunger up or down the tube.

(2) A demonstration model of a longitudinal wave is also presented in Fig S-7b.



S-7c Sticks, Xylophone, and a Glass Tumbler

(1) Sticks when dropped on a table give tones covering one octave. Some students can play a tune with them.



S-7c (Continued)

(2) A toy xylophone.

(3) A glass tumbler. Put a finger in a little vinegar and then rub on the top edge of the tumbler. A rather high frequency sound will be heard.

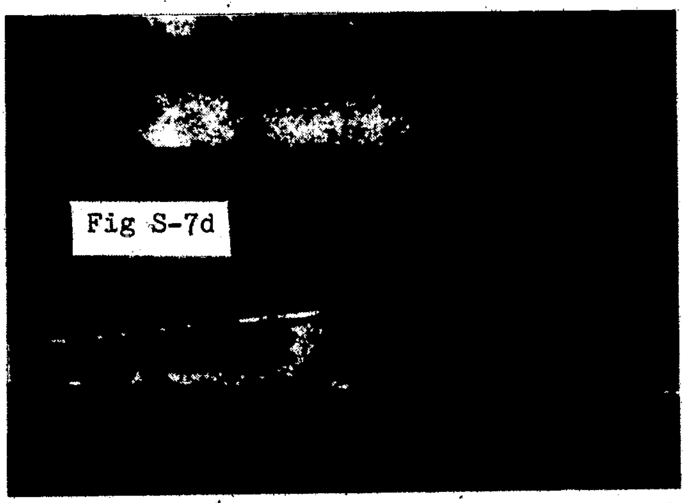


Fig S-7d

S-7d Chladni's Sand Figures

Chladni's sand figures may be obtained with the apparatus shown in Fig S-7d. Mount one of the plates on the holder at the right in the photograph. Then move the bow along the edge and the figures will appear. Sand must be scattered on the plate.

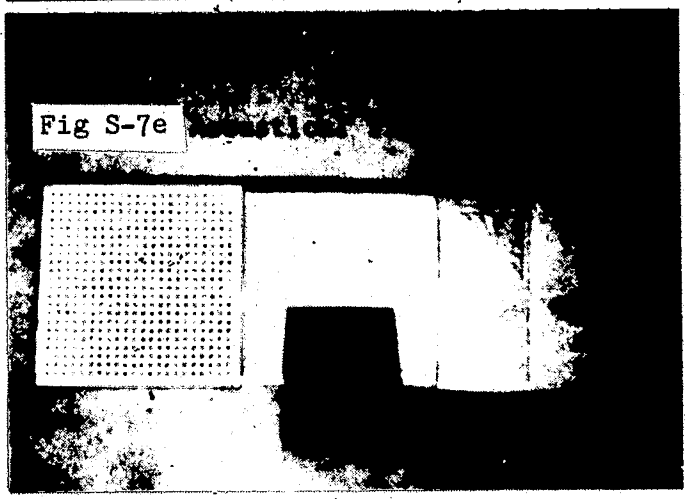


Fig S-7e

S-7e Acoustical Tiles

When discussing acoustical impedance and absorption coefficients of acoustical materials, it may be helpful to show the class some of the various types of acoustical tile. See Fig S-7e.

ELECTRICITY

E-1 STATIC ELECTRICITY

E-1a The Electroscope

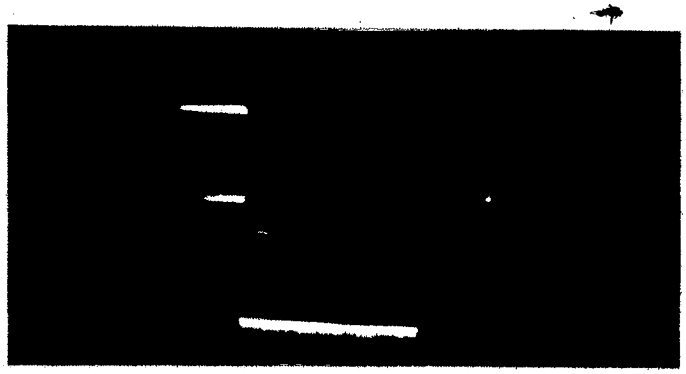
Fig E-1a shows four different types of electroscopes and several materials for producing + and - charges.

E-1b The Electrophorus and Accessories

Other items for static electricity demonstrations are shown in Fig E-1b and include: (1) an electrophorus, (2) conducting sphere, (3) ellipsoidal conductor, (4) hollow cylinder conductor, and (5) a Leyden jar.

E-1c Electrostatic Attachments

Other items for demonstrating static electricity are shown in Fig E-1c. They are: (1) lightning demonstration apparatus, (2) metal conductor and pith balls, (3) bar-form electroscope, (4) induction spheres, and (5) Volta's hailstorm and smoke condensor.

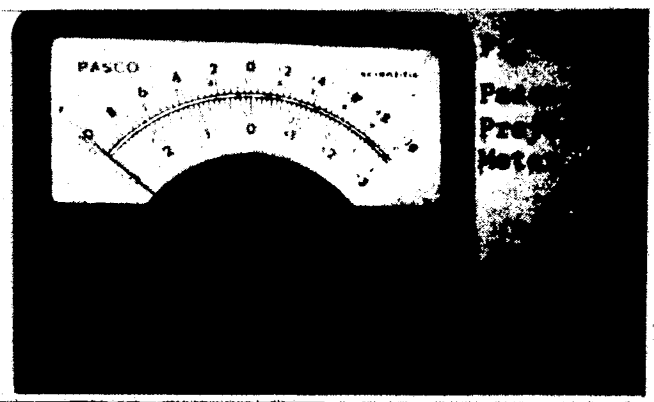


E-1d Pasco Electrostatics Demonstration Equipment

The Pasco electrostatics demonstration equipment consists of an electrometer, two charge producers, two proof planes, Faraday ice pail, variable capacitor, two large spheres on stands, tapered cylinder on plate, field plotter and D.C. power supply. These are shown in Fig E-1d. A complete set of instructions for this equipment is available.

E-1e Pasco Projection Meter

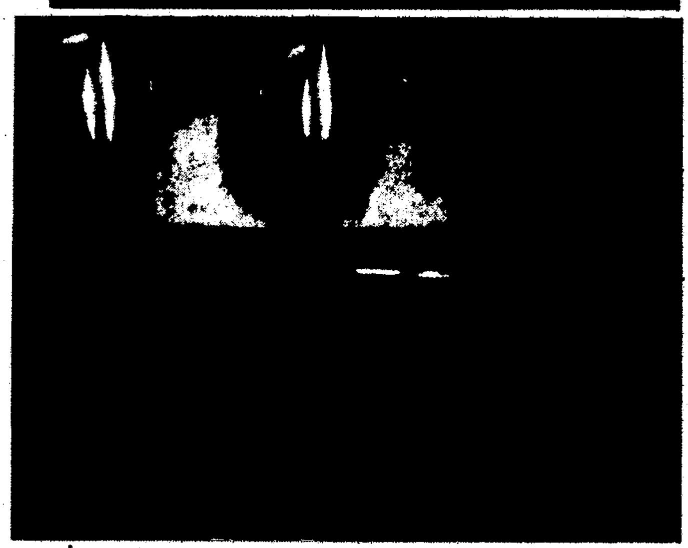
In order for the entire class to see the electrometer reading, a projection meter for use with an overhead projector is available. A photograph of the image of the meter on the classroom screen is shown in Fig E-1e.



E-1f The Leybold Electroscope

This electroscope is very useful for small classes. In Fig E-1f, it is shown with the Pasco conducting spheres.

It has a variety of uses in the teaching of electrostatics.



E-1g Charging by Induction

In Fig E-1g, a charged sphere is brought near to another (uncharged) sphere which is connected to the electroscope by a wire. The electroscope and sphere are said to be charged by induction.

E-1h Faraday Ice Pail

In this demonstration the Leybold electroscope is being used as the detector in the Faraday ice pail experiment.

E-1i Wimshurst Machine

A small Wimshurst machine may be used for electrostatic demonstrations. It is shown in Fig E-1i

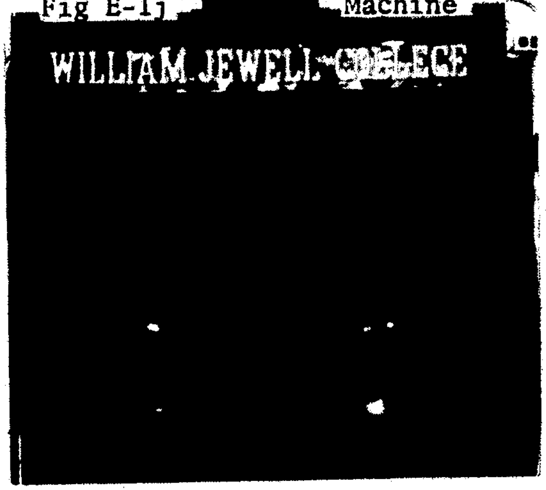
E-1j Large Holtz Machine

'The large Holtz machine will easily produce a 10-inch spark and is a very dramatic demonstration. It was obtained about 1915 from a hospital in Excelsior Springs and has been used in the physics lecture room since that time. It is a working historical machine and is described in: S. H. Monell, MANUAL OF STATIC ELECTRICITY IN X-RAYS AND THERAPEUTIC USES, 1897, Wm Beverley Harison.

Fig E-1j Holtz Machine

E-1k Detector of Negative charge

The apparatus shown in Fig E-1k consists of a triode vacuum tube with a neon glow tube in its plate circuit. A heavy wire above the chassis is connected through the chassis to the grid of the tube. In operation, the neon tube glows until a negatively charged rod is brought close to the grid, at which time the grid becomes negatively charged and stops the flow of electrons through the neon glow tube.



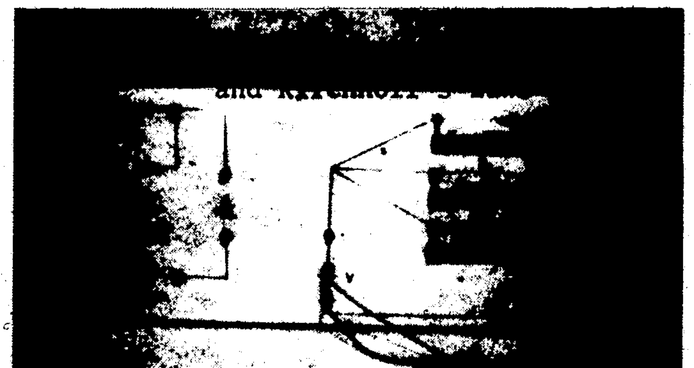
E-2 FLOW OF CHARGE: CURRENT

E-2a Projection Meters

When giving many demonstrations on electricity, it is desirable to have large meters so that all members of the class may see. Projection meters that may be used with the overhead projector are very helpful. Shown in Fig E-2a are two projection meters, one of which is a galvanometer; the other may be used as a D.C. ammeter or A.C. ammeter. Resistors and shunts are available so that the meters may be used at several ranges of voltage and current. THE METER SHOULD BE SECURELY ATTACHED TO THE OVERHEAD PROJECTOR FOR THE SAFETY OF THE METER.

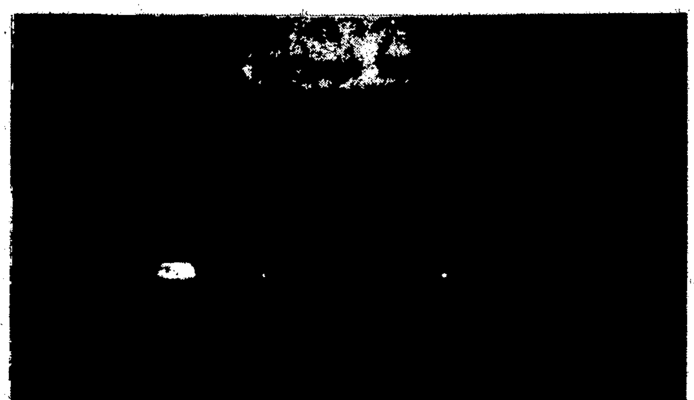
E-2b Series-Parallel Circuits and Kirchoff's Laws

Fig E-2b shows a demonstration board for teaching series-parallel circuits and Kirchoff's laws. A mimeographed sheet is given to each student for recording data, most of which is taken from meter readings on the classroom screen.

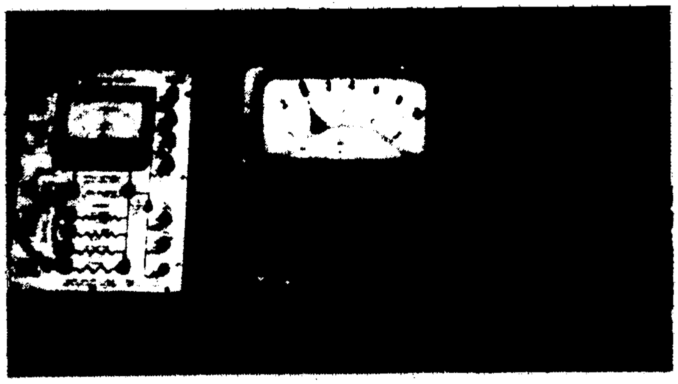


E-2c Drop in Voltage Across Resistors

The IR drop across resistors is demonstrated with the equipment shown in Fig E-2c. It consists of four 300-watt lamp bulbs with wire resistors between each bulb. The IR drop is indicated by the voltage reading across each bulb as projected on the screen from the projection voltmeter. Typical voltages are 120 V AC, 100 V AC, 80 V AC and 60 V AC across the four bulbs.



E-2d Other Demonstration Meters

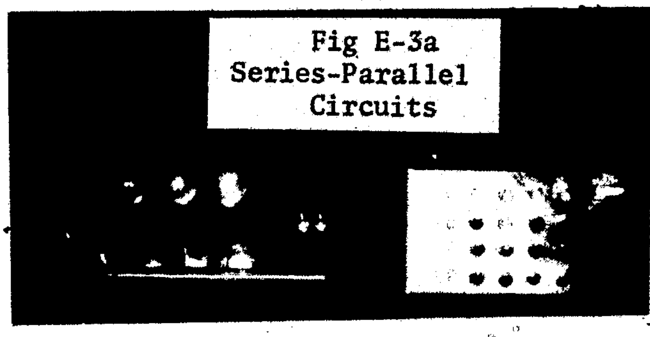


For small classes the demonstration meters shown in Fig E-2d may be adequate.

(1) Welch multimeter
(2) Leybold multimeter
(3) Welch galvanometer

E-3 ELECTRICAL CIRCUITS

E-3a Series-Parallel Circuits

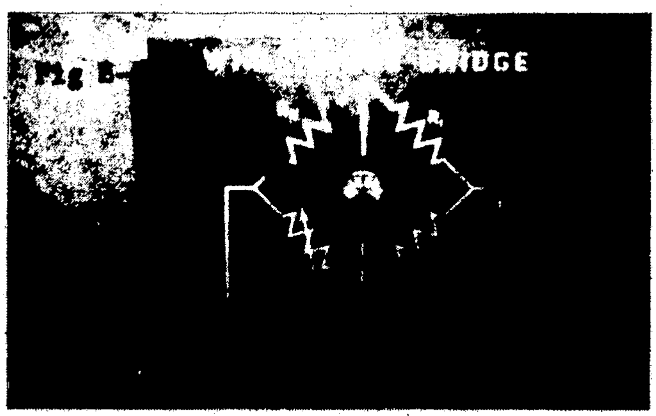


Two pieces of equipment are shown in Fig E-3a.

(1) This a series-parallel circuit with three light bulbs and six switches. There are 14 ways that the circuit may be connected.

2) The game of NIM and binary notation are related to this unit, which consists of 4 10-position switches and 16 lights. A description of its use is given in POPULAR ELECTRONICS, Vol 8, January 1958, pp 37 - 41, 68 - 69.

E-3b Wheatstone Bridge



A demonstration Wheatstone bridge is shown in Fig E-3b. Several plug-in resistors are provided, four of which are shown at the bottom of the photograph.

E-3c Potential Divider

A 6-volt battery is connected across the potential divider shown in Fig E-3c. A projection meter is connected to the slide terminal and one end of the divider. As the slide is moved the meter reads from 0 to 6 volts.

A more accurate potentiometer is also shown in Fig E-3c.

E-3d Three-Way Switch

Some beginning students are interested in the circuit for a three-way switch. Fig E-3d shows a schematic diagram, below which is a demonstration board with a light bulb and two switches.

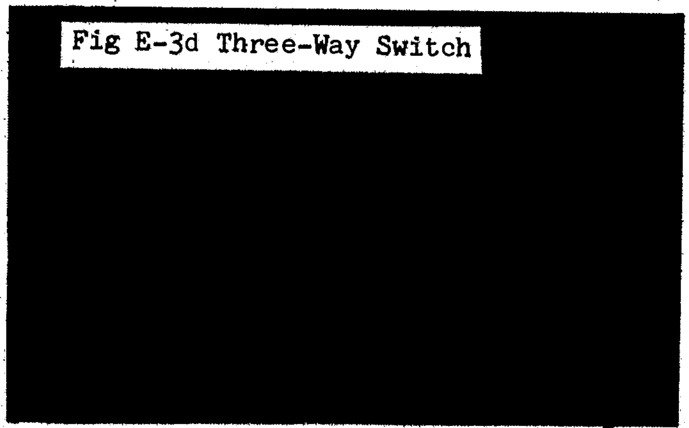
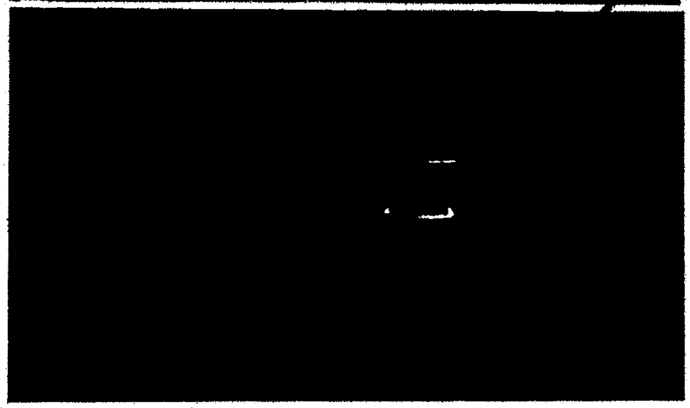


Fig E-3d Three-Way Switch



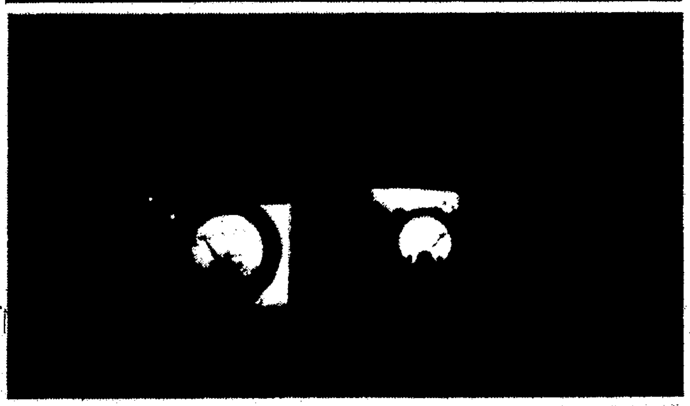
E-3e One Boat, a River and Six People

Three young men and their brides wish to cross a river. Only two people can ride in the only available boat. None of the boys will permit his wife to be on the other side of the river unless he, the husband, is also there. How do they get across in the one boat?

The apparatus shown in Fig E-3e is an electrical device for solving the problem. It consists of six double-pole-double-throw switches. Each switch represents a person.

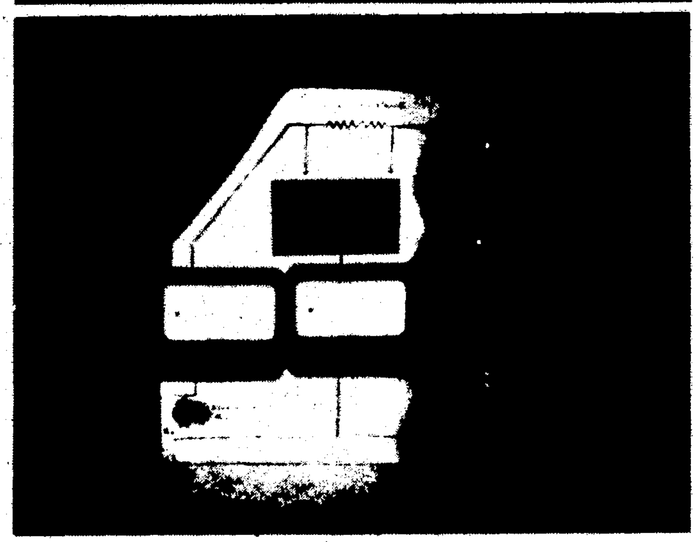
The electrical circuit is described by Harvey Pollack in POPULAR ELECTRONICS, Vol 3, November 1955, pp 52-54.

Most students are interested in playing the game. Some will be interested in the circuit.



E-3f Sun Batteries

Two small sun batteries are shown in Fig E-3f. Each is connected to a meter and may be used as a classroom demonstration.



E-3g Line Loss in Power Transmission

The apparatus shown in Fig E-3g may be used to demonstrate line loss in power transmission. See article by T. J. Blisard and B. A. Greenbaum, AMERICAN JOURNAL OF PHYSICS, Vol 21, pp 109-11, 1953.

E-4 CAPACITANCE

E-4a Capacitors

Several types of capacitors are shown in Fig E-4a. They include Leyden jars, parallel-plate, cylindrical, electrolytic, and ceramic capacitors.

E-4b Equation: $Q = CV$ or $V \alpha \frac{1}{C}$

A capacitor attachment for an electroscope is shown in Fig E- 4b. On the left in the photograph is the Leybold design and on the right is the Welch design, which is mounted with an optical system for projecting an image of the leaves of the electroscope on the classroom screen. By charging the top plate (which is separated by a non-conductor from the bottom plate) and then touching (grounding) the bottom plate, causing it to take on an equal and opposite charge, a charged capacitor exists, and there is no charge on the electroscope. Then by lifting the upper plate, the capacitance is decreased and the voltage increases, as indicated by separation of the leaves of the electroscope. This is a simple check on the formula:

$$V = Q/C.$$

E-4c Capacitance and Voltage Relationships

A slightly more complex demonstration of the experiment discussed in Experiment E-4b is described in the brief paper which is reprinted from the AMERICAN JOURNAL OF PHYSICS, Vol 22, p. 146, March 1954.

Capacitance and Voltage Relationships*

WALLACE A. HILTON
William Jewell College, Liberty, Missouri

IN the general physics course, $Q = CV$ is a familiar equation. Apparatus to demonstrate this relationship of capacitance and voltage is shown in Fig. 1. A small power supply provides a potential difference of about 400 volts across a parallel-plate capacitor.[1] Immediately after the power supply is disconnected, the plates are separated. As the capacitance decreases, the voltage across the plates increases. In this case the increase is usually up to as much as 1200 volts, and will vary depending upon the time constant of the circuit and elapsed time between the disconnecting of the power supply and the separation of the plates.

The moisture content of the air seems to have some effect upon the resistance of the dielectric. A sheet of exposed x-ray film has proved satisfactory for the dielectric and does not seem to be affected by high relative humidity as much as some others that were used.

All of the switching is controlled by a motor, which when operated continuously repeats the cycle each 12 seconds. Small pilot lamps are used to indicate (1) when the power supply is connected across the plates, (2) when the power supply is disconnected, and (3) when the plates begin to separate. The voltage across the plates is read on a Heath[2] vacuum-tube voltmeter with high voltage probe.

* A prize winner at the 15th Annual Colloquium of College Physicists, State University of Iowa, June 17–20, 1953.
[1] Central Scientific Company, Catalog J150, Item 83605.
[2] Heath Company, Model V-6 Vacuum Tube Voltmeter.

E-4c, continued

Fig. 1. The apparatus is standing on a table. The capacitor occupies a central position between the two supports. The upper plate of the capacitor is raised and lowered by a small wire attached over a bolt that protrudes from the rim of a rotating wheel. A schematic diagram is attached to the power supply which is located on the upper right side of the stand. The vacuum-tube voltmeter and the high-voltage probe are supported on the upper left side of the stand. The panel lights which indicate the various switching arrangements are shown in the upper center.

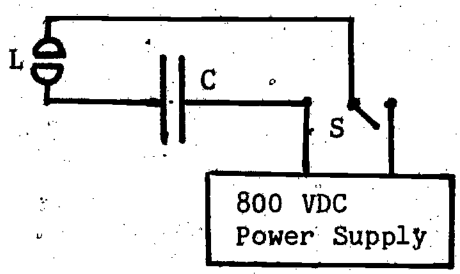
E-4d Capacitance and Voltage

The apparatus shown in Fig E-4d demonstrates the same principles as the equipment used in the two previous experiments. Shown is a variable parallel-plate capacitor by Pasco and a Leybold electroscope. It makes good demonstration for small classes.

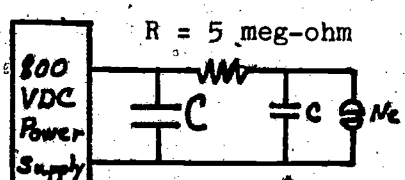
E-4e Charge and Discharge of a Capacitor; a Capacitance-Resistance Oscillator

Shown in Fig E-4e is an 800 VDC power supply which is connected through a neon glow lamp to a 16 mfd capacitor. When the switch is closed, one side of the glow lamp lights until the capacitor is charged. Throwing the switch discharges the capacitor, and the other side of the lamp glows. The schematic diagram is below and the apparatus is labeled (1) in the photograph.

(2) In the oscillator, the 800 VDC power supply is connected to a 8 mfd capacitor. The capacitor then discharges through a 6 meg-ohm resistor to a 0.25 mfd capacitor, which in turn discharges through a small



(a)



(b)

E-4e, continued

glow lamp. This repeats itself several times each minute depending upon the time constant of the circuit. See Fig E-4e (2). The schematic diagram of the circuit is labelled (b).

See V. Wouk, AMERICAN JOURNAL OF PHYSICS, Vol 13, pp 415-17, Dec. 1945.

E-4f A Flashing Neon Light

A similar demonstration to the one just described is contained in the paper reprinted here from SCHOOL SCIENCE AND MATHEMATICS, June 1951, p 485-86."

This small piece of equipment was constructed in 1949 by Wesley E. Moore and is still in operation as a Corridor Demonstration. Batteries have been replaced every 2-3 years.

A FLASHING NEON LIGHT

WESLEY E. MOORE[1] AND WALLACE A. HILTON
William Jewell College, Liberty, Missouri

An interesting demonstration for the physics class, which will also attract the attention of the non-science student, is a flashing neon light which may be placed in the physics demonstration case and continue to operate for 1½ to 2 years.

The apparatus is arranged as in Fig. 1 where (*L*) is a Type NE-2 GE neon glow lamp, (*C*) is a .05 mfd capacitor, (*R*) is a resistor of about 60,000,000 ohms, and (*B*) consists of four 30 volt hearing aid batteries connected in series. This makes for a very compact piece of equipment.

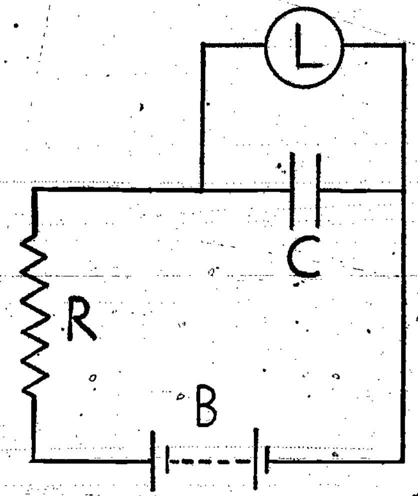


FIG. 1. Flashing neon light.

When operating, the battery (*B*) charges the capacitor (*C*) through the resistance (*R*) until the potential across the capacitor is about 90 volts. This is the voltage necessary to cause the neon lamp to glow. When this potential is reached, the capacitor partially discharges through the lamp. This process is repeated several times per minute.

At William Jewell College this apparatus was set up in a display case on March 28, 1949. At that time the bulb flashed 31 times per minute. Two years later, March 28, 1951, it was still flashing, but only 4 times per minute.

In constructing this equipment, it should be remembered that increasing the resistance decreases the frequency of the flashes, and that an increase in (*C*) provides a brighter light at lower frequency. Also as the EMF of (B) is increased above 90 volts, the frequency of the flashes increases.

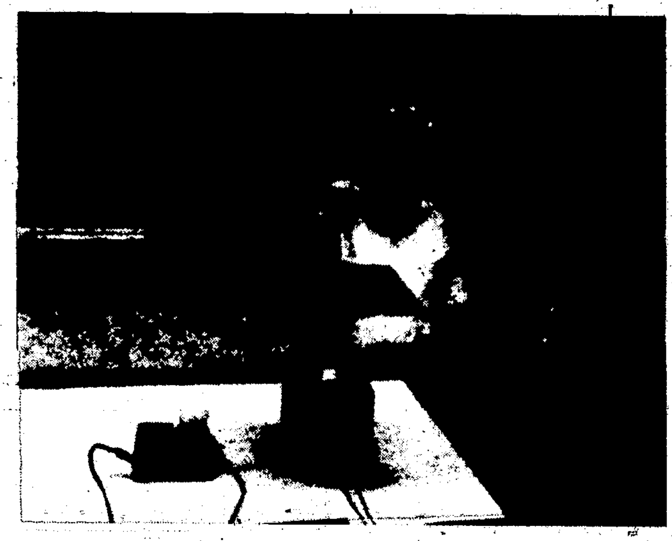
[1] Now at Vanderbilt University.

E-4g Capacitance Operated Relay

The Capacitance Operated Relay shown in Fig E-4g was assembled by Walter Grayum in 1953 from information given in the following articles: RADIO NEWS, Feb. 1947, p 50; RADIO AND TV NEWS, Dec. 1952, p 50. In operation a square piece of aluminum serves as one plate of a capacitor. A per-

E-4g (Continued)

son's hand serves as the other plate. Moving the hand toward or away from the aluminum plate changes the capacitance of the electronic circuit in such a way that a relay closes a switch which turns on a light or rings a bell.



E-5 ELECTRIC FIELDS AND POTENTIAL

E-5a Bring a piece of paper and a cat's fur to class. Place the piece of paper on the chalkboard and rub it hard and fast with the cat's fur. Then announce to the class that you want them to know that voltage is doing work on charge:

$$V = W/q.$$

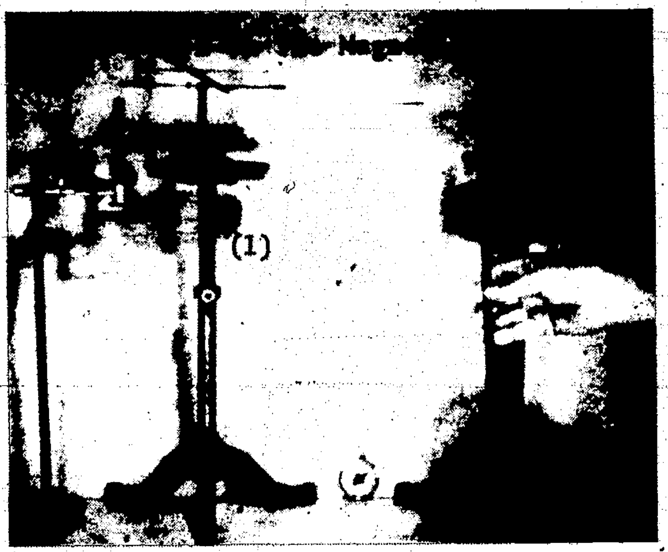
E-5b Van de Graaff Machine
See Experiment A-17b

E-5c Holtz Machine
See Experiments E-1i & E-1j

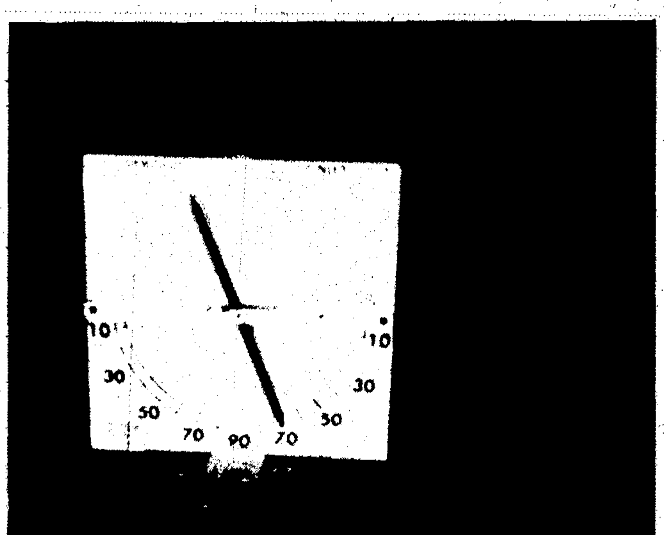
E-6 MAGNETISM

E-6a The Magnetic Compass

Two magnetic compasses are shown in Fig E-6a.



(1) One has a thermocouple loop around it. When the thermocouple is heated a magnetic field is produced which affects the magnetic field of the compass. The compass is placed on a tall stand so as to be partially removed from the field due to the metal table.



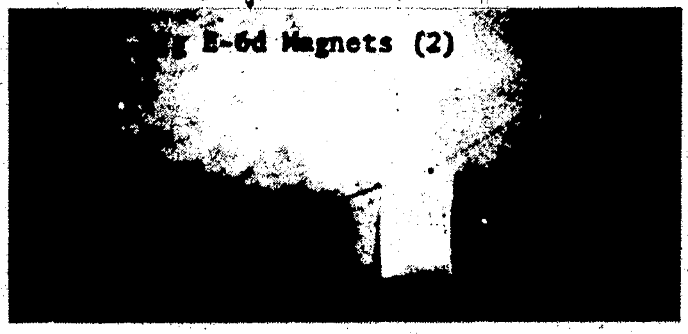
(2) A high permeability, low retentivity and low saturation alloy rod is held near a magnetic compass. This permalloy rod has the very interesting property of changing its polarity when rotated 180° in the earth's magnetic field.

E-6b Magnetic Dip Needles

Two magnetic dip needles are shown in Fig E-6b. The magnetic angle of dip at Liberty, MO is about 70°.

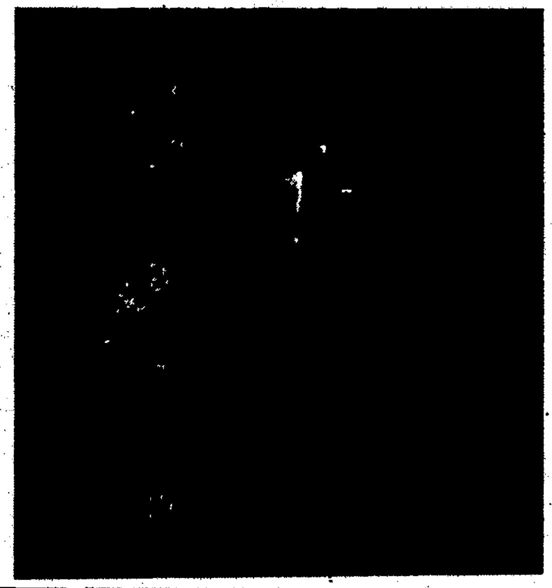
E-6c Magnets (1)

Fig E-6c presents several types of magnets for demonstration purposes. They are:
(1) Electro-magnets
(2) Magnetic rubber
(3) Circular magnets
(4) Alnico magnets
(5) Magnetic compass for use on an overhead projector.



E-6d Magnets (2)

Fig E-6d shows four very strong alnico magnets and a kit of materials for performing several experimental demonstrations. A booklet of instructions is included with the kit.



E-7 CURRENT CARRYING CONDUCTORS

E-7a Joseph Henry's Experiment

Joseph Henry, first American physicist, demonstrated that a rectangular loop of wire would set itself perpendicular to a magnetic field. Fig E-7a shows a working model of Henry's experiment. (See: C. L. Andrews, Joseph Henry, THE PHYSICS TEACHER, Vol 3, pp 13-17, January 1965.)

E-7b Oersted's Experiment (1)

Two pieces of equipment related to Oersted's discovery of the magnetic field about a current-carrying wire are shown in Fig E-7b.

(1) In the first, a flexible wire is above a small magnet. When current passes through

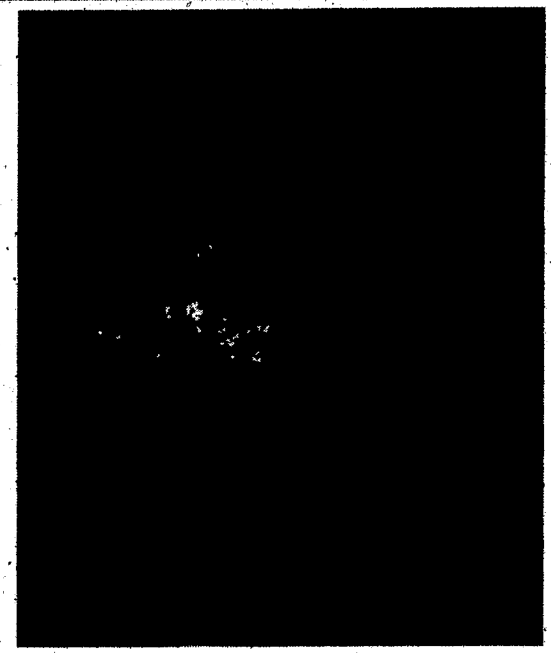
the wire, the wire moves. Reverse the current and the wire moves in the opposite direction.

(2) In the second, the magnetic field about a current-carrying wire causes a deflection of a magnetic compass above or below the wire. (Welch)

E-7c Oersted's Experiment (2)

Another way to present Oersted's discovery is to use the items shown in Fig E-7c with an overhead projector. The items include two loops of wire, a straight piece of wire, magnetic compasses and batteries. These items were developed as an aid in teaching this material from the PSSC text.

E-7d Using Light Bulbs



Three light bulbs are shown in Fig E-7d.

(1) This is a bulb containing a small magnet near the single filament, which vibrates due to the AC current in the in the magnetic field.

(2) Two carbon filament lamps are shown. One is connected to 110 VAC and the other to 110 VDC. A lens is used to project images of the filaments on the screen. When a magnet is brought near the AC lamp, the filament vibrates. When it is brought near the DC filament it moves in one direction only. This is easily observed on the screen.

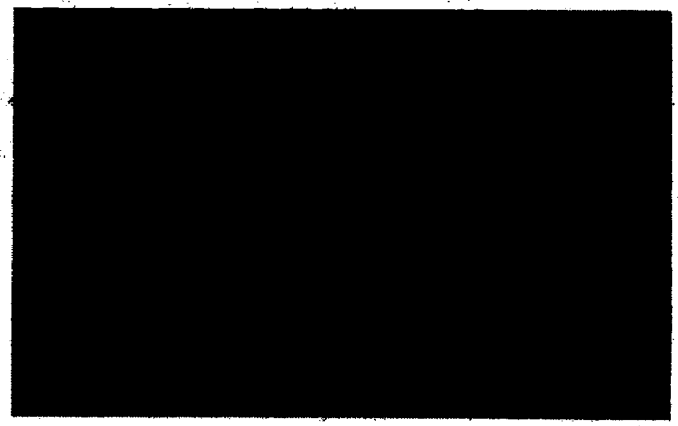
E-7e Faraday's Motor

Fig E-7e shows a model of the first electric motor developed by Michael Faraday. A 6-12 VDC source is required. The magnetic fields of the solenoid and the wire interact so that the wire moves in a circle. The lower end of the wire is in contact with a circular pool of mercury. This is an historic demonstration.

E-7f Electric Motor

A demonstration electric motor is shown in Fig E-7f. A source of 10-18 volts is required for its operation.

The item may also be operated as a DC or AC generator.



E-7g Barlow's Motor and a Magnetic Pump

(1) A Barlow's motor is shown in Fig E-7g. It requires a 6-volt DC source.

(2) A laboratory-constructed magnetic pump is shown in Fig E-7g. A circular dish, half filled with a conducting solution such as copper sulphate is placed between the poles of a magnet. Wires from a 6 VDC battery touch the liquid at the center of the dish and at the edge of the dish. The switch is closed and the liquid flows in a circle.

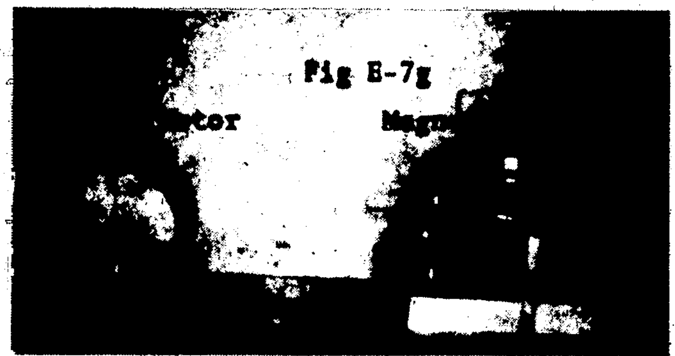


Fig E-7g

E-8 INDUCED CURRENTS

E-8a Induced Current in a Coil

A circular coil of many turns (shown in Fig E-8aa) is held by a student (Fig E-8ab). The wires from the coil are connected to a galvanometer on an overhead projector. The image of the meter's scale is focused on the classroom screen. When the student rotates the coil through 180°, a deflection of the galvanomemeter is observed. (Fig E-8ac).

Fig E-8aa Large Coil of Many Tu

If a magnet is thrust through the coil a much larger deflection is observed. Other facets of the demonstration may include: rotating the coil in the opposite direction, moving the magnet in different directions, etc.

E-8b Generators

(1) The model of a single-turn coil shown in Fig E-8b is very helpful to use with a chalkboard drawing when discussing the theory of a simple generator.

(2) This is a simple demonstration model of a generator and is similar to the one shown in Fig E-7f. It may also be used as a motor.

(3) This is an AC generator which will light a small 110 VAC bulb. This type of generator was a part of telephones made before 1925.

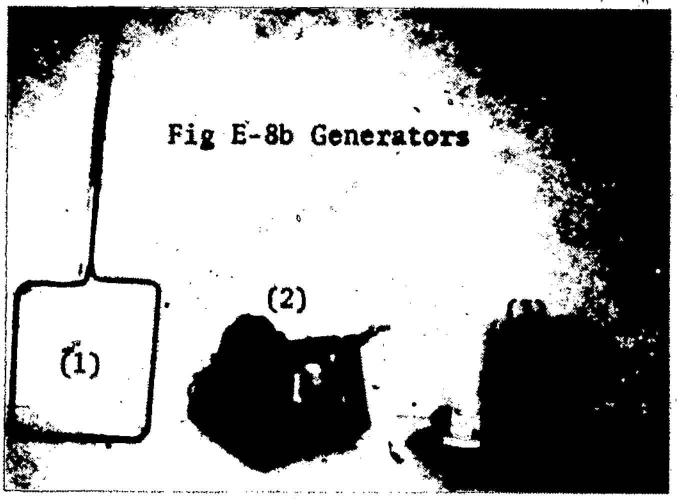


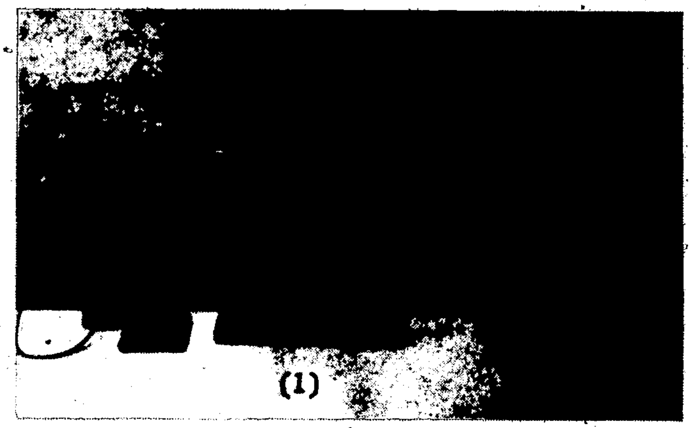
Fig E-8b Generators

E-8c Generator and Motor Principles

This little device includes two magnets and two coils. When one coil moves over a magnet, the current generated causes the other coil to move in its magnetic field.

A battery may be connected through a key. When the key is closed, the motor effect is observed. (1)

Permanent magnets used with this equipment often become weak. To re-magnetize them the Welch apparatus shown in this Fig may be used. (2)



E-8d Eddy Currents (1)

Eddy currents in a moving disk may be demonstrated with the apparatus shown in Fig E-8d. A circular copper disk rotates rapidly under a magnetic compass. The ends of the compass needle rotate in the same direction as the disk.

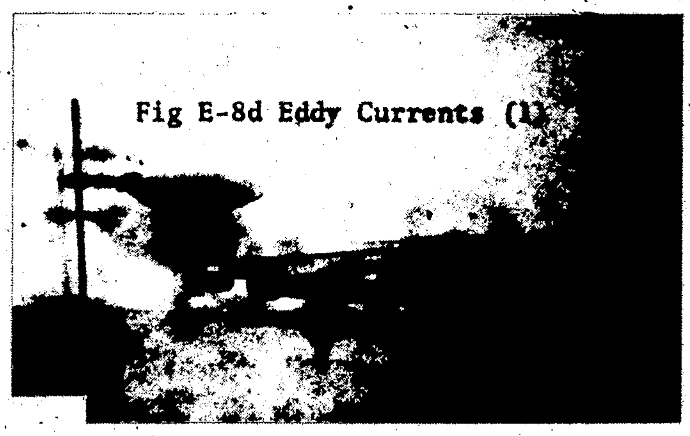


Fig E-8d Eddy Currents (1)

E-8e Eddy Currents (2)

The swinging piece of copper shown in Fig E-8e comes to a quick stop when it approaches the magnetic field near the poles of the magnet; however, when the magnetic field is reduced to zero, the metal swings freely. This magnetic braking effect is due to Eddy currents which are induced in the copper plate.

E-9 MAGNETIC INDUCTION

E-9a Parallel Conductors

When deriving the equation for the force between two parallel current-carrying wires, it may be helpful to the student to see a demonstration of this force with the equipment shown in Fig E-9b. A 6-volt D.C. source capable of delivering 15 amperes is required.

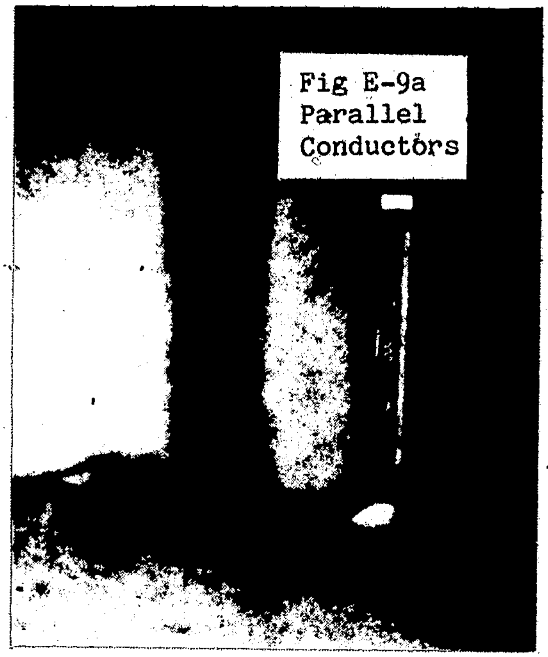


Fig E-9a Parallel Conductors

E-9b Long Solenoid

When discussing the theory and applications of a long solenoid, one may point out an application, such as an experiment to measure the ratio of charge to mass of an electron. The solenoid for this experiment is shown in Fig E-9b (p. 63).

E-9c Helmholtz Coils

One of the many uses for Helmholtz coils is shown in Fig E-9c. A large uniform magnetic field is needed for the special tube used for determining the mass of the electron.

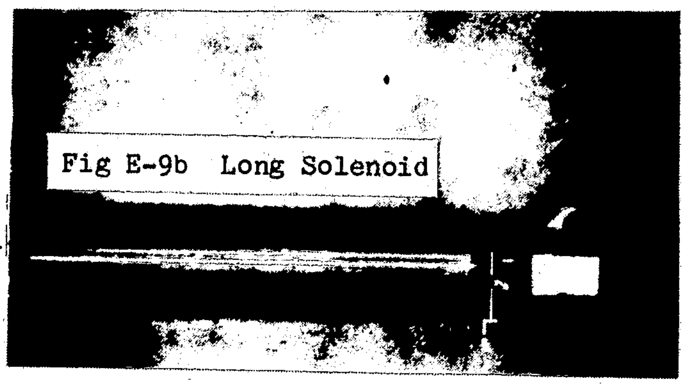


Fig E-9b Long Solenoid

E-10 MAGNETIC PROPERTIES OF MATTER

E-10a Curie Temperature

The Curie temperature for iron is 770°C and is the point at which it loses its ferromagnetic properties. Two demonstrations are shown in Fig E-10a.

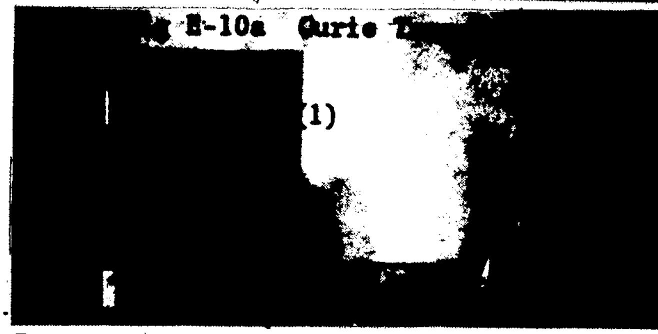
(1) A small nickel wire is attached to a string and is attracted toward a magnet. Heating the nickel to its Curie temperature causes it to lose its ferromagnetic properties and it falls away from the magnet.

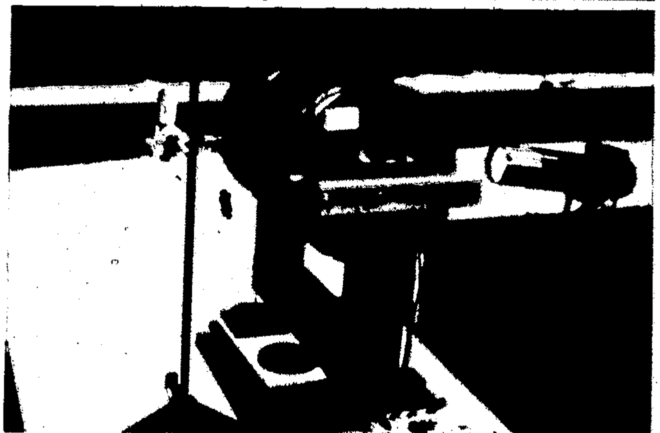
(2) A circular piece of soft iron is pivoted near the poles of a magnet. Heat from a laboratory burner is applied to one edge of the circular disk. When the temperature of the edge of the disk reaches the Curie point (770°C), it loses its magnetic properties, and the disk begins to turn very slowly.

E-10b Diamagnetic Materials

Diamagnetism was discovered by Michael Faraday in 1846 when he observed that bismuth was repelled in a strong magnetic field. With the magnet shown in Fig E-10b, a small piece of bismuth is attached to a light string and hung between the pole pieces of the magnet. A light source and a lens make possible its projection on the classroom screen as shown in Fig E-10bb. By turning up the voltage on the magnet's power supply, the entire class can observe the bismuth being repelled in the magnetic field.

Fig E-9c Helmholtz Coils





E-10c Hysteresis Loop

Strings support two iron bars which are located at the center of a coil of about 100 turns of No. 14 copper wire. The coil is connected through a reversing switch to a DC power supply which is controlled by a varible voltage transformer. With the switch closed, the current through the coil is gradually increased to about 15 amperes, during which time the iron bars become magnetized and slowly spread apart. The current is gradually decreased to zero and the two bars approach each other but do not touch, staying about 1/2 inch apart. Now throw the reversing switch and gradually increase the current. The bars first come together, and then separate. As you decrease the current to zero, the bars again approach each other but do not touch. The cycle may be repeated several times, and the phenomenon observed and compared to a hysteresis loop.

E-10d Barkhausen Effect

The Barkhausen effect is the sudden flipping of the domains in a ferromagnetic material and was discovered by H. Barkhausen in 1919. The apparatus is shown in Fig E-10d. A piece of soft iron is inserted in a coil of wire which is connected to the input of an audio amplifier and speaker. When a magnet is moved quickly along the soft iron, the flipping of the domains induces an emf in the coil and a loud rushing noise is heard from the speaker. Moving the magnet slowly produces clicks. (Reference: John W. Hilton, Independent Study and Research Papers, William Jewell College Physics Department, Vol. 5, pp 222-26, 1965-66)

E-11 TRANSFORMERS

E-11a The Induction Coil

The induction coil in Fig E-11a makes a good demonstration when the theory of this type of transformer is presented.

E-11b Climbing Spark

The transformer shown in Fig E-11b will deliver 15 milliamperes at 15,000 volts and is VERY DANGEROUS. It is mounted about 7 feet above

floor level in the lecture room and the switch should be locked except when being used as a demonstration for the "Climbing Spark." The spark starts at a 3/8-inch gap at the lower end and climbs to the top by ionization of the air above it due to the heat from the spark.

Fig E-11b The Climbing Spark

E-11c Transformers

Fig E-11c shows three transformers that may be used for demonstrations in the classroom.

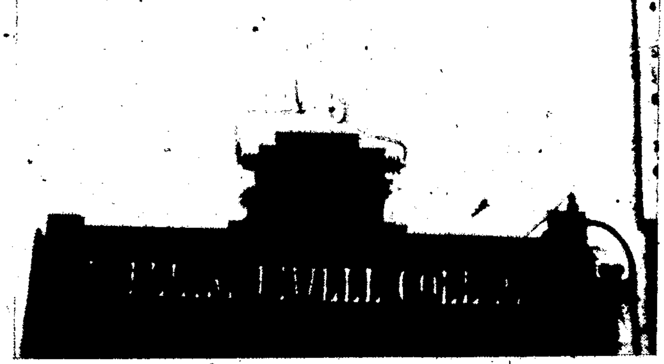


Fig E-11c Transf

E-11d Thompson Type Apparatus

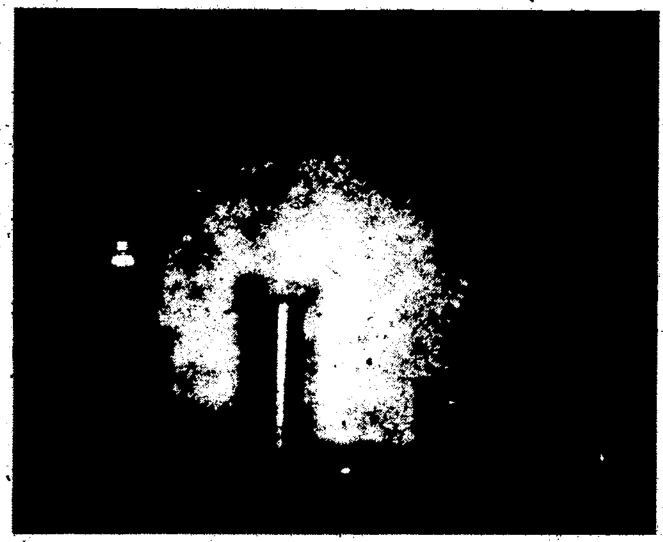
The Cenco, Elihu Thompson type electromagnetism apparatus is shown in Fig E-11d. The equipment makes possible several worthwhile demonstrations, including the jumping ring, the dancing coil, submerged lamp, rotating disk, spinning ball, heating copper or aluminum by induction, boiling water by induction, etc.

E-11e The Tesla Coil

Two Tesla coils are shown.
(1) The one on the left in Fig E-11e was assembled by Charles Don Geilker in 1951, and was based on an article in POPULAR SCIENCE MONTHLY, Jan. 1946, pp 191-194.
(2) The other was assembled by John W. Hilton in 1964 and was based on an article in the June 1964, POPULAR SCIENCE, pp 169-73.

An interesting article on Nikola Tesla, by Haraden Pratt, appeared in the PROCEEDINGS OF THE IRE, Vol 44, pp 1106-08, 1956.

Many interesting demonstrations may be performed with this equipment. Instructions appear in the articles listed above.



E-12 INDUCTANCE

E-12a Inductive Coils

Inductance is associated with a coil of wire. Several types of inductors are shown in Fig E-12a.

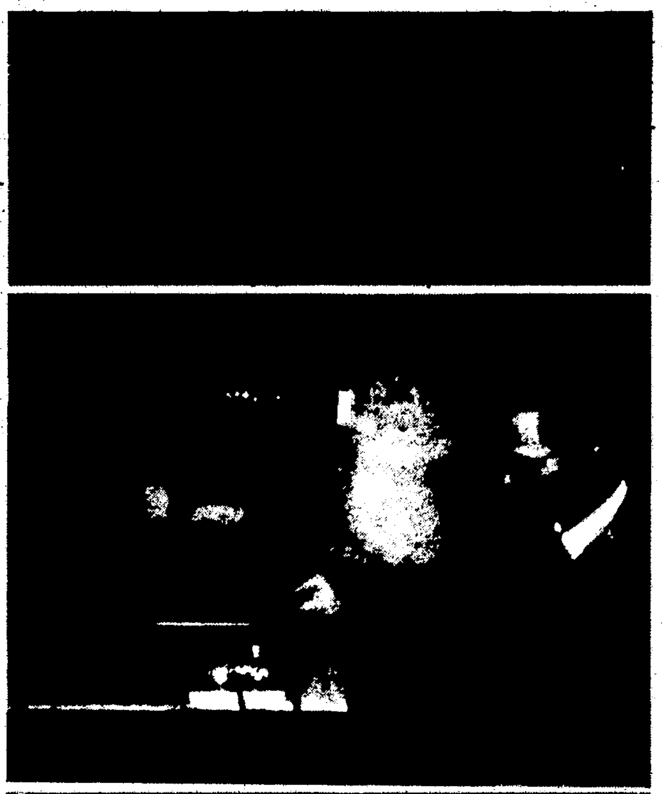
C.D.Geilker

E-12b Back E.M.F.

Back E.M.F. is associated with the equation: $E = -L\, di/dt$. Joseph Henry observed that when a switch is closed in an inductive circuit, no spark is observed; when the circuit is broken by opening the switch a BIG SPARK is evident.

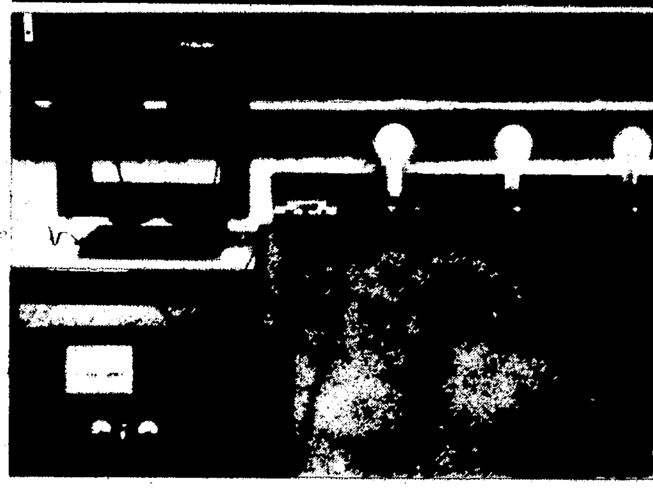
In Fig E-12b a switch is shown which connects a 110 VDC power supply to the two large inductive coils shown. There is no spark when the switch is closed. When the switch is opened a hot one-inch spark is observed. This is due to the back E.M.F. and is a demonstration of the formula: $E = -L\, di/dt$. The energy of the inductor is given by:

$$W = 1/2\, LI^2.$$



E-12c Time Constant

The time constant of an inductive circuit is given by the equation: $t = L/R$, where L is the self inductance of the coil and R is the resistance of the coil. To demonstrate the time constant, connect one or more light bulbs in series with the inductor. This is demonstrated with the equipment shown in Fig E-12c. When the switch is thrown there is a noticeable time lag before the lights come to full brightness.

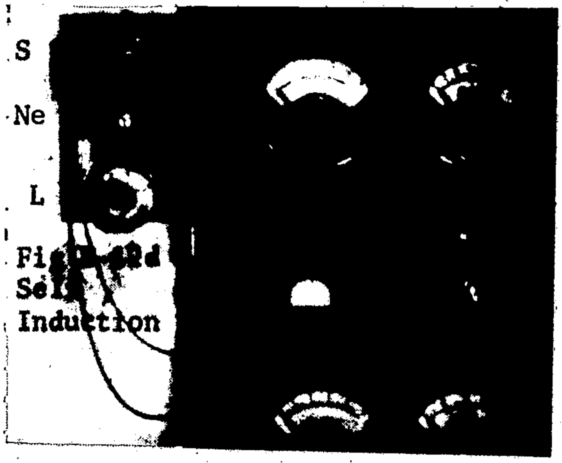


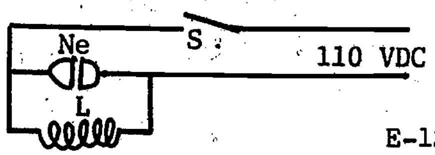
E-12d Self Induction

The apparatus to the left of the power supply in Fig E-12d is shown in the schematic diagram on the next page. When the switch is closed, the neon light glows on one side and then goes

E-12d, continued

out. When the switch is opened the other side of the glow lamp flashes and then goes out. This is due to the back E.M.F. in the inductance when the switch is closed, which causes the current to build up slowly in the inductor. When the circuit is opened, the decreasing magnetic field induces a back E.M.F. which furnishes sufficient current to light the other half of the glow lamp.



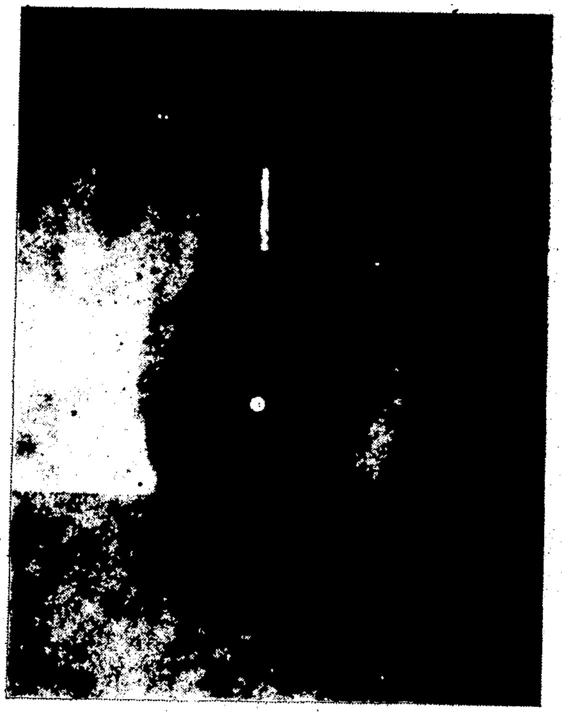


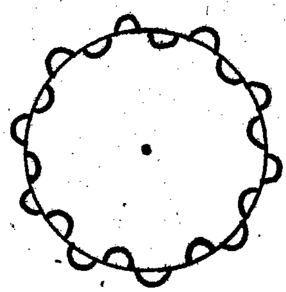
E-12d

E-13 ALTERNATING CURRENT

E-13a Demonstration of Alternating Current

A 2-watt neon glow lamp is rotated in a circle with a hand rotator as shown in Fig E-13a. Since the lamp is connected to 110 VAC, 60 Hz, only one side of the lamp is on during each 1/120 second period. When the lamp is rotated at sufficient angular speed, this is apparent to the eye, since the light from the neon glow lamp will appear similar to the diagram below it.





E-13a

E-13b Parallel Resonance

The apparatus shown in Fig E-13b may be used to demonstrate parallel resonance.

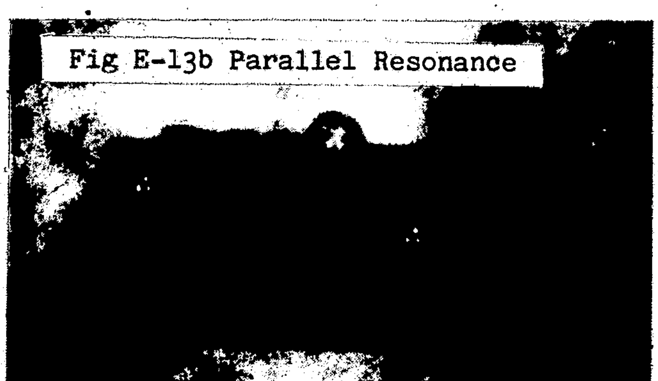
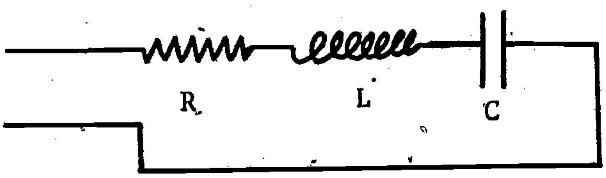
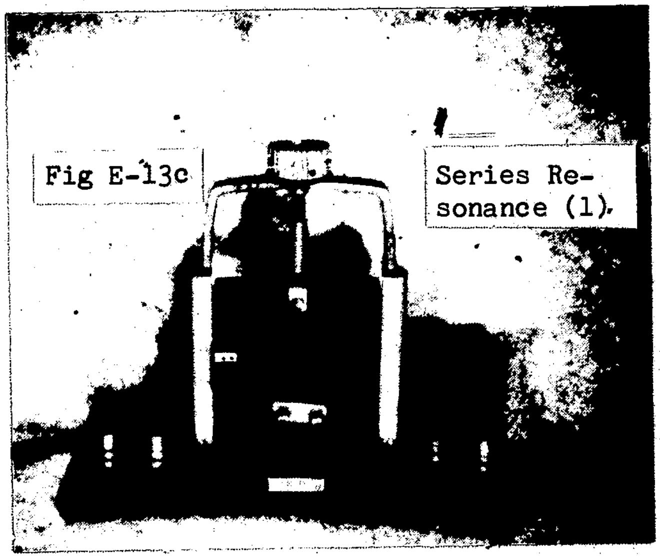


Fig E-13b Parallel Resonance

E-13c Series Resonance (1)

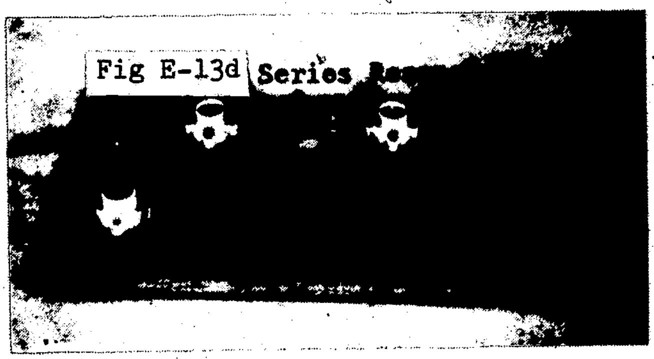
A resistor, an inductor, and a capacitor are connected in series as shown in Fig E-13c. A schematic diagram of the circuit appears below.





E-13d Series Resonance (2)

Another piece of apparatus for demonstrating series resonance is shown in Fig E-13d. Shorting out the capacitor will make a circuit that is sometimes used as a light dimmer.



E-13e Resonance Experiment

The brief paper below is reprinted from the AMERICAN JOURNAL OF PHYSICS, Vol 36, January 1968. It makes a good demonstration or laboratory experiment.

Resonance Experiment

INEXPENSIVE equipment for demonstrating electrical resonance may be constructed by winding about 100 turns of No. 16 copper in-

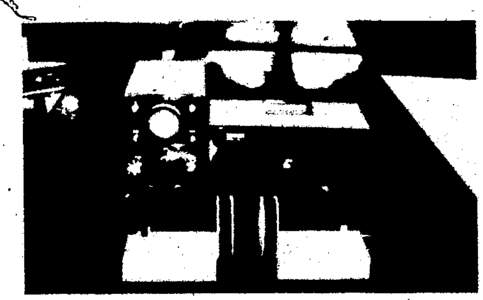


FIG. 2. Arrangement of oscilloscope, oscillator, capacitor, and coils for resonance experiment.

sulated wire around two wooden circular frames, each about 3 in. diam. Coil 1 is connected to the output of an audio oscillator. A 0.1 μF capacitor is placed across coil 2 which is connected to the input of a cathode-ray oscilloscope.

The coupling between the two coils is adjusted so that the signal from the LC circuit may be observed on the oscilloscope. By varying the frequency of the oscillator, electrical resonance is obtained when maximum signal is observed on the oscilloscope. Several different capacitors may be used to find the resonant frequency as read on the oscillator scale. Then, by using the formula: $f = 2\pi(LC)^{-1/2}$, and solving for L, the approximate inductance of the coil may be circulated. Figure 2 shows the arrangement of this equipment.

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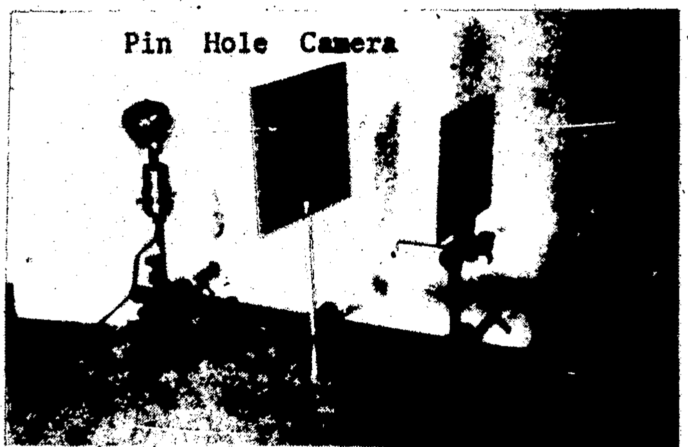
O1 PROPERTIES OF LIGHT

O-1a Pin Hole Camera

This demonstration consists of a coiled-filament lamp for the source, a piece of metal with two small holes in it, and a screen. Two images are easily seen on the screen, or only one image when one of the holes is covered.

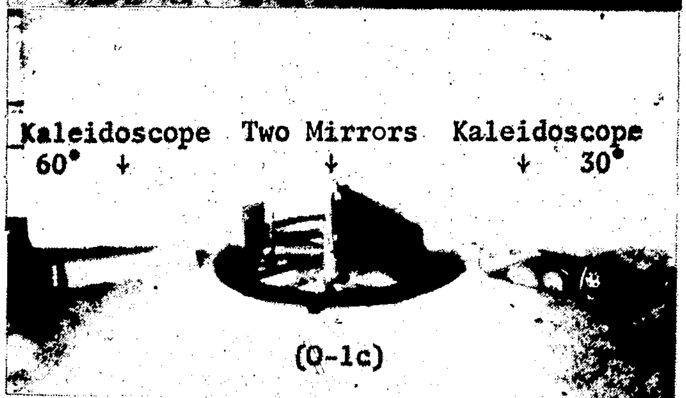


O-1b Inverse Square Law and Foot-Candle Meter

Fig O-1b shows a device which demonstrates the inverse square law, as it relates to light, sound, etc. A Weston-type foot-candle meter is also shown.

O-1c Reflection from Plane Mirrors

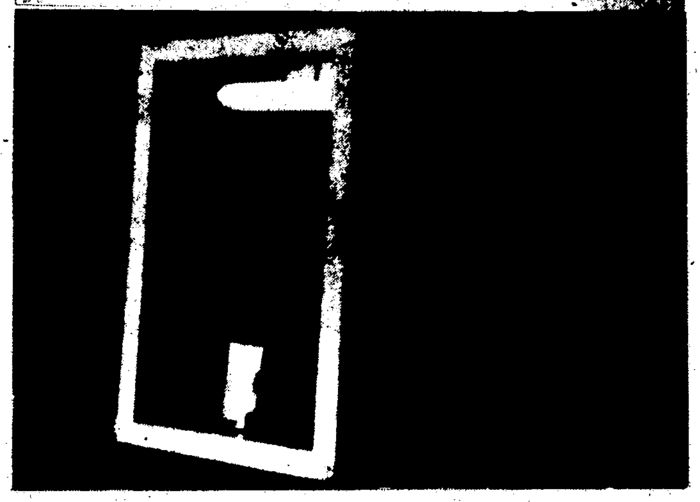
A 60° and a 30° kaleidoscope are shown. Six images are observed with the 60° and 12 with the 30° unit. In the center is a method of demonstrating the number of images seen when two mirrors are at various angles to each other.



(O-1c)

O-1d Large Plane Mirror

A large plane mirror, about three feet in height, may be used to show that it is of sufficient size for a person six feet in height. The geometry of this problem may be shown on the board.



O-1e Object and Image Distances with a Concave and Convex Mirror

A screen, an object, and a concave mirror are shown on the following page. A convex mirror is on the side opposite the concave mirror.

O-1f Concave and Convex Mirrors

Larger mirrors have value in a bigger classroom. A 16-inch diameter convex mirror is shown with a 16-inch concave mirror. An Edmund Scientific Co. 3-inch diameter telescope mirror is also shown. This is satisfactory to use with the object in Fig O-1e to project an image on the classroom screen.

O-2 REFRACTION OF LIGHT

O-2a Minimum Angle of Deviation

This article is reprinted from THE PHYSICS TEACHER, Vol 7, p 513 (Dec. 1969).

Large Scale Demonstration of the Minimum Angle of Deviation

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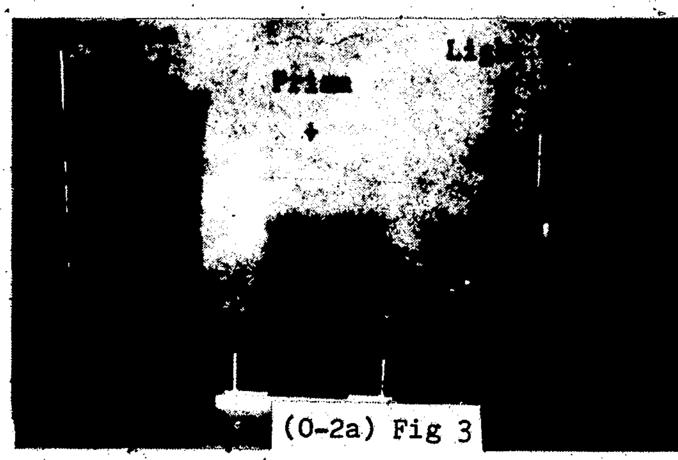
Many students when using a prism spectrometer experience difficulty in obtaining the minimum angle of deviation for the various lines of a spectrum.

Equipment for demonstrating a method for determining the minimum angle of deviation to an individual or to a class is shown in Fig. 3. A 60° prism is mounted on a table that may be rotated slowly. A light source that has a single filament bulb is mounted in a vertical position in a metal box. A lens is used to project the image of the filament on the classroom screen or wall.

When the light is directed through the prism, the beam is deviated through an angle that may be observed by the change in position of the image on the screen. As the prism table is rotated slowly, it will be observed that there is a position of the prism at which the deviation of the image of the spectrum formed on the screen is minimum. This is the minimum angle of deviation for the spectrum projected on the screen. Red, blue, or other filters may be placed in the path of the light and the minimum angle observed for various colors.

It should be pointed out to the student that there is greater dispersion for flint glass prisms used in a spectroscope and that the minimum angle of deviation can be obtained for each spectral line.

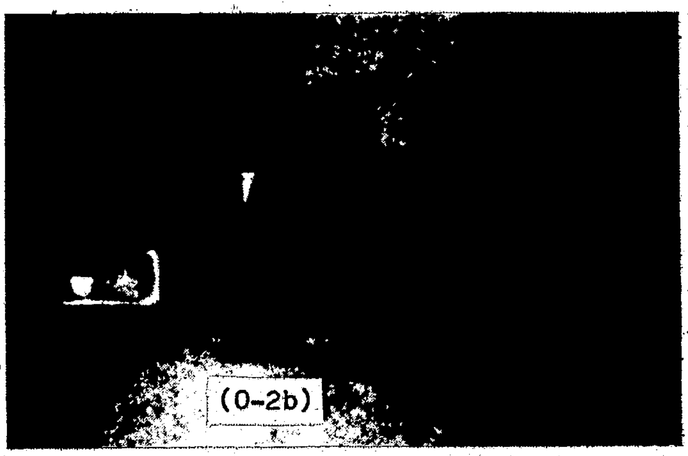


(O-2a) Fig 3

O-2b Index of Refraction of Air

This experiment is usually done in the laboratory, but may be done as a demonstration.

The article below is reprinted from THE PHYSICS TEACHER, Vol 6, p. 176, 1968.



Index of Refraction of Air

Wallace A. Hilton
William Jewell College, Liberty, Missouri 64068

Measuring the index of refraction of air at atmospheric pressure can be an interesting and worthwhile experiment for the beginning student. The equipment needed includes a vacuum pump, a monochromatic light source, and a PSSC Advanced Topics Michelson interferometer with vacuum chamber. (Macalaster Scientific Co., 60 Arsenal St., Watertown, Mass. Item Number 3500, \$20.00.) This apparatus is shown in Fig. 1.

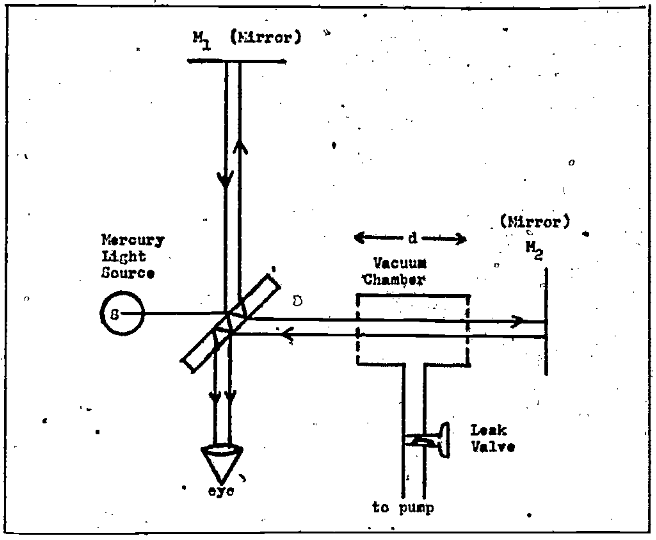


Fig. 1. The PSSC Advanced Topics Michelson interferometer.

The interferometer is adjusted so as to see circular fringes; straight or curved fringes are also satisfactory. It is desirable to observe first the fringes without the vacuum chamber in place and, later, with the vacuum chamber in the beam of light on one arm of the interferometer. The chamber is evacuated, after which air is slowly leaked into the chamber, thus increasing the optical path as indicated by fringes moving across the field of view. If the chamber is 5 cm long and the 5461 Å green line of mercury is used as the monochromatic light source, about 50 fringes will be observed to move across the field.

The change in optical path, $\Delta x = N\lambda/2$, where N is the number of fringes moving past a reference point when air is leaked into the vacuum chamber, and λ is the wavelength of the light. Let d be the optical length of the vacuum chamber and d' be the optical length when filled with air at atmospheric pressure. Also, let n be the index of refraction of the vacuum and equal to 1.00000. Let n' be the index of refraction of air in the chamber; then $d' = nd$ (optical path in vacuum) $+ \Delta x$ (the increase in optical path due to the air). Thus $d' = nd + N\lambda/2$ since $\Delta x = n\lambda/2$.

Dividing both sides of this equation by d the following equation is obtained:

$$\frac{d'}{d} = \frac{nd}{d} + \frac{N\lambda}{2d}.$$

Since $n' = d'/d$ and $n = 1.00000$, the equation becomes

$$n' = 1 + \frac{N\lambda}{2d}.$$

Thus by counting the number of fringes N and measuring the length of the chamber d, the index of refraction of air at atmospheric pressure may be calculated. For example, if $N = 53$ fringes, $d = 5$ cm, and $\lambda = 5461 \times 10^{-8}$ cm, the index of refraction of air n' will be 1.00029 which approximates handbook values. Errors may be due to the lack of a perfect vacuum and to variations in atmospheric pressure.

The experiment may be repeated using carbon dioxide or some other gas that is available in the laboratory.

0-2c Total Reflection and Refraction

Several prisms for demonstrating total reflection and refraction are shown in Fig 0-2d.

0-2d Fiber Optics and Internal Reflection

Five different light pipes are available for demonstrating Fiber Optics and internal reflection, as shown in Fig 0-2e.

0-3 DISPERSION

0-3a Dispersion can be demonstrated by using a prism and a light source to produce a spectrum on a screen.

0-4 LENSES

0-4a Image Location from Lenses

The set of lenses shown in Fig 0-4a may be used with an "Object Source" and a screen to demonstrate the six general cases for object and image distances: (real or virtual, smaller or larger, etc.). In some cases it will be useful to project the image on the classroom screen.

0-4b Optical Disk

About 25 optical demonstrations may be performed with the optical disk shown in Fig 0-4b, such as reflection, refraction, measurement of focal length of mirrors and lenses, total internal reflection, spherical aberration, variation of index of refraction with color, etc.


Fig 0-2c

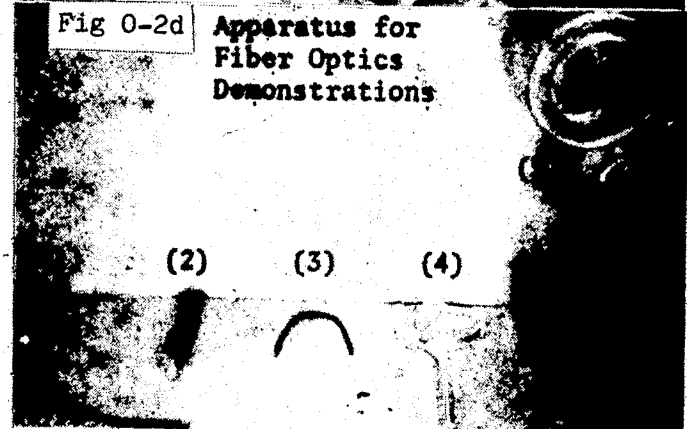
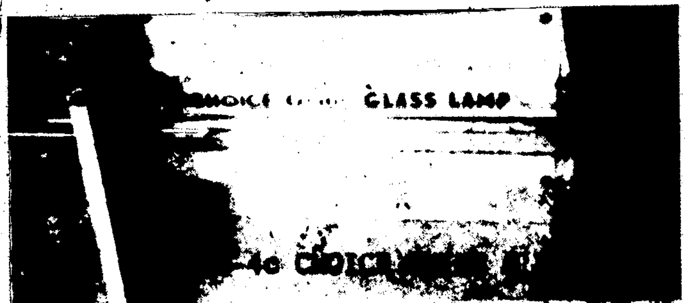


Fig 0-2d Apparatus for Fiber Optics Demonstrations

O-4c CHOICE OXIDE GLASS LAMP

If CHOICE OXIDE is written in <u>red</u> and GLASS LAMP is written in <u>blue</u> and a tube filled with water is placed in front of the words, the words GLASS LAMP appear to be inverted when viewed through the tube of water. WHY? This is a corridor experiment. (J. S. Miller, AMERICAN JOURNAL OF PHYSICS, Vol 23, p 71, 1955)



O-5 OPTICAL INSTRUMENTS

O-5a Cameras: Among the cameras that may be exhibited before a class are: an early model press camera, a Bolex 8 mm movie camera, a Nikon 35 mm camera, and a Century Graphic 2 1/4" x 3 1/4" press camera.

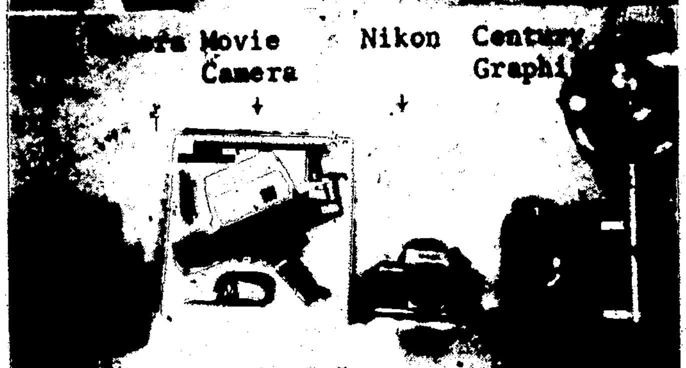


Fig O-5a

O-5b The Eye and a Bigger "Eye"

A model of the human eye is available for the classroom and a Questar telescope is available for a visit to the roof of Science Hall for a look at the sun, moon, planets, stars, etc. A filter is available for observing sun spots, eclipses, etc.

Fig O-5b

O-5c Metallograph

Some students may want to see the Unitron Metallograph in the Optics Laboratory.

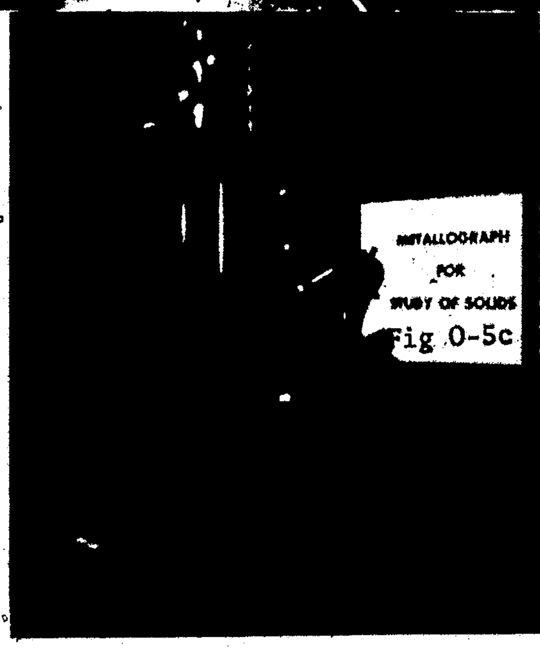


Fig O-5c

O-5d UV-Visible Monochromator

Interested students may receive a demonstration of the Jarrel-Ash Monochromator in the Optics Laboratory.

O-5e Sun Telescope

The description of the sun telescope is reprinted from AMERICAN JOURNAL OF PHYSICS, Vol 38, pp 391-92, March 1970.

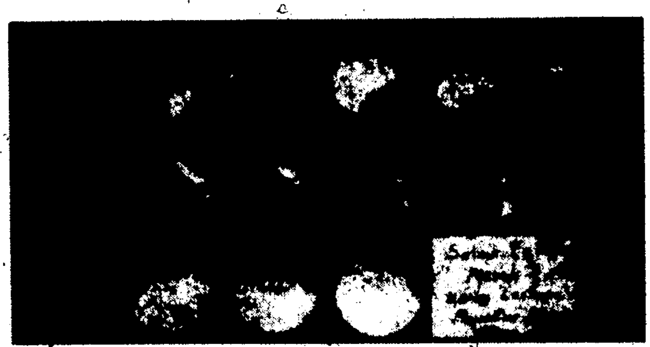


Fig O-5e Photographs taken from classroom screen of the March 7, 1970, eclipse of the sun.

A Solar Telescope for the Classroom*

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William Jewell College, Liberty, Missouri 64068
(Received 4 September 1969)

A visit to the McMath Solar Telescope[1] suggested the idea for a sun telescope for the physics lecture room.

A room is needed which is light-tight except for one small window on the south side of the room. With the window open, the heliostat shown in Fig. 1 is placed in the opening so that light from the sun strikes the mirror M_1 at an angle so that it will be reflected to the mirror M_2. The axis of the two mirrors, M_1 and M_2, is adjusted to be parallel to the earth's axis, which is in the direction of Polaris, the north star. This makes it possible for the motor[2] to rotate M_1 and thus track the sun as it moves across the sky.

Light is then reflected from mirror M_2 horizontally across the room (15–40 ft) to the mirror M_3. Mirrors M_1 and M_2 are optical flats which were obtained from surplus optical equipment and then coated with a thin aluminum film. M_3 is a concave mirror,[3] 3 in. in diameter and has a focal length of 30 in.; however the focal length is not critical.

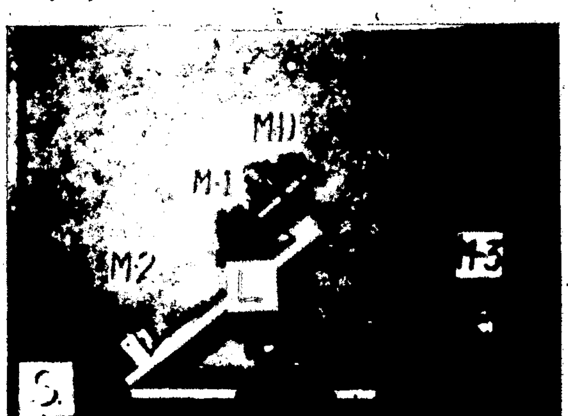


FIG. 1. Heliostat showing the motor-drive M-D and the front surfaced mirrors M_1 and M_2. When in operation, the mirror M_3 and the achromatic lens L are located on the lecture room table and the screen is located just above the heliostat.

The light reflected from M_3 forms a small image of the sun at its focal point, or about 30 in. from the mirror M_3. This image of the sun then becomes the object for the achromatic lens L of 1-in. focal length. The lens is then adjusted so as to form a large image of the sun on the screen, which may be located on the wall just above the open window where the heliostat is located. Careful adjustment and the right touch will be required to get the three mirrors and the lens in proper adjustment. The arrangement of the heliostat, the concave mirror M_3, the achromatic lens L, and the screen is shown in Fig. 2.

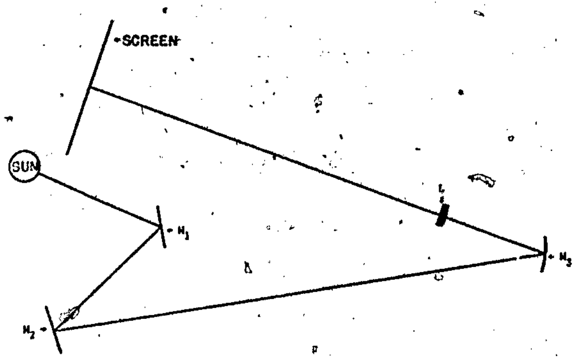


FIG. 2. Arrangement of the heliostat, the mirror M_3, the achromatic lens L and the screen.

This apparatus makes it possible for an entire class to see the image of the sun and to observe sunspots on the classroom screen.

* Exhibited at the AAPT Apparatus Competition, New York Hilton Hotel, 3–6 February 1969.
[1] Located at Kitt Peak, near Tucson, Ariz.
[2] Edmund Scientific Co., Item No. 70 726.
[3] Edmund Scientific Co., Item No. 50 082.

0-5f Larger Telescopes

Three small refracting telescopes are available for observations on the roof of Marston Science Hall. The diameters of the objective lenses are 2.75", 3", and 4".

Two reflecting type telescopes made by W. A. Hilton are also available for use. See Fig 0-5f.


Fig 0-5f

0-5g A Small Planetarium

A description of "A Planetarium for the Amateur Astronomer" is reprinted from SCHOOL SCIENCE AND MATHEMATICS, February 1957.

A PLANETARIUM FOR THE AMATEUR ASTRONOMER

WALLACE A. HILTON
William Jewell College, Liberty, Missouri

For the past several years, small planetariums[1] have been available for home use; however when the stars are projected on the ceiling and walls of the ordinary room the constellations are distorted.

In order to prevent this distortion, it is necessary to have a hemispherical dome. An easily constructed and simple type dome is shown in Fig. 1. The supporting frame is sawed from ¾ inch plywood and the pieces are nailed together so as to make the diameter of the dome six feet. Cheesecloth is stapled to the structure and the planetarium is mounted at the center of the dome. In this case the dome is mounted in a home garage and just above the engine-space of the family car.

[1] Spitz Jr. Planetarium, Spitz Laboratories, Yorklyn, Delaware.

In the evening when the room is dark, the ribbed structure cannot be seen through the cheesecloth and the stars are easily seen in their correct position when projected on the dome.

In order to make the planetarium show more interesting to the local grade school and high school astronomers, flashlight bulbs are placed on the west and east sides of the dome. These are controlled by rheostats. The setting sun is represented by dimming the bulb in the west, and then after seeing the stars of the entire night, the bulb to the east is gradually turned on to indicate the rising sun.

O-5h A Planispheric Planetarium

A description of "A Planispheric Planetarium for the Astronomy Club" is reprinted from SCHOOL SCIENCE AND MATHEMATICS, February 1940.

A PLANISPHERIC PLANETARIUM FOR THE ASTRONOMY CLUB

WALLACE A. HILTON
Hickman High School, Columbia, Missouri

Astronomy Clubs at the high school level are in need of better ways of studying the celestial bodies. Star maps in general do not reveal the movement of the stars and other bodies of the sky. Neither do they point out the place of the horizon at the various times of the day and the year or the movement of the sun and moon among the stars.

In an effort to overcome these problems the Astronomy Club at Hickman High School has a so-called "Planispheric Planetarium." This piece of astronomical apparatus is a home-made device which does show the movement of the stars, the sun, and the moon during every day and hour of the year. This instrument is powered by a small electric motor which turns at 4800 revolutions per minute; however it is geared down so that the time for one revolution of the map, which corresponds to one day of twenty-four hours, is about five minutes. This is made possible by a group of pullies which are so arranged so as to reduce the speed about 10,000 times.

All of the stars that may be seen throughout the year at Columbia are drawn on the map that is four feet in diameter. Since all of these stars cannot be seen at any one time, the map is placed behind a frame that is so designed to show only that portion that may be seen at any one time. The edge of this frame which represents the horizon is not a true circle but rather more or less eliptical or egg-shaped. This is due to the change from polar coordinates to plane coordinates and is obtained by some simple calculations in spherical trignometry.

Objects which represent the sun and the moon are placed just in front of the map so that the paths that they take as they apparently travel through the stars may be easily seen, the sun making a revolution with every 365 revolutions of the stars, and the moon making a revolution each twenty-eight days. A mechanical clock is connected so as to give the exact time of the day and a mechanical calendar gives the date of the various months.

This instrument which we have termed a Planispheric Planetarium has helped to increase the interest and knowledge of the members of the Hickman Astronomy Club in the study of the celestial bodies.

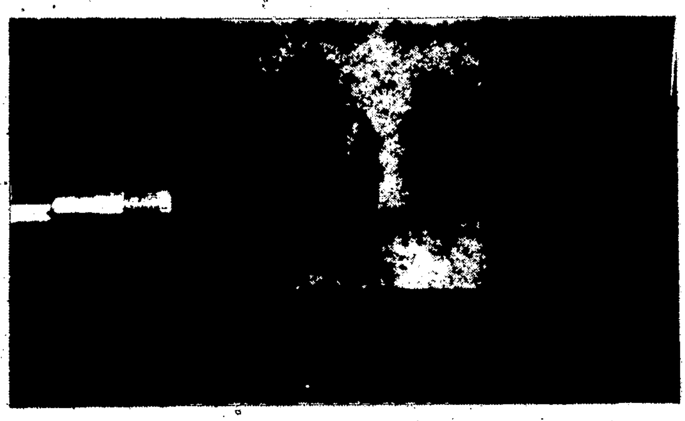
O-6 COLOR

O-6a Welch Color Apparatus

The Welch Color Apparatus is a very useful piece of equipment for demonstrating the addition of the primary colors: red, green, and blue.

O-6b Cenco Color Apparatus

The Cenco Color Apparatus is similar to the Welch apparatus in that the primary colors may be projected on the classroom screen, and the addition of colors observed.



O-6c Filtergraph

The Cenco Balinkin-Dwight Filtergraph has four filters with four corresponding spectrographic diagrams and a slide. It may be used with an overhead projector or a 3 1/4" x 4" projector.

0-7 DIFFRACTION AND INTERFERENCE

0-7a Single and Multiple Slits

Several years ago the Physics Department purchased 24 of the Cornell Interference and Diffraction Slitfilm Demonstrators. These are shown in Fig 0-7a, together with several diffraction gratings, red and blue filters, single filament light bulb, gas discharge tubes, and a Hg light source which is covered with black tape so as to make it a long-line Hg source. The instructions which were received with the Cornell Slitfilm Demonstrator appear below and opposite.

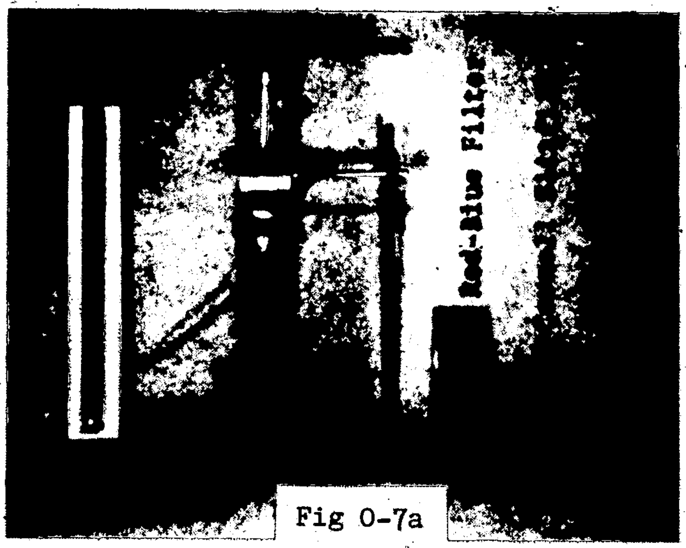
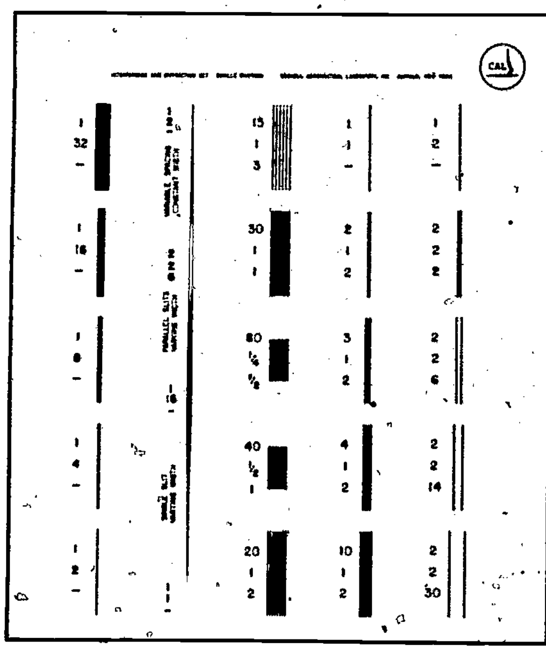


Fig 0-7a



PROPERTIES REQUIRED FOR THE DEMONSTRATION

For best results in demonstration of interference and diffraction, each student should have a slitfilm for his personal use during lecture discussions. Equally usable is the glass-bound slitfilm, or the film itself unbound, although the latter, subject to surface scratching, is likely to become less effective upon the diffusion of light through a scratched surface.

For viewing the phenomena through the slitfilm, one requires a clear glass single-filament lamp, such as Type T-10 120-volt clear showcase lamp, 1¼" in diameter, 5⅝" long, available in any electric or hardware store for about 29c, or for large classes, a tubular clear glass showcase lamp, Type 40-T8, 40 watts, 120 volts, 12" long, approximately $1.20.

MANUFACTURED AND SOLD BY
THE NATIONAL PRESS
PALO ALTO, CALIFORNIA
but no longer available here.

0-7b Interference in Thin Films

Colored interference fringes may be obtained by filling a shallow pan with water and then letting a small drop of oil fall on the water. A thin film of oil will spread over the surface. Then light reflected from a ceiling light at the two surfaces of the oil film will appear blue if the thickness of the oil film is such as to cause constructive interference for blue light. Moving the iron bar so as to change the thickness of the film will produce other colors of the spectrum. Moving the bar decreases the area of the oil film and thus increases the

DIRECTIONS FOR USING THE CORNELL INTERFERENCE AND DIFFRACTION SLITFILM

1. Set the lamp with the filament *vertical* at any convenient distance from the observer, from one foot to fifty feet. A single lamp is sufficient for a whole class.

2. Hold the slide with the long dimension *vertical*, with the Cornell Aeronautical Laboratory monogram (monogram) in the *upper right* corner, as illustrated on the chart.

3. Hold the film *close to the eye* (almost touching the eye) and *look through the slide at the single-filament lamp.*

4. More than twenty different patterns may be seen by looking through the different elements on the slide. For example, on the left is a column of single slits of different widths. The slit at the top is so wide that things will appear quite normal when seen through it. As one goes down the column, the slits get narrower, and the single-slit diffraction pattern gets broader. (The filament becomes less distinct and "broader.")

On the right, except for the top element which is a single slit, there is a column of double slits of different spacings. The farther apart the slits, the closer together are the interference fringes of the double-slit interference pattern.

In the fourth column is a group of multiple slits; secondary maxima can be seen in at least two of the patterns.

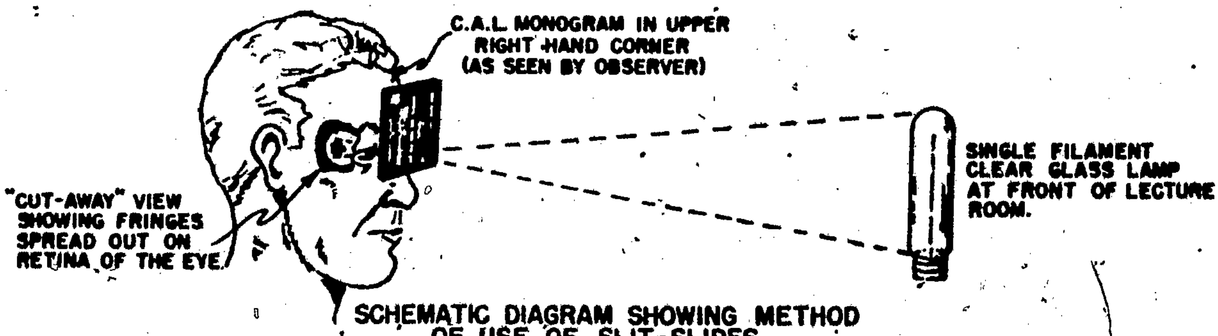
In the middle column is a group of coarse diffraction gratings having various ratios of slit widths to slit spacings.

The pattern in the center of the slide gives the greatest dispersion. With this pattern coarse measurements may be made of the wavelength of the green mercury line in an ordinary fluorescent lamp (covered by a narrow slit), or of the most prominent neon lines in a neon lamp, etc. The second "column" shows a double slit of variable spacing but constant width, faired into a double slit of constant spacing but varying width, faired into a single slit of varying width. When this pattern is drawn past the eye (vertically), many phenomena can be seen.

5. Many additional phenomena can be demonstrated. One may use blue and red color filters over the lamp, from which it will be seen that the patterns are wider with the longer wavelength red light. One may observe the position of "missing orders," although in the closely spaced patterns, it is not possible to control missing orders too well. If one looks at a pattern of closely spaced sources (for example, a transparent line source with lines spaced about ¼ inch apart), then many interesting phenomena can be seen. Tilting the slide about a vertical axis in effect varies the slit spacing. In respect to directional characteristics, it is desirable to draw analogies among optics, sonar, and radars, etc.

6. It is worth noting why the filament of the lamp appears to be spread out in a series of fringes. Actually, the filament is not altered when the slit is put in front of the eye, but the slits produce interference or diffraction patterns focussed and *spread out on the retina* of the eye. Because the pattern is spread out on the retina, we "see" the pattern spread out in space.

7. For further information on the slitfilm, see Seville Chapman and Harold Meese, *American Journal of Physics*, 25, 135-138, March 1957. For further information on the phenomena to be observed, consult any good book on physical optics (for example, Jenkins and White), and study the chapters on interference and diffraction.



SCHEMATIC DIAGRAM SHOWING METHOD OF USE OF SLIT-SLIDES.

O-7b, continued

thickness. The oil must be of low viscosity, such as old crank-case oil from a car. The film may be removed by sliding the bar across the top of the pan. This is an excellent demonstration.

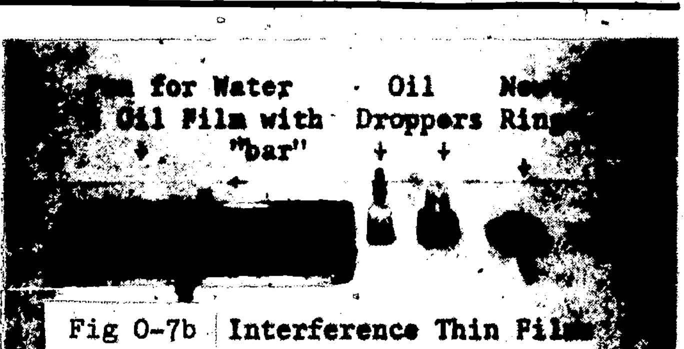


Fig O-7b Interference Thin Film

O-7c Pohl's Experiment

Pohl's experiment on interference may be performed with a good quality mica sheet and a mercury light source. The interference pattern formed by reflection betwen the two surfaces of the mica will produce circular fringes which may be easily observed on the classroom screen.

A mercury light source that may be used for this and other experiments is described in the following reprint from the AMERICAN JOURNAL OF PHYSICS, Vol 19, p 248, April 1951.

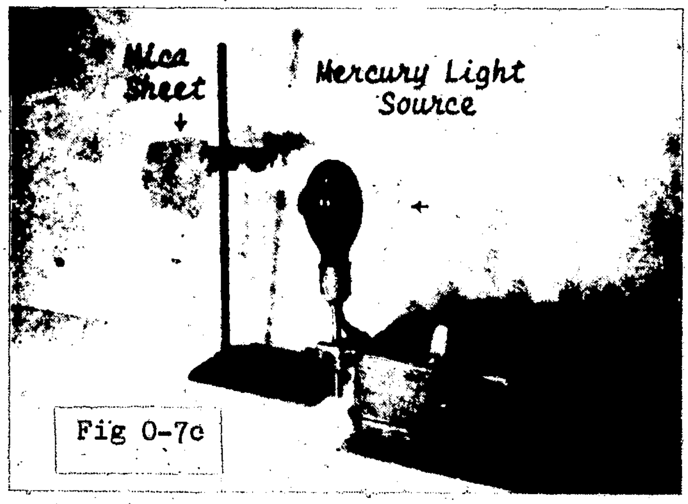


Fig O-7c

SEVERAL economical types of mercury light sources have been suggested for the beginning laboratory. Schwinn[1] has suggested the use of a type 816 mercury-vapor rectifier. Kirkpatrick[2] suggests an ordinary fluorescent lamp while McCay and Bishop[3] use a standard germicidal lamp.

Another satisfactory source may be constructed with parts usually found in a physics laboratory plus three items that may be purchased for less than $15.00. These items are a GE S-4 sunlamp which operates from a (GE No. 58G720) ballast, and the special socket for the lamp. The other parts consist of a tin can for the lamp house, a ring stand to hold the lamp at the desired height, and a small metal cabinet to house the ballast. An off-on switch may be mounted on one side of the cabinet. It may also prove convenient to have an outlet on the same side of the cabinet which will permit the lamp to be disconnected. A filter holder may be constructed of plywood or some other material and clamped to the lighthouse with a coil spring. At William Jewell College we have constructed several of these units, one of which is shown in Fig 1.

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Liberty, Missouri

[1] M. W. Schwinn, Am. J. Phys. 15, 279 (1947).
[2] P. Kirkpatrick, Am. J. Phys. 15, 359 (1947).
[3] M. S. McCay and E. S. Bishop, Am. J. Phys. 16, 361 (1948).

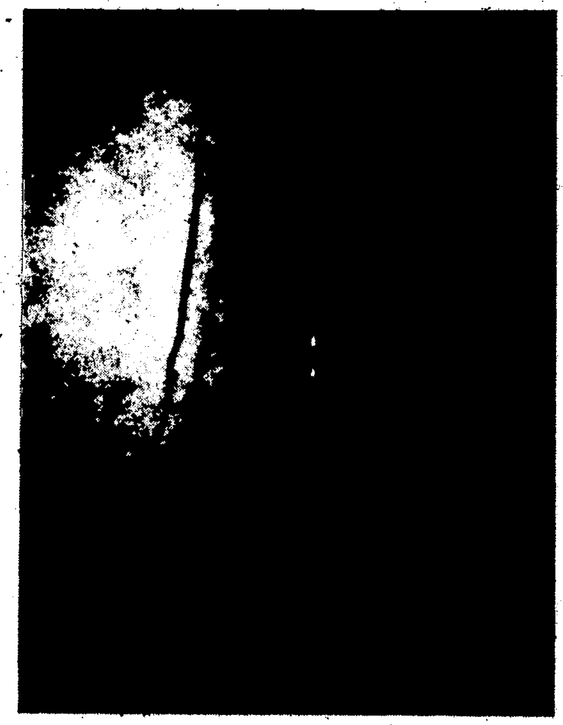

FIG. 1. Mercury light source.

O-7d Interference Fringes, Newton's Rings, Arago White Spot

The thickness of thin metallic films may be observed with a 36 in^2 broad source Helium lamp or more accurately with a sodium source and a microscope. Newton's rings may be observed with either light source. An optical flat is available for determining the flatness of other pieces of glass.

A demonstration of the Arago White Spot, located in the physics department hall, is described below in a paper reprinted from the AMERICAN JOURNAL OF PHYSICS, Vol 36, pp 9-10, April 1968.

Arago White Spot

GENERAL physics texts[1-2] usually include a description of the experiment by Jean Arago which is one of the most convincing demonstrations of Fresnel diffraction theory. Usually called the Arago white spot, it may be observed in the shadow cast by a small ball bearing from a point source of light. The result is a white spot in the center of the shadow and circular fringes surrounding it. This famous experiment may be presented as a permanent corridor demonstration by placing a small flashlight bulb at one end of the hall and a small telescope at a distance of from 75 to 125 ft away. A small ball bearing is placed midway, and in line with, the lamp and the telescope. When the light is turned on and the ball bearing carefully adjusted for alignment with the telescope, the Arago white spot and the circular fringes may be observed.

This demonstration, using a GE No. 13 bulb, a ball bearing 10 mm in diameter, and a small 10X telescope has been exhibited in the William Jewell College physics corridor for over 15 yr. The distance between the bulb and the telescope is 90 ft, with the ball bearing being 30 ft from the telescope; however, these distances are not critical.

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ROBERT SANDQUIST
Smithville, Missouri, H.S.

[1] W. W. McCormick, *Fundamentals of College Physics* (The Macmillan Company, New York, 1965), pp. 671–673.
[2] F. W. Sears and M. W. Zemansky, *College Physics* (Addison–Wesley Publishing Co., Inc., Reading, Mass., 1960), 3rd ed.

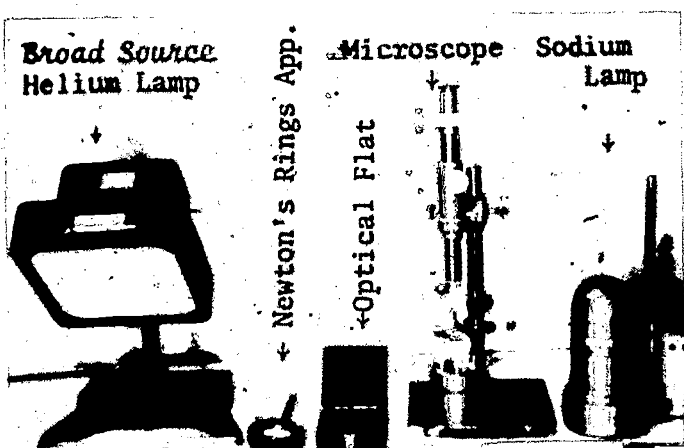


Fig 0-7d

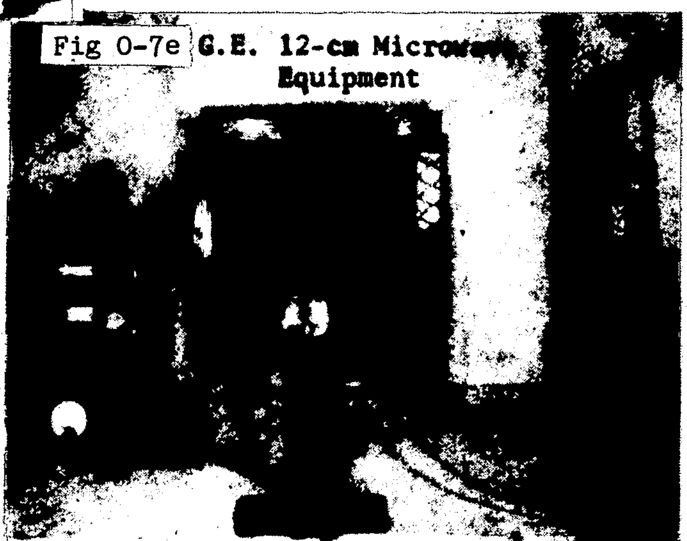


Fig 0-7e G.E. 12-cm Micro... Equipment

0-7e Microwave Optics: S-Band, 2cm

The General Electric microwave equipment is available for demonstrations to large classes.

0-7f Microwave Optics: X-Band, 3cm

The Budd-Stanley 3cm Microwave Equipment is useful in smaller classes and for individual laboratory work.

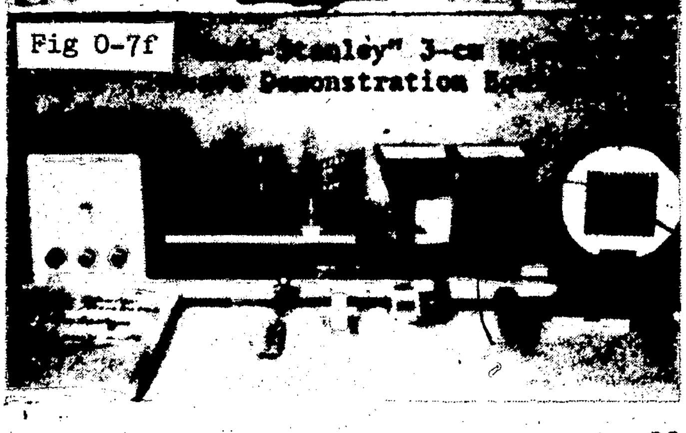


Fig 0-7f ...Stanley" 3-cm ... Demonstration ...

O-7g Double Slit and Fresnel Zones

The equipment shown in Fig O-7g is used with the 12-cm microwave oscillator to demonstrate double slit interference and Fresnel zone interference to large classes.

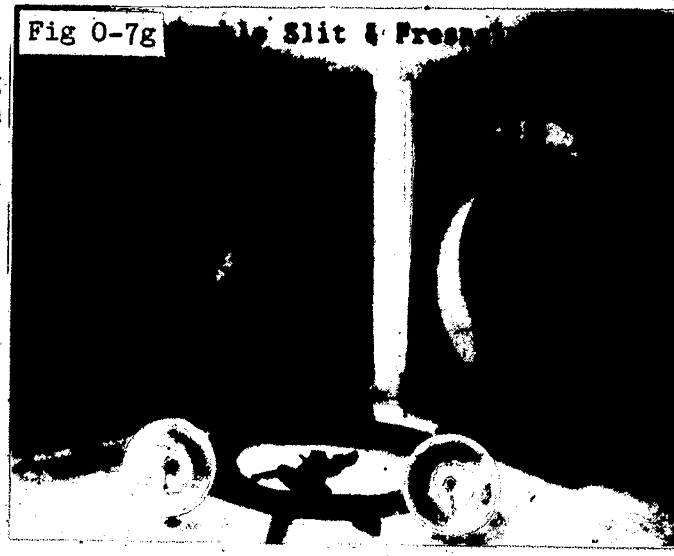


Fig 0-7g

O-7h Microwave Demonstrations, 420 mHz

Microwave demonstrations using 420 mHz are described in the article below, reprinted from the AMERICAN JOURNAL OF PHYSICS, Vol 20, pp 307-08, May 1952.

Microwave Demonstrations*

JOSEPH W. CHASTEEN† AND WALLACE A. HILTON
William Jewell College, Liberty, Missouri
(Received January 14, 1952)

THE importance of microwaves in the teaching of physical optics has been pointed out by Andrews[1] using 2500-megacycle (12-cm) commercial equipment.

Persons interested in constructing rather inexpensive microwave equipment (420 megacycles) that may be used for this purpose may find the circuits and description of this type equipment which appeared in a recent issue of *Ham News*[2] of interest.

Two 420-megacycle oscillators, together with antenna, intensity meter, and Lecher-wires are shown in Fig. 1. This apparatus may be used to demonstrate several properties of electromagnetic waves, such as interference, reflection, polarization, standing waves, etc. It may also be used in the teaching of microwave transmission as applied to radio and television.

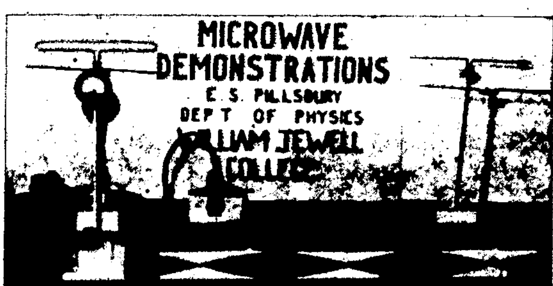


FIG. 1. Microwave demonstration apparatus.

Experiments that may be performed include the following:

1. Reflection may be studied using a metal reflector or a half-wave wire reflector.
2. Radio fading may be shown using a reflector to represent the ionosphere.
3. Standing waves may be shown by moving the intensity meter between the antenna and a reflector.
4. Polarization may be shown by rotating the intensity meter, or by the insertion of a parallel wire screen between the antenna and intensity meter.
5. Field pattern of an antenna may be observed by reading the intensity meter at various locations.
6. Focusing of electromagnetic waves may be demonstrated with a half-wave reflector.
7. The effect of a reflector on a television antenna may be shown by using a half-wave reflector with the intensity meter.
8. Using a Lecher-wire system, standing waves may be demonstrated and the frequency of the oscillator measured.

* Exhibited at the 12th Annual Colloquium of College Physicists State University of Iowa, June 13-16, 1951.
† Now in United States Navy.
[1] C. L. Andrews, Am. J. Phys. 14, 379-82 (1946) and 17, 462 (1949).
[2] Ham News, "Table Top Antennas," 4, No. 1, 1-5, Jan.-Feb. (1949). General Electric Company, Schenectady, New York.

O-7i Acoustical Optics

Optical experiments that have been presented in Experiments O-7e, f, g, & h may also be demonstrated with sound waves of from 7000 to 10,000 Hz with the equipment shown in Fig O-7i. The following article from the AMERICAN JOURNAL OF PHYSICS, Vol 17, p 581, Dec 1949, describes a demonstration of acoustical interference.

The Acoustic Radiator

THE Schilling[1-2] articles of a decade ago gave impetus to the design of apparatus for the use of high frequency audible sound waves, in place of optical waves, to illustrate more easily Huyghen's wave principle, interference and diffraction phenomena.

One of the acoustical radiators,[3] manufactured to demonstrate the above principles, was purchased in 1939 by the University of Arkansas. The equipment has worked well except for the Galton whistle, which was used as the source of sound. Even with a constant pressure tank, the frequency would not always remain constant over any sequence of experiments. Following the war, the Galton whistle was replaced by a very small loud speaker placed within the tube. The sound was directed toward a parabolic reflector at the closed end. The reflected wave which passed through the open end has proved to be more satisfactory than that from the Galton whistle.

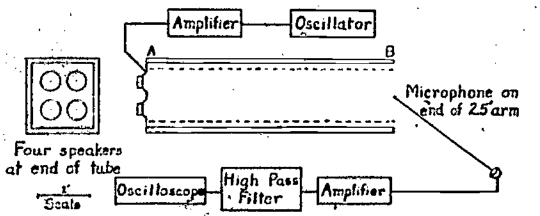
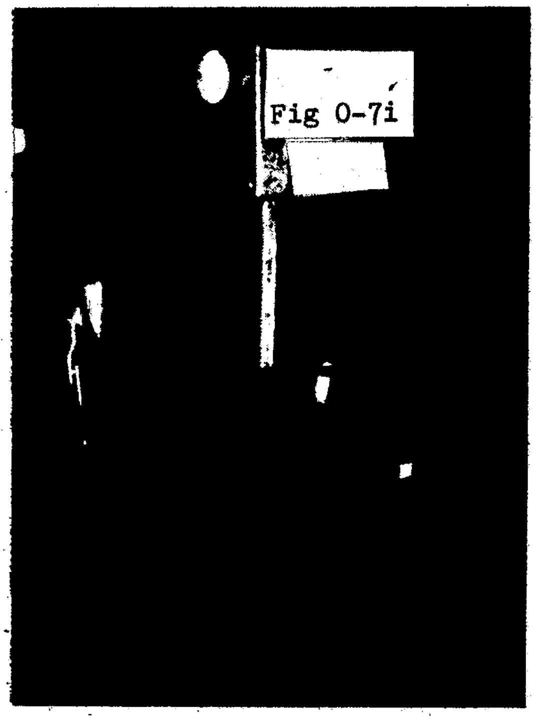


FIG. 1. An acoustic radiator designed to radiate plane waves at opening B by use of four speakers connected in series and located at end A.

The main purpose of this letter is to call attention to the loud speaker system used in a more recent construction of a complete acoustical radiator at William Jewell College. In this instrument four small loud speakers, connected in series, were placed at A of Fig. 1, the location of the parabolic reflector mentioned in the previous paragraph. This source has proved very satisfactory for a range of frequencies from 5000 to 10,000 cycle sec^{-1} to perform some 23 different experiments.



The tube is constructed of wood and lined inside with glass fiber one inch thick. The circular and rectangular slits are made from quarter-inch 3-ply wood. The semi-reflectors are made of painted screen wire. The arrangement for the oscillator, amplifiers, and oscilloscope is also shown in Fig. 1.

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[1] H. K. Schilling and W. Whitson, *Am. Physics Teacher* 4, 27 (1936).
[2] H. K. Schilling, *Am. Physics Teacher* 5, 280 (1937); 6, 156, 266 (1938).
[3] Central Scientific Co., Catalog J-141, Item No. 84685.

0-8 POLARIZATION

0-8a Polarization by Reflection

When unpolarized light falls on a piece of glass at an angle of incidence equal to about 57°, the reflected light is plane polarized. If this light is then directed to another piece of glass at about the same angle of incidence, but at 90° to the plane of polarization, the intensity will approach zero. Apparatus for this demonstration is shown in Fig 0-8a.

0-8b Polarization of Light Experiments

The kit for presenting several demonstrations using an overhead projector includes a piece of VW plate glass, tourmaline crystal, polarizers, calcite crystals, λ/4 plate, λ/2 plate, mica, several double-refracting materials, photo-elastic specimens, two 4-inch square Polaroid sheets and a sheet of plastic for use with the overhead projector. A rather dramatic demonstration of polarized light experiments may be presented with this equipment.

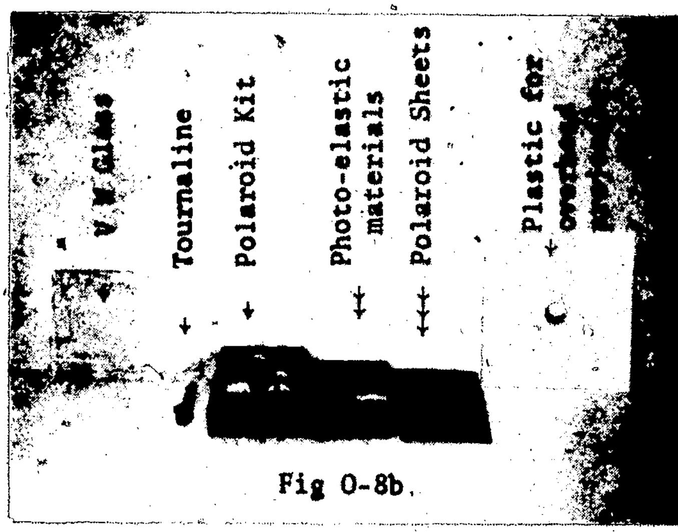
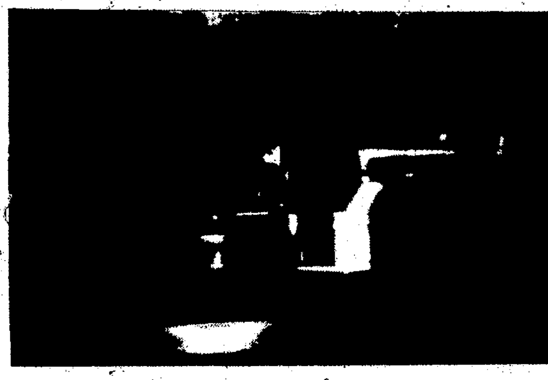


Fig 0-8b.

0-8c Retardation Plates and Ellipsometry

Several models of retardation plates are available and are briefly described in this reprint from the AMERICAN JOURNAL OF PHYSICS, Vol 21, pp 266-67, September 1953.

Students interested in this field may want to see an ellipsometer like the one shown in Fig 0-8c.



Demonstration Models of Retardation Plates in Polarized Light

WALLACE A. HILTON
William Jewell College, Liberty, Missouri

TEXTBOOKS on optics[1] give good explanations of the characteristics of retardation plates as related to plane-polarized light. However, models may serve as an additional aid to the instructor in presenting this part of the light and optics course.

Fifteen models[2] are proposed as an aid in the teaching of the following three topics:

1. A model of a half-wave retardation plate in which the plane of polarization is rotated through 90 degrees is shown in Fig. 1. The first model represents plane-polarized light, whose plane of vibration is oriented at 45 degrees to the optic axis of the retardation plate, thus making the ordinary and extraordinary waves of equal amplitude. This is shown in Model 2 of Fig. 1. A study of Models 3 and 4 demonstrates how the plane of polarization is rotated through 90 degrees due to the different velocities of the E and the O rays in the half-wave plate. This 90-degree rotation is indicated in Models 4 and 5 of Fig. 1.

2. In a similar manner models to explain how plane-polarized light becomes circularly polarized light after passing through a quarter-wave plate may be constructed.

3. Models which present an arbitrary retardation plate which gives elliptically polarized light may also be prepared.

After discussing each of the above, the relationship of the three types may be presented along with the fact that circularly polarized light and linearly polarized light are special cases of elliptically polarized light.

(Continued on next page)

These models are made of plastic and are supported on wooden pins and bases. Drawing ink is used to represent the waves.

[1] F. W. Sears, *Optics*. (Addison-Wesley Press, Cambridge, 1948), 3rd edition, pp. 185-91.
[2] Exhibited at the Colloquium of College Physicists, State University of Iowa, June 11-14, 1952.

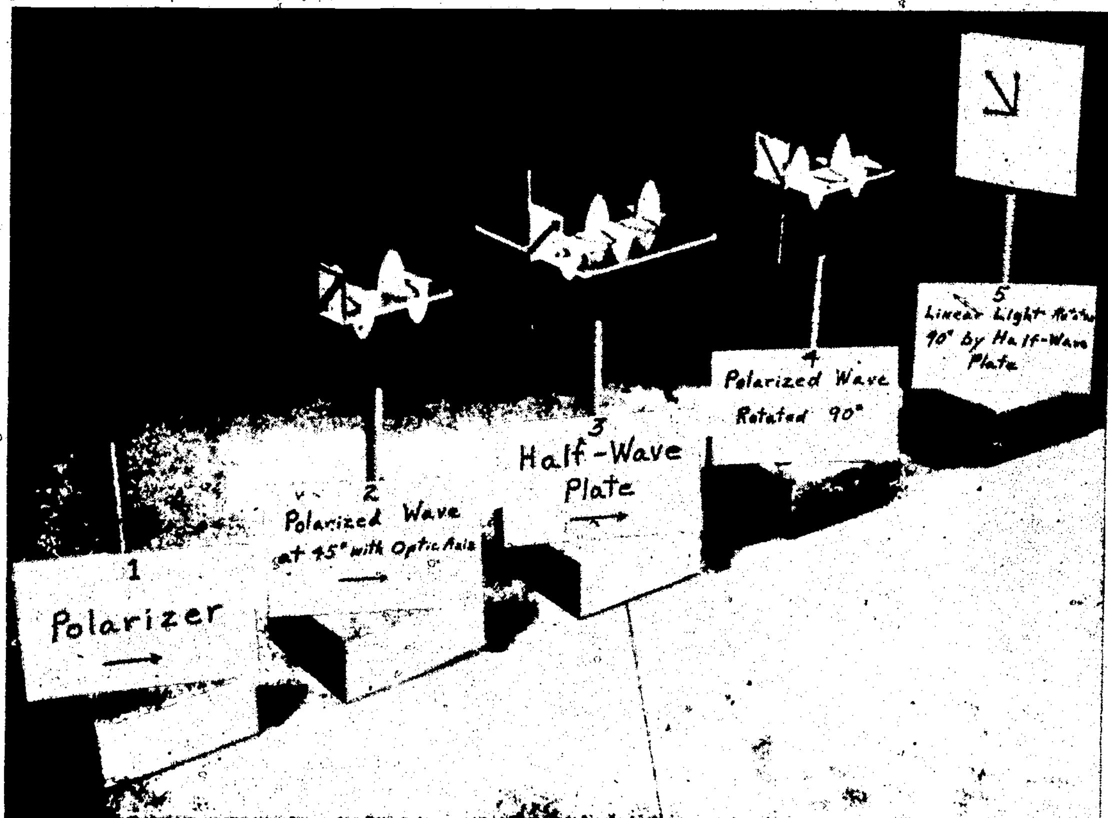
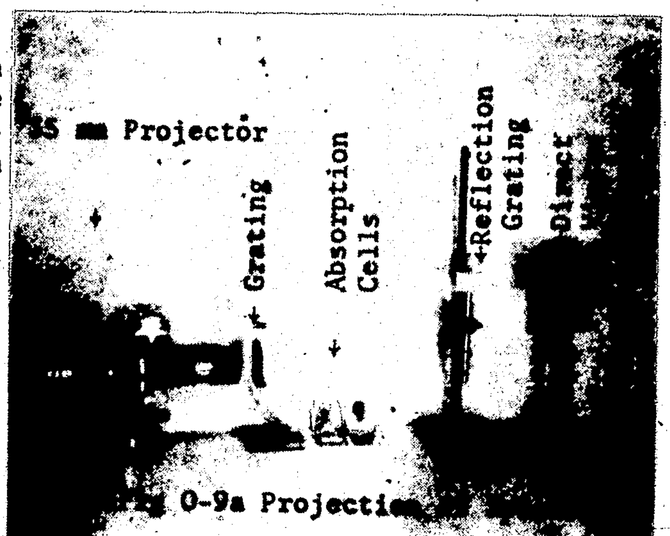


FIG. 1. Models for the explanation of a half-wave plate in polarized light.

O-9 SPECTRA

O-9a Spectra Projection on Screen

The B & L spectra projection kit is used with a 35mm slide projector to present a continuous spectrum on the classroom screen. Absorption cells which may be filled with various colored liquids may be placed in the slide projector and the absorption spectrum observed on the screen.



A reflection type grating is available for showing the visible spectrum. The Eaton's Direct Vision (Cenco) lecture table prism may also be used for this purpose.

0-9b Emission Spectra (1)

The apparatus shown in Fig 0-7a makes a very worthwhile demonstration experiment; Tube-Lite spectrum tubes with a 13,400 lines/inch grating are viewed by each student.

A calibrated grating spectrometer makes possible the reading of the approximate wavelength of the spectral lines; it is shown in Fig 0-9b. When light from the sky is focused on the slit, the Fraunhofer lines may be observed.

0-9c Emission Spectra (2)

A prism spectrometer may also be used to study emission spectra as shown in Fig 0-9c.

0-9d Absorption Spectra

The Barnes ES-100 Educational Spectrometer is helpful in demonstrating absorption spectra to small classes. A description of this topic is given in the following reprint from the AMERICAN JOURNAL OF PHYSICS, Vol 35, pp 542-43, June 1967.

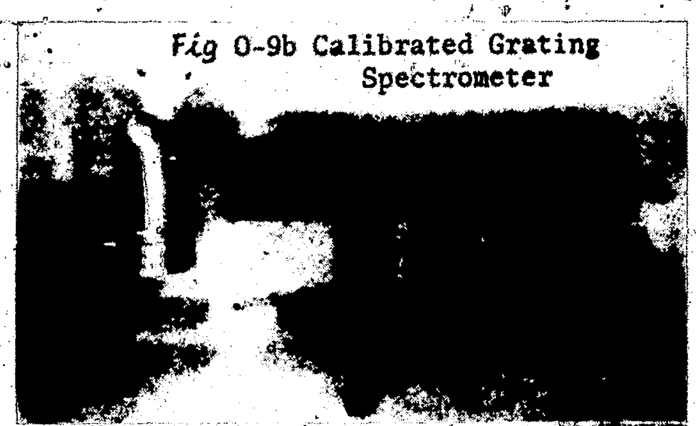
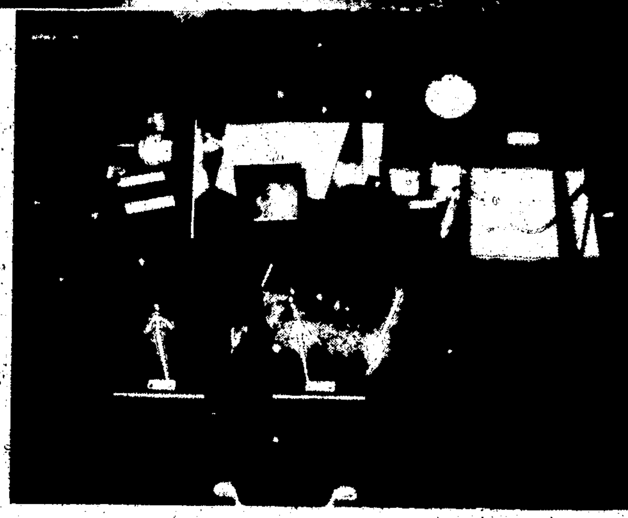


Fig 0-9b Calibrated Grating Spectrometer

Fig 0-9c Prism Spectr...



Using the Barnes ES-100 Educational Spectrometer

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William Jewell College, Liberty, Missouri

(Received 18 July 1966; revision received 1 December 1966)

In his evaluation of the Barnes ES-100 Educational spectrometer, Kaylor[1] pointed out that the unit included four filters and had as its light source a 12-V spun-filament automobile lamp.

In order to study the absorption of the four filters, the output of the lead sulfide detector was connected to the input of a 50-MV/cm strip chart recorder. A motor drive was connected to the grating, and the spectrum from 0.1 to 3.0 μ was scanned.

Each of the four filters, infrared-absorbing (IRA) glass, infrared-transmitting (IRT) glass, didymium glass, and germanium, was placed, one at a time, in front of the light source and the spectrum was scanned. The time for each scan was 250 sec. A comparison of the intensities transmitted by the filters with the intensity of the unfiltered light is shown in Fig. 1 and Fig. 2.

Another experiment was the study of the infrared absorption of a tinted glass recommended for automobiles with air-conditioning. Figure 3 shows the transmission curves of a piece of plate glass, 7.5 mm thick, a piece of automobile tinted glass, 6.5 mm thick, and a piece of Edmund Scientific Company heat-absorbing glass, 7.0 mm thick.

It was interesting to demonstrate the Wien displacement law by varying the input voltage to the 12-V transformer and observing the displacement of the maximum to shorter wavelengths as the voltage is increased. This is shown in Fig. 4.

* National Science Foundation Undergraduate Research and Independent Study Participant, 1965-66.
[1] H. M. Kaylor, Am. J. Phys. 34, 74-75 (1966).

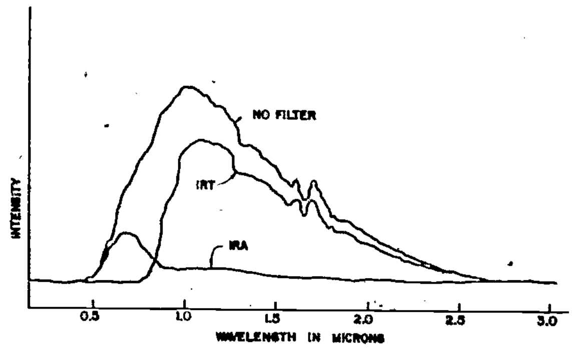


FIG. 1. The intensity of transmission of radiation from 0.1 to 3.0 μ for the infrared transmitting glass (IRT) and the infrared absorbing glass (IRA).

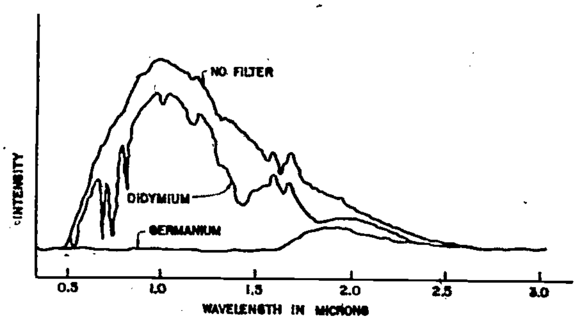


FIG. 2. The intensity of transmission of radiation from 0.1 to 3.0 μ for didymium glass and the germanium filter.

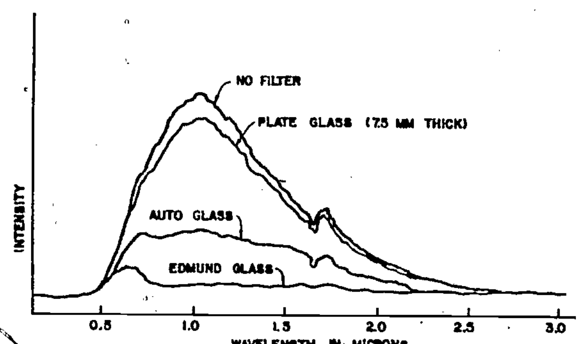


FIG. 3. The intensity of transmission of radiation from 0.1 to 3.0 μ for plate glass, automobile tinted glass, and Edmund heat absorbing glass.

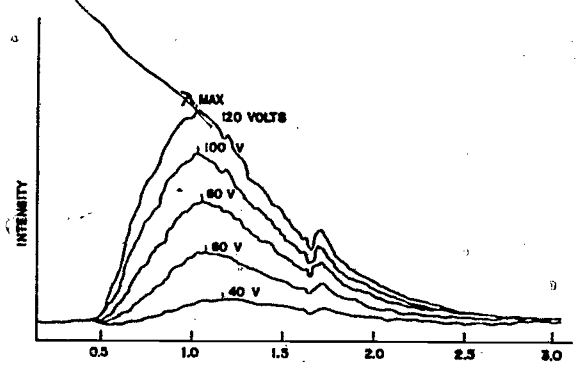
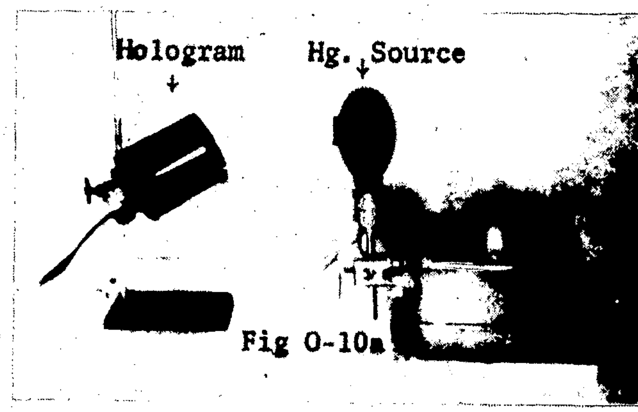


FIG. 4. The intensity of radiation from the 12-V spun filament lamp when operated at different temperatures by varying the input voltage of the 12-V transformer.

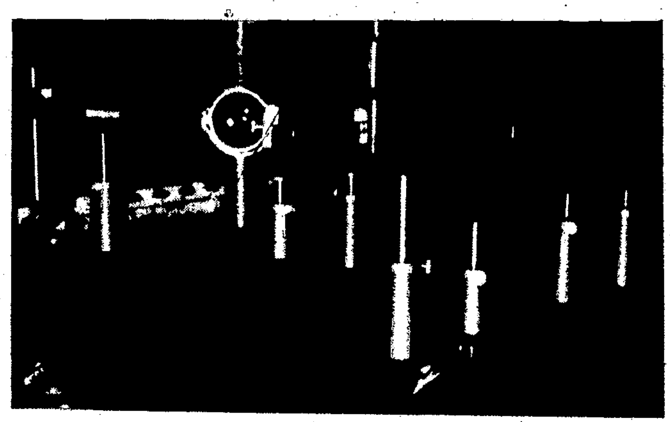
O-10 HOLOGRAPHY AND LASER PHYSICS

O-10a An amazing 360° hologram (Edmund Scientific Co. No. 71,101) may be observed with an intense Hg lamp with 5461°A green filter, or some other filter for another Hg line. A small motor turns the hologram through 360° in one minute.



O-10b Holographic Camera

The Gaertner holographic system for making holograms may be shown to interested persons following a class period. See Fig O-10b.



O-10c Laser Experiments

Many demonstrations may be performed with a laser using the kit of materials shown in Fig O-10c. These include interference, diffraction, a target bell, polarization, etc.

O-10d Fabry-Perot & Michelson Interferometer Experiments with Laser

The He-Ne Laser is very useful to demonstrate the interference phenomena associated with the Michelson and Fabry-Perot interferometers as shown in Fig O-10d. A low-cost Fabry-Perot etalon is described this reprint from the AMERICAN JOURNAL OF PHYSICS, Vol 36, January 1968.

Low-Cost Fabry-Perot Etalon

A DESCRIPTION of low-cost Fabry-Perot etalons has appeared in the literature.[1-4] Another method is to use surplus circular plates

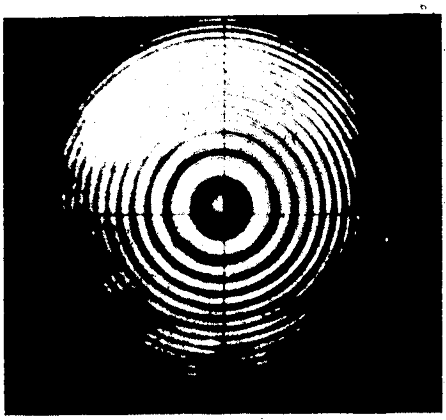


FIG. 1. Ring system of mercury 5461 A line using Edmund low-cost optical flat glass with aluminum coating.

of optically flat glass.[5] Aluminum is evaporated in a vacuum on the glass to produce a mirror-like deposit through which about 10% of the incident light is transmitted.

A 1-cm Invar spacer[2] was used between two such plates to obtain the 5461 A mercury fringes shown in Fig. 1.

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[1] J. K. Robertson, J. Opt. Soc. Am. 9, 611 (1924).
[2] W. A. Hilton, Am. J. Phys. 30, 724 (1962).
[3] A. P. French anl J. H. Smith, Am. J. Phys. 33, 532 (1965).
[4] F. M. Phelps III, J. Opt. Soc. Am. 55, 293 (1965).
[5] Edmund Scientific Co. Catalog 671, p. 79, Item No. 30,454, $1.50 per pair.

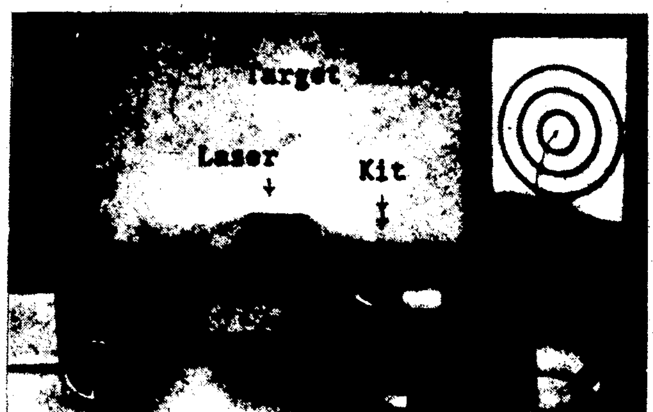
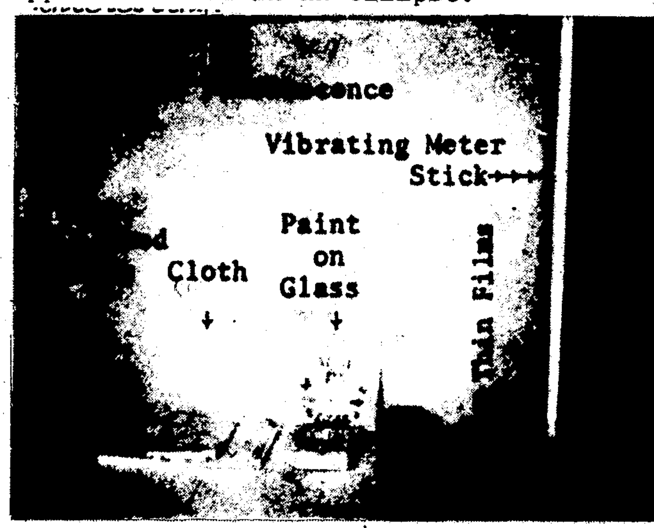


Fig O-10c

Fig O-10d

O-11 FLUORESCENCE AND PHOSPHORESCENCE; RETARDATION DEMONSTRATION

Fluorescence and phosphorescence are demonstrated with materials shown in Fig O-11. The retardation demonstration uses a vibrating meter stick. When viewed with a thin transparent film over one eye, the difference in optical path to each eye causes the meter stick (end) to appear to move in an ellipse.



A-1 STRUCTURE OF MATTER

A-1a Brownian Motion

A small smoke chamber with smoke from a lighted match is placed under a microscope. The Brownian motion is observed as the air molecules strike the smoke particles. Also shown in Fig A-1a is a small microscope for viewing the cubic structure of salt (NaCl). Since these are individual demonstrations, it may be better to exhibit them as students enter or leave the classroom.

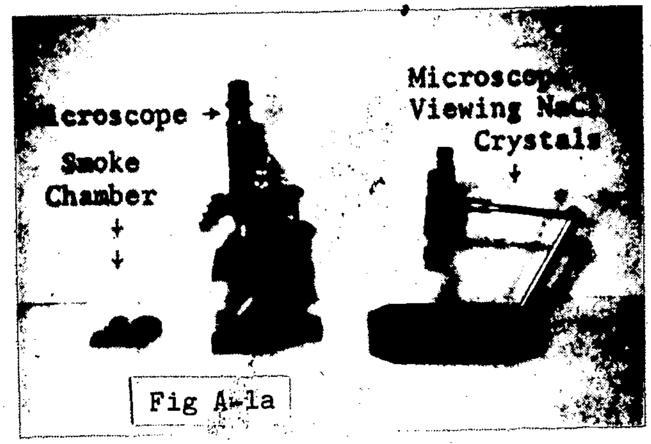


Fig A-1a

A-1b Crystal Lattice Models

Several crystal lattice models which are stored in a movable cart so that they can be taken easily from one room to another, together with large crystals of calcite and quartz, are useful teaching aids. The following models are available: Tungsten, copper, magnesium, sodium chloride, calcium fluoride, calcite, cesium chloride, and diamond. (See Fig A-1b)

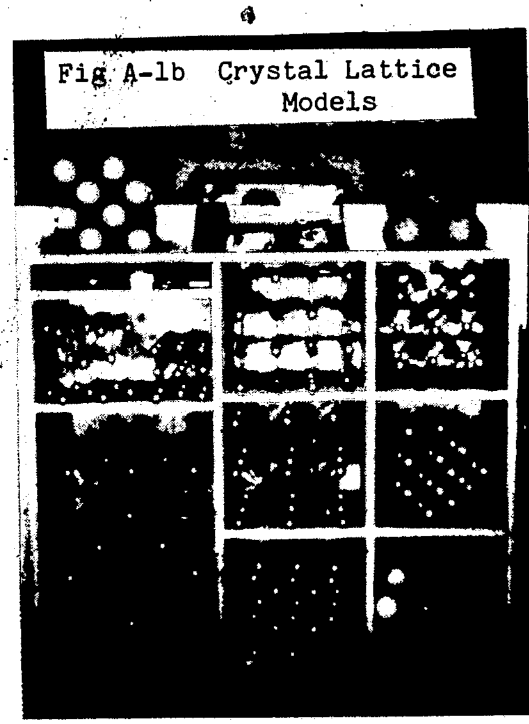


Fig A-1b Crystal Lattice Models

A-1c Other models

Styrofoam balls and steel ball bearings may also be used for crystal models as shown in Fig A-1c.

Special wooden trays have been built to hold both the steel and the styrofoam balls. (See THE PHYSICS TEACHER, September, 1970.)

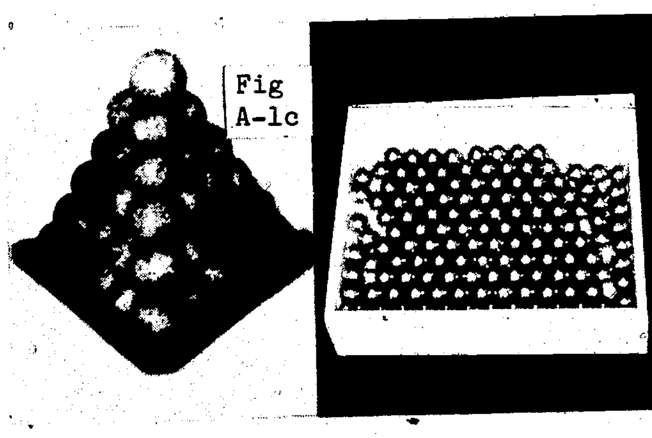


Fig A-1c

A-2 THE ELECTRON

A-2a Five Properties of Cathode Rays: (1) Have mass, (2) Travel in straight lines, (3) Fluorescence, (4) May be focused, (5) May be bent by a magnetic field. The tubes shown in Fig A-2a help to demonstrate these five characteristics of cathode rays.

A-2b Millikan Oil Drop Experiment

When discussing the Oil Drop Experiment, it may help to show and describe the equipment for doing this experiment.

A-2c Gaseous Discharge Tube (1)

The tube shown in Fig A-2c may be set up on the lecture room desk and connected to the vacuum pump under the table. The class may then observe the Crookes dark space, negative glow, Faraday dark space, striations, etc.

A-2d Gaseous Discharge Tube (2)

Some students may be interested in seeing a more complete vacuum system in one of the laboratories, which in addition to the one shown in the lecture room includes a diffusion pump, variable power supply, McLeod Gauge, Pirani Gauge, and a Thermocouple Gauge.

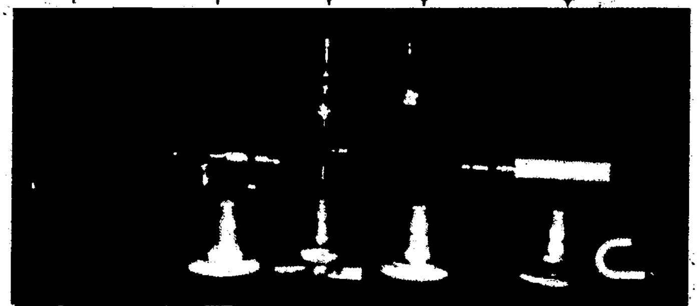
A-3 ATOMS

A-3a The Periodic Table

Welch and Cenco charts are on the lecture room wall. Students may want to purchase small size charts.

Fig A-2a, Cathode Rays

Have Mass | Straight Lines | Fluorescence | Focused | Bent in Magnetic Field



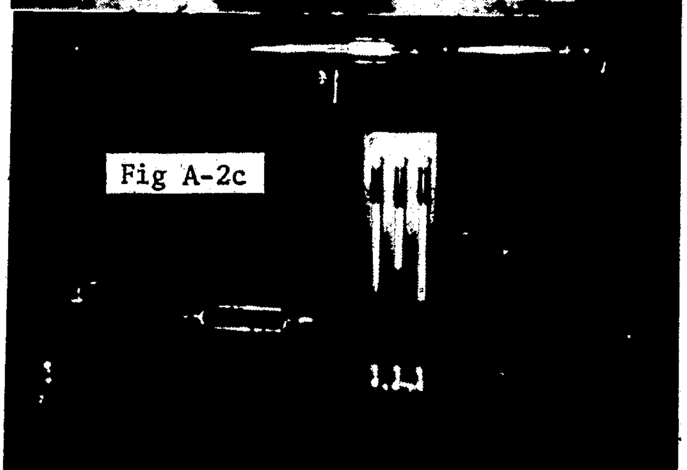


Fig A-2c

A-4 PHOTOELECTRIC EFFECT

A-4a The Photoelectric Effect (1)

Fig A-4a shows an electroscope with a piece of zinc attached. When the electroscope is charged negatively, light from the mercury source will cause it to discharge by the photoelectric effect. The carbon arc source may be used in place of the mercury source. If the electroscope is charged positively, the effect is not observed. Likewise no discharge is observed if a piece of glass is inserted be tween the mercury source and a negatively charged electroscope.

A-4b The Photoelectric Effect (2)

Fig A-4b shows an arrangement for ringing a bell by pointing a light source at a photoelectric cell.

A-4c The Photo-voltaic Effect

This is an arrangement for turning on a light or a bell using a light beam and a photo-voltaic cell.

A-4d Sound on a Light Beam

This is the familiar experiment of modulating a light beam by properly placing a lamp at the output of an amplifier with a microphone or a phono on the input. A photo detector a few feet away is sensitive to the modulated light. The signal is amplified-fied and heard on a speaker. This has also been done in our laboratory by modulating a laser beam.

(By C. Don Geilker)

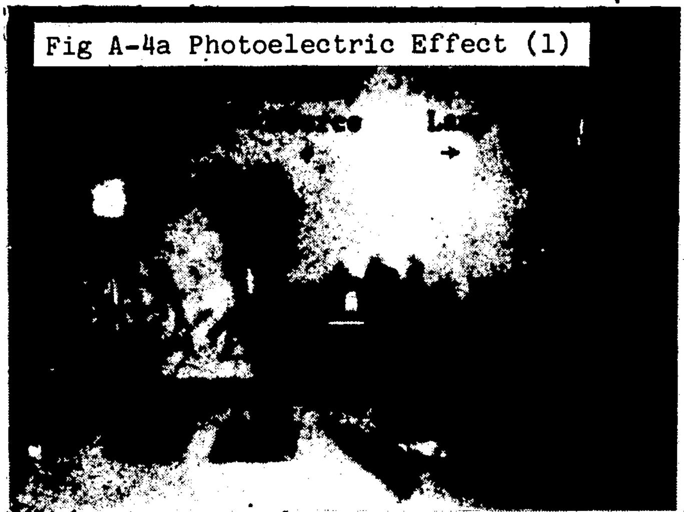


Fig A-4a Photoelectric Effect (1)

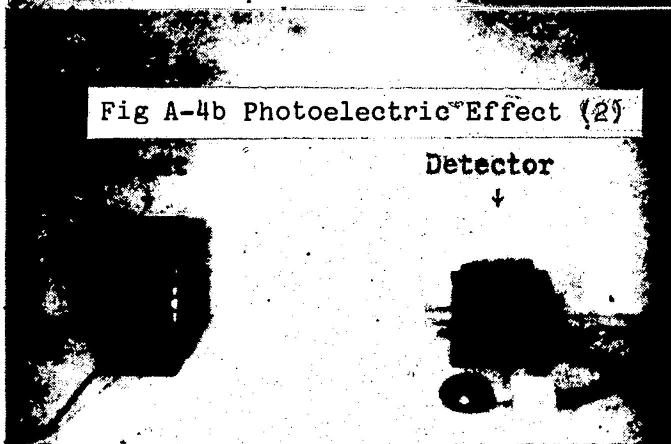


Fig A-4b Photoelectric Effect (2)

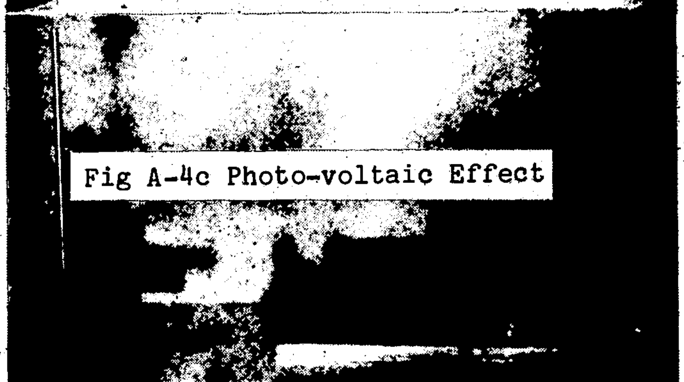


Fig A-4c Photo-voltaic Effect

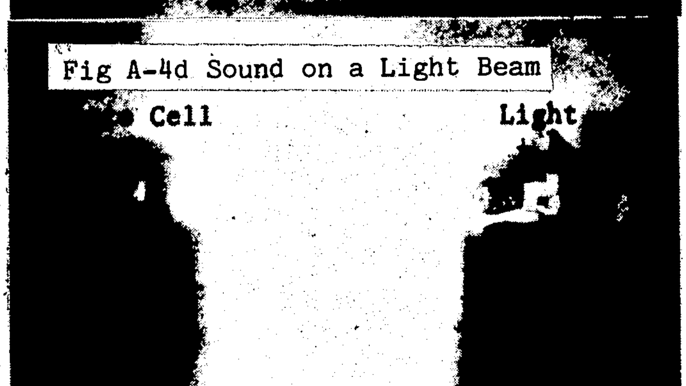
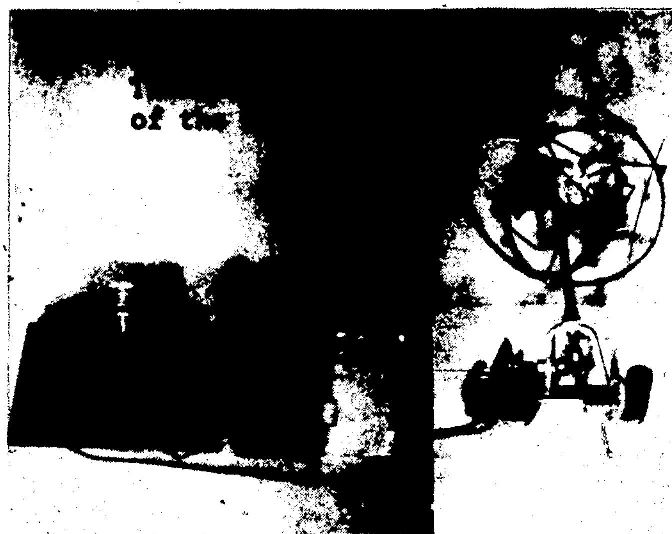


Fig A-4d Sound on a Light Beam

A-5 ATOMIC STRUCTURE



A-5a The Thomson Model of the Atom

This "plum-pudding atom" proposed by J. J. Thomson is described in H. E. White, MODERN COLLEGE PHYSICS, 5th Edition, p 452, and makes a good demonstration as an introduction to the Bohr model.

A-5b The Bohr Model of the Atom

The apparatus shown in Fig A-5b is helpful in explaining the Bohr model of the atom. An electric motor causes the electrons, which are small magnets painted with fluorescent paint, to revolve about the nucleus. If the lights in the room are turned off and an ultraviolet light source is used to illuminate the "electrons," a much better demonstration of the Bohr model of the atom is observed. Only the "electrons" and the "nucleus" appear to move.

A-6 SPINNING ELECTRONS

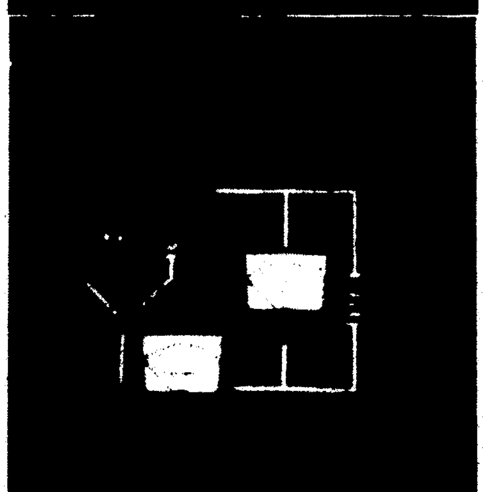
Fig A-6a

A-6a Larmor Precession

It may help to use a "bicycle wheel" gyroscope which may be mounted on a ring stand. The "bicycle wheel" precesses around an axis parallel to the earth's gravitational field, in a manner similar to a spinning electron in a magnetic field precessing around an axis parallel to the magnetic induction vector B. This is shown in Fig A-6a.

A-6b Ionization Potential

For small classes the apparatus shown in Fig A-6b will be helpful to demonstrate the ionization potentials of mercury and xenon.



A-7 X Rays

A-7a As an introduction to x rays, it may be useful to show a class some of the early x-ray tubes and a present-day tube. In Fig A-7a a cold cathode tube is shown on the left and a modern-day CA-7 by G.E. is shown on the right. Old medical and dental x-ray tubes are in the center of the photograph.

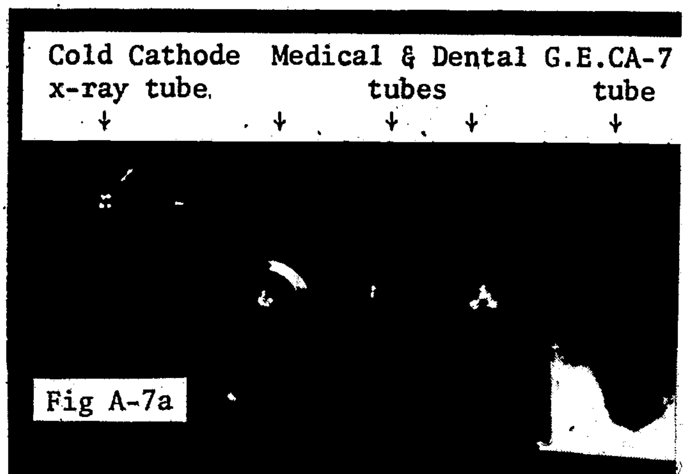
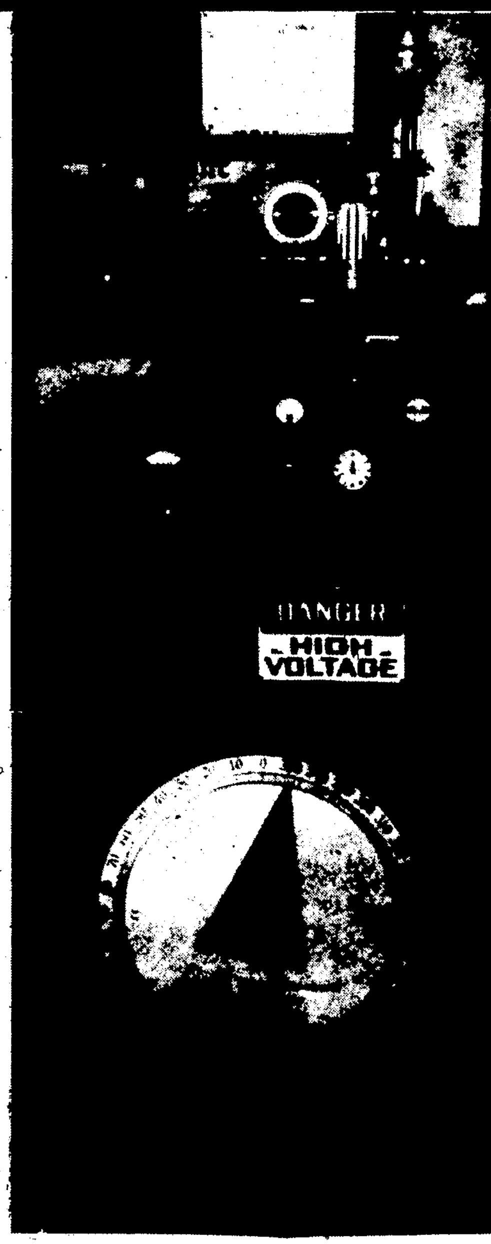


Fig A-7a

A-7b The class may be taken to the x-ray room and shown the x-ray equipment (See Fig A-7b). It consists of a G.E. XRD-1 which has been modified to use a G.E. CA-7 tube. A Laue camera is shown on the right and a powder camera is shown on the left. A Geiger tube detector and a camera for studying polarization of x rays are at the center and to the back. On the far left is apparatus for small angle x-ray diffraction.



A-7c A Demonstration Goniometer

A reflecting goniometer for measuring interfacial angles of crystals to within 1° may be demonstrated to the class. Actual use is limited to one student at a time.

A-7d Crystal Models

Crystal lattice models useful in the teaching of x-ray diffraction have already been shown in Fig A-1b. This figure shows the number and type of models available.

A-7e Laue Photographs

Several Laue photographs may be obtained from the x-ray laboratory and projected on an overhead projector upon the classroom screen.

A-7f Powder Patterns

X-ray powder patterns may be obtained from the x-ray laboratory and projected on an overhead projector upon the classroom screen for the entire class to see.

A-8 ELECTROMAGNETIC WAVES

A-8a Electrical Resonance

Each of two Leyden jars is connected to a rectangular loop of large wire. The two electrical circuits are placed about a foot apart and tuned to resonance. There is a gap of about 1 cm between the wire and the Leyden jars. When a high voltage from our Holtz machine is placed across one of the circuits, a small spark will be observed across the other gap if the two circuits are tuned to resonance.

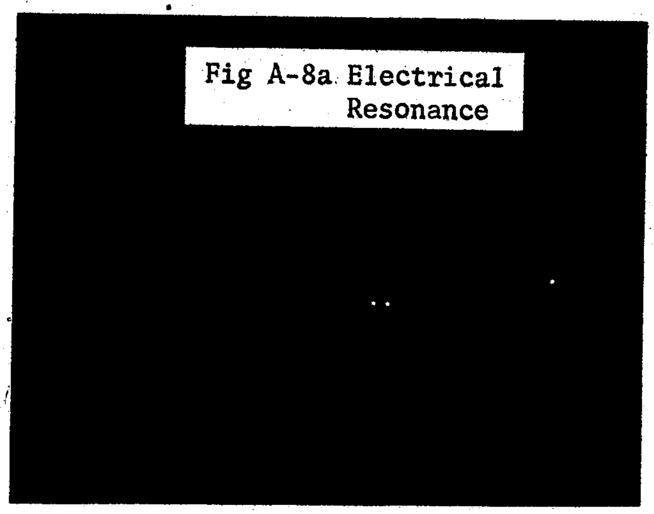


Fig A-8a Electrical Resonance

A-8b Mechanical Resonance

Two examples of mechanical resonance are shown. One consists of two hack saw blades which are mounted vertically on a flexible bar. Small weights are attached to the upper ends of the blades. When one blade is set in vibration, the energy is transferred to the other. This process is repeated several times.

A small Wilberforce's pendulum for showing mechanical resonance is shown in Fig A-8b. A much larger one is available in the demonstration laboratory.

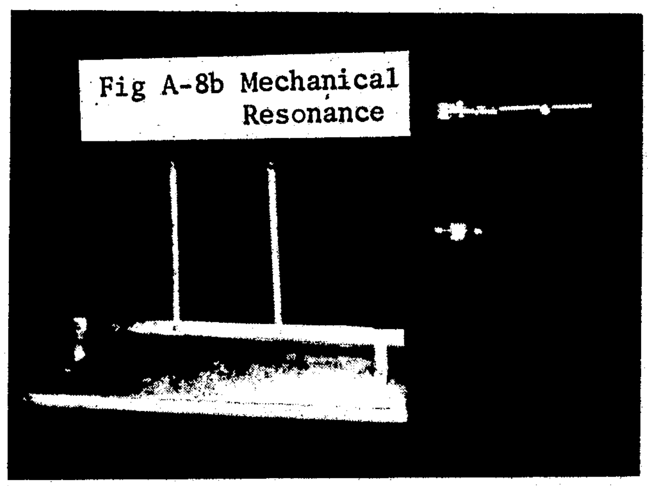
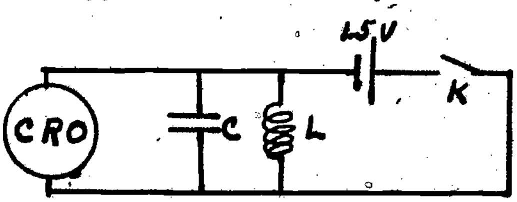


Fig A-8b Mechanical Resonance

A-8c Damped Electrical Oscillator

Fig A-8c shows equipment for demonstrating a damped electrical oscillation. The circuit is shown below. Tap the key and the damped wave appears on the "scope."



A-9 VACUUM TUBES

A-9a Diodes

The Welch demonstration power supply provides a convenient method for explaining the theory of a diode tube. With the aid of an oscilloscope, half-wave and full-wave rectification and filtering may be shown to the class.

A-9b The triode

Fig A-9b shows demonstration triode equipment. This is explained in a paper which is reprinted from the AMERICAN JOURNAL OF PHYSICS, Vol 23, pp 384-85, September, 1955.

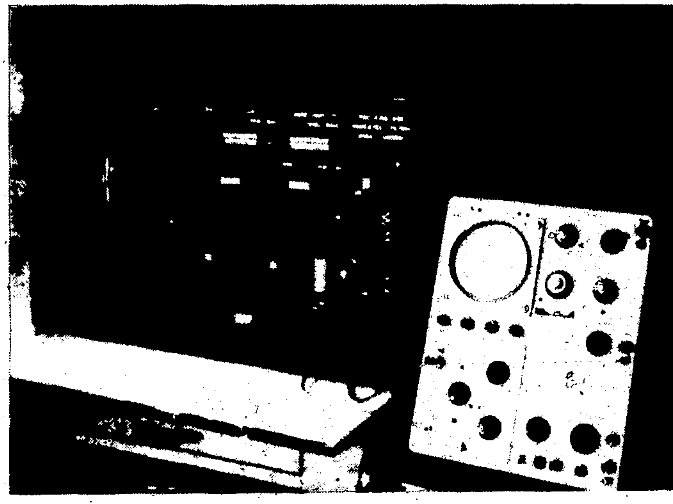
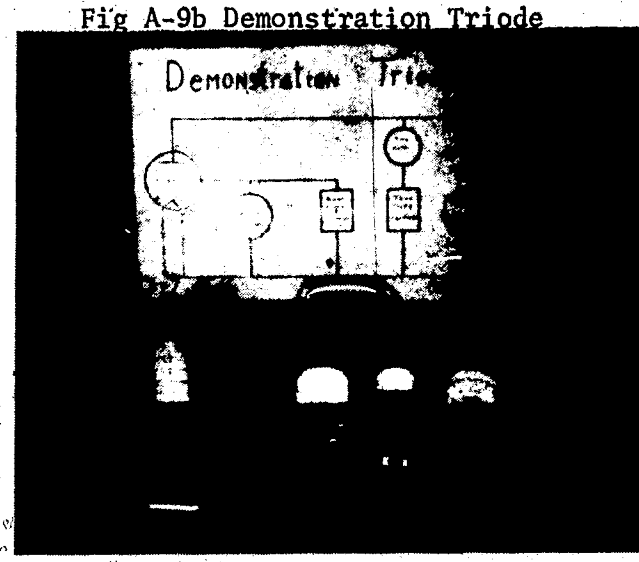


Fig A-9b Demonstration Triode



Demonstration Triodes

WALLACE A. HILTON AND GLEN T. CLAYTON
William Jewell College, Liberty, Missouri

TWO tubes, a WL787[1] and a 6J5, are used to demonstrate some of the characteristics of a triode. Figure 1 shows a schematic diagram of the WL787 demonstration triode, together with two variable power supplies for grid and plate voltages. Three meters are used to indicate the grid potential, the plate current, and the plate voltage. The fluorescent plate of the WL787 gives a visual indication of the plate current. The plate voltage may be varied from 0–500 volts, and the grid potential may be varied from minus 150 volts to plus 150 volts.

The effect of the electrostatic field produced by the charged grid is shown by the pattern of the fluorescence of the plate. When the grid bias is made sufficiently negative, the plate voltage may be adjusted so that the plate will fluoresce only between the grid wires. When the plate voltage is increased, the entire plate will fluoresce, but the section between the grid wires will be much brighter. This shows that the electrons are repelled by the negatively charged grid wires, and as they approach are "funneled" into the space between them, where they continue on to strike the plate.

If the grid is made positive, its attraction for the electrons causes them to be deviated toward the grid wires, and the section of the plate directly behind the wires can be seen to be brighter.

A less expensive arrangement consists of a 6J5 or similar triode mounted on a metal chassis with a neon glow lamp in the plate circuit. A heavy copper wire extending about 4 inches above the chassis is connected to the grid of the tube. The effect of making the grid negative is shown by bringing the negative electrode of a battery in contact with the grid. The neon lamp stops glowing; however, it will conduct again as soon as the battery lead to the grid is disconnected.

When studying static electricity in the general physics course, it is interesting to demonstrate that the glow lamp may be extinguished by holding an ebonite rod, which has been stroked with cat fur, a few inches from the grid electrode.

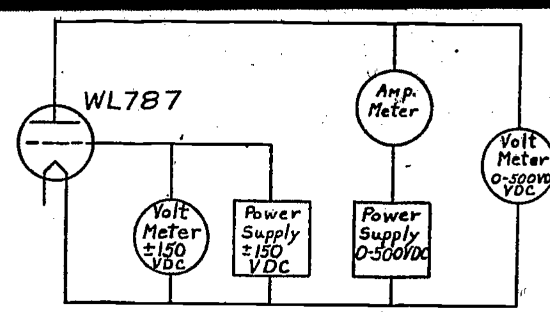


FIG. 1. Schematic diagram of apparatus to demonstrate basic principles of a triode by using a WL787 or similar triode, variable power supplies, and dc meters.

[1] A similar tube is used in Item 2152A, W. M. Welch Scientific Company. Catalog (1954).

A-9c Vacuum Tube Receiver

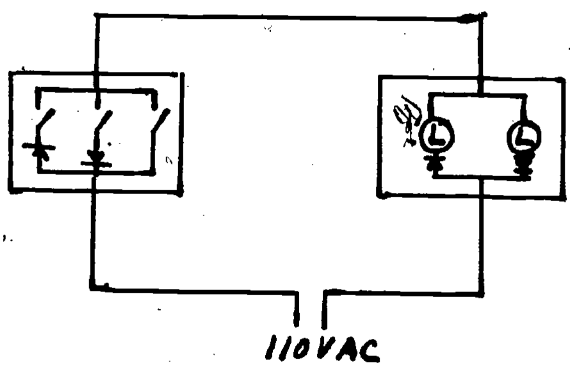
The Collins 75 A-2 receiver (using vacuum tubes) is a component of the William Jewell Radio Interferometer, and is shown in Fig A-9c.

Fig A-9c

A-10 THE SOLID STATE

A-10a A Solid State "Fun Circuit"

Two boxes are used. Only one wire leads to each box and only one wire leads out of each box. Switch 1 turns on one light. Switch 2 turns on the other light. Switch 3 turns on both lights. How does it work? The schematic is below, and uses four solid state rectifiers.



A-10b Integrated Circuits

A large selection of transistors and integrated circuits is available for showing to the introductory physics classes. Fig A-10b shows a greatly magnified integrated circuit taken in our laboratory with the Unitron metallograph and microscope with camera attachment (see Fig O-5c). The chip (integrated circuit) was less than 1 mm in area.

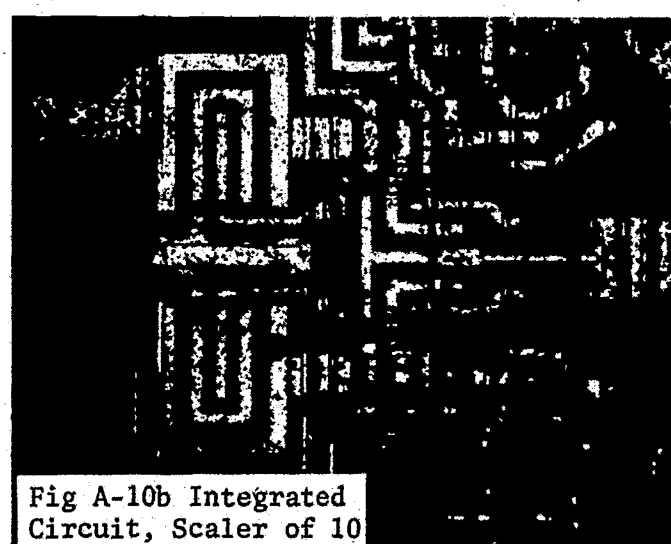


Fig A-10b Integrated Circuit, Scaler of 10

A-11 FRAMES OF REFERENCE

A-11a The PSSC 16 mm sound film "Frames of Reference" is a good teaching aid for this topic.

A-12 LASERS AND INTERFEROMETERS

A-12a Equipment described in experiments O-10c and d and Fig O-10c and Fig O-10d will be helpful for demonstrations on lasers and interferometers.

A-13 ELECTRON OPTICS

A-13a Cathode Ray Oscilloscope

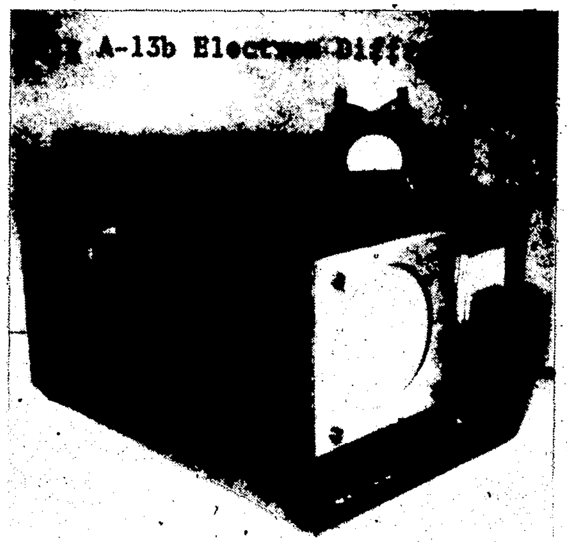
The cathode ray oscilloscope has been used several times for demonstrations (Fig A-8c and Fig A-9a); however, to help explain its operation the electron gun from a 5BP 1a cathode ray tube is helpful.

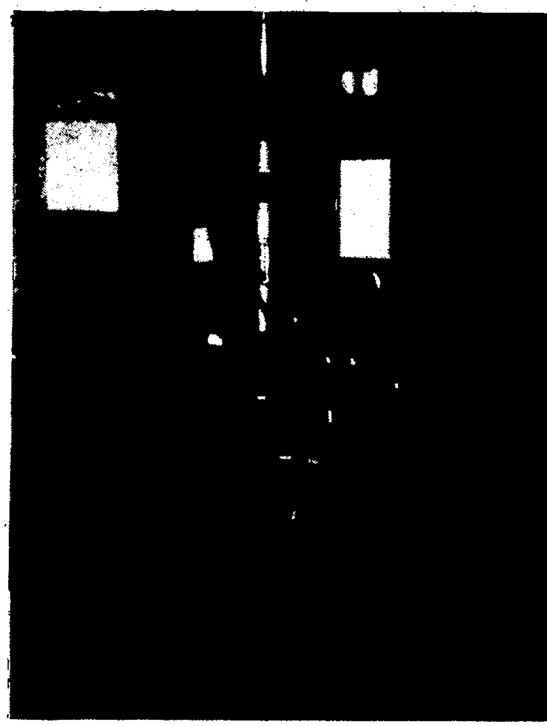
A-13b Electron Diffraction

The Welch Electron Diffraction apparatus is shown in Fig A-13b. It is used primarily as an experiment in the Atomic and Nuclear laboratory, but may be used as a demonstration in an introductory physics class. Care should be taken to keep the current at 15 ma or less.

A-13c Electron Microscope

Small groups may be taken to see the Electron Microscope. See Fig A-13c.





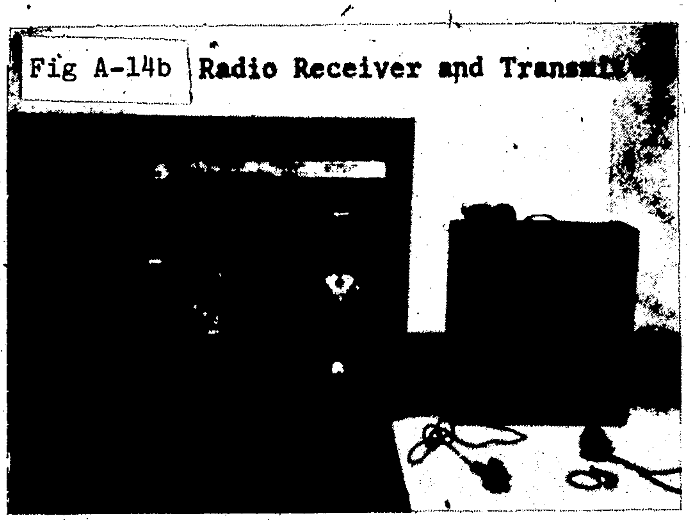
A-14 MICROWAVES, RADIO, TV

A-14a S-Band and X-Band Microwaves

The equipment shown in Fig O-7e, Fig O-7f, and Fig O-7g will be helpful in explaining 12-cm and 3-cm microwave apparatus.

A-14b Radio Receiver and Transmitter

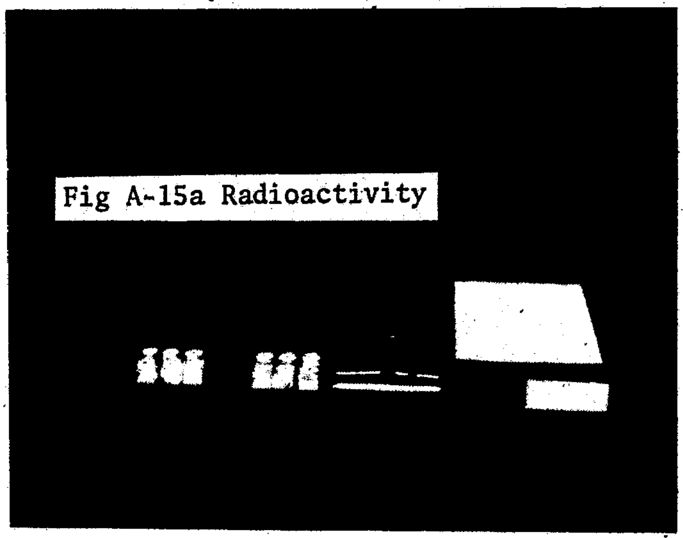
Fig A-14b shows a demonstration A.M. receiver for the regular broadcast band: 550 kHz to 1500 kHz. A low-power demonstration A.M. transmitter which will transmit up to a distance of 50 feet is also shown in Fig A-14b. Two microphones and a record player are available to modulate the transmitter. In operation, the receiver may be placed across the room from the transmitter.



A-15 RADIOACTIVITY

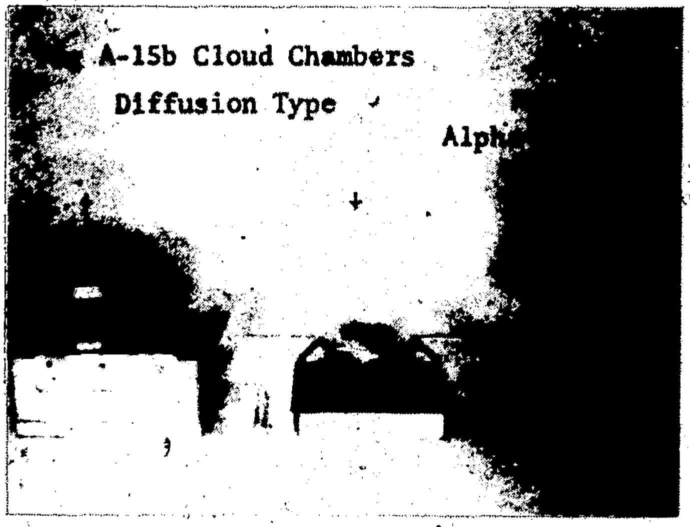
A-15a Detection of Radioactivity

Two boxes of six different materials, some of which are radioactive, are placed on top of a sheet of Polaroid Type 57, Black & White, 4" x 5" sheet film and left overnight. The next day the film is developed (use roller) in the classroom so that the students may see which of the 12 samples are radioactive. They may also be checked with a Geiger counter and scaler.(Fig A-15a)



A-15b Cloud Chambers

The department has several cloud chambers, three of which are shown in Fig A-15b. The two diffusion cloud chambers require dry ice. Small amounts of dry ice may be made in our department with the CRC "Frigimat" Dry Ice Maker. Care should be used in operating this equipment.



A-15c Range of Alpha Particles and Alpha Particle Counter

The range of alpha particle apparatus requires a darkroom; however, the techniques of operation and use may be more easily demonstrated in the classroom. Some students may want to do the experiment in a darkroom.

The Cenco Alpha Particle Counter consists of an alpha particle source, a spark chamber, and a 5000 VDC power supply. The unit may be connected to a scaler for counting the number of alpha particles which ionize the air in the spark chamber to produce a spark.

A-15d Half-Life Measurements

Approximately 22 ft^3 of air per minute is passed through a filter which is attached to one end of the air sampler shown in Fig A-15d. The collected radioactive dust (collected on the filter paper) is then placed under a G.M. tube of a count-rate meter or a "Radioassay" electroscope (Fig A-15d) to measure the half-life of the materials collected. A more complete description is given in the following reprint from AMERICAN JOURNAL OF PHYSICS, Vol 28, pp 743-744, November 1960.

Measurement of Half-Life

Wallace A. Hilton and Roger C. Crawford
William Jewell College, Liberty, Missouri

EXPERIMENTS[1] for the determination of half-life of the ever present short-lived isotopes from the air have been suggested using various types of equipment:

This type of experiment may also be performed using an air sampler, Geiger-Mueller tube, count rate meter, and a strip chart recorder. Approximately 22 cu ft of air per min is passed through the filter paper which is attached to one end of the air sampler for about 30 min. Particles of dust, etc., which contain the radioactive isotopes are collected on the filter paper, which is then placed under the Geiger-Mueller tube. The activity of the sample is then read on the rate meter and a permanent record is made by the strip chart recorder.

Figure 1 shows a record obtained on May 16, 1959 when the initial rate was 850 counts/min and after about 45 min

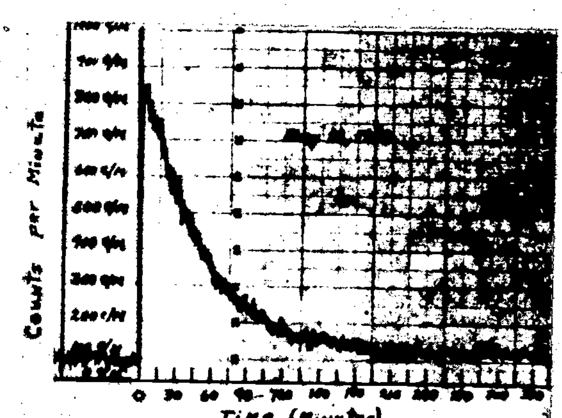


Fig. 1. Record of Radioactive decay, May 16, 1959.

was 425 counts/min. This includes background and all radioactive isotopes collected on the filter paper.

[1] T. Handley Diehl and C. Don Geilker, Science Teacher 25, 442 (1958).

A-15 Emanation Electroscope

The Welch Emanation electroscope is useful as an individual demonstration or as a laboratory experiment. It is described in the following paper.

Reprinted from AMERICAN JOURNAL OF PHYSICS, Vol. 29, No. 11, 789–790, November, 1961

Emanation Electroscope

WALLACE A. HILTON
William Jewell College, Liberty, Missouri

A review written at the request of the Committee on Apparatus of the AAPT.

THE Welch Emanation electroscope[1] which is shown in Fig. 1 serves as the basis for an interesting and instructive experiment for the measuring of the half-life of a radioactive material.

It is small, measuring 14 in. in height and is mounted on a wooden base 7×10 in. It appears to be well constructed, not too elaborate, but attractive in appearance. No problem in maintenance or repair has been observed by the 12 students and staff members who used and tested this equipment in the performance of this basic experiment on the measurement of the half-life of the radioactive material furnished with the unit.

The apparatus is based on a design, the principle of which has been in use for several years.[2] The unit is made of three metal chambers which are mounted vertically one above another. A microscope is mounted on the top chamber so as to observe the deflection of the leaf of the electroscope which is connected to a collector in the ionization chamber immediately below. Thorium emanation is pumped into the ionization chamber from the storage and filter bottles which are housed in the lower chamber as shown in Fig. 2. A double-valved rubber bulb is used to pump the thorium emanation through the filter bottle and into the middle chamber where is surrounds the collector and causes the leaf to discharge.

A 150- to 300-v battery or a regulated power supply may be used to charge the electroscope. The 180-v output of the Welch No. 0620K power unit has been found satisfactory.

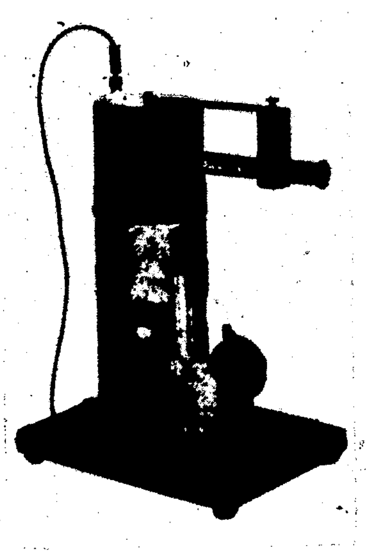


FIG. 1. The Welch emanation electroscope.

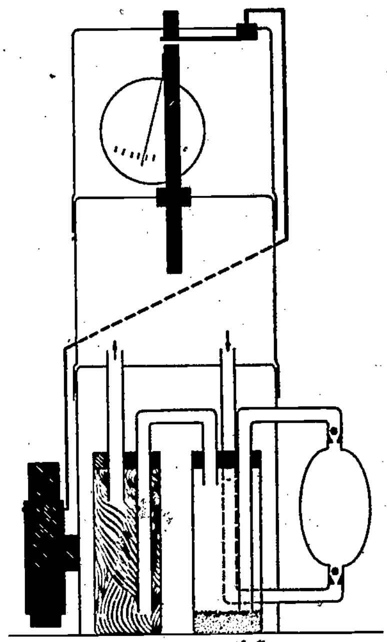


FIG. 2. Schematic drawing of the unit.

The leaf may also be charged by means of the electrostatic charging rod which is included as a part of the unit, however it takes a little more time to get the leaf back into the exact position for the next observation. The leaf is connected to the charging potential by a contact button on top of the unit.

After the thorium emanation is pumped into the ionization chamber, the rate of fall of the leaf through some arbitrary scale distance, as seen through the microscope, is observed. This is repeated several times until sufficient data are obtained to plot a decay curve and to calculate the half-life.

The manufacturer states that the radioactive material (thorium oxide) furnished with the unit is adequate for years of use and that it causes no contamination problem since it has low activity and is circulated in a system that is normally closed to the atmosphere.

The apparatus is easy to understand and is simple to operate and to maintain. It is recommended for use in a basic experiment in the introductory laboratory.

[1] No 619 Emanation electroscope, W. M. Welch Scientific Company, 515 Sedgwick St. Chicago 10, Illinois. Price $60.00.
[2] K. T. Bainbridge and J. C. Street, Am. Phys. Teacher 6, 99–102 (1938).

A-15f Half-Life of Silver

The measurement of the half-life of silver activated by a neutron source (Fig A-18a) is done in the introductory laboratory and may also be done as a lecture demonstration experiment.

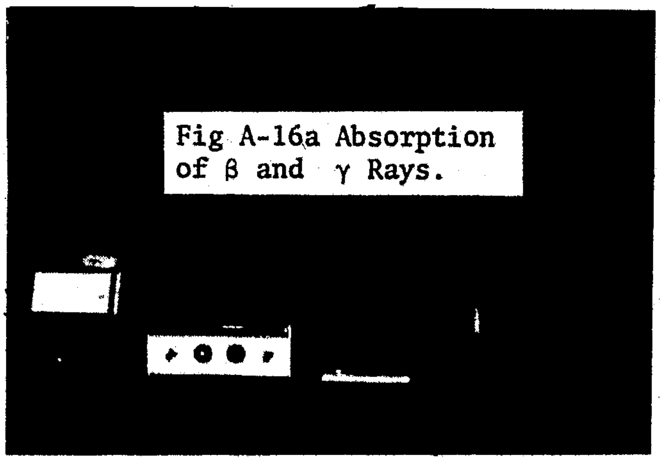


Fig A-16a Absorption of β and γ Rays.

A-16 BETA AND GAMMA RAY ABSORPTION AND SPECTROSCOPY

A-16a Beta and Gamma Ray Absorption

Equipment for demonstrating α, β, and γ ray absorption is shown in Fig A-16a. A set of aluminum absorbers is also shown.

A-16b Beta and Gamma Ray Spectroscopy

While experiments with this equipment are usually done in the junior-level laboratory, the equipment is located in a corridor demonstration room and may be shown to small groups. A NaI (Th) crystal is used for the detection of gamma rays and an anthracene crystal detects beta particles.

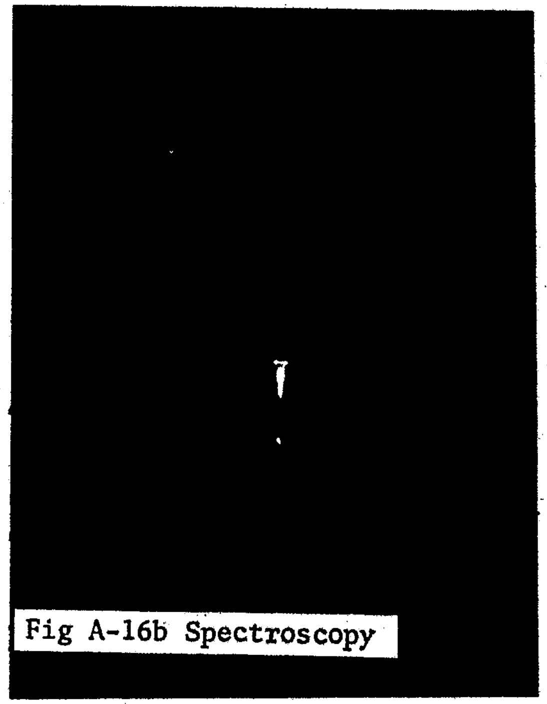


Fig A-16b Spectroscopy

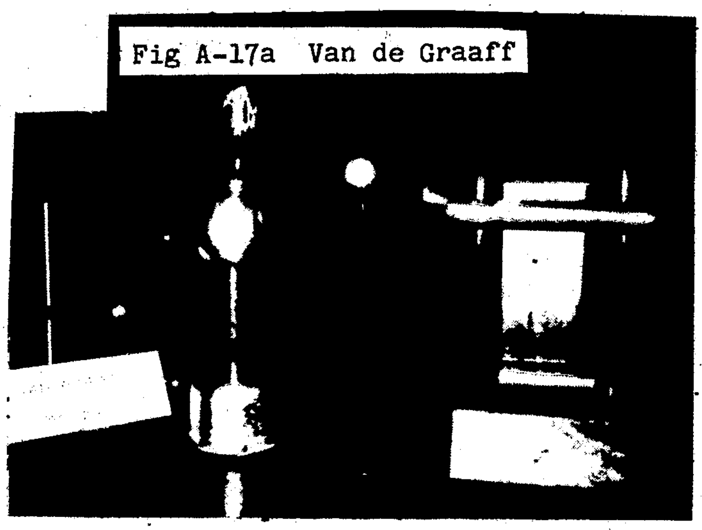


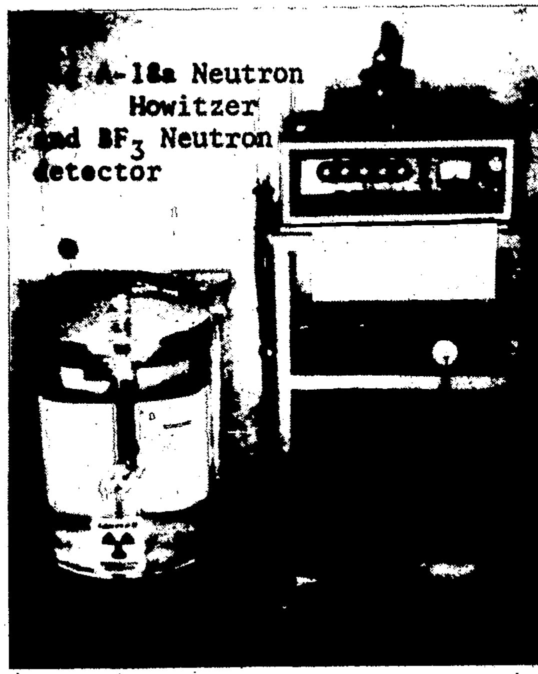
Fig A-17a Van de Graaff

A-17 PARTICLE ACCELERATORS

A-17a Van de Graaff Machine

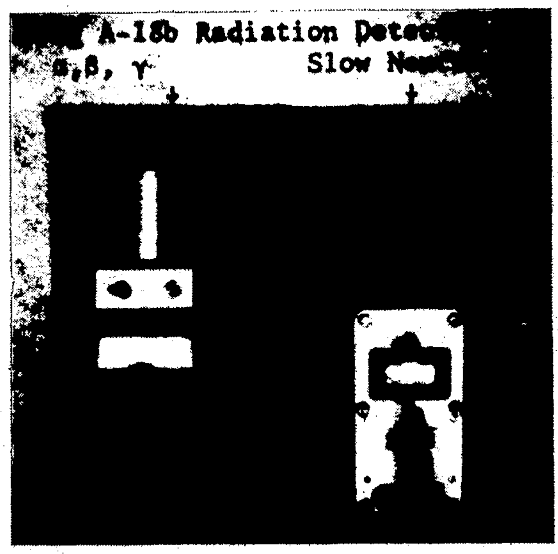
Fig A-17a shows two small Van de Graaff machines which may be used to demonstrate some of the principles of this type accelerator.

A-18 NEUTRON AND GAMMA RAY REACTIONS



A-18a Neutron Howitzer

A 2-curie neutron source is shown in Fig A-18a together with a BF_3 neutron detector, scaler and ratemeter for measuring the neutron flux within the neutron howitzer. Care should be used when moving the howitzer into the lecture room. The neutron source is used for several experiments in the introductory and intermediate laboratories.



A-18b Radiation Detectors

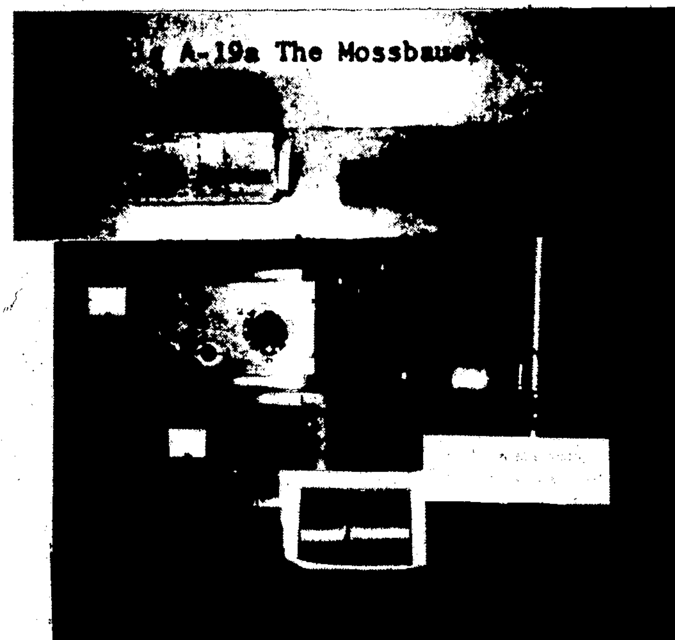
Fig A-18b shows a Baird-Atomic Model 415 Survey Meter which will detect alpha, beta, and gamma radiation. Also shown is a Baird-Atomic Model SN-87 Slow Neutron Monitor. These detectors may be used with the neutron howitzer.

A-18c Half-Life of Radioactive Silver

A silver half-dollar placed near the neutron source becomes radioactive. Half-life measurements may be made as in Experiment A-15f.

A-18d Radioactive Plate Source

Several years ago red "Fiesta" plates could be purchased at many stores. One such plate and a salt shaker are shown in Fig A-18d. Activity may be checked using a Geiger counter (see Experiment A-16a).



A-19 MOSSBAUER EFFECT AND NUCLEAR MAGNETIC RESONANCE

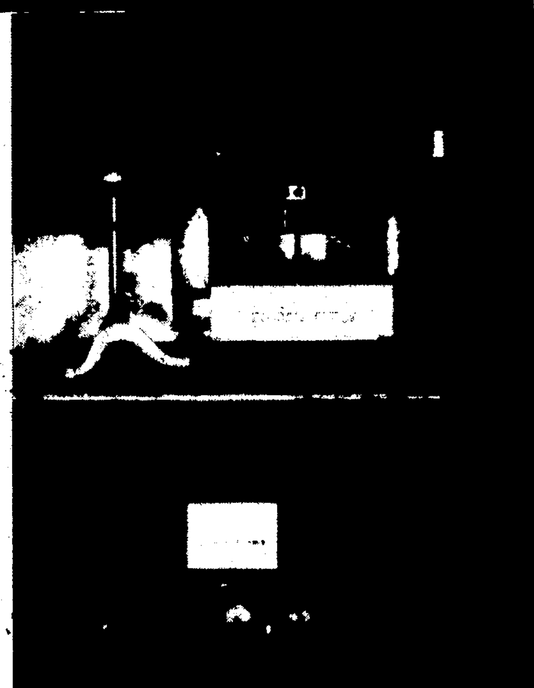
A-19a Mossbauer Effect

This has been an independent study project; however, the equipment is available for demonstration purposes.

A-19b Nuclear Magnetic Resonance

This equipment is primarily for independent study and research by physics majors; however, it may be shown to small groups.

A-20a ZEEMAN EFFECT



This experiment is set up once each year in the Optics Laboratory, at which time it may be demonstrated to small groups. Fig A-20a shows the Fabry-Perot, the magnet and light source (neon), and the magnet power supply. The spectrometer is to the left of the Fabry-Perot, but not shown in the photograph.

A-21a THE ATOMIC NUCLEUS

The Welch Rutherford Scattering experiment is done in a sophomore laboratory, but it may be demonstrated in the classroom as an introduction to the experiment.

A-22 REACTOR PHYSICS

A-22a The Ray-Actor

Fig A-22a shows an Atomic Laboratories Ray-Actor which is an electronic device in which the electronic circuit parameters are substituted for those encountered when operating a nuclear reactor. It has not worked very well; however, it may have value in some small classes when reactor physics is being studied.

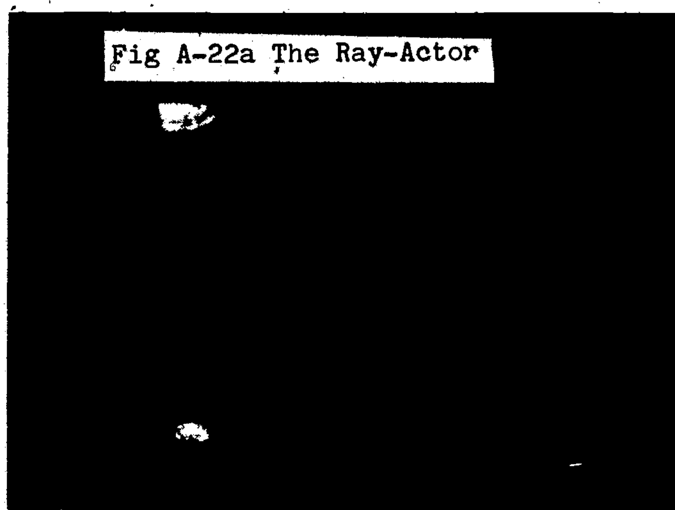


Fig A-22a The Ray-Actor

A-23 ELEMENTARY PARTICLES

A-23a Nuclear Emulsion Plates

We have several nuclear emulsion plates which have been exposed to radiation at Brookhaven National Laboratory. When these plates are placed under a microscope photographic-emulsion stars may be observed. Fig A-23a is a photographic-emulsion star taken with our Unitron microscope. See Fig O-5c.