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PLANNING, CONSTRUCTION, AND EVALUATION OF MEDIA FOR TEACHING HIGH SCHOOL AND JUNIOR COLLEGE SCIENCE VIA TELEVISION FOR USE IN SELF INSTRUCTION. FINAL REPORT.

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THIS IS AN OUTLINE OF PROCEDURES FOLLOWED IN DEVELOPING EXHIBITS SUITABLE AS AUTOINSTRUCTIONAL DEVICES AND AS DEMONSTRATION DEVICES FOR EDUCATIONAL TELEVISION PROGRAMS. THE 27 TEACHING EXHIBITS WERE DESIGNED TO HELP STUDENTS UNDERSTAND CONCEPTS AND PERFORM EXPERIMENTS IN PHYSICS, MATHEMATICS, CHEMISTRY, AND BIOLOGY. SOME OF THE EXHIBITS EMPLOYED FILMS, MICROSCOPES, AND SOUND TAPES. AN APPENDIX PICTURES AND DESCRIBES THE OPERATION OF EACH DEVICE. ALSO APPENDED ARE 10 EXPERIMENT SHEETS FOR USE IN PHYSICS. EVALUATION DATA IS NOT INCLUDED. (JM)

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March 31, 1967

U. S. DEPARTMENT OF
HEALTH, EDUCATION AND WELFARE

Office of Education
Bureau of Research

PLANNING, CONSTRUCTION AND EVALUATION OF MEDIA
FOR TEACHING HIGH SCHOOL AND JUNIOR COLLEGE SCIENCE
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Contract No. OEC 4-6-062435-0646

Harvey E. White
Director, Lawrence Hall of Science

March 31, 1967

The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

University of California
Lawrence Hall of Science

Berkeley, California

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I. INTRODUCTION

"Ninety percent of all high school students who have an IQ equal or superior to the IQ of the average Ph.D. never finish college" - American Biology Teacher, April, 1967.

The staff of the Lawrence Hall of Science believes that two things are vital in education today - motivation of students and clear presentation of complex subject matter. Too many students shy away from science subjects and courses because they believe them difficult and dull. Unfortunately, many courses are this way because of inadequate school facilities and poorly trained teachers. The tragedy is that many students with high science potential and ability are being lost to other fields. Scientists today seem to be products of accidental brushes with people or topics which directed them into a science career. The Lawrence Hall of Science as a research center in science education is finding ways of solving these problems. One part of the program is to design, construct, and evaluate special devices which motivate, demonstrate and teach science concepts.

This contract was a continuation of the program previously funded by U.S. Office of Education, Contract OE 3-16-037, with the same title. Therefore, this report does include work initiated under the preceding contract.

The purpose of this study was to research and develop new methods and materials for science education at the high school and junior college level. Specifically the Lawrence Hall of Science was to produce media suitable for self-instruction situations where no teacher would be needed and also demonstration devices for educational television programs.

II. METHOD

Development of new teaching media is a team effort and the Lawrence Hall of Science is fortunate to have a staff which includes two university professors, four high school teachers (with an average of 15 years science teaching experience each), an industrial designer and several laboratory mechanicians with extensive Research and Development backgrounds.

After several trial efforts the following sequence of action was adopted and used for each item of new media:

1. Group discussion by staff and consultants to advance ideas, determine feasibility, and find the best procedure for presenting a scientific concept.
2. Industrial designer made preliminary drawings with ideas for layout, graphics, and construction.
3. Staff meeting to modify or improve design.
4. Construction by shop.

5. Testing for reliability, readability and function.

6. Evaluation of teaching capability.

It became necessary to provide for alterations and modifications all through this procedure because many times the original idea or method could be improved or simplified. Materials of this nature must be attractive, simple, clear and free of maintenance. This requires organization, much patience and fusion of many talents.

III. RESULTS

The Lawrence Hall of Science began developing devices for self-instruction in 1963 under Contract #OE3-16-037. A total of 27 have now been designed and are in various stages of production and testing. Appendix 1 gives the subject, title, and status of all Lawrence Hall of Science teaching exhibits to date. See Appendix 2 for details of exhibits. The ones in the design and mock-up stage will be constructed as funds become available. Further evaluation of exhibits will be done when the Lawrence Hall of Science building is completed. This is now scheduled for January, 1968.

Ten of the completed devices were, however, evaluated in a University of California non-science major, non-laboratory physics course. They were: Color of Ions, Summation of Parts, Pinball Error Curve, Inverse Square Law (from an AEC contract), Determination of the Nature of Atomic Nuclei, Friction and Streamlining, Interference of Two Waves, Reflection, Refraction, and Lenses-Spherical Aberration. Evaluation procedure was as follows: The total class enrollment of 425 students was divided into 26 discussion sections of 15 - 20 students each. Each section spent about two hours scheduled class time during the quarter with the teaching exhibits. They were given an experimental write-up sheet to turn in as part of this section grade (see Appendix 3). The rooms containing the devices were left open and the students were encouraged to come in any time and use the teaching devices.

To the students the sessions with these teaching exhibits were the highlight of the course. The reason was probably because this was the only chance they had to "do something" to participate in an experiment instead of just listening. Each section looked forward to its chance on the "machines." The teaching assistants were impressed with the animated response of the class, the questions asked and the additional interest in subject matter. We were encouraged because there were no breakdowns or maintenance problems during the entire quarter. This proved that our design and construction techniques were adequate for hard-use situations.

The problems which did develop were concerned with "software." These included such things as ambiguous copy or instructions, deficiencies in the experiment plan which prevented the reaching of a conclusion, subject treated in too advanced a manner for the level of students using the exhibits, etc. The solution to these difficulties is, unfortunately, a matter of trial and error with many individuals and groups required to serve as test subjects.

Three teaching exhibits - Reflection, Lenses-Spherical Aberration and Conductivity of Solutions - were placed in the Albany High School Library for a period of one month to see what interest they would generate. Counters installed in the exhibits indicated over 1,200 users during this time. The librarians reported that there were large groups of students waiting each morning to use the machines, and there was disappointment when the machines were removed and no replacements installed.

Three other exhibits - Refraction, Voltaic Cells, and Interference of Two Waves - were placed in a hallway of Berkeley High School for a one-month period. The counters again showed over 1,000 users. The same result was found at Mt. Eden High School in Hayward.

The Chabot Observatory in Oakland has had these six exhibits for over a year, and they are used by the science students of the Oakland area.

Another type of teaching exhibit is the large programmed Periodic Table of the Chemical Elements planned for the Hall of Science. Preliminary design has been completed and construction will begin when sponsoring funds are obtained. This table will be 24 feet long, 16 feet high and have 18 vertical columns for the families of elements. The columns will be rotating trilons so that each chemical element will have three faces containing information on its properties. By simultaneous or individual rotation of the columns and lighting of individual elements, it is possible to create many teaching programs on chemistry. These can be conducted by a live instructor or automatically presented by means of visitor-operated consoles containing audio-visual equipment and control circuits. (See Final Report for Office of Education Contract #OE6-10-056, The Design, Development and Testing of a Response Box, A New Component for Science Museum Exhibits). As much flexibility as possible has been built into the exhibit so that many types of programs can be used - elementary, secondary, college, or general public. Provision for fast programming changes has also been incorporated.

In order to make the teaching exhibits more attractive (to encourage participation), the Lawrence Hall of Science has been developing a design which standardizes the appearance of the exhibit and at the same time makes the most efficient use of space. To this end, some exhibits have been built in cabinet style boxes and others in more open display type enclosures (approximate size 6 ft. x 3 ft.). The Lenses-Spherical Aberration Exhibit (see Appendix 2) illustrates the box style and the Friction and Streamlining Exhibit the display enclosure. The display enclosure is more expensive but enables a greater variety of things to be done with individual exhibits and yet keep the group appearance harmonious. It has been decided to repackage all the box-style exhibits into the display format.

Two of the teaching exhibits have been adapted for mass production capabilities so that they may be purchased by schools. They are the portable Calcium Nutrition Exhibit and a smaller version of the Periodic Table Exhibit. The Calcium Nutrition Exhibit has been loaned to schools and educational meetings with great success and we have had requests for purchase. Like the larger exhibit hall version, it has an attraction for teenagers who seem to react better when a machine, instead of parental nagging, tells they they are not getting enough calcium in their diet.

The small version Periodic Table is designed for use in educational television and enables a lecturer (as on the larger version) to present a varied program on chemistry. Because of the three separate face construction he can present material that can be seen by everyone in the classroom in an additive fashion, thereby building his conclusion without overwhelming an audience with the usual single chart filled with small numbers. Both of these teaching exhibits could be mass produced for about $200 each.

IV. DISCUSSION

Science educators are today faced with two all-important problems: 1) How to stimulate more students to study science, and 2) how to develop meaningful laboratory experiences for those that elect science. In spite of a tremendous effort in curriculum rebuilding such as PSSC, CHEM, CBA, IPS, etc., the enrollment in the physical sciences is not keeping pace with the growth in school population. It is generally agreed that the importance of these subjects to the general education of citizens is such that an all-out effort to reverse the downward trend in enrollment is more than justified. However, if this is accomplished, then science teachers would be faced with an almost overwhelming task of providing meaningful laboratory experiences for the many more additional students.

The Lawrence Hall of Science staff is fully aware of these problems and has developed a set of teaching exhibits which may contribute to their solution. The exhibits have the following major objectives:

1. Develop the student's interest by presenting him with a challenging question or problem which has relevance to him.

2. Provide instructions and readily usable equipment so the student can obtain the data needed to find the problem's answer.

3. Provide an opportunity for the student to test his comprehension of the new knowledge he has just learned.

4. Incorporate an evaluation system so that the exhibit's educational value can be determined.

The results of using the teaching exhibits in the U.C. non-laboratory physics course indicate that the objectives are being realized. The only indication we have so far from pre-college students is that they are very interested in using the machines and will willingly spend their time operating them. It remains for further research to determine whether the presence of these exhibits in a school for any length of time influences the enrollment in science. It has, however, been proved that this type of teaching media can improve a non-laboratory science course because of the increased interest shown by the students.

The ability to handle large groups of students is also significant. While individual laboratory practice can never be completely replaced, certainly a portion of it can be handled by a teaching exhibit of this type. A well-planned and constructed exhibit with adequate accompanying software can demonstrate a single science concept to many students without the need of a laboratory course or expensive equipment (which is usually found stored under a bench). As we have shown, these demonstration devices can be set up in a 30 x 30 ft. room and any student can come in at any time to perform an experiment and gather data, either for his own edification or as part of a formal course. It is impractical to put a complete set of everything in every school, but it would be possible to equip the newly established district science centers with this kind of media. After the initial cost of setting up an exhibit series, these centers would then be able to operate with a minimum of scientific staff and expensive-to-operate laboratory space. Hundreds of students could then participate in science experiments very economically.

By incorporating the new question and answer devices for exhibit learning and evaluation (see Final Report, Office of Education Contract #OE6-10-056, The Design, Development, and Testing of a Response Box, A New Component for Science Museum Exhibits, March, 1967), it is now possible to test and score exhibit participants. These automatic question and answer testing devices enable a sequence of teaching exhibits to be set up in a programmed learning mode. This is done by means of a group of devices covering a subject such as physics, each demonstrating a single principle with the participant being tested and scored as he progresses from the elementary to the complex.

Programming large exhibits such as the Lawrence Hall of Science Periodic Table of Chemical Elements with special motion picture loops, random access slide projectors and accompanying sound tape has great promise for converting ordinary "look and learn" exhibits into "do and learn" teaching exhibits; thereby increasing the educational value. The ability to change programming can be used to alter the level of presentation as well as the subject matter. It would be possible to prepare these programs in foreign languages for visitors or special classes.

The wide range of subjects for the teaching exhibits was chosen to determine the problems of adapting the participation device concept to the various sciences. Several things have become evident. Physics and mathematics are the easiest to construct because of the basic electrical-mechanical nature of the topics. The speed at which things happen is not critical and routine servicing is minimal. Nuclear physics is also relatively easy for these same reasons. The major problem is to insure radiological safety if radioactive materials are used. A successful series of this type has been constructed with funds provided by the Atomic Energy Commission (see Final Report AEC Contract AT(04-3)-322). Chemistry is more difficult because of the necessity of material replenishment and a natural deterioration of some items. Therefore, our first chemical exhibits were physical-chemical in nature; but we are now solving these problems, and students will soon be able to handle chemicals themselves. Biology is very difficult to present in participation devices. Not only is there a material problem but also a time problem. Things don't happen very fast in biological experiments. One solution is to use film such as in the Story of a Living Cell Exhibit. There are many excellent short film loops available today showing microbiological events. We have chosen *Amoeba proteus*, Mitosis, *Euglena gracilis*, and *Paramecium aurelia*. Each film is about four minutes long and is projected by demand onto the screen of an hexagonal exhibit housing. We have, however, designed an exhibit utilizing a microscope to examine a drop of water containing live protozoans. The microscope is fixed with a water drop automatically titrated on to the slide.

Now that the basic series of teaching exhibits has been designed and/or constructed, we plan additional studies as funds become available. The question and answer devices, teaching exhibits, and experiment write-up sheets will be combined into a program designed to test the over-all appeal and teaching ability of the participation learning devices. We expect that the development of the experiment sheets will be the major effort. The results from the previous evaluation indicate this to be the critical factor in getting across the desired scientific point.

The Lawrence Hall of Science has designed an automatic paper-tape recorder to assist in the evaluation of this type of educational media. This recorder can be plugged into the exhibit and will indicate:

1. the number of people who approach the exhibit
2. the number who participate in the demonstration portion
3. the number who answer the question
4. the resulting score

It will also show the time involved for each participant to go through the procedure. It is possible that a device of this type would have use in museums to help evaluate visitor response to exhibits. Construction of prototype recorders will be done as funds become available.

V. CONCLUSION

Teaching exhibits for demonstration learning can be designed and constructed for many scientific fields and principles. They are effective in increasing student response to a scientific subject. Use of these machines can provide laboratory experiences to general liberal arts students at a fraction of the cost of the standard laboratory with its duplication of equipment and technical personnel requirements. The combination of student participation, automatic testing and accompanying software to enhance the presentation is the best way of accomplishing the objective.

VI. SUMMARY

A series of 27 teaching exhibits have been developed by the Lawrence Hall of Science. They enable high school and college students to perform laboratory experiments in the fields of physics, mathematics, chemistry, and biology. By using this type of teaching media, numbers of students can be accommodated in a simple facility with little operating expense.

Ten of these teaching exhibits were evaluated in a university introductory physics course for non-science major students. They were successful as teaching devices and added a meaningful type of laboratory to a course which is usually taught by lecture alone.

Two of these exhibits were also produced in a portable form for use in the classroom and on educational T.V. programs.

APPENDIX 1

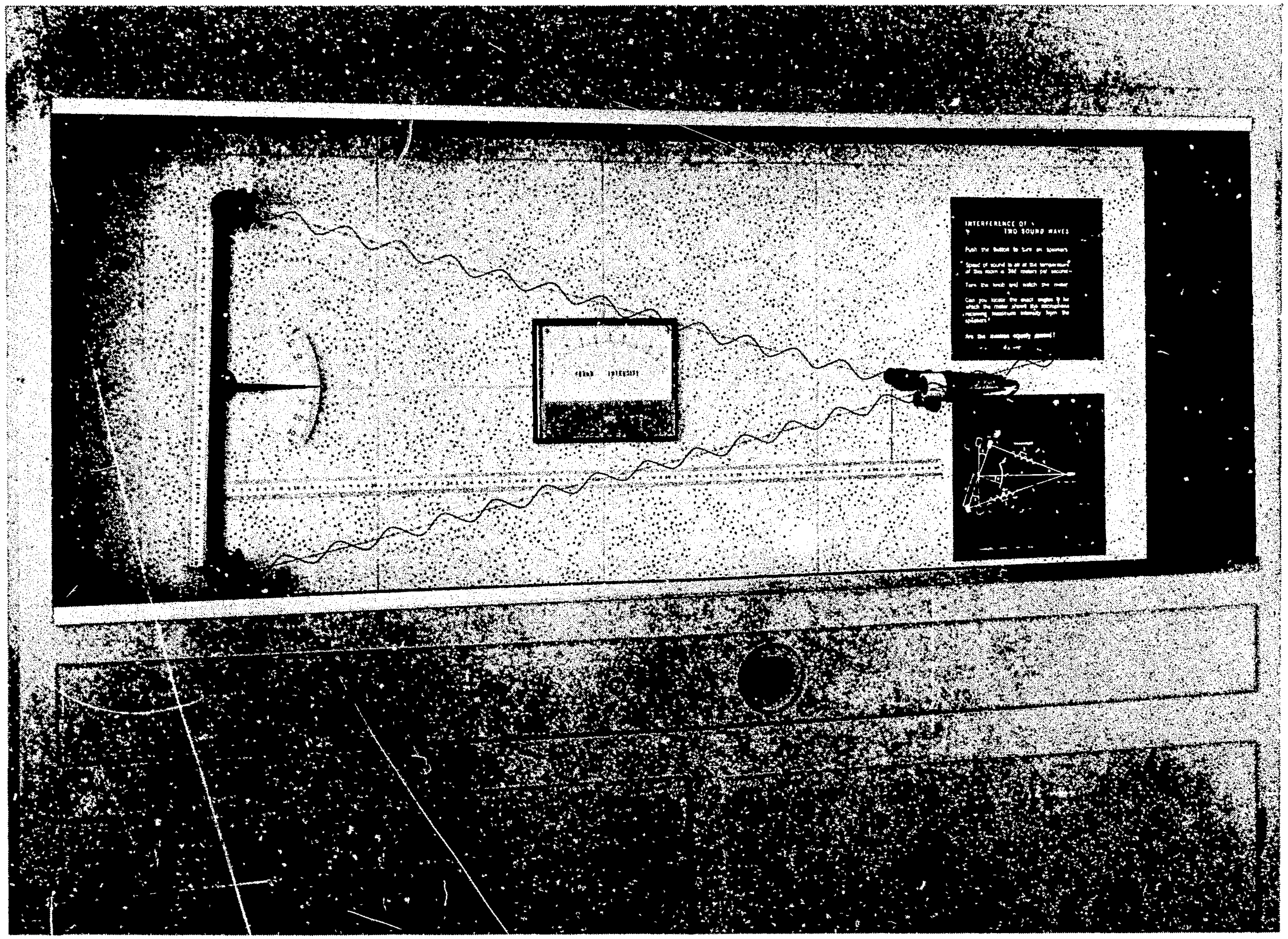
Teaching Exhibits Produced by Lawrence Hall of Science

Subject	Name	Designed Mocked-up	Constructed and Tested	Evaluated
Physics	Interference of Two Waves	X	X	X
	Friction and Streamlining	X	X	X
	Stroboscope	X	X	
	*Real Images - Phantom Bouquet	X	X	
	Coriolis Force	X		
	Diffraction Grating	X	X	
	Charging of a Capacitor	X	X	X
	Refraction	X	X	X
	Reflection	X	X	X
	Lenses - Spherical Aberration	X	X	X
Nuclear Physics	Mechanical Cyclotron	X	X	
	Mechanical Linear Accelerator	X	X	
	Determination of the Nature of Atomic Nuclei	X	X	X
	Rutherford Scattering	X	X	
	Elastic Scattering	X	X	
	Phase Stability	X		
	*Inverse Square Law	X	X	X
	*Gamma Ray Absorption	X	X	
	*Differential Absorption	X	X	
	*Half-life of Silver	X	X	
	*Back Scattering	X	X	
	*Magnetic Deflection of Beta Rays	X		
	*Random Counting	X	X	
Mathematics	Summation of Parts	X	X	X
	*Pinball Error Curve	X	X	X
	*Pythagorean Theorem	X	X	
	*Mathematical Minimum	X	X	
	*Dice Game	X	X	
	*Binomial Probability	X		
Chemistry	Large Periodic Table of Chemical Elements	X		
	Classroom Periodic Table	X	X	
	Chromatography	X	X	
	Electrolysis of Water	X	X	
	Are You Getting Enough Calcium?	X	X	X
	Portable Calcium Counter	X	X	X
	Color of Ions	X	X	X
	Conductivity of Solutions	X	X	X
	Voltaic Cells	X	X	
Biology	Story of Living Cells	X		
	Life in a Drop of Water	X		

*Funded by other contracts and grants

APPENDIX # 2

EXHIBIT DESCRIPTION AND ILLUSTRATION



INTERFERENCE OF TWO WAVES

Two high-frequency speakers are mounted at the ends of an arm which can be rotated on an axis midway between the speakers. The speakers are automatically aimed at a microphone no matter what the position of the arm. When the speaker arm is vertical then both speakers are equidistant from the microphone. As the arm is turned one speaker gets closer to the microphone while the other one moves farther away. Both speakers are made to produce 5 KC sine wave sound by a transistor oscillator. The microphone is connected to an amplifier and the relative sound intensity shown on a meter. When the waves from the two speakers are in phase, a maximum reading is obtained on the meter. When the waves are out of phase, a minimum is recorded. The frequency of the sound wave can be determined by making quantitative measurements of the geometry of the parts.

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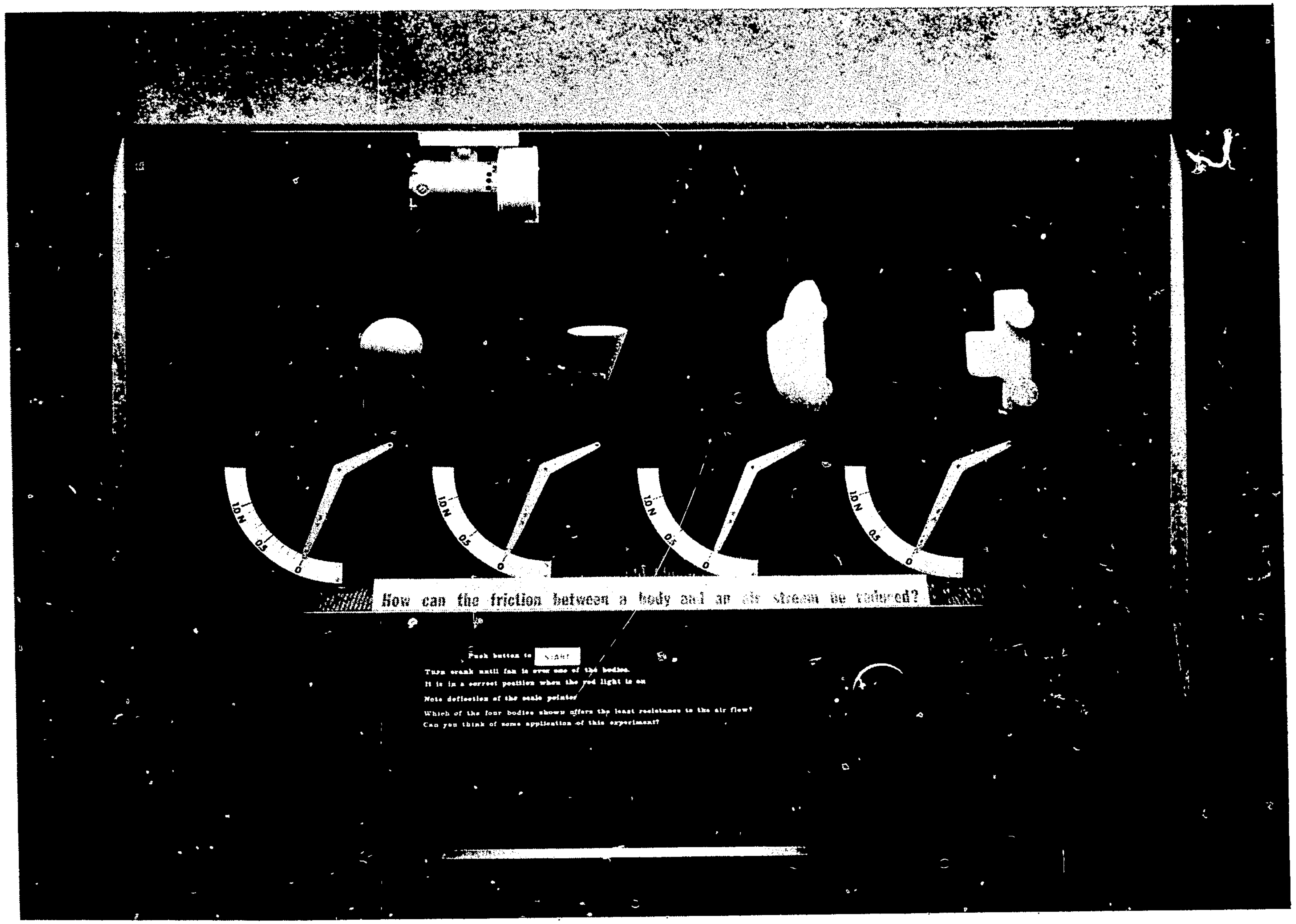

FRICTION AND STREAMLINING

An electric blower travels on a track over four objects of different shapes. As the viewer positions it above each of the objects, it comes on and produces an airstream against the object. The objects are mounted on calibrated pivot arms so the amount of "push" can be measured in newtons. The relationship between shape and air friction can be seen.

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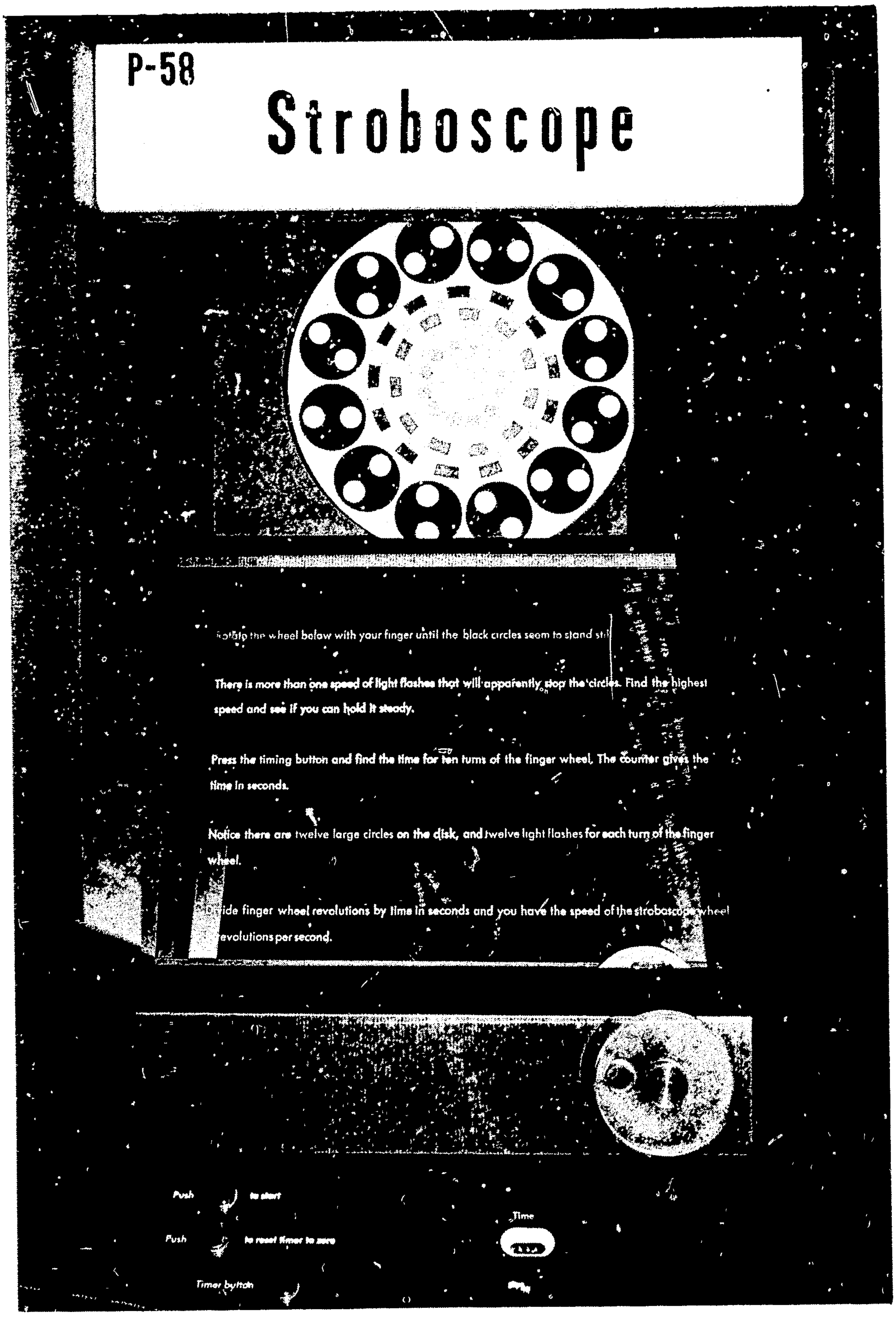

STROBOSCOPE

A 14" stroboscope wheel with 12 black circles rotates at a constant speed. This wheel is illuminated by a strobe light which flashes 12 times for each spin of a knob on the front of the exhibit. There is also an interval timer mounted on the exhibit front. The participant spins the knob until the black circle on the strobe wheel seems to stand still. He then presses the timer start button and determines the time for ten spins of the knob. By dividing the knob revolutions by the time in seconds, the speed of the strobe wheel in RPS is found.

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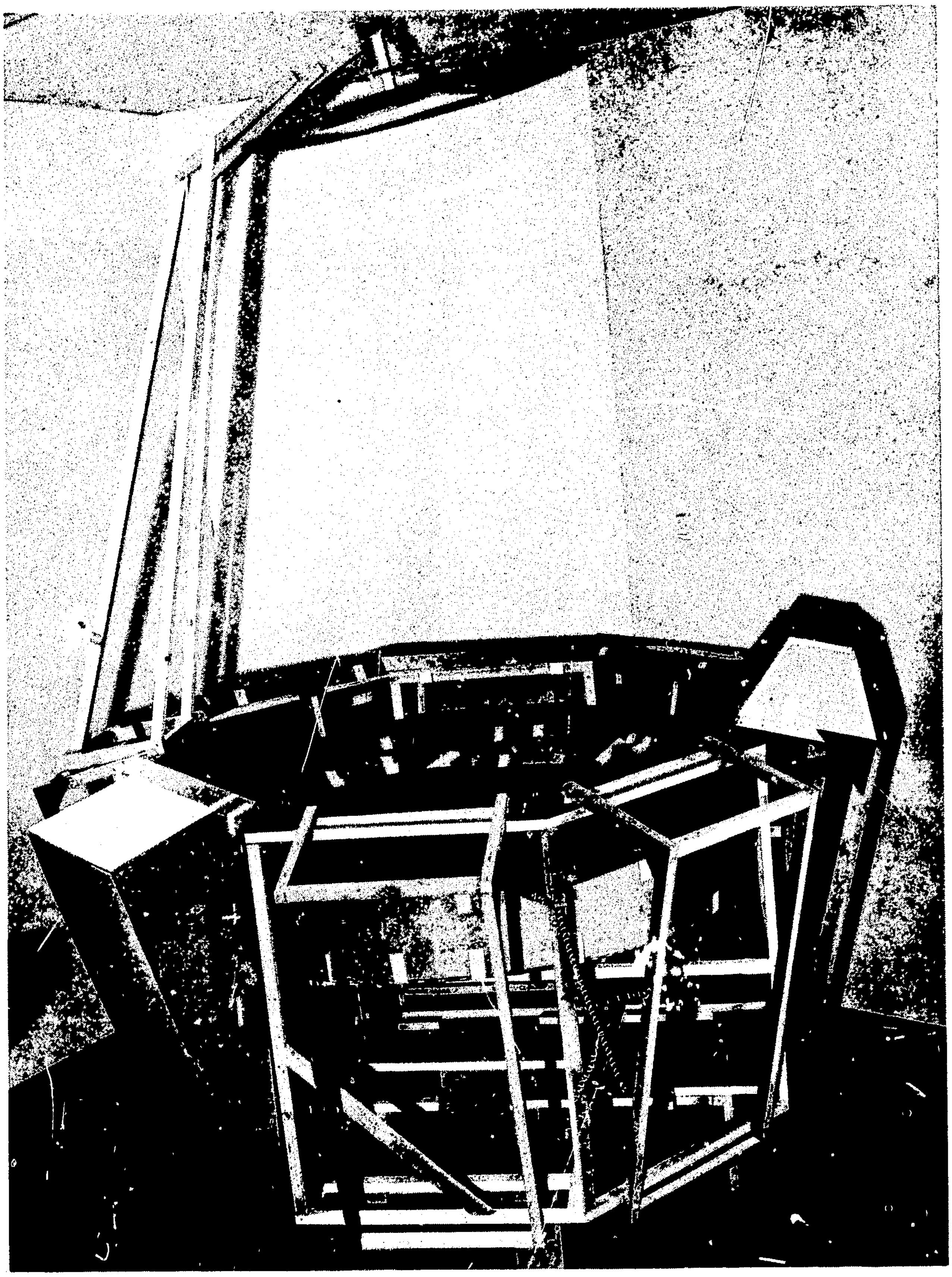

CORIOLIS FORCE

The curved path of a projectile in a rotating frame of reference is demonstrated in this exhibit. A stream of water issues from a jet which is mounted on a rotating disc. A rotating prism moving with the same angular speed as the disc is used to view the stream of water. This enables the observer to view the water stream as if he were in the rotating frame.

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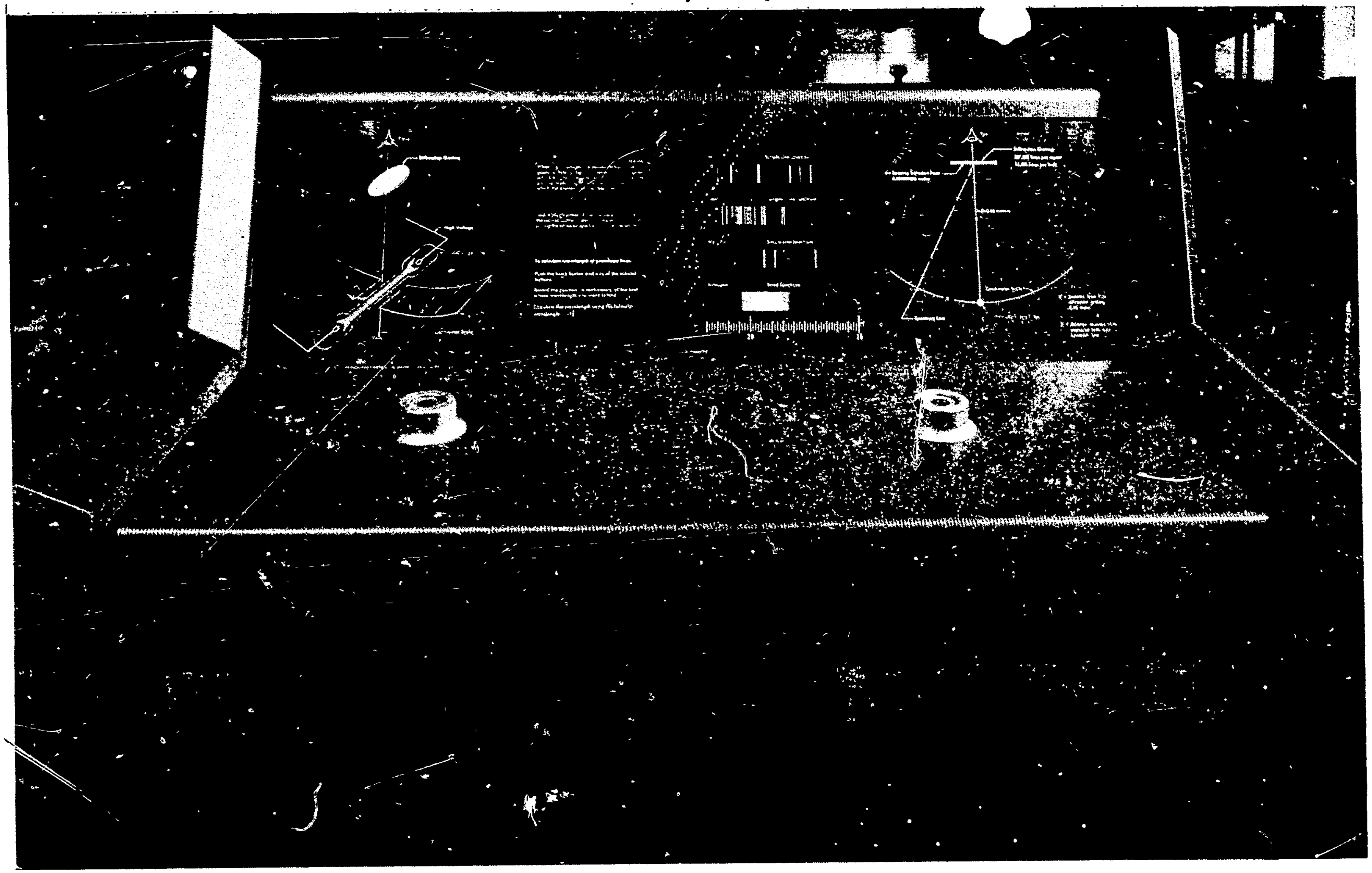

DIFFRACTION GRATING

This exhibit is divided into two sections - one with helium and neon discharge tubes below an eyepiece containing a diffraction grating and the other with mercury and nitrogen discharge tubes. The viewer looks through an eyepiece and lights one of the tubes by pressing a corresponding panel-mounted button. He then sees the emission spectrum of an element. The element may be identified by comparing the observed spectrum with charts shown on the exhibit. Another button illuminates a calibrated scale which enables a measurement to be made of each spectrum line from the center. Using this value and other dimensions given in the exhibit, the wavelengths of the spectral lines can be calculated.

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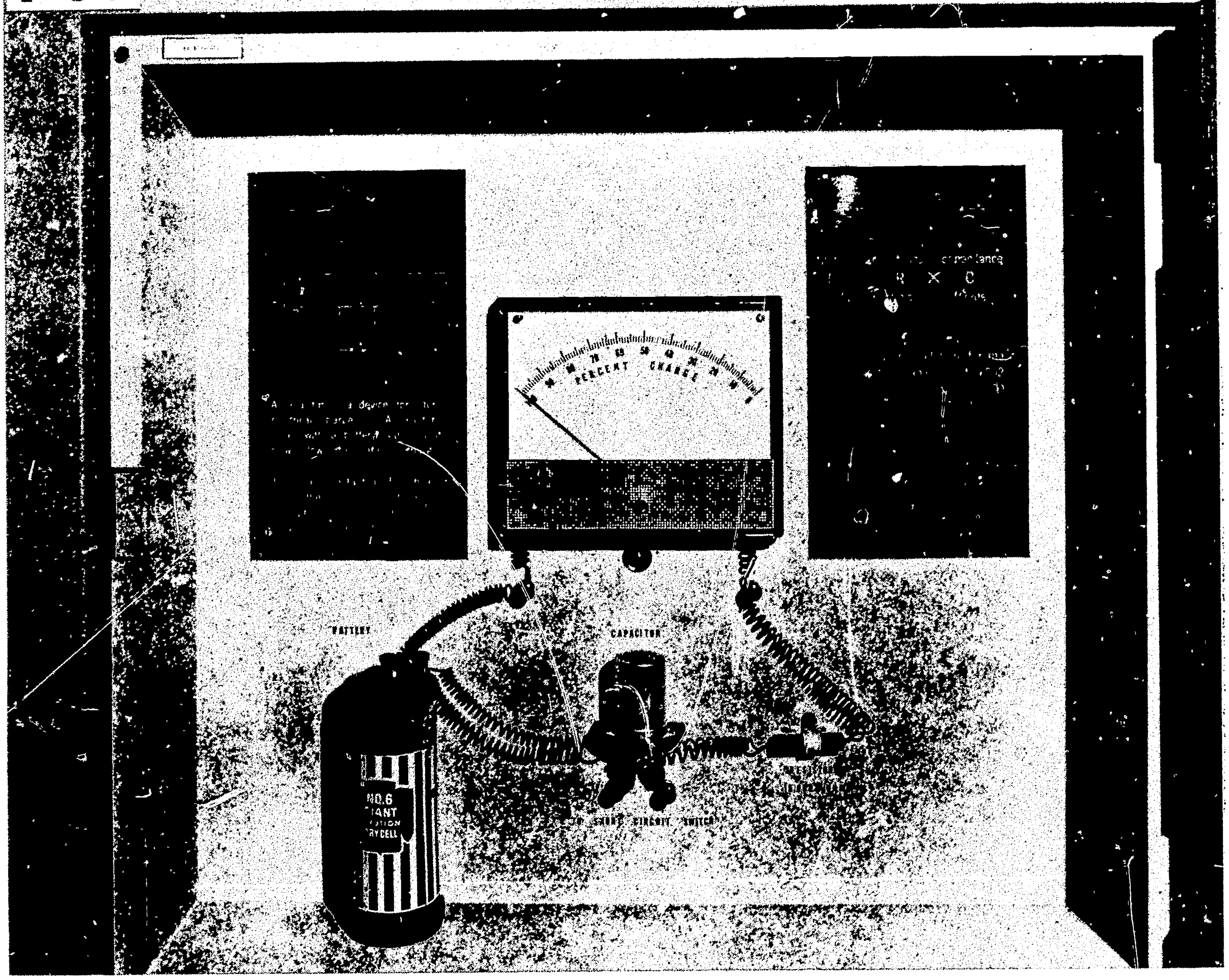
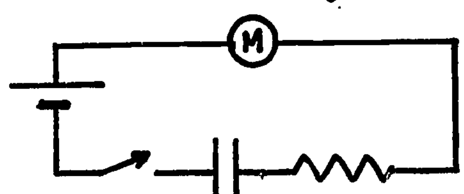


CHARGING OF A CAPACITOR

A .002 farad capacitor is connected across a battery through an ammeter and 15,000 ohm resistor as follows:



The meter is calibrated in percentage of charge (when the capacitor is fully charged, no current flows). A one-second interval flashing light is used as a timer to determine the time required for the capacitor to charge to 63% of full value. The formula T seconds = R ohms x C farads can thereby be verified.

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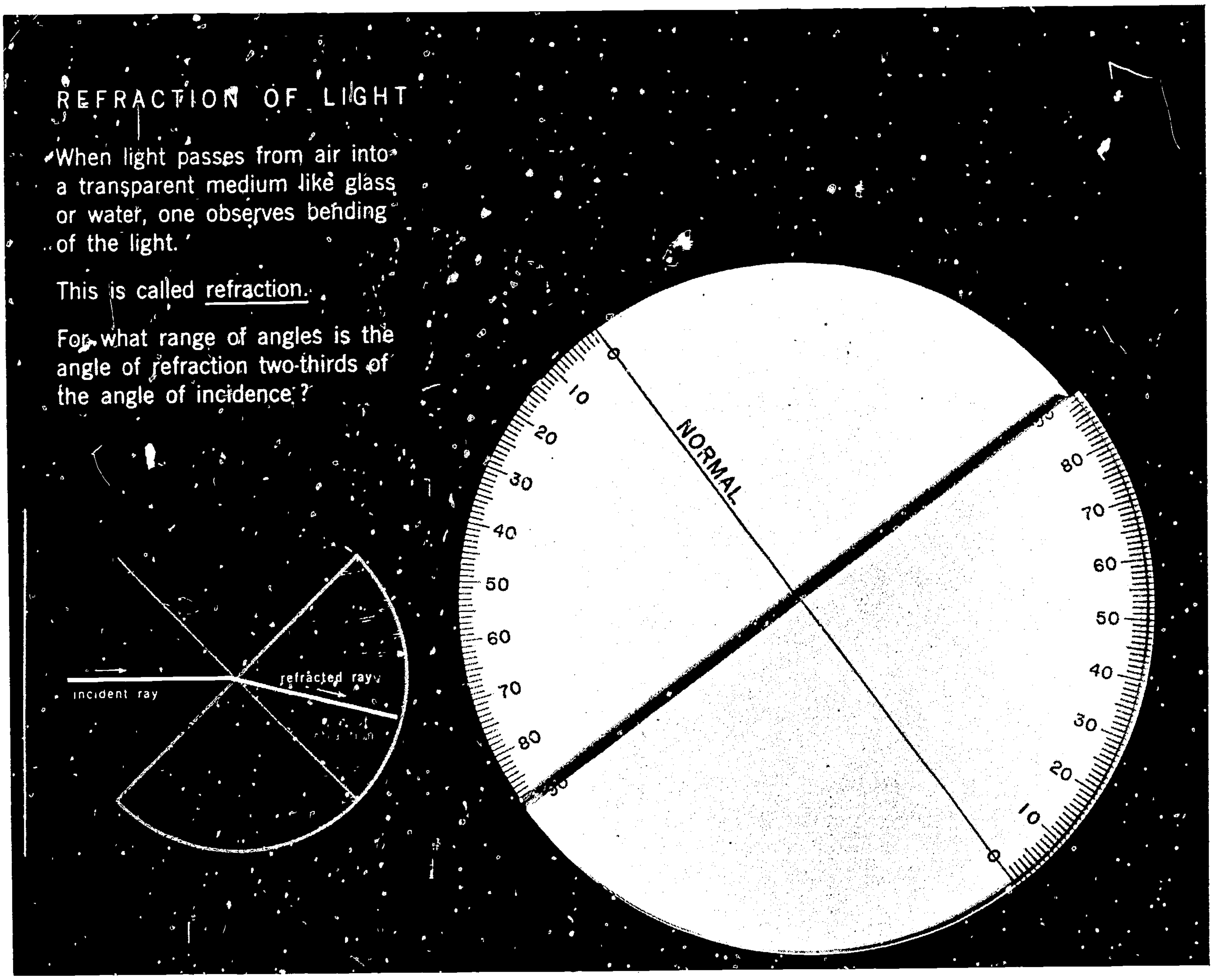

REFRACTION

A large plastic plano-convex disc is mounted on a wheel. This wheel can be rotated through a 90° angle by turning a knob on the front panel of the exhibit. A fixed light beam strikes the plane side of the disc and the light path is visible before and after entering the disc. The wheel is calibrated in degrees which makes it possible to measure the angle of incidence and the angle of refraction, and to calculate the index of refraction for the plastic.

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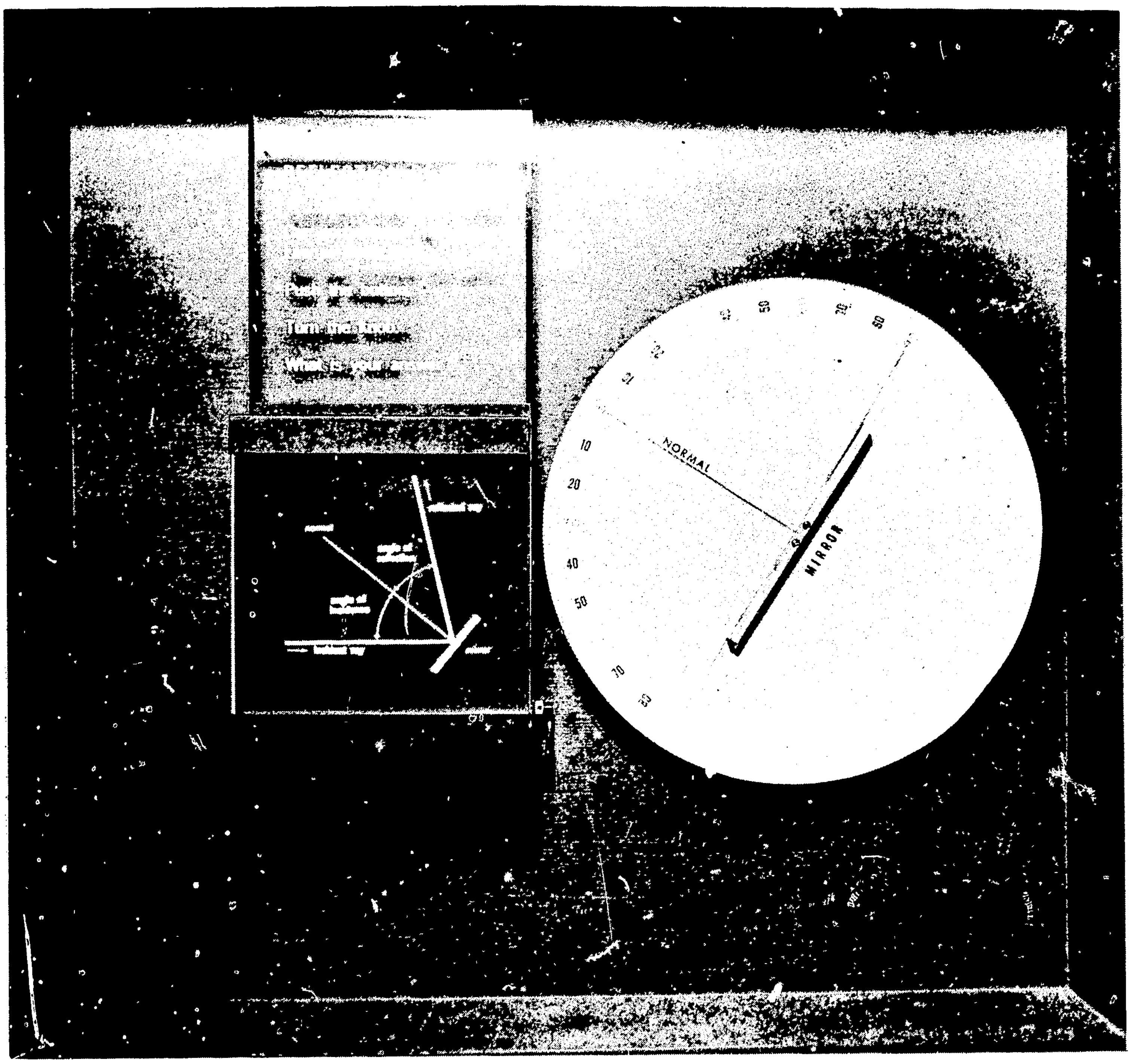

REFLECTION

A mirror is mounted on a movable calibrated wheel. A light beam is reflected at different angles as the wheel is turned. The "angle of reflection equals the angle of incidence" law can be deduced.

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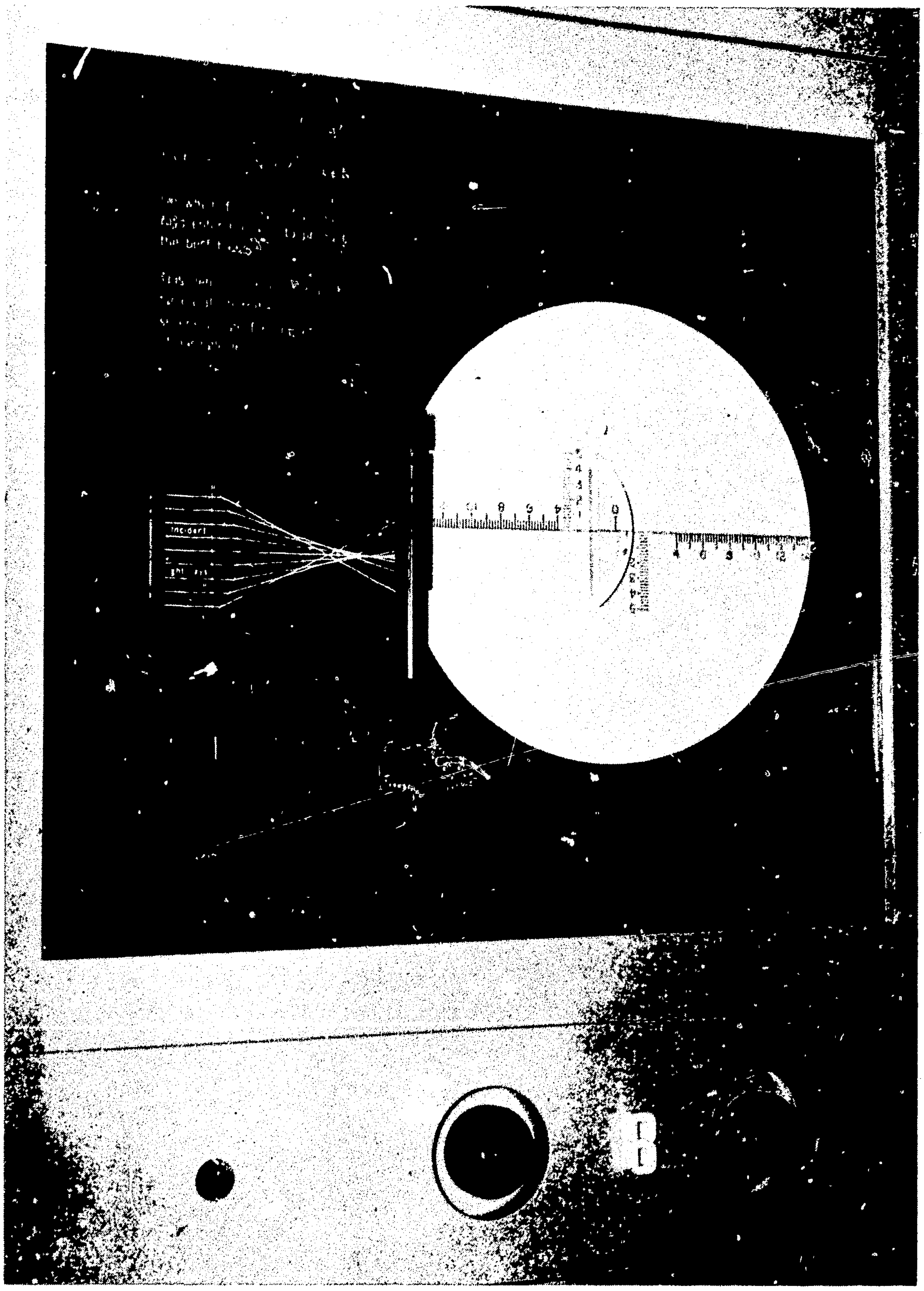

LENSES - SPHERICAL ABERRATION

A plastic disc in the shape of a plano-convex lens is mounted on a movable wheel. A fixed light source with parallel beams is arranged so that the path of the beams can be seen as they enter and leave the lens. By turning the wheel with the front knob the observer can see which face the rays should enter to produce the best focus. In addition each beam can be sent through the lens individually and the distance from the lens to where the beam crosses the principal axis can be measured. This makes it possible to observe spherical aberration and its cause.

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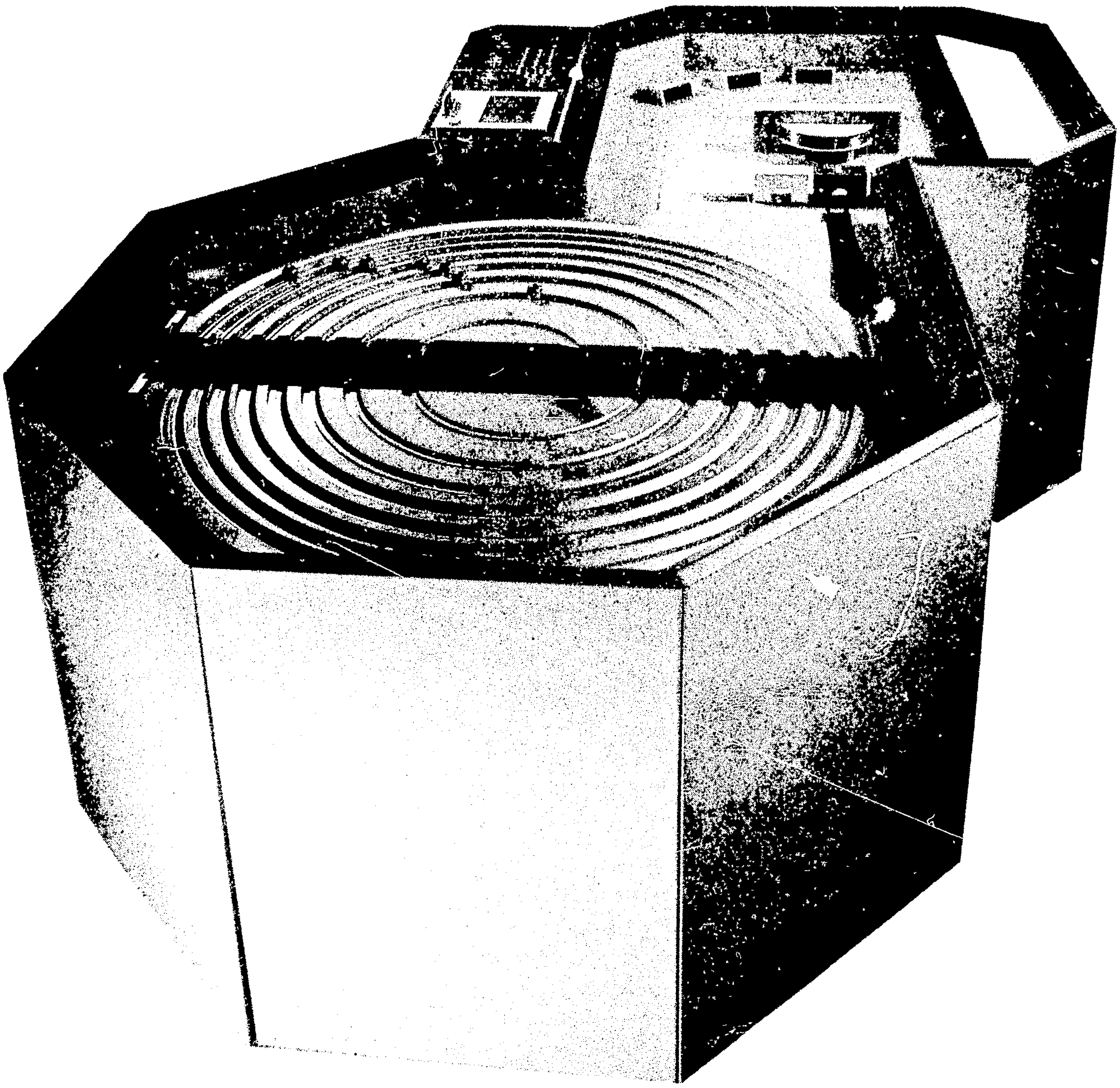

MECHANICAL CYCLOTRON

The "dees" or accelerating chambers of the cyclotron are simulated by two semi-circular metal discs which are free to move up and down with respect to each other. They are joined by a straight piece of metal which makes a slope from one semi-disc to the other. A spiral track is cut in the disc starting at the center and moving out to a target area. Steel balls representing deuterons or protons are injected at the center of the spiral and accelerate each time they go down the slope. The increasing path length and acceleration the ball receives each time it goes downhill are so arranged that the time taken to make a turn around the spiral is always the same. This makes it possible for all the balls to be accelerated no matter where they are in the spiral path. When the balls reach the end of the spiral, they shoot toward the simulated target. The simulated products of the interaction between the balls and target are sent through a "mass spectrograph" (represented here by a model of an electromagnet) and are deflected according to their mass, velocity, and charge. The viewer can select targets showing the production of neutrons by deuterons striking a beryllium target, the formation of alpha particles by protons on an aluminum target, and proton production by deuterons on a lithium target.

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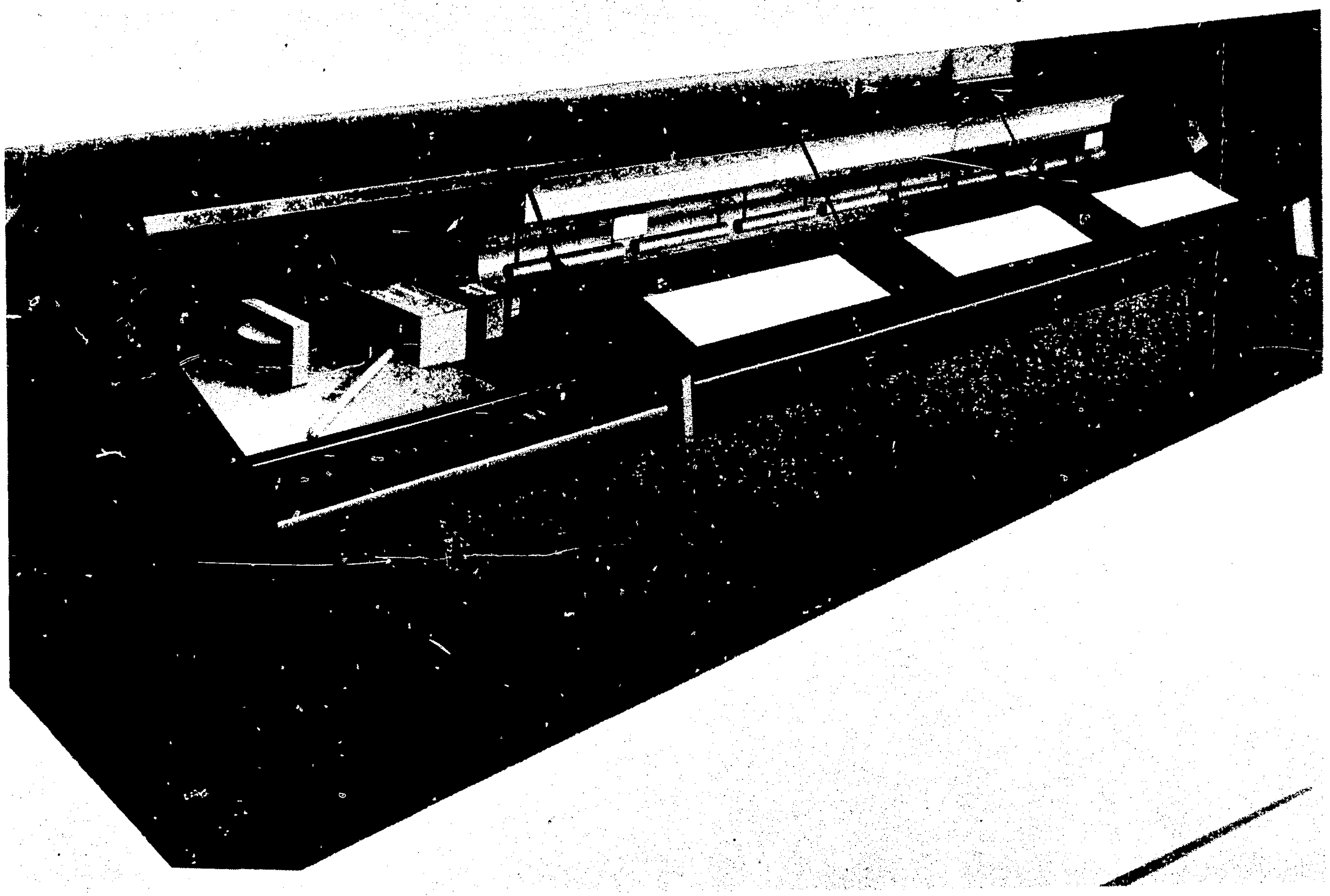

MECHANICAL LINEAR ACCELERATOR

Steel balls representing electrons are fed onto a sectionalized metal track. The sections move up and down with respect to each other so that as each ball gets to a junction it goes down a small hill. This acceleration is analogous to the acceleration electrons get when they go from one drift tube to another. The rocking movement is synchronized with red and green lights labeled (- and +) showing how electric fields are responsible for the acceleration of electrons. At the end of the run the balls drop out of sight under the "Primary Target", from which comes a flash of light labeled "gamma ray." This ray leads into the "Secondary Target" producing one of four simulated events: 1) an electron pair, 2) pion pair, 3) photoelectron, and 4) an electron and a gamma ray.

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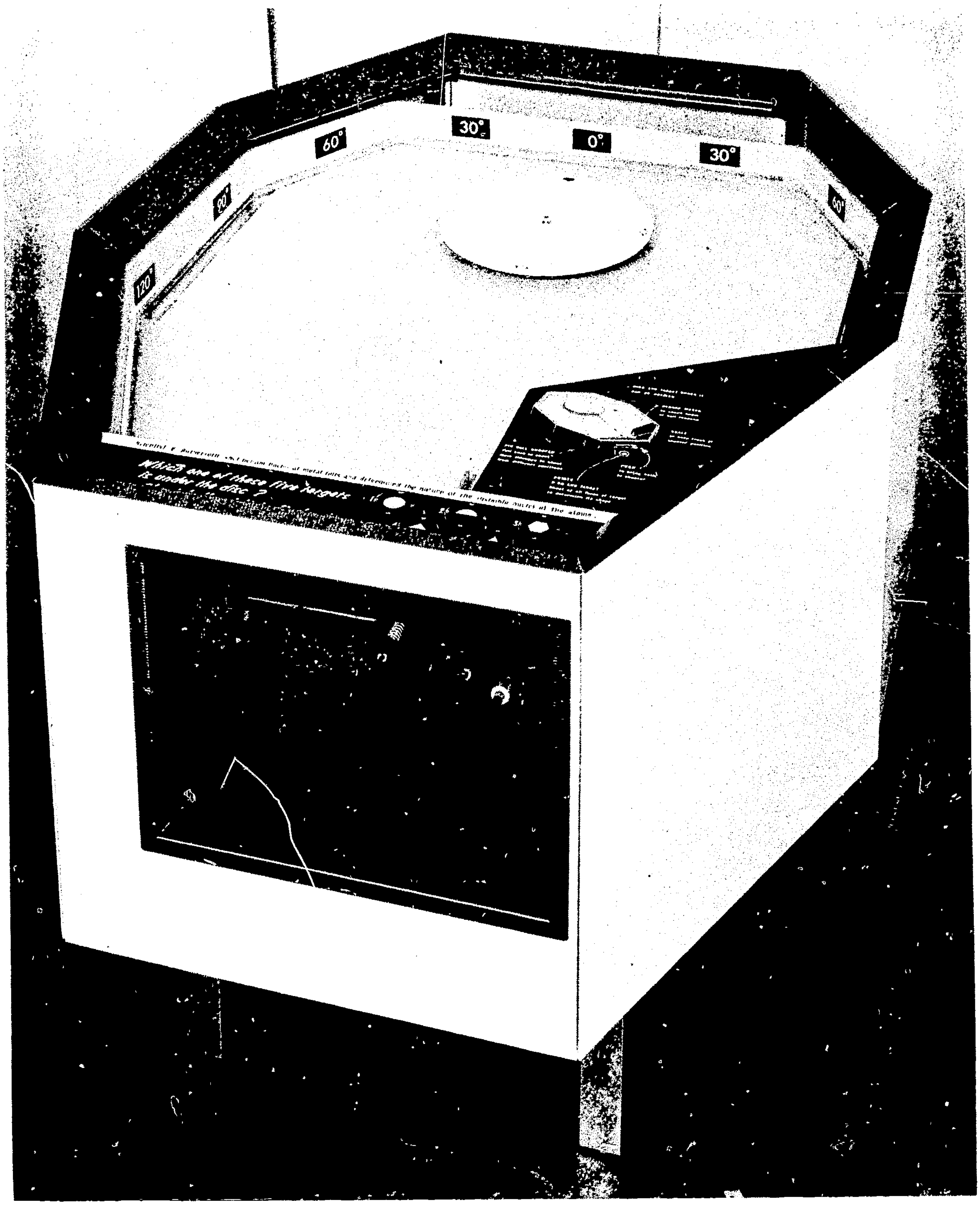

DETERMINATION OF THE NATURE OF ATOMIC NUCLEI

This is a mechanical analogy device which demonstrates how scientists discover things by indirect measurements. The exhibit shows how the properties of the atomic nucleus were determined by shooting helium nuclei (represented by steel balls) at thin gold foils. The way the nuclei scattered when striking the gold foil gave clues as to the structure of the atom (the hidden target). In this exhibit the target is one of five different shaped geometric figures shown on the exhibit panel. This target is hidden from view by a covering disc but may be rotated to expose the sides to a pinball shooter. The viewer shoots the balls and tries to find the shape of the target by the way the balls rebound from it.

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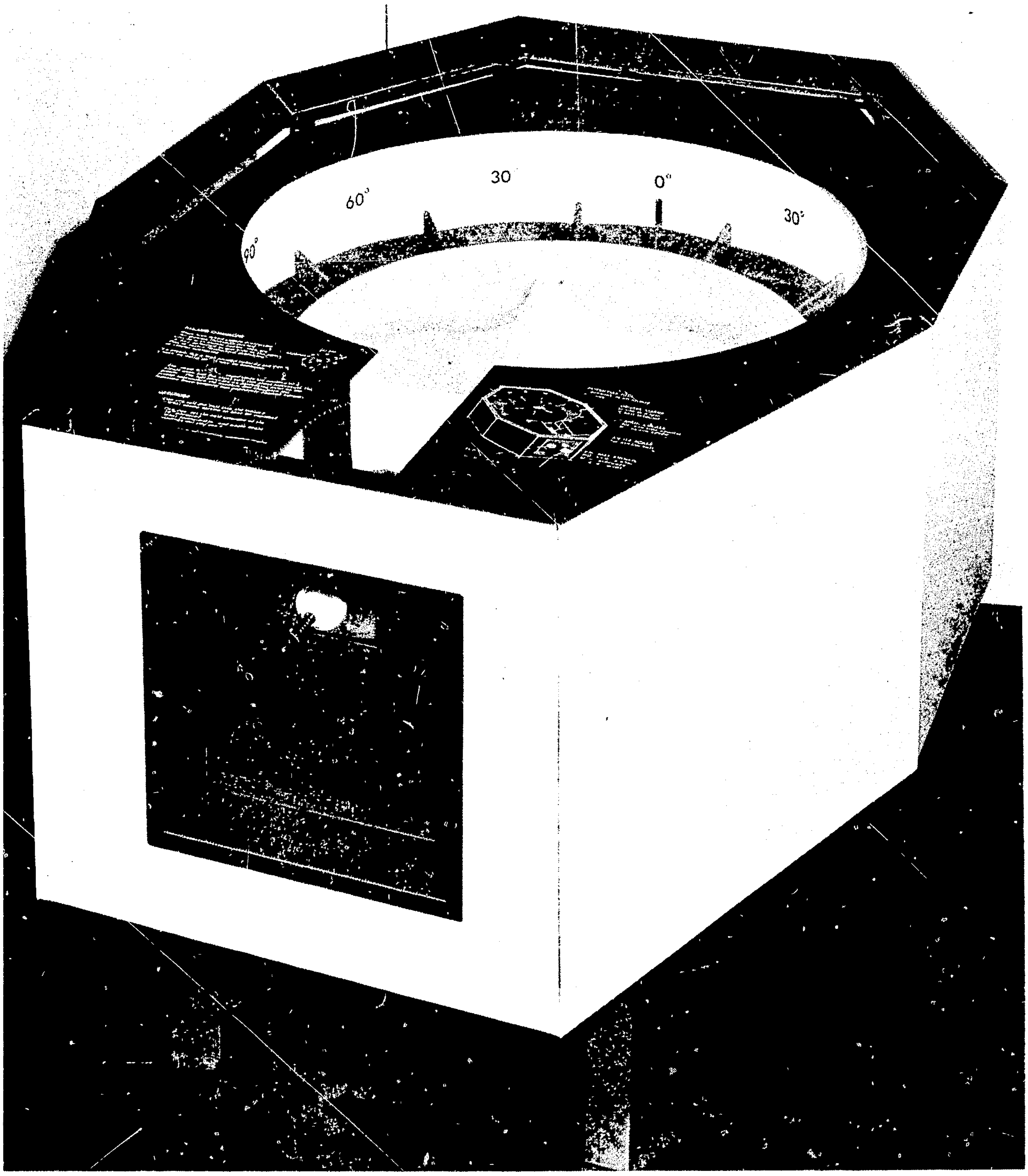

RUTHERFORD SCATTERING

When high speed charged atomic particles (such as protons) collide with atomic nuclei they are usually deflected due to the repulsive electrostatic forces. If the particle has sufficient energy to overcome these coulombic forces, as they are called, and makes a headon collision it may be captured. These effects are demonstrated by shooting steel balls at a volcano-shaped cone. The sloping side simulates the increasing force affecting the particle as it approaches the nucleus. Most of the balls will deflect off the hill but a few will go into the center of the cone. This last represents a capture of the particle by the nucleus.

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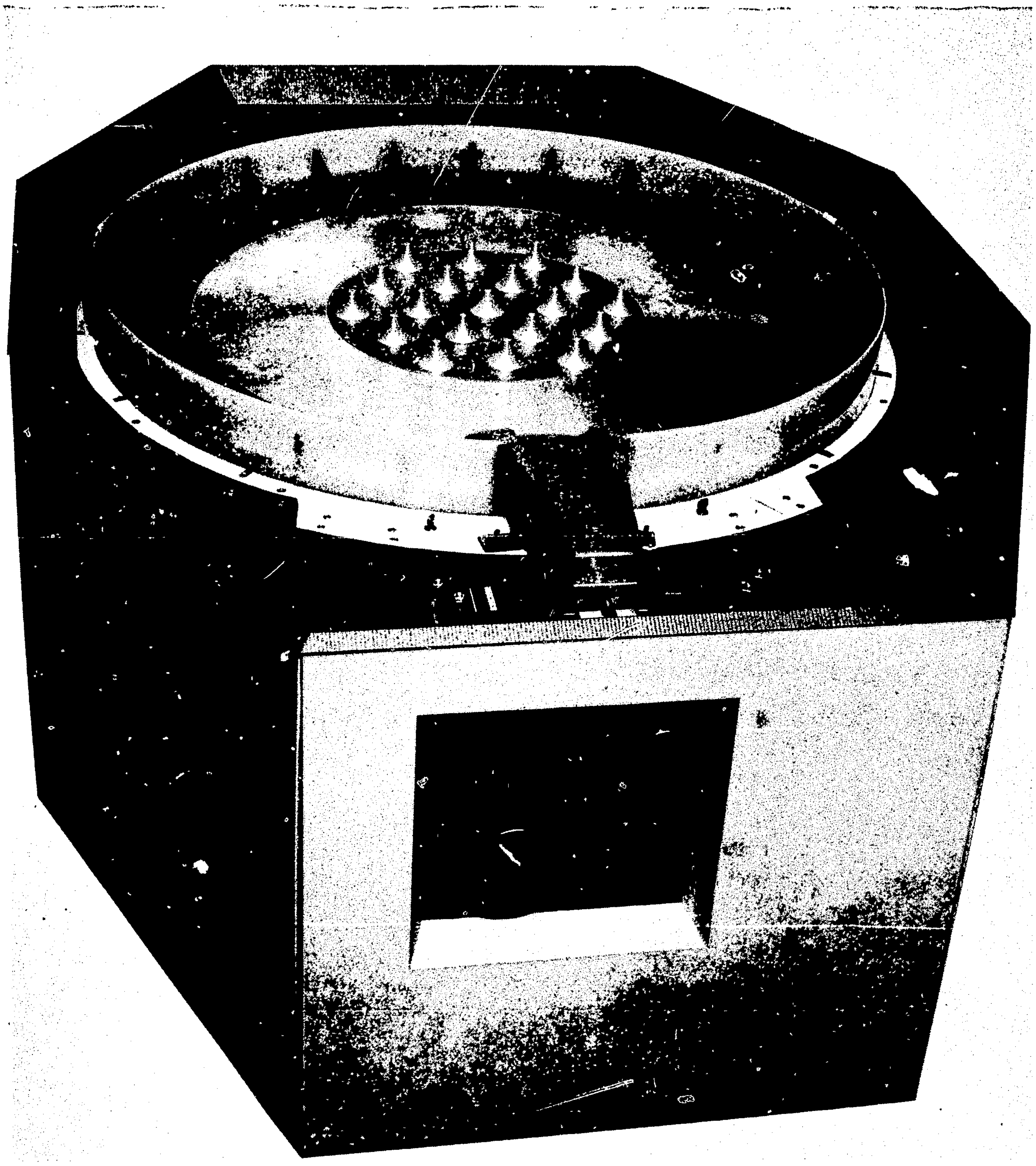

ELASTIC SCATTERING

Scientists have determined the size of the atomic nucleus by shooting atomic particles at metal targets composed of millions of atoms. Many of the particles scatter off the individual nuclei within the target as if they were perfectly elastic spheres. Nineteen small cones mounted on a disc represent atomic nuclei in a solid target. Steel balls shot from a pin ball shooter represent atomic particles. The cone shape is analogous to the electric potential around an atomic nucleus. In operation the disc with the cones rotates back and forth a few degrees and as balls are shot they collect in pockets around the periphery of the disc. As more and more balls are shot one sees that more collect in some pockets than others. By studying the distribution of balls it is possible to draw some conclusions about the geometry of the target.

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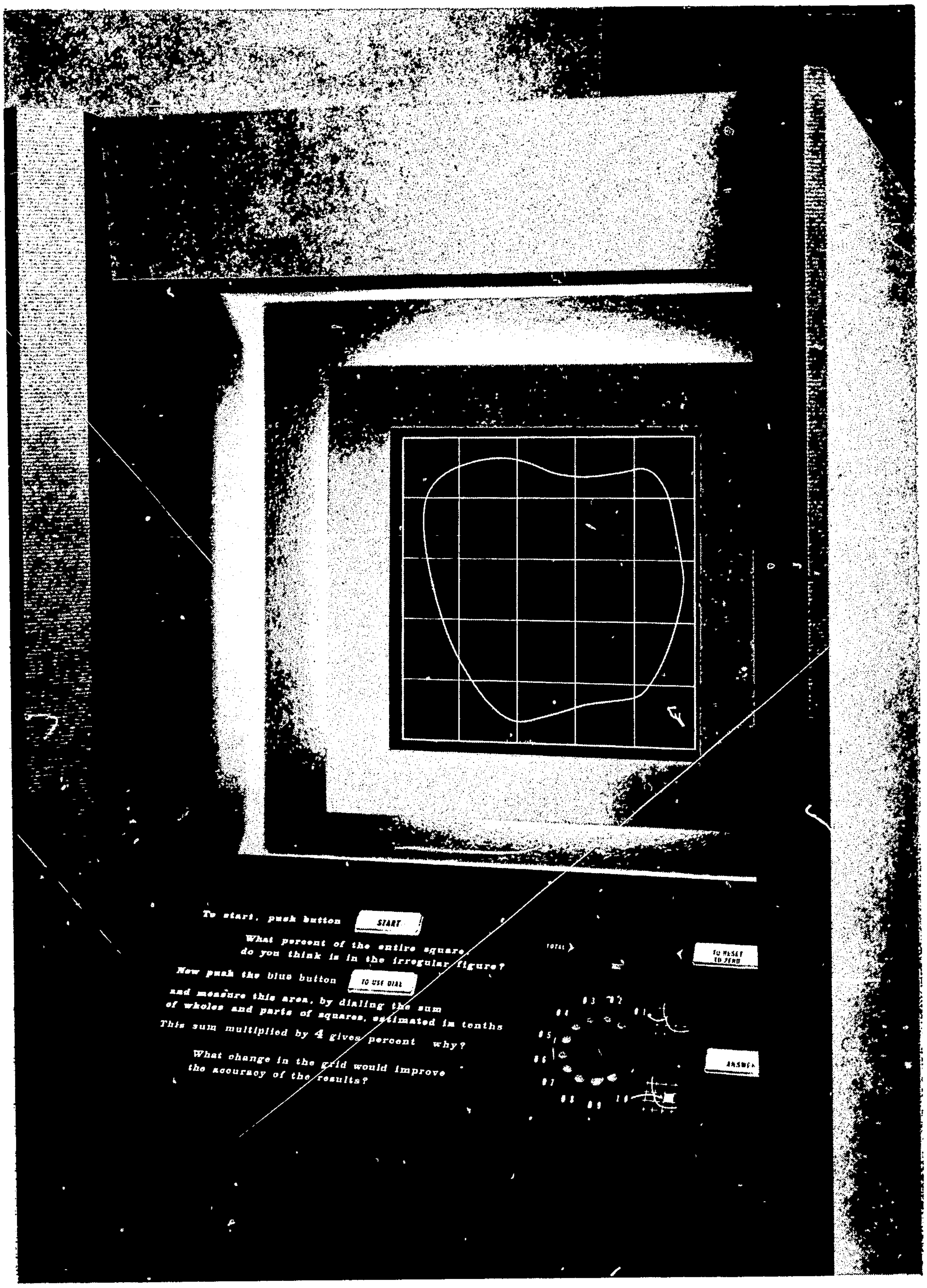

SUMMATION OF PARTS

The percentage of area occupied by an irregular figure in a large square is first estimated without grid lines. A grid is then turned on and areas within each square are estimated and tabulated by means of a modified telephone dial and counter. The participant sees how much more accurately he can find the total area by dividing it up and summing estimates of smaller parts.

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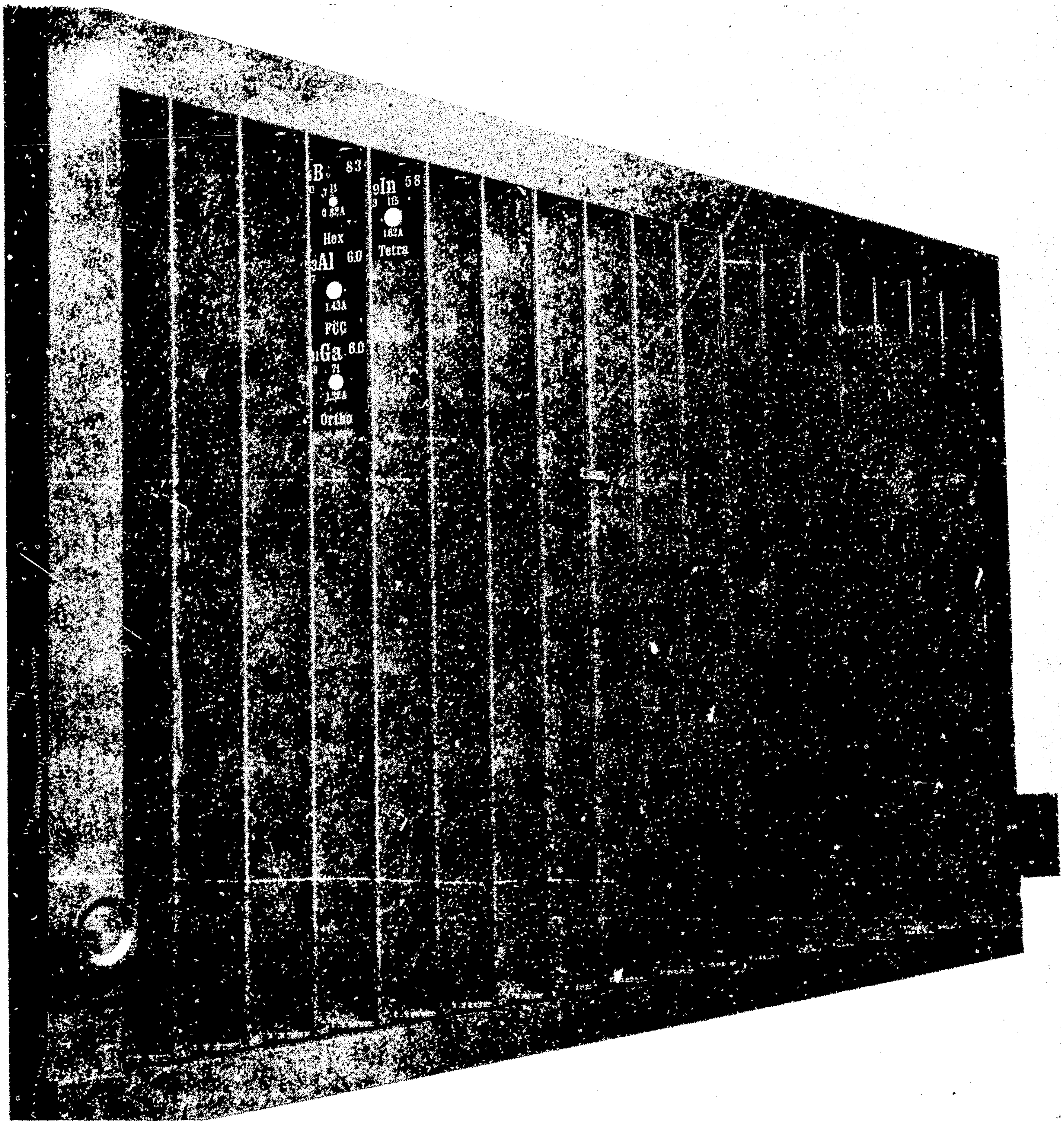

CLASSROOM PERIODIC TABLE

Eighteen metal trilons (three-faced vertical columns) are mounted in a 52" x 86" frame. Each trilon is 45" long and has 4" wide faces. These trilons have vertical edge slots which allow cardboard squares to be inserted and held. Information about each chemical element is reproduced photographically from master negatives and mounted on the squares which are placed in the correct position on the table. There are three cards for each element - one for each trilon face. The first card has the general information about the element, the second has information used in physics and the third has information used in chemistry. The trilons may be rotated separately or simultaneously enabling the lecturer to present subject matter in a variety of ways.

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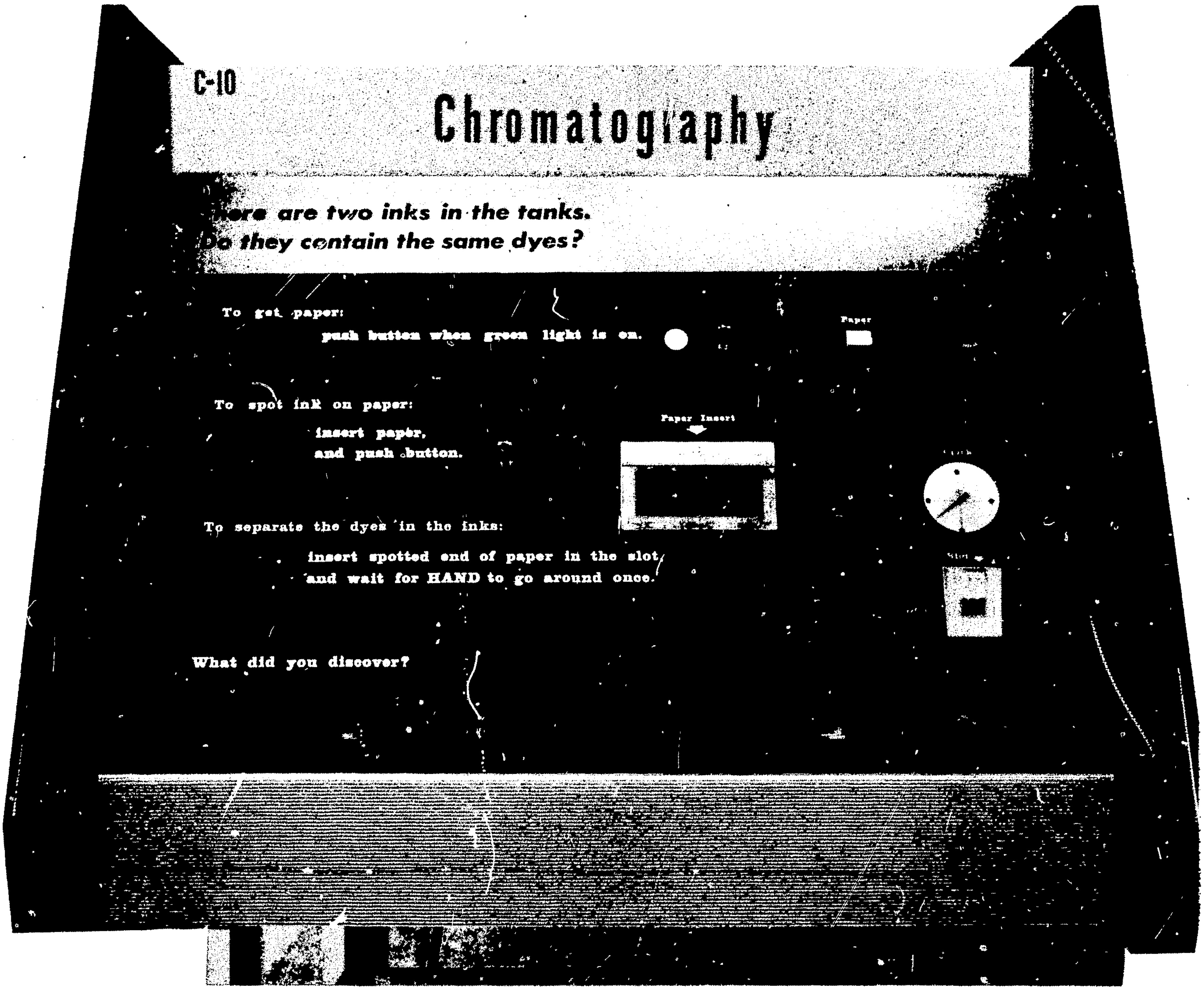

CHROMATOGRAPHY

A filter paper strip is obtained from a slot and inserted into another slot where it receives two spots of identically appearing mixed dyes. The paper strip is put into a small plastic well containing water at the bottom. As the water migrates up the filter paper strip the two dye spots spread out into a vertical stripe and the different dye components are seen.

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ARE YOU GETTING ENOUGH CALCIUM?

The visitor sets ten knobs to indicate the type and amount of each food he normally eats in one day. A calibrated meter is then switched on and it shows the total amount of calcium in that diet. The visitor can reset the knobs and see the changes in diet calcium brought about by increasing or decreasing the intake of the various food groups.

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PORTABLE CALCIUM COUNTER

This is a smaller version of the Hall's Are You Getting Enough Calcium exhibit. Knobs are set to indicate the type and amount of each food a person normally eats in a day. The meter indicates the total calcium in that diet.

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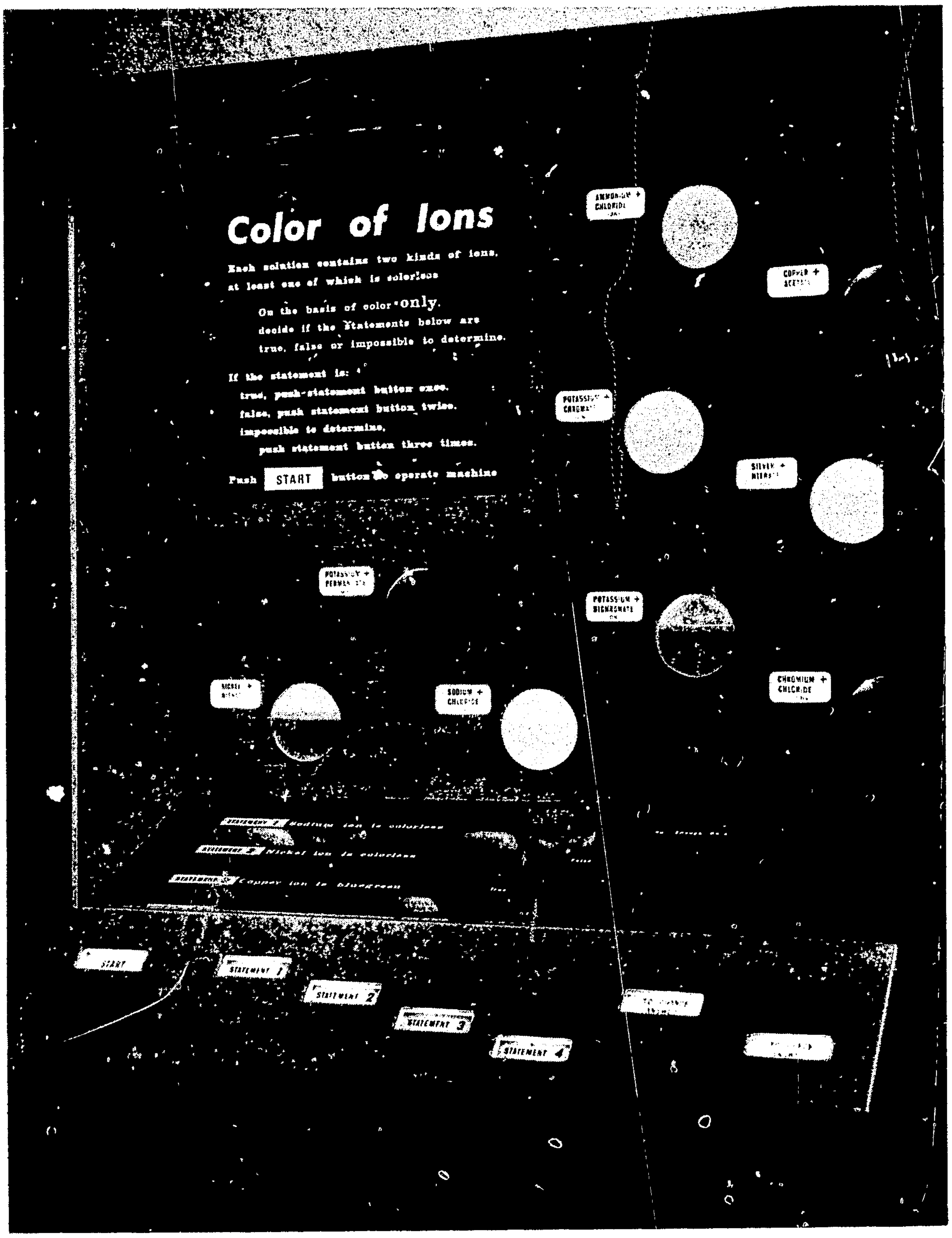

COLOR OF IONS

Ten chemical solutions are displayed in such a manner that their colors are readily apparent. The observer (using the color of these solutions as his only source of information) answers four questions on the colors of chemical ions in the following manner:

1) True if the evidence is such that the statement can be proved correct.
2) False if the evidence is such that the statement can be proved wrong.
3) Indeterminate if the evidence is insufficient to determine if the statement is right or wrong.

The observer can immediately check his answer to see if his reasoning is correct.

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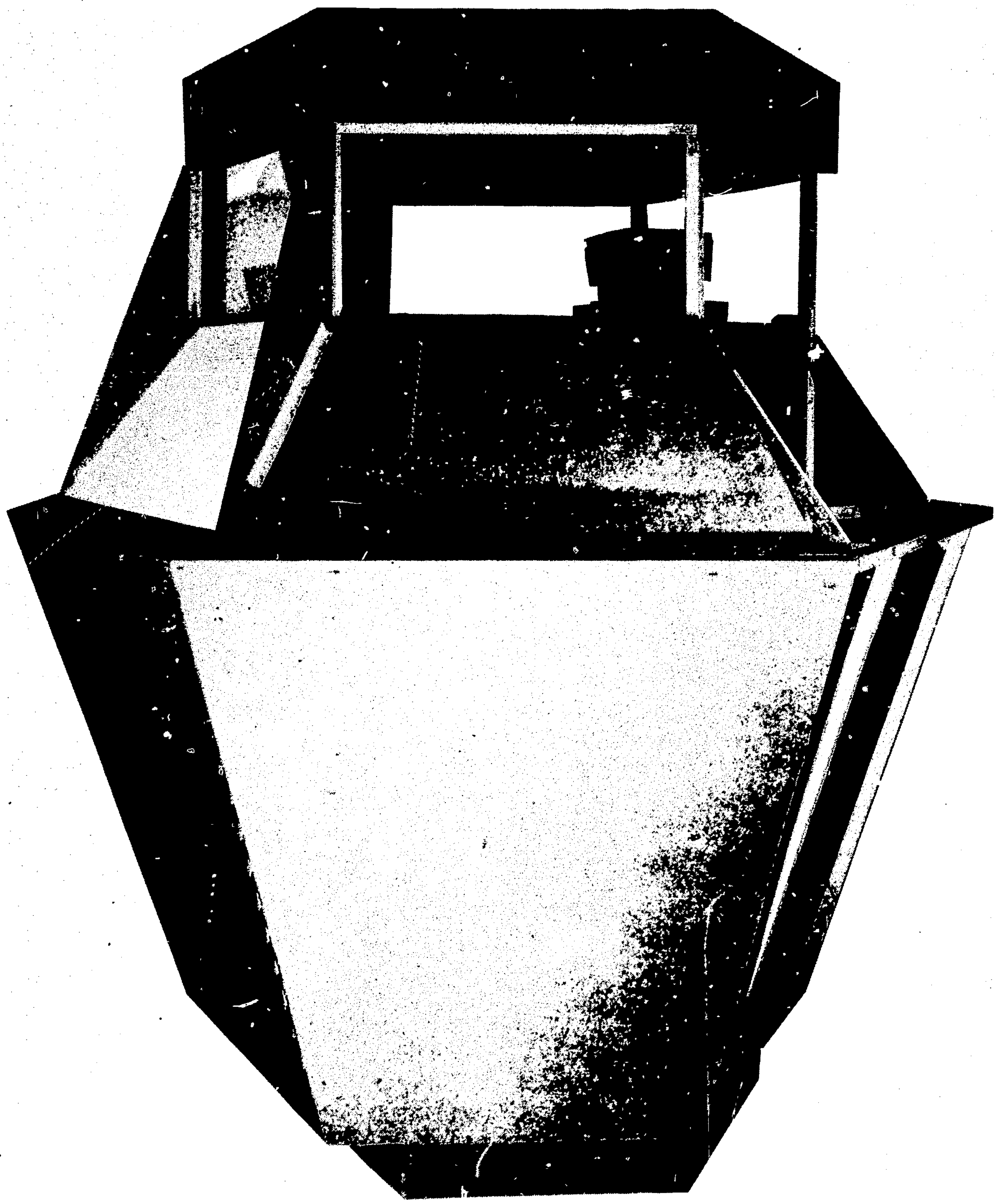

THE STORY OF A LIVING CELL

Three 8-mm instant motion picture projectors and rear projection screens are mounted in a hexagonal cabinet. The projectors are controlled by audio-tape recorders. Each projector and recorder combination delivers a four-minute illustrated talk on a different microbiological subject. Programs can be easily changed and the projector programmed to stop at any point on the film while the audio track gives additional explanation. The systems automatically reset and re-synchronize at the completion of each film.

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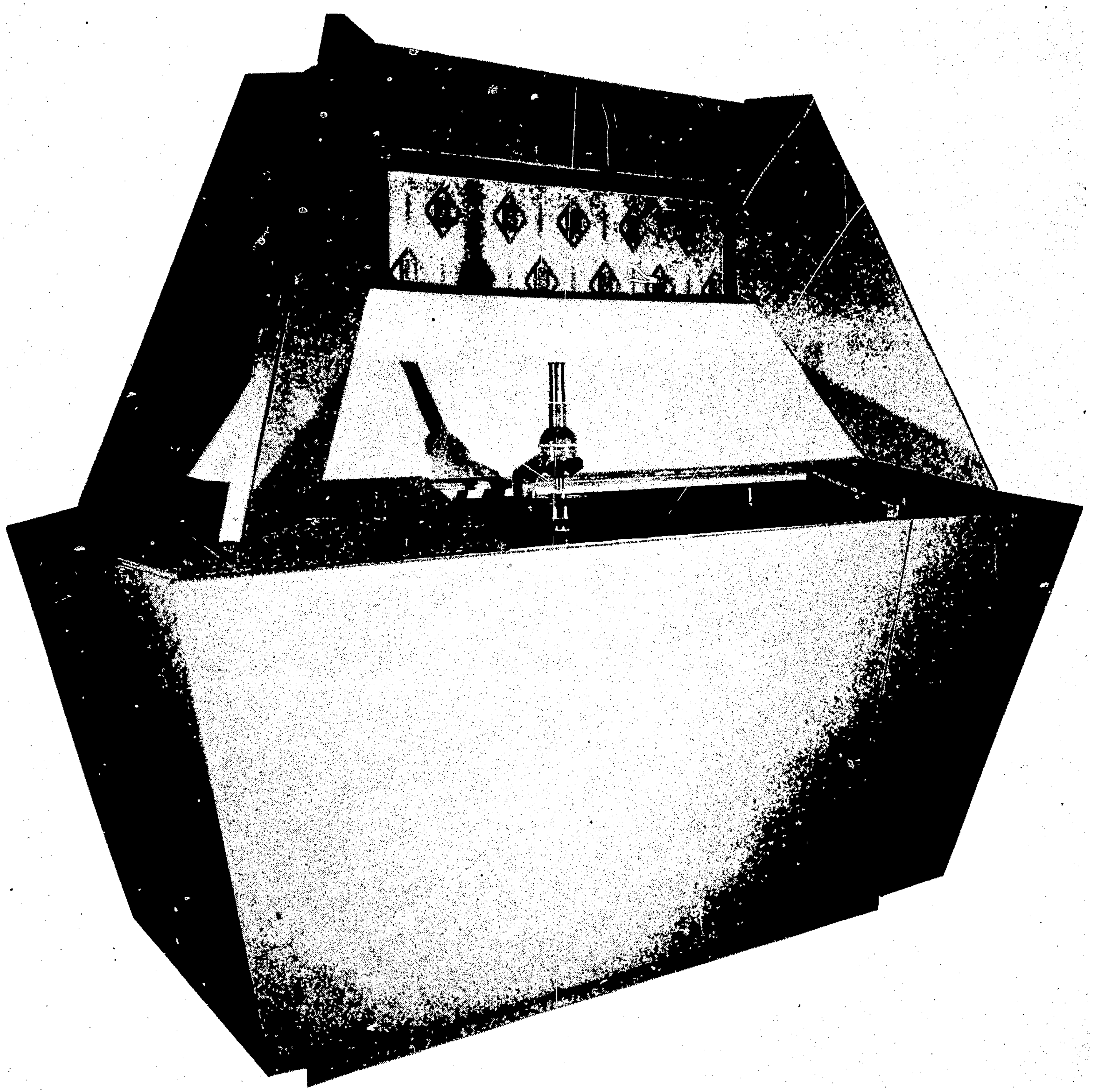

LIFE IN A DROP OF WATER

Fresh water microorganisms are cultured in a tank. Drops of this culture are metered onto a trough slide mounted on the stage of a low power microscope. The microscope is fixed with the participant able to focus with the fine adjustment knob. Upon looking through the scope one sees a slow flow of liquid containing the organisms across the field. Four such microscopes are contained in the single cabinet. An internal slide projector shows pictures of plants and animals which may appear in the culture. At night the flow is switched from culture to wash solution in order to minimize the buildup of algae.

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The following exhibits are under construction and no pictures are available:

CONDUCTIVITY OF SOLUTIONS

Ten solutions containing various solutes are connected in turn to a source of alternating current. A meter is connected in the circuit to measure the amount of current flowing through each solution. The observer is able to record these currents and determines the relative conductivity of the solutions.

VOLTAIC CELLS

Five half cells are arranged on a disc so that any one of the five can be selected by turning a knob. A half cell is chosen and a salt bridge lowered into the solution to complete the circuit. A voltmeter is used to read the potential of the combination. The observer's understanding of the concept of half cells is tested by having him calculate what the potential should be on the last cell before he measures it.

ELECTROLYSIS OF WATER

A direct current source is connected to two platinum electrodes which are immersed in water containing a small amount of sulfuric acid. The electrolysis of the water produces two volumes of hydrogen gas at the cathode for every one volume of oxygen at the anode. A scale in the gas collecting chambers enables the observer to measure this ratio. The two gases are then mixed in a single chamber where a spark causes a small explosion resulting in the formation of water vapor and heat. The conservation of energy is demonstrated by this use of electrical energy to decompose the water and the release of heat energy when the elements recombine into water.

APPENDIX #3

EXPERIMENT SHEETS

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Physics 10

Experiment C-42 - Color of Ions   Name ______________________

Repeat after me three times, "Each sample contains one or two colorless ions." Also assume each ion has a unique color. Using these as premises, you should be able to answer the four questions posed in the experiment. Write your justification for each answer here. Don't rely on previous knowledge since it may lead you astray in your conclusions.

1. Sodium is colorless.

2. Nickel is colorless.

3. Copper is blue-green.

4. Potassium is colorless.

In addition what can you say (color, colorless, or not enough information to conclude anything) about the following?

5. Chloride ion ______________________

6. Ammonium ion ______________________

7. Acetate ion ______________________

8. Chromate ion ______________________

9. Dichromate ion ______________________

10. Permanganate ion ______________________

11. Nitrate ion ______________________

12. Chromium ion ______________________

13. Silver ion ______________________

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Physics 10

Experiment M-40 - Summation by Parts   Name ____________________

Mathematical integration is a process of adding together many pieces to get the whole. In this demonstration you perform an integration by counting the number of complete squares and parts of squares that are included in an irregular closed curve. In this way you determine the area inside the curve compared to the area (25) of the surrounding square. The object is not to see how close you can come to the answer, but rather to be amazed at how close you come with only the smallest effort.

Truthfully, what percent of the area is inside the irregular curve? Don't be afraid to make a hasty guess based on your background knowledge.

____

Perform the integration by letting the telephone dial counter keep the sum for you.

How many squares do you obtain as inside the curve ____ x4 = ____ %

$\left(\frac{100\%}{25 \text{ squares}} = 4\% \text{ / square}\right)$

How far off was your original guess? ____________________

How far off was your integration of the area? ____________________

What would you do to the grid to make the process even more accurate?

____

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Physics 10

Experiment M-41 - Pinball Error Curve   Name ____________________

Even though a coin has turned up "heads" in five consecutive throws, the probability is only 50% that it will be "heads" on the sixth throw. Each toss is independent of previous or future events. In the present demonstration the ball is faced with a decision to fall to the right or left of each peg. If it falls to the right and left an equal number of times, it will emerge from the pattern near the center. On the other hand, if it chooses the left side more frequently than the right, then it emerges on the left side.

Find the probability distribution for this sytem by observing how the steel ball emerges from the pattern during many tries. Mark an X in the appropriate square for each try. Set the "catcher" off to one side during your experimental runs.

-6	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	+6

Where would you place the "catcher" to have the highest probability of catching the ball?

For example, what could cause the highest probability to occur to the left of center?

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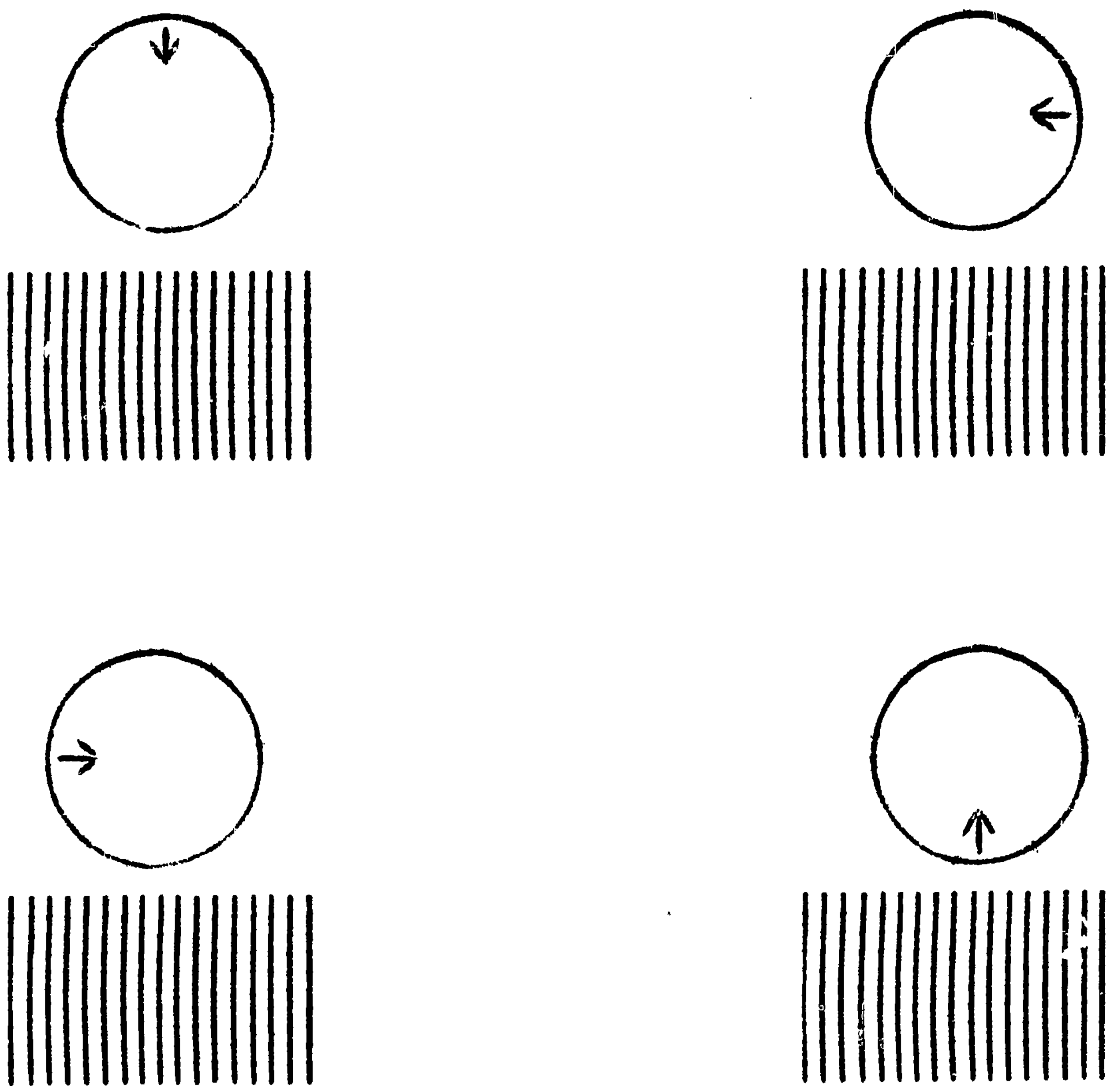
Physics 10

Experiment N-20 and N-21 - Determination of the Nature of Atomic Nuclei

Name ______________________________

Much can be learned about a system that you can't see---provided you have some means of probing the system. No one has ever seen a nucleus, yet there is information about its size, shape, mass, etc. Some of this information has come from scattering experiments. In these experiments you can deduce the shape of an object you can't see. Be systematic in your effort.



What are your conclusions about the exact shape of the unknown?

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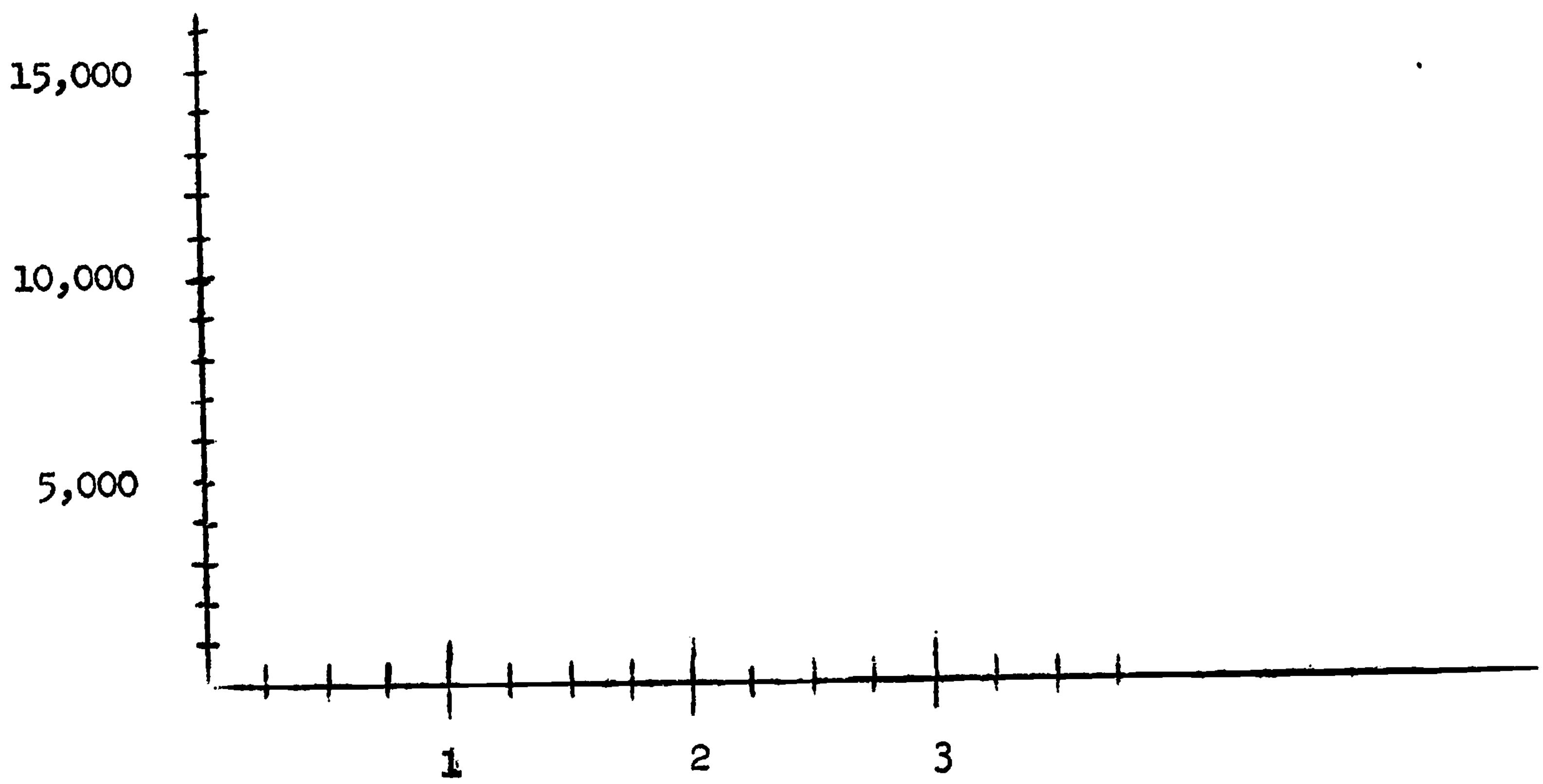
Experiment N-30 - Inverse Square Law Name ______________________

Intensity at distance r = $\frac{I_0(\text{at } r=1)}{r^2}$ describes many phenomena in physics: gravitational force between masses, the electric force between charges, the decrease in light or sound intensity around an omnidirectional source, etc., etc., etc.

In this demonstration you use the gamma rays (γ-rays) from a radioactive source to observe the inverse square law. Plot the gamma ray counts/minute versus the distance. Remember to subtract off the cosmic ray background before plotting.



Distance (arbitrary units)

Does your experiment follow the inverse square law?

What is your prediction for the counting rate at 6 units of distance?

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Physics 10

Experiment P-10 - Friction and Streamlining Name ________________

Streamlining is desirable when one wishes to reduce frictional energy losses. Sometimes just the opposite effect is wanted, such as during satellite re-entry when the atmosphere is used to slow the vehicle down.

Observe the frictional force measured in Newtons exerted on each of the objects.

________ ________ ________ ________

Make some empirical comment about how to streamline an object.

Think of several examples where you have noticed streamlining.

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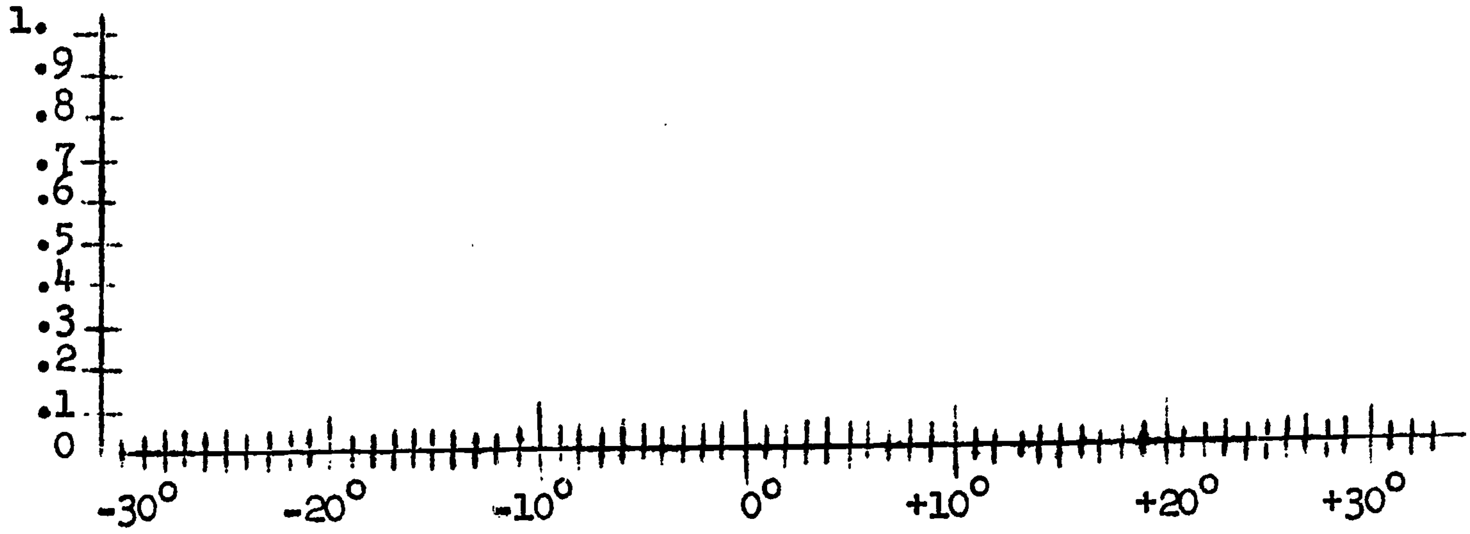
Physics 10

Experiment P-40 - Interference of Two Waves Name ______________________

All kinds of waves interfere: light, sound, electrical, matter, water, etc., etc., etc. As a result many natural phenomena can be explained by interference (for example, the production of colors from a thin film of oil on the surface of water). In this demonstration you observe the interference of two sound waves.

(a) Plot the sound intensity as a function of angle of the loudspeaker holder.



(b) For maximum intensity, the waves from the two loudspeakers must be in step at the microphone. That means their difference in travel distance must be whole wavelengths. You can use this idea to find the wavelength of the sound.

	Angle of Loudspeaker Holder	Distance from Upper Speaker	Distance from Lower Speaker	Difference Between the Two Distances
(1)				
(2)				
(3)				
(4)				

What is the wave length?

(c) What is the frequency of the sound? ($\lambda f = v$)

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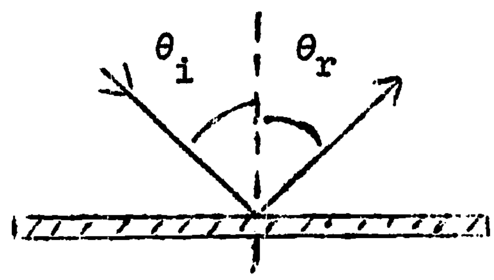
Experiment P-50 - Reflection Name ______________________________

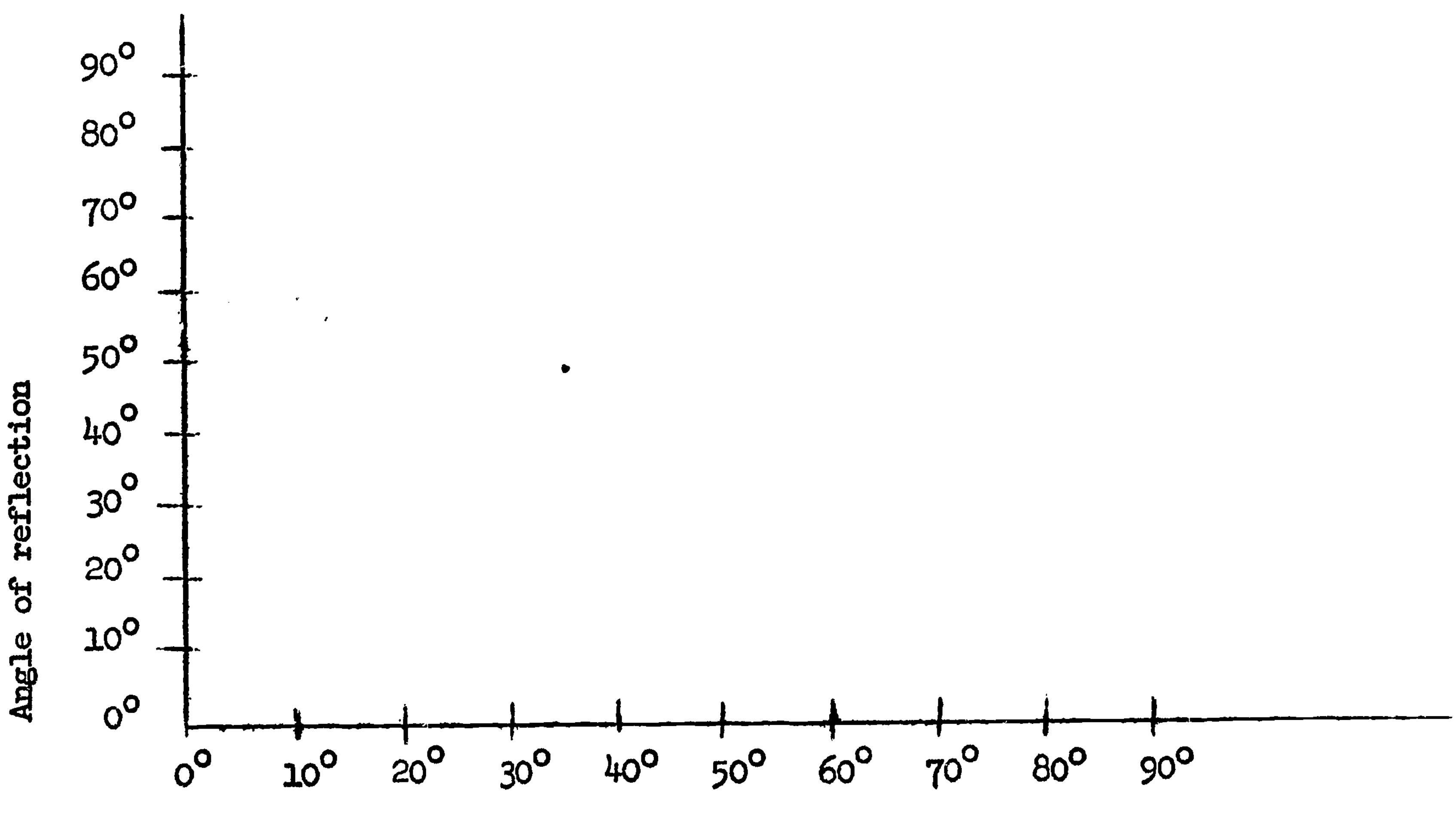
The law of reflection from a plane mirror is

Angle of incidence = Angle of reflection

where the angles are shown in the figure.



Verify the law by taking data from the demonstration at every 5° interval.



What kind of curve can you draw through your experimental points?

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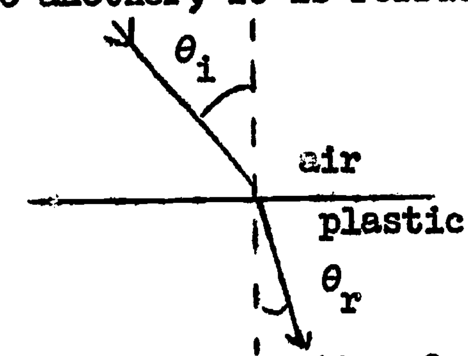
Physics 10

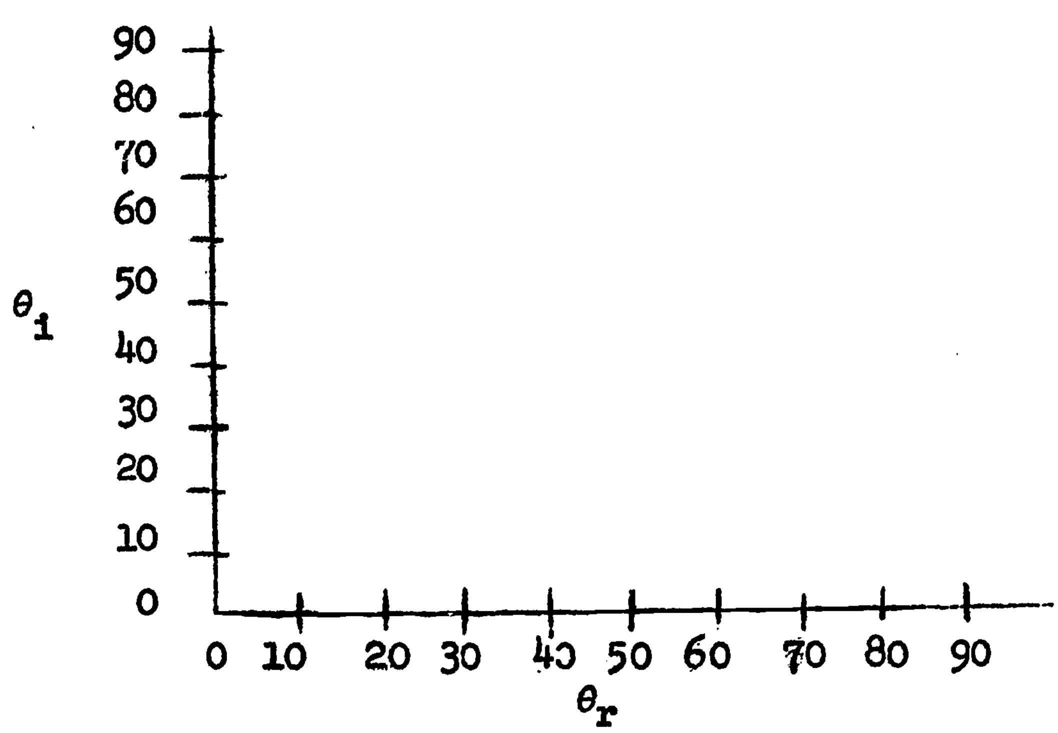
Experiment P-51 - Refraction Name ____________________

When light passes from one medium into another, it is refracted (bent). The angle of incidence and the angle of refraction are related by Snell's law $\mu_{air} \sin \theta_i = \mu_{plastic} \sin \theta_r$ where θ_i is the angle of incidence, θ_r is the angle of refraction, μ_{air} is the index of refraction for air, and $\mu_{plastic}$ is the index of refraction for plastic.



The index of refraction is defined as the ratio of the velocity of light in a vacuum to the velocity of light in the medium. $(\mu = \frac{C}{V})$ $\mu_{air} = 1$ $\mu_{plastic} = ?$

Obtain some information about refraction by looking every 5° and plotting your observations.



θ	$\sin \theta$
0°	.000
5°	.087
10°	.174
15°	.259
20°	.342
25°	.423
30°	.500
35°	.574
40°	.643
45°	.707
50°	.766

Draw a smooth curve through your experimental points.

From any one point on your graph solve for

$$\mu_{plastic} = \frac{\sin \theta_i}{\sin \theta_r} = \underline{\qquad\qquad\qquad}$$

Compute the velocity of light in the plastic.

$$v = \frac{186{,}400 \text{ mi/sec}}{\mu_{plastic}} = \underline{\qquad\qquad\qquad}$$

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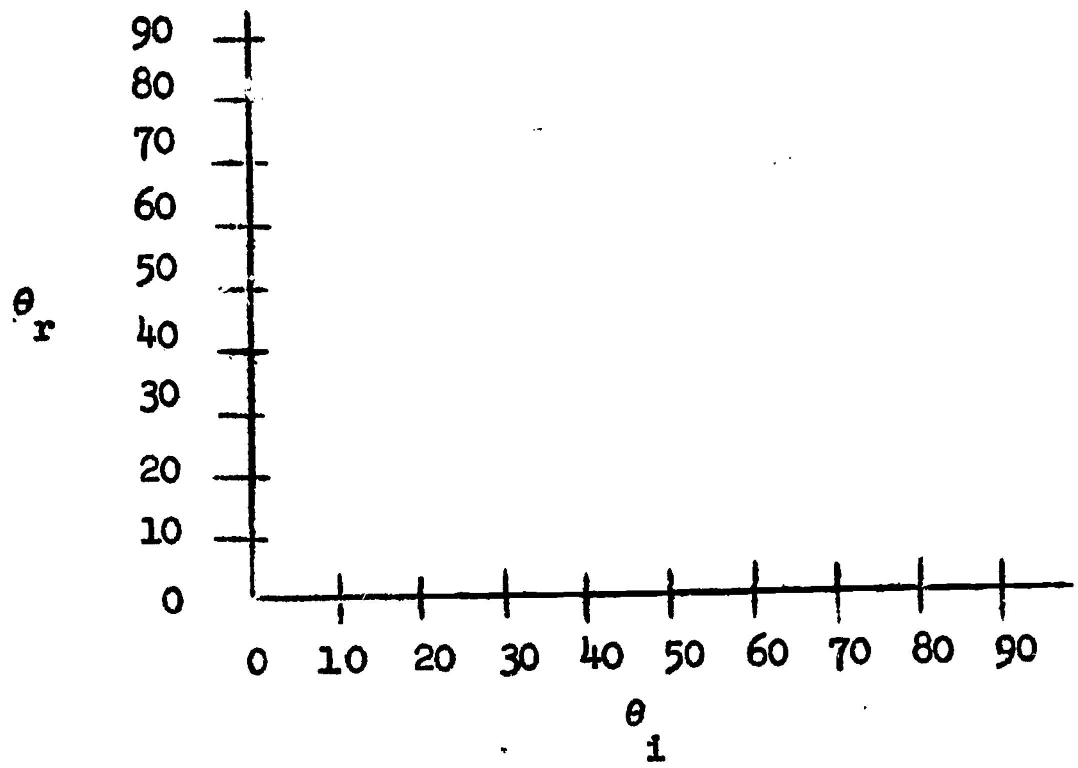
Physics 10

Experiment P-51 - Refraction   Name ______________________

Draw a graph by looking every 5° and plotting your observations of the angle of incidence and the angle of refraction.



Draw a smooth curve through your experimental points.

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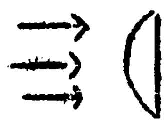
Physics 10

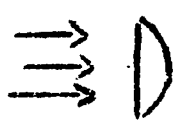
Experiment P-55 - Lenses - Spherical Aberration   Name ____________________

With the lens in this orientation  , what is the approximate focal length of the lens? ______________________________

What is the approximate focal length of a ray near the axis? ________

What is the approximate focal length of a ray far from the axis? ____

Observe the rainbow of colors dispersed on the right side of the enclosure. Has red or blue been deviated the most? ______________

With the lens in this orientation  , what is the approximate focal length of the lens? ______________________________

What is the approximate focal length of a ray near the axis? ________

What is the approximate focal length of a ray far from the axis? ____

Notice the amazing phenomena of (100%) "total internal reflection" inside the lens as you rotate it.

Draw the effect here