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SCIENCE COURSE IMPROVEMENT PROJECTS. 2, SCIENCE TEACHING EQUIPMENT.

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SCIENCE EQUIPMENT, TEACHING AIDS, AND MODELS THAT HAVE BEEN OR ARE BEING DEVELOPED THROUGH THE NATIONAL SCIENCE FOUNDATION'S SCIENCE TEACHING EQUIPMENT DEVELOPMENT PROGRAM ARE DESCRIBED IN THIS BULLETIN. REPORTS FROM ALL PROJECTS SUPPORTED UP TO MARCH 15, 1963, ARE INCLUDED. ITEMS ARE CLASSIFIED ACCORDING TO DISCIPLINE AND APPROPRIATE INSTRUCTIONAL LEVEL. DESCRIPTIONS OF THE PROJECTS INCLUDE--(1) THE DIRECTOR'S NAME, DEPARTMENT, AND INSTITUTION, (2) A BRIEF SUMMARY OF THE PROJECT ACTIVITIES, AND (3) SOURCES OF FURTHER INFORMATION. THIS DOCUMENT IS ALSO AVAILABLE AS NSF 63-15 FROM THE NATIONAL SCIENCE FOUNDATION, OFFICE OF SCIENCE INFORMATION SERVICE, WASHINGTON, D. C. 20550. (AG)

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# SCIENCE COURSE IMPROVEMENT PROJECTS

## 2 *Science Teaching Equipment*

SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION

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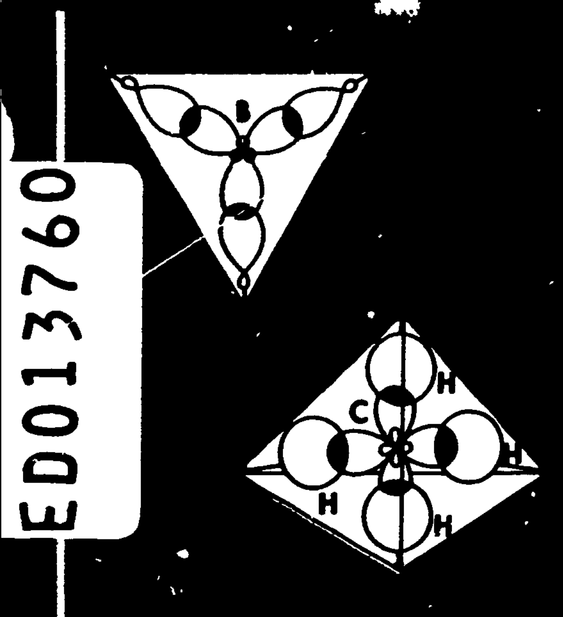


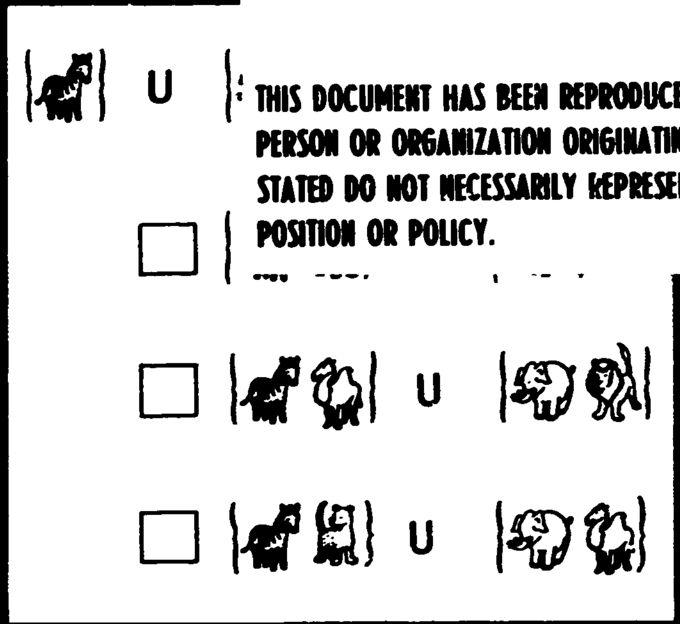


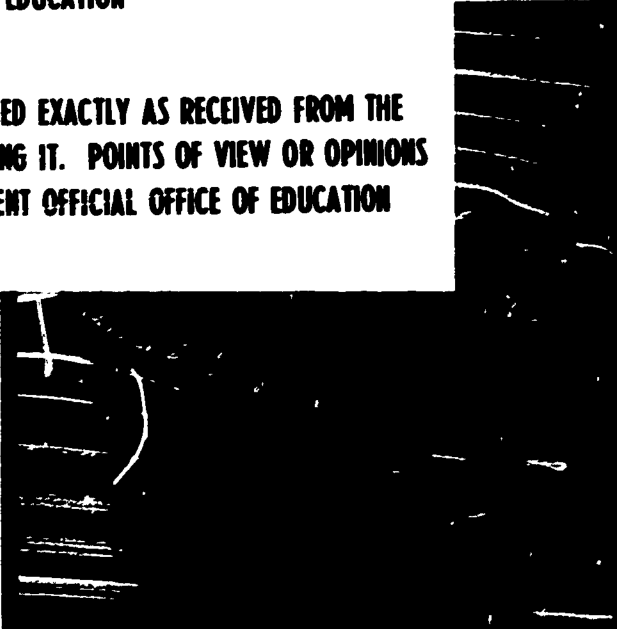

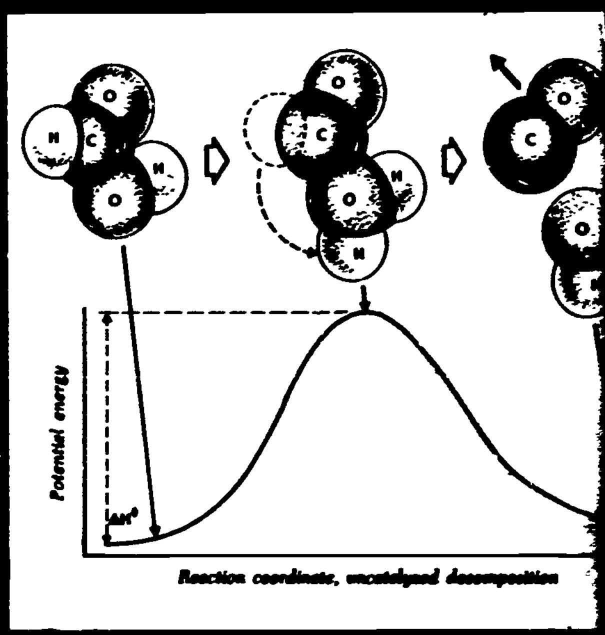


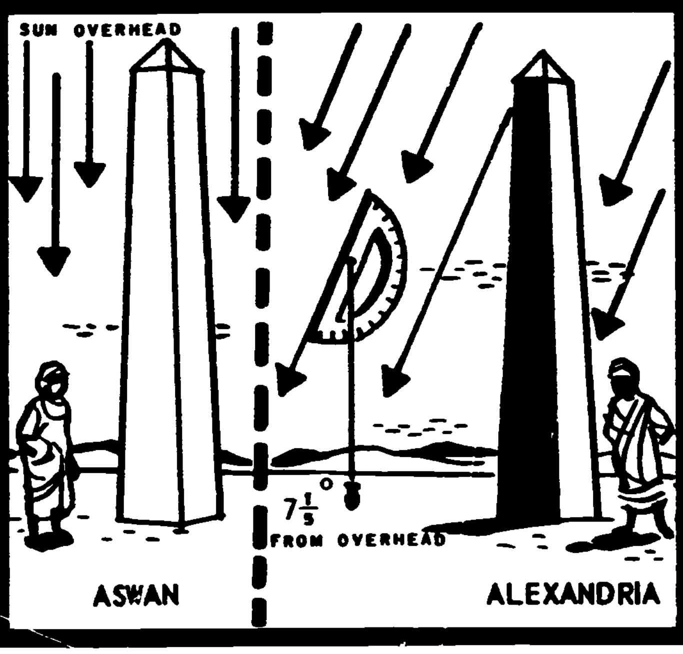


LLEGE & UNIVERSITY • SECONDARY • ELEMENTARY

## FOREWORD

Science and the applications of science are rapidly changing the conditions of life on this planet. Today, for the first time in history, there is no need for anyone to go hungry. Progress in understanding living things promises greater and greater success in overcoming disease. Increasingly, also, man is freeing himself from drudgery while multiplying the variety of things it is possible for him to do. In very many ways the plans and expectations of Americans, and indeed of people everywhere, depend upon a strong and growing science and technology.

The increasing importance of science to our Nation and the world creates pressing educational demands. Literacy in science is becoming essential for all citizens who wish to comprehend the world they live and work in and to participate in the increasing number of local and national decisions, some of gravest import, that require an understanding of science. Further, more and more students must be attracted to scientific and technical pursuits, and these students must be prepared to work with increasingly sophisticated ideas and techniques.

Very practical considerations compel us to give attention to the strengthening of science education. But there is another aspect of the matter, namely, the principle held by those taking part in the reform of science education that more emphasis should be given to disciplined, creative intellectual activity as a noble enterprise and to intellectual achievement as a worthy end in itself. There is a desire to allow each student to experience some of the excitement, beauty, and intellectual satisfaction that scientific pursuits afford. Similar movements also aimed at giving the student experiences and points of view heretofore largely limited to professionals in a field are beginning to go forward in the humanities and the arts. These experiences, it is hoped, will lead many to enter scholarly professions themselves and others to adopt some of the scholarly and artistic modes of thought in their work and their avocations.

Good teachers and good schools have always worked individually to give students the best educational fare they could. Nowadays, however, the task of bringing the best that has been thought to all students—in ways appropriate to their varied interests, abilities, and future lives—requires new strategy and tactics. We live in an age of explosive growth of knowledge. More scientific and technological discoveries have been made in the past fifteen years than in all previous recorded time. Powerful new insights are being gained into the fundamental structure of major areas of inquiry. Moreover, traditional assumptions about what students at given levels of development can learn are increasingly found to be misleading in many ways. Finally, society can no longer afford to wait a generation or more for new knowledge to make its way gradually into school and college programs.

In the last few years, mathematicians, scientists, engineers, and educators have taken up these new educational challenges with great vigor. Working together, and aided by increasing public and private support for educational research and development, they have undertaken a number of fresh approaches to the improvement of school instruction in mathematics and science. In colleges and universities, research scientists have been taking an increasing interest in undergraduate instruction. The aim has been to see that instruction presents contemporary knowledge as well as contemporary viewpoints on knowledge established earlier. In many cases it has seemed best to start anew rather than merely to patch up older courses. A distinctive feature of many projects is the effort made to go beyond the presentation of what is known and to provide students with experience in the processes by which new facts, principles, and techniques are developed.

The purpose of this booklet is to help make information widely available on course improvement projects supported by the National Science Foundation. Decisions on what to teach remain, in the healthy American tradition, the exclusive responsibility of individual schools and teachers. The National Science Foundation *does not* recommend the adoption of any specific book, film, piece of apparatus, course or curriculum. It is hoped, however, that the products of these projects will prove to merit serious consideration by every school and college.

BOWEN C. DEES
*Assistant Director for*
*Scientific Personnel and Education*

# TABLE OF CONTENTS

## INTRODUCTION

The National Science Foundation's Course Content Improvement Program is designed to help bring scholarship of the highest order to the development of courses and instructional materials, including apparatus and equipment, that reflect contemporary scientific knowledge and points of view. The program is concerned with the substance of courses in science and mathematics in elementary and secondary schools and in mathematics, science, and engineering in colleges and universities. It thus complements the wide variety of educational programs of the National Science Foundation designed to assist students to pursue scientific studies and to enable scientists and science teachers to keep pace with the progress of research.

One sub-program in the course content improvement area is the Science Teaching Equipment Development Program (previously called the New Laboratory Equipment Program). Its purpose is to provide assistance to mathematicians, scientists, and engineers in the development of prototypes of modern instructional equipment suitable for widespread use in schools and colleges. Support is limited to design and development of new equipment. Preliminary versions may be tested in selected schools, but the final products are expected to make their way on their own merits. Full information about these projects will be made readily available to appropriate segments of the scientific and educational communities, but grant funds may not be used for promotional purposes.

This publication includes reports from all projects supported up to March 15, 1963, under the Science Teaching Equipment Development Program.* Each description is taken from information supplied by the project director and represents the director's view of the project. The project director's name, department, and institution are given following the title of the project (more than one name is given when there are co-directors). Unless otherwise noted, the grant supporting the project was made to the director's institution or organization. Dates in parentheses refer to the period of support by the National Science Foundation.

Projects are classified by discipline, as shown in the Table of Contents. The sequence within a discipline is essentially chronological according to starting date. Descriptions of projects involving more than one discipline are put in what seems to be the most appropriate place, with cross references under other appropriate disciplines. It should be noted that experiments listed under one field are frequently useful in other disciplines. If no educational level is cited, the equipment is designed for use in colleges; other educational levels are given in parentheses following the title.

It is hoped that many persons concerned with education in the sciences will find it useful to look through the entire book, in addition to giving more careful scrutiny to projects in their own fields of interest. In almost all cases, a source of further information is given.

*Inquiries concerning individual projects should be sent to the project director or other source cited and* **not** *to the National Science Foundation.*

* A companion volume, SCIENCE COURSE IMPROVEMENT PROJECTS 1, ***Courses, Written Materials, Films, Studies*** (NSF 62-38), describes all other projects, including a number dealing in part with the laboratory, supported under the course content improvement program up to October 1, 1962.

# SCIENCE TEACHING EQUIPMENT PROJECTS

## A. Anthropology

**1. MUSEUM OF MAN: BASIC SLIDE COLLECTION FOR ANTHROPOLOGY COURSES.** JACK CONRAD, Department of Sociology and Anthropology, Southwestern at Memphis, Memphis, Tennessee. (1960–1961)

*Museum of Man* is a collection of 300 color projection slides (35 mm) in cardboard mounts, designed to facilitate the teaching of college anthropology courses. For the most part, the slides show artifacts and displays found in major American museums. A 120-page descriptive catalog accompanying the set provides basic information about each slide. The collection contains 25 slides in each of the following twelve areas: 1. *Symbol Systems:* (a) pictographs, (b) logographs, (c) syllabaries, (d) alphabets, (e) language and reality, (f) other symbolic forms; 2. *Tools and Devices:* (a) fire making, (b) cutting and pounding, (c) scraping and grinding, (d) piercing and weaving, (e) transporting; 3. *Food and Drink:* (a) lures, (b) traps, (c) weapons, (d) storing and processing, (e) serving; 4. *Clothing and Ornamentation:* (a) grooming, (b) alteration, (c) ornamentation, (d) clothing; 5. *Social Organization:* (a) age and sex, (b) marriage and family, (c) leadership; 6. *Social Control and Social Relations:* (a) internal order, (b) ownership and exchange, (c) war and peace; 7. *Religious Systems:* (a) shamans and priests, (b) spirits and gods; 8. *Functions of Religion:* (a) man and men, (b) man and nature, (c) man, disease and accidents, (d) man and death; 9. *Religious Masks:* (a) African, (b) American, (c) Oceanic; 10. *Plastic Arts:* (a) formal, (b) representative, (c) symbolic; 11. *Musical Arts:* (a) ideophones, (b) membranophones, (c) aerophones, (d) chordophones; 12. *Functions of the Arts:* (a) object elaboration, (b) personal beautification, (c) status, (d) religion, (e) amusement.

**Sources of Further Information:**

The slides and descriptive catalog are available from the project director for $100; other distribution mechanisms are under negotiation.

**2. KINSHIP MODELS.** EDWARD A. KENNARD, Department of Anthropology, University of Pittsburgh, Pittsburgh 13, Pennsylvania. (1961–1962)

A kit of materials for the construction of a three-dimensional representation of kinship structures is being prepared. A ball-and-stick model system with color, form, and alpha-numerical coding permits representation of kin groups (families, lineages, and clans), marriage systems (symmetrical first or second cross-cousin marriage), and kin terminologies.

**Sources of Further Information:**

A preliminary report can be obtained from the project director.

**3. GRAPHIC AIDS FOR BASIC ANTHROPOMETRY.** R. F. G. SPIER and DALE R. HENNING, Department of Sociology and Anthropology, University of Missouri, Columbia, Missouri. (1961–1962)

The objective of this project is to help give anthropology students and interested amateurs a basic knowledge of anthropometric technique. The project has developed: (1) exact bone reproductions, in unbreakable plastic, with measurement points clearly marked and accompanying desk- and wall-charts indicating measurements to be taken; (2) color slides depicting actual measurement of skeletal materials; and (3) inexpensive but reasonably accurate anthropometric instruments.

**Sources of Further Information:**

A report on this project is available from the Missouri Archaeological Society, 15 Switzler Hall, University of Missouri, Columbia, Missouri.

## B. Biology

**4. TEACHING AIDS FOR INTEGRATED EMBRYOLOGY-COMPARATIVE ANATOMY COURSES.** *(Secondary, College)* LOUIS E. DELANNEY, Department of Zoology, Wabash College, Crawfordsville, Indiana. (1959–1963)

*Pig embryo: Differentially colored, three-dimensional, plastic model.* The transparent plastic model will help students to identify positions of single sections in the whole embryo.

*Dissectable models of skulls.* Skulls of a primitive amphibian, a selected reptile, and a selected mammal will be sculptured so that they can be separated into individual bone components and can be reassembled to test knowledge of individual components of a specific skull. Substitutions from one type of skull to another can be made to simulate evolutionary changes.

**Sources of Further Information:**

Further information can be obtained from the project director.

**5. WORKING MODEL OF HUMAN CIRCULATORY SYSTEM.** *(Elementary, Secondary, College)* THOMAS I. MARX, Engineering Division, Midwest Research Institute, Kansas City 10, Missouri. (Present address: Sigma Instruments, Incorporated, Braintree 85, Massachusetts.) (1959–1960)

The circulatory model contains a heart, aorta, arterioles, capillary beds, veins, and pulmonary circuit. The heart consists of passive atrial chambers plus ventricles pumped by a motor-driven mechanism. All four heart valves are represented. The aorta is made of thin-walled rubber tubing which distends to accept the surge of liquid with each heart beat. Other blood vessels are made of clear plastic tubing. Constrictor bars on the arterioles are used to regulate blood flow through plastic-foam capillary beds. The pulmonary circuit consists of a thin-walled pulmonary artery, a plastic-foam lung bed, and a pulmonary vein. Mercury manometers are used to indicate arterial and venous pressure, and an orifice-plate meter indicates blood flow rate. The two heart sounds can be heard through a stethoscope placed on the aorta. Experiments can be performed to show the effects of heart rate, stroke output, peripheral resistance, and blood volume on blood pressure and cardiac output. The type of flow (i.e., steady or pulsatile) can be observed at various points in the circulatory system.

**Sources of Further Information:**

A report describing the circulatory model, its construction, and uses is available from the Midwest Research Institute.

**6. STUDENT OPHTHALMOSCOPE.** *(Secondary, College)* THOMAS I. MARX, Engineering Division, Midwest Research Institute, Kansas City 10, Missouri. (Present address: Sigma Instruments, Incorporated, Braintree 85, Massachusetts.) (1959–1960)

A very simple but striking experiment within the scope of college and high school biology courses is ophthalmoscopic examination of the human eye. The instrument permits observation of active blood vessels and nerves in the intact, unanesthetized eye. The ophthalmoscope illuminates the fundus of the eye so that the observer can see structures of the fundus while avoiding reflections from the cornea. The instrument can also be used in physics classes for demonstrations in geometrical and physiological optics.

The project report describes a number of experiments which encourage students to become proficient in using the instrument and provides an introduction to the physiology of the eye. The instrument will be marketed by the Central Scientific Company, Chicago, Illinois.

**Sources of Further Information:**

Thomas I. Marx, "The Construction and Use of a Simple Ophthalmoscope," *The American Biology Teacher* 23, 71 (1961).

A report is available from Midwest Research Institute.

**7. INDIVIDUAL LABORATORY KITS FOR HIGH SCHOOL BIOLOGY COURSES.** *(Secondary, College)* NORMAN MOLOMUT and LEO GROSS, Waldemar Medical Research Foundation, 16 Sintsink Drive East, Port Washington, Long Island, New York. (1959–1964)

Kits have been developed to broaden laboratory experiences in high school biology. The kits, which cost $2.00 to $5.00 each, contain all materials needed for experiments during a classroom period. Each kit includes a classroom-tested manual.

Three kits will be available in 1963. The *Fruit Fly Kit* is designed for use by individual pupils or teams of two or three and requires no teacher participation; a novel feature is the use of cooling to immobilize the flies. *Experiments in Bacteriology* should be supervised initially by the teacher to insure that students adequately learn basic bacteriological techniques; the pupils can then proceed on their own. The *Cell Study Kit* is designed for use in the classroom and at home. Materials required for classroom experiments are in the teacher's kit, and materials for individual pupil use are in the pupil's kit; the teacher's kit is designed for a class of twenty-five or more students. The three kits will be produced by Science Materials Center, 59 Fourth Avenue, New York, New York.

Six additional laboratory kits will be developed during the next two years. These kits will furnish laboratory materials permitting direct student investigation in biochemistry, embryology, plant growth and seed development, polymers and plastics, spectroscopic analysis, and histology.

**Sources of Further Information:**

Isador Halpern, "The Fruit Fly Kit," *The Science Teacher* 27, 39 (1960).

Leo Gross and Isador Halpern, "Immobilization of Fruit Flies by Hypothermia," *Turtox News*, October 1961.

Information concerning all kits can be obtained from the Waldemar Medical Research Foundation.

**8. STEREOPHOTOMICROGRAPHY AND OTHER METHODS FOR TEACHING SUBMACROSCOPIC ANATOMY.** *(College, Graduate School)* T. WALLEY WILLIAMS, Department of Microanatomy and Organology, Medical Center, West Virginia University, Morgantown, West Virginia, and CHARLES C. BOYER, Department of Anatomy, Indiana University Medical Center, Indianapolis, Indiana. (1959–1964)

Highly specialized techniques have been developed for the preparation of tissues and organs so that they can be photographed in three dimensions to show structural relationships not observable by the usual histological techniques.

**Sources of Further Information:**

Further information can be obtained from the project directors.

**9. X-RAY CIRCUIT MODEL FOR STUDYING X-RAY CIRCUIT PARAMETERS.** *(Secondary, College)* LLOYD M. BATES, Department of Radiological Sciences, School of Hygiene and Public Health, Johns Hopkins University, Baltimore 5, Maryland. (1960–1961)

The model is a basic X-ray generator circuit, but the potential differences generated in the secondary part of the circuit are less than 300 v. The circuit will not generate X-rays, of course, but circuit component values are chosen so that circuit parameters are similar to those in an X-ray generating circuit. The model includes relay switching, autotransformer and rheostat voltage control, full-wave rectification, tube current and voltage meters, and primary and secondary circuit pilot lights. A light-producing tube is incorporated in the circuit. The intensity of the light emitted from this tube varies with the "X-ray" tube voltage and current in approximately the same manner as X-ray intensity would vary. The wiring display permits study of the circuit. Component contacts are exposed so that voltmeters and oscilloscopes can be connected at any desired points in the circuit. Jacks incorporated in the model make it possible to place current measuring instruments in the circuit without disconnecting leads.

**Sources of Further Information:**

A brochure which includes a complete description of the model, a wiring diagram, a parts list, a shop drawing for chassis construction, and a manual of experiments for the model will be available early in 1963 from the project director.

**10. PLANT GROWTH CHAMBER.** *(Secondary, College)* F. W. WENT, Director, Missouri Botanical Garden, 2315 Tower Grove Avenue, St. Louis 10, Missouri. (1960–1963)

Small, climate-controlled plant growth chambers have been constructed which can be utilized by schools and colleges which lack a suitable greenhouse. The chambers permit control of temperature, light, ventilation, and moisture. Detailed information on construction will be published, along with instructions for classroom experiments which use the chambers to study such problems as rooting of cuttings, germination of plants, growth and development, and flowering responses to photoperiod.

**Sources of Further Information:**

Further information can be obtained from the project director.

**11. LABORATORY EXERCISES FOR THE STUDY OF FOREST MICROCLIMATES.** FRANK W. WOODS, School of Forestry, Duke University, Durham, North Carolina. (1960–1961)

Laboratory exercises have been developed to provide twenty-four to thirty hours of field work for the study of microclimates in forests. The exercises are useful primarily for college teachers with students at an elementary level of ecological perspective. However, the work can easily be modified to meet the needs of advanced students by increasing the complexity of instrumentation. The laboratory manual includes instructions and a list of materials necessary for the construction of towers, outlines the sequence of field work to be performed, and cites instruments to be used for making measurements. It also includes instructions for preparing and reporting exercises, forms for the collection and compilation of data, lists of selected references, sets of leading questions, and a sample exercise.

**Sources of Further Information:**

The manual can be obtained from the project director.

**12. TRANSISTORIZED CIRCUITS FOR INTEGRATION OF SOLAR RADIATION, TEMPERATURE, AND HUMIDITY.** *(Secondary, College)* WILL J. CLOYD and JOE A. CHAPMAN, Department of Biology, Carson-Newman College, Jefferson City, Tennessee. (1961–1962)

Integrating recorders for solar radiation, temperature, and humidity are being constructed and calibrated under field conditions. The recorders are to show essentially linear response and are to be battery-powered, readily portable, and weatherproof.

**Sources of Further Information:**

Further information can be obtained from the project directors.

**13. GRAPHIC METHODS FOR TEACHING PHYSIOLOGY.** *(Secondary, College)* FRED E. D'AMOUR, Department of Zoology, University of Denver, Denver, Colorado. (1961–1962)

The following devices have been built to provide graphic demonstration of various physiological functions:

1. *Respiratory System.* Lungs (plastic bags) are alternately inflated and deflated by the movements of a diaphragm activated by a motor. The chest wall rises and falls and simultaneously the abdominal wall moves in and out. The system has a "respiratory center" and "phrenic nerves" whose functions are traced by the lighting up of small electric lights at proper times.

2. *Circulatory System.* This demonstrates the blood circulation of the body. Blood to the lungs is blue but turns red in passing through pulmonary capillaries; the reverse change takes place in systemic capillaries. The heart consists of four metal bellows which alternately expand and contract. It also has valves, with lights representing operation of the S-A and A-V nodes, and a "banger" representing heart sounds. All events are properly synchronized with the heart beat. Recordable blood pressure can be varied at will by narrowing stopcocks representing arterioles.

3. *Muscle Action.* Inflatable plastic bags simulate the biceps and triceps muscles. On inflation, the biceps thickens and shortens, elevating a forearm and hand holding a large plastic ball. Inflation of the triceps has the opposite effect. Variable nerve impulses to the muscles show, by means of small electric lights, how muscle responds to nerve action.

4. *Knee Jerk.* Striking the patella with a hammer causes nerve impulses (electric lights) to pass up a sensory nerve to the spinal cord, where a synapse is made with a motor neuron. Nerve impulses pass down the motor nerve to the quadriceps, and the leg (activated by a solenoid) flies upward. Impulses continue to pass up the cord to the cerebral cortex but are seen to reach there only *after* the leg has responded. This makes clear the fact that the knee jerk is strictly a spinal reflex.

5. *Small-Animal Respirator.* By the use of a small synchron motor (cost $2.75) as timer, plus a solenoid magnet (cost $3.50) and a pair of plastic bellows (cost 20 cents), a respirator can be built for $10. (Similar commercial models cost $75.) The bellows force fresh air into and out of the animal's lungs.

6. *Distribution of Optic Nerves.* By means of electric lights, a panel shows nerve impulses being aroused in the retina, their course through the optic nerve, their distribution through the optic chiasma, and their transmission through the optic tracts to the occipital lobe.

7. *Functioning of the Muscles of the Eyeball.* Colored plastic bags are used to represent the six muscle pairs to the eyeballs. Inflation of the bags with air causes the eyeballs to turn in the appropriate direction. Operation of the three pairs of cranial nerves supplying these muscles is simulated by small electric bulbs.

8. *Nature of the Nerve Impulse.* This demonstration starts with the nerve fiber in its polarized state. Application of a stimulus to the center of the fiber produces an area of depolarization which moves in both directions, and is immediately followed by a wave of repolarization.

9. *Properties of Conduction at the Synapse.* Two panels illustrate (a) delay at the synapse, (b) polarity of conduction, (c) temporal and spatial summation, and (d) after-discharge (chemical and electrical theories of conduction are both illustrated).

**Sources of Further Information:**

Further information can be obtained from the project director.

**14. INEXPENSIVE ELECTRONIC EQUIPMENT FOR QUANTITATIVE PHYSIOLOGICAL STUDIES.** *(Secondary, College)* CHARLES K. LEVY, Department of Biology, Boston University, Boston 15, Massachusetts. (Former director, GEORGE P. FULTON.) (1961–1964)

Most modern equipment for teaching physiology in the laboratory is modified research equipment which is too expensive and too complicated for use by small schools. For this reason, the project is attempting to design simple, rugged, and inexpensive physiological equipment made from standard electronic parts and specifically designed for school laboratory work. The equipment will be prepared as (1) do-it-yourself assembly kits, and (2) already assembled models. Built-in test-jacks and ready access to electronic components permit simple repair and replacement of parts. Simplified but detailed wiring diagrams in layman's language will accompany the equipment; an instructor's manual of suggested laboratory experiments for using the equipment will also be supplied. Four pieces of equipment are now under development: (1) an electronic stimulator which will provide shock stimuli over a wide range of parameters, (2) a simple amplifier to magnify bioelectric responses, (3) an electronic paper drive recorder, and (4) a simple, cheap. rugged electric kymograph.

**Sources of Further Information:**

The stimulator and a prototype amplifier have been completed. Further information can be obtained from the project director.

**15. INSTRUMENTS FOR THE STUDY OF PHYSIOLOGICAL PHENOMENA.** *(Secondary, College)* NORMAN N. GOLDSTEIN, JR., Engineering and Sciences Extension, University of California, Berkeley 4, California. (Address: Sir Francis Drake High School, San Anselmo, California.) (1961–1964)

Inexpensive instruments are being developed to improve the teaching of physiological phenomena. The basic set of instruments is designed to be built for about $90-$175. The project stresses the use of instruments as data-gathering extensions of the senses and will make possible the introduction of instrumentation early in science teaching. The work will be with live organisms and tissues. Simplified versions of contemporary research instruments permit teachers to present concepts of electrophysiology of heart, nerves, and sense organs, as well as many other aspects of vascular, muscular, and respiratory functions, to secondary and lower-college level students. Such presentations provide a rich source of laboratory activity, with emphasis upon quantitation and problem solving.

**Sources of Further Information:**

Circuit diagrams, directions for construction and use of the instruments, instructions for laboratories and demonstrations, and suggestions for special projects will be ready for dissemination in the summer of 1963. Further information is available from the project director.

**16. TEACHING AIDS IN BIOLOGY.** *(Secondary, Junior College)* FREDDY HOMBURGER, Bio-Research Institute, Incorporated, Cambridge 14, Massachusetts. (1961–1962)

A new type of non-breakable, plastic lantern slide called the Syndaktograph makes possible lantern projection, direct inspection of color or black-and-white transparencies, and microscopic study of actual tissue sections. A series of Syndaktographs will be developed of the anatomy of certain small reptiles, amphibians, and small rodents, as well as rabbit, hamster, and mouse embryos. The Syndaktographs will be packaged in pocket-size folders in groups of 5 or 6 with explanatory text. In conjunction with the preparation of the Syndaktograph slides, exercises will be developed which permit students to conduct their own experiments in such areas as immunology and histochemistry. The materials needed to carry out these experiments will be available in compact study units. Information necessary to conduct demonstration experiments in these and other fields of biology will be prepared in manual form for use by teachers.

**Sources of Further Information:**

Information on Syndaktographs and study units can be obtained through Cambosco Scientific Company, 36 Antwerp Street, Brighton Station, Boston, Massachusetts.

**17. MODELS OF STRUCTURAL RELATIONSHIPS IN HUMAN ANATOMY.** JOHN FRANKLIN HUBER, Department of Anatomy, School of Medicine, Temple University, Philadelphia 40, Pennsylvania. (1961–1963)

Plastic models are being developed of various human structures which students have particular difficulty in visualizing. The models are suitable for use on monochrome closed-circuit television. Structures illustrated are the larynx (with special reference to functional mechanisms), the inguinal canal, the perineal region, and the general relationships of larger structures within the human. The models will readily and rapidly give an initial over-all concept of structural relationships, serving as a basis or visual framework to which the details of the area can be added. Since basic understanding is often the most difficult goal to achieve, construction of the models requires a careful selection of the amount of pertinent detail basic to the visualization of the structure. Details which are shown will be represented as accurately as possible.

**Sources of Further Information:**

Further information can be obtained from the project director.

**18. STUDENTS' WARBURG AND OTHER RESPIROMETRIC APPARATUS.** *(Secondary, College)* THOMAS I. MARX, Engineering Division, Midwest Research Institute, Kansas City 10, Missouri. (Present address: Sigma Instruments, Incorporated, Braintree 85, Massachusetts.) (1961–1962)

Apparatus of different degrees of refinement has been developed. The simplest, a Fenn volumeter, consists of two small flasks connected by a horizontal capillary tube carrying a drop of liquid. When the respiration of a simple biological system placed in one of the flasks causes the pressure in the flask to change, the liquid drop moves so as to equalize the pressure in both flasks, giving a measure of the biological gas exchange. Oxygen and carbon dioxide rates are separated by chemically absorbing the latter gas in a duplicate experiment. The second type of respirometer, a Warburg apparatus, consists of a reaction flask connected to a vertical U-tube manometer which contains a reservoir of manometer fluid in a rubber bulb. The bulb can be compressed to bring the liquid in the closed arm to a reference point. The open arm of the manometer can be connected to a temperature and pressure control flask.

**Sources of Further Information:**

A report on the apparatus is available from Midwest Research Institute.

**19. MANIKIN FOR TEACHING ENDOTRACHEAL INTUBATION.** *(College, Medical School)* DONALD W. BENSON, Johns Hopkins Medical Institutions, Baltimore 5, Maryland. (1962–1963)

A manikin is being developed in which the head and neck model of the human body is anatomically correct and suitable for the teaching and practice of endotracheal intubation. A metal skeleton-like super-structure which imitates the normal maneuverability of the cervical spine and the atlanto-occipital joint will be designed. New plastic techniques will make possible the simulation of the texture, strength, and maneuverability for all the tissues of the oropharyngeal cavity and the larynx.

**Sources of Further Information:**

Further information can be obtained from the project director.

**20. MONITORING PHYSIOLOGICAL PARAMETERS IN THE STUDENT LABORATORY.** *(College, Graduate School)* ROBERT MACEY and LESTER PACKER, Department of Physiology, University of California, Berkeley 4, California. (1962–1964)

Devices are being constructed for use in student laboratories in college physiology to study quantitative relations between metabolism and specialized physiological functions. In particular, a polarographic apparatus is being developed for measurement of oxygen tension, to be used in conjunction with one of several other devices to measure ion transport, muscle contraction, or membrane permeability, together with oxygen utilization. Simple and economical block construction methods are planned to allow for preassembly or student assembly of the components.

**Sources of Further Information:**

Further information can be obtained from the project directors.

**21. MODEL OF HUMAN BRAIN FOR INDIVIDUAL STUDENT PRODUCTION AND USE.** DOROTHY N. NAIMAN, Department of Physiology, Health and Hygiene, Hunter College, New York 68, New York. (1962–1964)

The project will include a search for materials and methods to be used in preparing a mold of the brain from which students can readily make casts for their own use. The mold is designed to be relatively easy to make from an original model, and durable. The casts will be made of an inexpensive material which is rigid, capable of being cut or sawed into sections, and, preferably, light enough so that the sections can be reassembled into a fairly stable whole.

**Sources of Further Information:**

Dorothy N. Naiman and B. G. Konheim, "A Student-Constructed Model for the Study of Neuroanatomy," *Journal of the Association of American Medical Colleges* 23, 303 (1948). Further information can be obtained from the project director.

**22. STUDENT LABORATORY EQUIPMENT IN VISUAL SCIENCE.** *(College, Graduate, and Medical School)* THORNE SHIPLEY, Department of Ophthalmology, School of Medicine, University of Miami, Miami 36, Florida (1962–1965)

The development of several student laboratory instruments for use in various college courses in visual science is in progress. These will allow student testing of visual acuity, dark-adaptations, color perception, binocular vision, and certain associated basic visual functions, with simple and inexpensive apparatus not previously available. The project will entail the construction of one working model of each instrument. The instruments are intended for use in such courses as a one-year graduate laboratory course in visual science, undergraduate psychology, first-year medical school physiology, and resident training in ophthalmology.

**Sources of Further Information:**

Further information can be obtained from the project director.

**23. PREPARING ANIMALS IN THREE DIMENSIONS FOR VISUALIZATION OF ANATOMICAL RELATIONSHIPS.** CARL N. SHUSTER, JR., Department of Biological Sciences, University of Delaware, Newark, Delaware. (1962–1963)

The over-all plan is to: (1) perfect the techniques of preparing serial sections of whole animals for quick, easy, and immediate use in the laboratory and for a permanent record in plastic mounts or black-and-white or color photographs which can be used in an anatomical atlas or as transparencies, filmstrips, or movies; (2) provide a cost analysis of equipment and labor for making preparations of this type.

**Sources of Further Information:**

C. N. Shuster, Jr., and A. F. Eble, "Techniques in Visualization of Organ Systems in Bivalve Mollusks," *1961 Proceedings, National Shellfisheries Association* (in press). Further information can be obtained from the project director.

*Other projects related to projects 4-23:*

102. OVERHEAD PROJECTION SERIES OF LECTURE EXPERIMENTS IN THE SCIENCES

## C. Chemistry

**24. NEW ATOMIC, MOLECULAR, AND CRYSTAL MODELS.** *(Secondary, College)* R. T. SANDERSON, Department of Chemistry, State University of Iowa, Iowa City, Iowa. (1959–1964)

The new atomic and molecular models developed in this project, although designed primarily to aid in lectures, can also be used in a wide variety of laboratory exercises. Such exercises require students to make predictions of both physical and chemical properties of compounds from examination of either models of the component atoms or molecular models of the compounds. Alternatively, students may be asked to predict properties of component elements from an inspection of models of compounds. Other laboratory exercises may require students to construct their own atomic or molecular models, which can easily be made with inexpensive, readily available materials. The models are made of polystyrene foam purchased in spherical shapes of various sizes. They can be painted to represent electronegativity values (in atomic models) or partial charge (in molecular models). The molecules and crystals are easily assembled, using wood or pipe cleaner connectors and glue. The atomic models and at least some of the molecular models are equipped with small balls attached to the atomic surface to represent outer-shell electrons and vacancies and placed appropriately to indicate the directional nature of the orbitals.

A special set of thirteen atomic models consists of thirteen styrofoam balls about 2½" in diameter, of like color, and with outer electronic configurations represented on the surface. The models include both ground-state and valence-state structures and are used in a laboratory exercise on valence. Students examine each model, identified only by code, and decide its bonding capacity, direction, formulas of combinations with other atoms, etc.

**Sources of Further Information:**

R. T. Sanderson, *Teaching Chemistry with Models*, Van Nostrand Company, Princeton, New

Jersey, 1962. This book suggests in detail many ways in which these models may be used in the teaching of chemistry, both as lecture aids and in student exercises. It provides the necessary fundamental data for construction of thousands of models, with complete details for over 400, and photographs of over 270 models, half of which are in full color. In addition, three 45-minute sound-color lecture demonstrations on film describing the models and their construction and teaching uses are available for rent or purchase from Extension Division, State University of Iowa, Iowa City, Iowa. A booklet supplementing the films, *Principles and Construction of New Chemistry Teaching Aids*, is supplied with each film rental. Also see articles by R. T. Sanderson, *Journal of Chemical Education*, from 1951 to present. Reprints of some of these are still available, without charge, from the author.

**25. INTEGRATED SET OF ANALYTICAL INSTRUMENT BUILDING BLOCKS.** *(Secondary, College)* EDWARD N. WISE, Department of Chemistry, University of Arizona, Tucson, Arizona. (1959–1963)

An integrated set of instrument building blocks is being designed to permit a student to study a single instrumental principle in detail and then to make and study a complex instrument by interconnecting the building blocks (or modules). The modules are being designed with the following goals in mind: (1) simplicity of construction, (2) accessibility of all parts, (3) complete interchangeability of units having similar functions, (4) low cost, and (5) ruggedness to withstand student handling, inspection, and operation. Each unit will be sufficiently simple to permit construction by a department with a limited budget. The list of modules tentatively includes: photovoltaic cell housing, microammeter, light source, light source supply transformer, beam splitter, test tube holder, beaker holder, prism monochromator, grating monochromator, interference filter-wedge monochromator, vacuum phototube housing, gas phototube housing, resistance photocell housing, high impedance amplifier, current amplifier, regulated power supply, variable power supply, photomultiplier housing, photomultiplier power supply, aspirator burner, magnetic stirrer, ultraviolet source, ultraviolet power supply, millivolt selector and terminating relay, first and second derivative amplifier and terminating relay, solenoid burette pinch clamp, constant current regulator, mechanical counter with motor drive, syringe micrometer burette, servo-amplifier, X-Y recorder, plus seven modules of more specialized character.

**Sources of Further Information:**

Most of the modules have been designed and prototypes are being tested by students. Construction information, including reduced scale drawings, are being submitted to a suitable journal (probably the *Journal of Chemical Education*). A report with full-scale drawings will be published by the project director.

**26. COMPONENTS FOR STUDENT-BUILT INSTRUMENTS FOR INSTRUMENTAL ANALYSIS.** GALEN W. EWING, Department of Chemistry, New Mexico Highlands University, Las Vegas, New Mexico. (1960–1964)

Prototypes of the following units have been designed and built: (1) a general purpose rectifier power supply, (2) an electronic voltage regulator, (3) a D.C. vacuum tube electrometer, (4) a 1000-cycle tuning fork oscillator, (5) a Wheatstone bridge, (6) a phase-sensitive detector, (7) a one-milliampere recorder (Rustrak), (8) a low-voltage, high-current metered rectifier, (9) a variable source of polarizing potential, and (10) a servo-amplifier and servo-motor-driven autotransformer. Nearly completed are a number of optical components, including interchangeable light sources, prism and grating monochromators, a light chopper, and a photocell housing. These units can be interconnected in many different configurations to produce workable instruments with adequate accuracy in the fields of electroanalytical and optical chemistry.

**Sources of Further Information:**

Further information can be obtained from the project director.

**27. APPARATUS FOR CHEMICAL ANALYSIS AND PREPARATION ON THE MICRO- AND SEMI-MICRO SCALE.** *(Secondary, College)* JOHN T. STOCK, Department of Chemistry, University of Connecticut, Storrs, Connecticut. (1960–1965)

1. *Equipment for qualitative analyses on the small scale.* A stand, constructed from aluminum strip, although only 10 inches long, accommodates practically all of the individual equipment needed for inorganic qualitative analysis and for the sure and safe detection of "elements" in organic compounds.

2. *A simple micro apparatus for extraction-evaporation analysis.* The aim is a simple and very inexpensive apparatus for drop-scale identifications on filter paper.

3. *A titration controller for demonstrating the behavior of acid–base indicators.* This is a simple transistorized device that is used in conjunction with a pH meter to perform automatically the back-and-forth titration with acid and alkali of a solution containing an appropriate indicator.

4. *The safe use of toxic volatile reagents in introductory experiments.* These reagents are stored in sealed melting point tubes that are opened right inside the small-scale preparative apparatus.

5. *A compact set of semi-micro apparatus for general chemical operations.* The set consists of a half dozen or so major but simple parts that can be used for many purposes. Designed with high schools in mind, the set is simple, sturdy, safe, and very versatile.

6. *A simple device for indicating pH change during acid–base titrimentry.* This is a simple transistorized pH meter with a switching device that renders standardization very easy. It is used with a platinum–quinhydrone indicator electrode and a silver–silver chloride reference electrode made from a medicine dropper. The whole apparatus can be made by a high school student with a liking for simple electronics.

7. *A simplified apparatus for nitrogen determination by the Kjeldahl method.* After digestion, ammonia is distilled out of the digestion flask without transference of liquid contents. The semimicro distillation assembly is compact, easily stored, and not readily broken. It is intended for introductory courses in analytical chemistry.

**Sources of Further Information:**

Reprints of the article "Equipment for Qualitative Analysis on the Small Scale," *Laboratory Practice* 10, 406 (1961), are available from the project director.

**28. EQUIPMENT AND EXPERIMENTS FOR TEACHING INSTRUMENTAL ANALYSIS.** *(Secondary, College)* FREDERICK D. TABBUTT, Department of Chemistry, Reed College, Portland, Oregon. (1960–1963)

The primary purpose of this project is to develop inexpensive simple equipment to be assembled by students as a means for teaching experimental instrumentation. The following table outlines the main features of the equipment:

| Instrument | Specifications | Price of Parts[1] | Construction Time (hr)[1] |
|---|---|---|---|
| Poggendorf Apparatus (includes Weston cell and calomel electrode) | Sensitivity 0.7 mv out of 1.25 volts Accuracy 3 mv | $36 | 2 |
| Magnetic Stirrer | | 7 | 1 |
| pH Meter | Accuracy 0.05 pH units | 6 | 1 |
| Polarograph | Sensitivity $10^{-10}$ amp | 2 | 0 |
| Servomechanism for use as recording potentiometer | Sensitivity 1-5 mv | 72 | 5 |
| Recording Polaragraph | | 11 | 0 |
| Amperostat | | 0 | 0 |
| Potentiostat | 1-5 mv | 0 | 0 |
| Automatic Titrator (records titration curve and can shut off automatically) | Accuracy 1% | 0 | 0 |
| Ebert Monochromator | | 75 | 8 |
| Spectroscope | | 0 | 0 |
| Spectrograph | Resolution better than 0.7 A at 5000 A (first order) | 6 | 1 |
| Emission Spectrophotometer | | 9 | 2 |
| Absorption Spectrophotometer | 1% accuracy in intensity for 5 mμ resolution | 10 | 1 |
| Recording Single Beam Spectrophotometer | | 0 | 0 |

[1] Since many of the components are used interchangeably in these instruments, the cumulative total of this column for any instrument represents the maximum cost (or time) for that instrument (figures rounded to nearest dollar or hour).

**Sources of Further Information:**

Details of the experiments and the equipment can be obtained from the project director for $2.50.

**29. MULTI-PURPOSE INSTRUMENT FOR QUANTITATIVE CHEMICAL MEASUREMENT.** *(College, Graduate School)* DONALD D. DEFORD, Department of Chemistry, Northwestern University, Evanston, Illinois. (1961–1964)

The instrument is being designed primarily for electroanalytical chemistry and titrimetry but will be useful for a wide variety of other types of measurement and control. The final apparatus will be basically an analog computer, with the measurement and control components incorporated in the computer loop, and may be programmed in much the same manner as one programs a computer. When completed, the instrument can be used for voltammetry and related techniques, titrimetry, electroanalysis, coulometric analysis, and as a general-purpose recorder. The cost of the instrument is estimated at $4,000 to $5,000.

**Sources of Further Information:**

Further information can be obtained from the project director.

**30. LOW-COST TETRAHEDRAL MODELS.** *(Secondary, College)* LOUIS F. FIESER, Department of Chemistry, Harvard University, Cambridge 38, Massachusetts, (1961–1963)

Inexpensive plastic tetrahedral models are being developed for use in teaching concepts of asymmetry, optical activity, geometric isomerism, and conformational analysis.

**Sources of Further Information:**

These models are now in the testing stage. Further information can be obtained from the project director.

**31. MODELS OF CRYSTALLOGRAPHIC SPACE GROUPS.** ALBERT J. FRANK, Department of Geology, and HAROLD ZABSKY, Department of Chemistry, St. Louis University, St. Louis 4, Missouri. (LYMAN J. WOOD, former project director, deceased.) (1961–1964)

This material consists of: (1) eighty-five stereo-slides in color prepared by photographing symmetry models of a number of the space groups which have been and are being constructed in the authors' laboratory; (2) a 100-page descriptive monograph to be used while viewing the slides. The symmetry models are of two sorts: models constructed of cork balls, and models made of cardboard. The centers of cork balls of different colors have coordinates which are derived by means of crystallographically significant symmetry operations. The orientations of the cork balls are fixed by colored pegs inserted in such a way that a ball and inserted pegs can be treated (in most cases) as an unsymmetrical unit. Many of the cardboard models have been prepared from descriptions of Fedorov's stereohedra; some of these will aid in understanding the Bravais translations.

**Sources of Further Information:**

Arrangements have been made to supply the stereo-slides at cost to interested scholars.

Further information can be obtained from Dr. Frank.

**32. QUANTITATIVE MOLECULAR MODELS REPRESENTING THE MOLECULAR CHARGE DISTRIBUTION.** KARL H. ILLINGER, Department of Chemistry, Tufts University, Medford, Massachusetts. (1961–1963)

Molecular models which represent quantitatively the molecular charge distribution are being developed. Initially, this representation will be applied to individual molecules representative of the important types of bonding systems encountered in chemical problems. Subsequently, it is proposed to study the systematic development of representations of the charge distribution of molecular segments which may be used to construct, within tolerable limits of accuracy, models for the types of molecules frequently encountered in chemical problems.

**Sources of Further Information:**

Further information can be obtained from the project director.

**33. MULTI-PURPOSE ANALYTICAL CHEMICAL INSTRUMENT EMPLOYING OPERATIONAL AMPLIFIERS.** CARL M. STEVENS, Department of Chemistry, Washington State University, Pullman, Washington. (Former director, CHARLES F. MORRISON, JR.) (1961–1963)

A very widely adaptable manifold for operational amplifiers is mounted near an auxiliary panel containing the most commonly needed hardware items (switches, relays, bias packs, meters, etc.). These units are rack-mounted with power supplies and a strip-chart recorder. By the use of patch cords and plug-in resistors, capacitors, diodes, etc., the device can be programmed to serve the electronic functions of many instruments. Thus far, over thirty practical instruments have been synthesized. These include IR-compensated polarographs, coulometers, conductance devices linear in conductance, chronopotentiometer, digital integrator for a gas chromatograph, potentiometric autotitrators, etc. Complex units are made up on plug-in boards so that they need not be disassembled to free the console. Several applications can be used at the same time.

Facilities needed for construction are those of routine electronic repair or construction. A drill press and light sheet metal tools are desirable. Approximate cost of construction, including a good selection of amplifiers and a commercial power supply, is $2,000. This includes labor but not the strip-chart recorder. The availability of a sensitive oscilloscope makes possible a number of additional applications and aids in the testing of new circuits.

**Sources of Further Information:**

Copies of a complete report giving construction details, theory of operation, and typical applications will be distributed free of charge to all four-year U. S. colleges and universities. Limited numbers of additional copies will be available from the project director.

**34. ELECTRONIC INSTRUMENTATION FOR QUANTITATIVE CHEMISTRY.** CHARLES N. REILLEY, Department of Chemistry, University of North Carolina, Chapel Hill, North Carolina. (1961–1962)

Equipment and apparatus which illustrate the more advanced aspects of electronic instrumentation for quantitative chemistry, and suitable panel layouts and experimental procedures have been developed:

1. *Analysis of Passive Networks.* A panel layout demonstrates the properties of resistors, capacitors, and inductors in resonant circuits, filters and phase-shifting networks. Transient and steady-state currents are studied. The Laplace transform method is emphasized as a useful tool in circuit analysis.

2. *Operational Amplifiers.* These amplifiers are used to illustrate the basic principles of feedback as applied to analog computation. An instrument demonstrates the use of these amplifiers in performing the operations of addition, subtraction, integration, and differentiation in various combinations. The use of operational amplifiers for control purposes (i.e., through establishing an identity) is shown.

3. *Analog Computer.* A small computer using operational amplifiers solves the differential equation of damped, simple harmonic motion, the equation of first-order chemical kinetics, and linear simultaneous equations in two variables.

4. *Feedback Amplifier.* A two-stage amplifier on a panel layout illustrates in detail the principles of regenerative and degenerative feedback.

5. *Servomechanism.* A panel layout illustrates the important principles of servomechanisms. It can also be used as a recorder.

6. *Semiconductor Components and Non-linear Circuitry.* A panel layout demonstrates the characteristics and applications of transistors, diodes, and photocells. It includes a transistorized phase-shift oscillator, and diode modulating, dipping, limiting, and clamping circuits.

7. *Multivibrators.* The principles of monostable, bistable, and astable multivibrators and the Schmitt trigger are illustrated by a panel layout. Transistorized circuitry is used.

8. *Special Purpose Tubes.* Panel layouts illustrate the principles and applications of neon bulbs, voltage regulators, thyratrons, and electron ray tubes. A panel demonstrates the glow-tube counter and its use in a two-stage decade counter.

**Sources of Further Information:**

C. N. Reilley and D. T. Sawyer, *Experiments for Instructional Methods, Part V*, McGraw-Hill Book Company, Inc., New York, New York, 1961. Further information can be obtained from the project director.

**35. PRESSURE-JUMP APPARATUS FOR MEASURING RATES OF RAPID REACTIONS IN SOLUTION.** EDWARD M. EYRING, Department of Chemistry, University of Utah, Salt Lake City 12, Utah. (1962–1963)

Several research techniques broadly classified as "relaxation methods" have been developed recently for measuring specific rates as large as $10^{11}$ $M^{-1}$ $sec^{-1}$ for chemical reactions in aqueous solution. In particular, the pressure-jump apparatus devised by Strehlow and co-workers is useful for measuring relaxation times of pressure dependent, ionic equilibria in the range 1 to $10^{-4}$ sec. The design for such an apparatus is being simplified, where possible, for use in a physical chemistry laboratory at the junior level. A complete description of the construction, operation, and utilization within the curriculum will be made available at the end of the 1962-63 academic year.

**Sources of Further Information:**

An article for publication in the *Journal of Chemical Education* is in preparation. Further information can be obtained from the project director.

**36. NUCLEAR MAGNETIC RESONANCE SPECTROMETER.** W. C. GARDINER, JR., Department of Chemistry, University of Texas, Austin, Texas. (1962–1964)

A nuclear magnetic resonance (NMR) spectrometer is being developed for use in demonstrating the technique to undergraduates. The device is to be simple to construct, foolproof in operation, and relatively inexpensive. Within these bounds the instrument will duplicate, at very limited resolution, the functioning of the complex NMR spectrometers used in research, especially with regard to the display of the resonance signal. Experiments for undergraduate laboratory teaching will be prepared.

**Sources of Further Information:**

Further information can be obtained from the project director.

**37. THREE-DIMENSIONAL MODELS FOR PHASE RULE STUDIES.** RALPH H. PETRUCCI, Department of Chemistry, Western Reserve University, Cleveland 6, Ohio. (1962–1964)

The objective is to develop three-dimensional models to teach phase rule principles. A number of methods for constructing three-dimensional phase rule models have been described in the literature, particularly in the *Journal of Chemical Education*, but none of these models is available in large numbers at low cost. The new models will be dissectable in such a way that constant temperature, constant pressure, and constant composition sections can be shown. They will be of lightweight construction and non-breakable. Where possible, the models will represent actual systems in accordance with the best data available. It is hoped that methods will be found for producing them in large numbers at relatively low cost.

**Sources of Further Information:**

Further information can be obtained from the project director.

**38. EQUIPMENT FOR DEMONSTRATING MAGNETIC SUSCEPTIBILITY AND ABSORPTION EMISSION SPECTRA.** EUGENE G. ROCHOW, Department of Chemistry, Harvard University, Cambridge 38, Massachusetts. (1962–1963)

Two pieces of lecture demonstration equipment will be constructed. The first will be a projecting spectroscope for both absorption and emission spectra: the second will contain a Gouy balance with a projecting scale for measurement of magnetic susceptibility. These pieces will be useful in large lecture classes of 300 to 400 students.

**Sources of Further Information:**

Further information can be obtained from the projector director.

*Other projects related to projects 24-38:*

42. SIMPLE OPTICAL TWO-CIRCLE GONIOMETER
79. ATOMIC AND MOLECULAR RELATIONSHIPS IN THE STUDY OF PROPERTIES OF ENGINEERING MATERIALS
80. PROJECTION SLIDES FOR MATERIALS SCIENCE
81. LECTURE DEMONSTRATION EQUIPMENT FOR MATERIALS SCIENCE
82. MICROSCROPY IN TEACHING THE SCIENCE OF SOLIDS
102. OVERHEAD PROJECTION SERIES OF LECTURE EXPERIMENTS IN THE SCIENCES
116. NEW TYPES OF CHRISTIANSEN FILTERS
124. BASIC MASS SPECTROMETER
135. SEMICONDUCTOR PARTICLE DETECTORS IN MAGNETIC-DEFLECTION BETA-PARTICLE SPECTROMETERS
138. VERSATILE NUCLEAR COINCIDENCE APPARATUS FOR UNDERGRADUATE USE
141. VACUUM CHAMBERS FOR NUCLEAR PHYSICS EXPERIMENTS
142. APPARATUS FOR ADVANCED UNDERGRADUATE PHYSICS LABORATORY

# D. Earth Sciences

**39. GROUND WATER FLOW MODELS.** *(College, Graduate School)* JOHN W. HARSHBARGER, Department of Geology, University of Arizona, Tucson, Arizona. (1961–1962)

The ground water flow models consist of consolidated porous and permeable media made of sand and epoxy resin simulating sedimentary rock, enclosed in a watertight plexiglass case. Basic geologic structures and lithologies are synthesized within the models. Water is pumped into the recharge end of the model and moves through the consolidated media and is pumped out of the discharge end. Flow proceeds through the consolidated media because of the maintenance of a hydraulic gradient between the recharge and discharge ends of the model. Colored inks are inserted into the flow system, forming visible flow lines and enabling a visual study of ground water flow within various geologic environments as simulated by the models. The porous media are permanently consolidated and should provide constant experimental results throughout the life of the models, estimated to be ten or more years.

The sizes of standard models range from 12 to 36 inches in height, 18 to 36 inches in length, and 1 to 4 inches in thickness. The models can be built in a standard shop. Materials cost $50 to $100, depending on the size. The labor expenditure is about ten man-days. Operation of the models requires a water course and drain, along with two Sigma-motor hydraulic pumps, at a total cost of $500. With this apparatus the models can be set up to operate semi-automatically, permitting continuous movement of water through the synthetic rocks.

**Sources of Further Information:**

A progress report can be obtained from the project director.

**40. EQUIPMENT FOR PHOTOELASTIC STRESS ANALYSIS OF STRUCTURAL GEOLOGY PROBLEMS.** E. G. BOMBOLAKIS, Department of Geology, Boston College, Chestnut Hill 67, Massachusetts. (1963–1964)

A loading frame system will be designed and constructed for use with a diffused-light polariscope in photoelastic stress analysis of two-dimensional models in structural geology. The system will be designed for a load range on the order of 4,000 pounds biaxial compression with no significant buckling of the model.

**Sources of Further Information:**

Further information can be obtained from the project director.

**41. TRANSPARENT THREE-DIMENSIONAL HYDRAULIC FLOW MODELS.** JOHN W. HARSHBARGER, Department of Geology, University of Arizona, Tucson, Arizona. (1963–1964)

The objective is to develop preliminary prototypes of transparent three-dimensional models consisting of transparent plastic cases containing porous transparent media immersed in transparent liquid of the same refractive index as the media. Colored dyes inserted into the flow system of the model will form flow lines which will be visible in three dimensions. These flow lines can be observed and analyzed in order to understand more clearly the pattern of laminar ground water flow as it is controlled by geologic factors and such man-made disturbances as wells.

**Sources of Further Information:**

Further information can be obtained from the project director.

**42. SIMPLE OPTICAL TWO-CIRCLE GONIOMETER.** WILLIAM D. JOHNS, Department of Earth Sciences, Washington University, St. Louis 30, Missouri. (1963–1964)

An inexpensive, simple, optical two-circle goniometer for crystallographic studies will be designed, constructed and developed, and subsequently improved and modified as shown to be necessary through use in an undergraduate course in crystallography.

**Sources of Further Information:**

Further information can be obtained from the project director.

*Other projects related to projects 39-42:*

- 50. INVISIBLE FIXED AND FLUIDIZED BEDS FOR LABORATORY DEMONSTRATION AND STUDY
- 57. PNEUMATIC LOADING DEVICE FOR PURE DEVIATORIC LOADING OF SOILS
- 59. EXPERIMENTAL STRESS ANALYSIS DEMONSTRATIONS
- 61. DIMENSIONAL ANALYSIS—ITS APPLICATION IN SOIL MECHANICS
- 91. ANALOG MATERIALS FOR STUDYING THE PLASTIC FLOW OF METALS

# E. Engineering

## Aeronautical Engineering

**43. INEXPENSIVE SUPERSONIC WIND TUNNEL.** *(Secondary, College)* GABRIEL D. BOEHLER, Department of Aeronautical Engineering, Catholic University of America, Washington 17, D. C. (1959–1960)

A small supersonic wind tunnel which can be built for $300 to $500 has been constructed. The low cost of this tunnel is possible through the use of a government surplus small gas turbine air compressor (AiResearch Model GTC-43-44-6). The tunnel is 2″ x 2″ in size and is capable of creating air speeds between Mach 1.5 and 2.5 for a period of five to ten minutes.

**Sources of Further Information:**

Plans and details of construction can be obtained from the project director.

**44. SMOKE TUNNEL.** *(Secondary, College)* ROBERT S. EIKENBERRY, Department of Aeronautical Engineering, University of Notre Dame, Notre Dame, Indiana. (1960–1962)

A small, inexpensive, three-dimensional smoke tunnel useful in secondary schools and colleges for the study of fluid mechanics and aerodynamics has been designed and built. It is now being tested, and working drawings and construction instructions are being prepared.

**Sources of Further Information:**

Construction information for the smoke tunnel can be obtained from the project director.

**45. SUPERSONIC STREAMLINE VISUALIZATION.** *(College, Graduate School)* VINCENT P. GODDARD, Department of Aeronautical Engineering, University of Notre Dame, Notre Dame, Indiana. (1960–1961)

A Mach 1.38 indraft supersonic wind tunnel with a working cross-section of 2½" x 2½" has been modified for streamline visualization by (1) the addition of a large inlet reduction cone, (2) the addition of heavy anti-turbulence screening at the entrance of the inlet cone, and (3) replacement of the solid, one-piece, bottom nozzle block by a block made by sandwiching a ½" sheet of lucite between two 1" metal plates. This arrangement permits indirect illumination of the smoke filaments.

Smoke is introduced into the air-flow upstream of the anti-turbulence screening through evenly spaced tubes to form an array of streamlines. The streamlines are made visible by illuminating the smoke from the bottom of the tunnel through the clear plastic. Three General Radio Strobolume flash lamps were found to be a suitable source of illumination. Other lighting techniques currently in use in subsonic smoke tunnel work can be used, but not without an increase in the light intensity required. Since the shock pattern is not directly visible (as is smoke), and the smoke is not ordinarily visible through a standard Schlieren system, an optical system was devised which permits the simultaneous photographing of the smoke lines and shock pattern.

The basic element of the system is a double pass (coincident type) Schlieren with the innovation of a red point source and a circular opaque stop. This modification produces a dark field with a bright shock. The dark field is necessary in order that the proper contrast between the smoke lines and the background be maintained. Nitrous oxide can be used in place of smoke. In this case the streamlines will be clearly visible along with the shock pattern through any standard Schlieren system.

**Sources of Further Information:**

V. P. Goddard, J. A. McLaughlin, and F. N. M. Brown, "Visual Supersonic Flow Patterns by Means of Smoke Lines," *Journal of the Aero/Space Sciences*, November 1959.

J. A. McLaughlin, "Techniques of Supersonic Flow Visualization by Means of Smoke Stream Tubes," Master's Thesis, University of Notre Dame (1960).

A detailed report incorporating the description of the techniques used and various photographs obtained during the project can be obtained from the project director.

**46. LECTURE DEMONSTRATIONS IN AERODYNAMICS.** *(Secondary, College)* ERIK MOLLO-CHRISTENSEN, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge 39, Massachusetts. (1961–1963)

A small wind tunnel has been built for lecture demonstrations in aerodynamics. The tunnel fits in place of the slide holder of a slide projector. Test sections for the tunnel are interchangeable, and can be changed in five seconds. The test sections contain geometric arrangements over which air can flow, and manometers.

A Hele-Shaw apparatus has been built for lecture demonstrations. The fluids used are air and cigarette smoke. It can be either vacuum-cleaner or lung driven.

Other work in progress: (1) *Vibration demonstrations.* A prototype arrangement has been built which allows a beam or section of a shell to be mounted in a slide projector. The model is excited into vibration by means of a loudspeaker, and the motion is projected using a stroboscopic light source in the projector. This equipment is being redesigned for an overhead projector. (2) *Structures demonstrations.* The first demonstrations are now being built for use with an overhead projector. They are intended to show Maxwell's reciprocity theorem, similarity laws and modes of buckling for slender columns, and strains in a slender beam. (3) *Tunnel for fluid dynamics demonstrations.* A tunnel for demonstrations of boundary layer flows is being designed. It will be used in connection with an overhead projector, and should show velocity profiles and Tollmien-Schlichting waves and transitions.

**Sources of Further Information:**

*Technology Review*, December 1960.

"Apparatus for Lecture Demonstrations in Aerodynamics," *MIT Fluid Dynamics Research Group Report No. 60-2* (available on request from the project director).

*Other projects related to projects 43-46:*

54. TRANSPARENT FLEXIBLE MODELS FOR OBSERVATION AND DEMONSTRATION OF INTERNAL DEFORMATION PATTERNS
55. DEMONSTRATION EQUIPMENT FOR STRUCTURAL ENGINEERING
60. STABILITY OF EQUILIBRIUM IN STRUCTURAL MECHANICS
84. SMALL HYPERSONIC WIND TUNNEL FOR STUDY OF HYPERSONIC GAS DYNAMICS
89. COMBINED SHOCK TUBE, SHOCK TUNNEL, LIGHT GAS GUN, AND HOT SHOT WIND TUNNEL APPARATUS

## Chemical Engineering

**47. EQUIPMENT FOR ADVANCED CONTROL AND PROCESS DYNAMICS.** *(College, Graduate School)* BERNET S. SWANSON, Department of Chemical Engineering, Illinois Institute of Technology, Chicago 16, Illinois. (1960–1962)

Equipment has been developed for construction from commercial parts or pieces by an average university shop to provide laboratory instruction in the principles of automatic process control and process dynamics. The equipment provides for analog simulation of processes, determination of controller characteristics, frequency response of simple electrical circuits and a pneumatic control valve, determination of process dynamics and control of a two-stage liquid level system, an air pressure system, and a tube-and-shell heat exchanger. The complete package is described, with the author's results included and sample experiments given. The price for all equipment is approximately $18,000, including a small electronic analog computer.

**Sources of Further Information:**

The first section of the proposed manual, which deals with analog computation, and the second section, which is a final report, are available from the project director.

**48. APPARATUS FOR FLOW-SYSTEM CHEMICAL REACTION RATE PHENOMENA.** H. B. KENDALL, Department of Chemical Engineering, Ohio University, Athens, Ohio. (1961–1962)

The equipment that has been assembled consists of a 6′ to 10′, 1″ ID Pyrex tubular reactor, together with auxiliary tanks, flow meters, and pumps. The reactor is constructed of 1′ sections so that baffles can be inserted at various positions in the tube and reactor length can be varied. Reactants are pumped from storage containers into one end of the tube through a mixing tee, and the conversion of the reactants to products is measured as a function of such things as flow rate, reactor length, baffles and baffle spacing, etc. In addition, shorter 2″ and 4″ ID tubes can be used in place of the 1″ ID tube in order to study the effects of length-to-diameter ratio on the kinetics of the system. Initially, the ethyl acetate–sodium hydroxide system has been used in the equipment. Total equipment cost is about $500.

**Sources of Further Information:**

A report on the project can be obtained from the project director.

**49. OPTICAL ANALOG OF AUTOMATIC X-RAY MONITOR AND CONTROL SYSTEMS.** GEORGE A. PARKS, Department of Mineral Engineering, Stanford University, Stanford, California. (1961–1963)

An effort is being made to build an optical analog of a continuous optical analysis and control system for less than $500. Continuous optical analysis of selected process streams is possible through photoelectric scanning of the intensity of light reflected or transmitted by the stream. Automatic control of process variables will be possible through use of the output of the scanning device. Components of the system are to be separable so that the effect of varying the sampling point can be observed. The prototype system will be built for use with existing high intensity electromagnetic ore concentrators operating on synthetic mixtures of black hematite and quartz. The hematite content of the products determines their reflectivity and is itself determined by several controllable operating variables of the separator. Preliminary work is being done using the output of the optical scanner, through relays and a motor-driven variable transformer, to control the magnet current.

**Sources of Further Information:**

A limited number of copies of progress reports describing tentative circuit diagrams is available on request from the project director. Subsequent reports will be prepared three times yearly in January, June, and September.

**50. INVISIBLE FIXED AND FLUIDIZED BEDS FOR LABORATORY DEMONSTRATION AND STUDY.** H. E. HOELSCHER, Department of Chemical Engineering, Johns Hopkins University, Baltimore 18, Maryland. (1962–1963)

The objective is to develop "invisible" fixed and fluidized beds for laboratory study by undergraduates at the senior level. This system requires that the particles be transparent and of the same refractive index and dispersivity as the liquid flowing through the beds. In such a fixed bed, colored tracers may be used to observe the various flow regimes of interest, and the isotropy of the system can be studied. Through these and other experiments, the entire structure of the fluidized particle system can be examined.

**Sources of Further Information:**

Further information can be obtained from the project director.

**51. MASS TRANSFER AND REACTOR DYNAMICS AND THE DYNAMIC TESTING OF CHEMICAL PROCESS SYSTEMS.** KARL B. SCHNELLE, JR., Department of Chemical Engineering, Vanderbilt University, Nashville 5, Tennessee. (1962–1963)

Liquid-liquid mixer-settler type extractor and bubble-cap plate equipment will be constructed to illustrate mass transfer and reactor dynamics. The mixer-settler will be convertible to stirred tank reactors. Using available transient response, frequency response, and pulse testing equipment, dynamic test experiments will be devised for use with the equipment. Further dynamic test experiments will be devised for use on liquid level, fluid flow, heat transfer, and control equipment similar to that developed in other laboratories. Both pneumatic and electronic analogs will be used to simulate the apparatus involved. The experiments will be designed to be used in conjunction with a senior undergraduate chemical process systems engineering course.

**Sources of Further Information:**

Further information can be obtained from the project director.

*Other projects related to projects 47-51:*

35. PRESSURE-JUMP APPARATUS FOR MEASURING RATES OF RAPID REACTIONS IN SOLUTION
41. TRANSPARENT THREE-DIMENSTIONAL HYDRAULIC FLOW MODELS
93. CONTROL SYSTEM ANALOG FOR TEACHING CLOSED-LOOP CONTROL THEORY
100. ELECTRICAL ANALOG FOR FLUID AND HEAT FLOW AND DIFFUSIONAL PROCESSES

## Civil Engineering

**52. ELECTRIC ANALOG TEACHING AID FOR MATHEMATICS, SCIENCE, AND ENGINEERING.** *(Secondary, College)* PAUL R. DE CICCO, Department of Civil Engineering, Polytechnic Institute of Brooklyn, Brooklyn 1, New York. (1960)

A portable electronic analog teaching aid package has been designed for classroom and laboratory to introduce electronic analog techniques in the simulation of systems and solution of problems in science and engineering. The package consists of: (1) a 3′ x 4′ problem board on which are mounted five articulated models for demonstration and study of spring-mass systems, the torsion pendulum, an automobile suspension system, viscous drag, and the static analysis of beam loading; (2) a 3′ x 4′ transfer or block diagram board with magnetic symbols of computer operational functions; (3) a 3′ x 4′ program demonstration unit consisting of ten model operational amplifiers with input, feedback, and output circuit jacks and external plug-in components for demonstrating the programming of analog computers; (4) a 3′ x 4′ photographic facsimile of the computer operating panel, the face being markable with crayon to demonstrate wiring techniques; (5) a 15-operational amplifier electronic analog computer with all necessary auxiliary components for problem solution and display; and (6) a computer programming unit for instructor use in demonstrations and for student use in self-checking of problems, which contains, in a series of switching circuits, all external components, power suppliers, and metering devices needed for rapid programming of the computer. The estimated cost for the teaching aid package, including the basic computer and all other components, materials, and labor is approximately $4,500.

**Sources of Further Information:**

A report is available from the project director. It includes an introduction to electronic analog techniques, description, drawings and photographs of each unit, and a series of typical problems.

**53. VORTEX TANK TUNNEL, VISUAL PIPE NETWORK, DYNAMIC MODEL, AND PORTABLE VIBRATION SIMULATOR.** RAYMOND R. FOX, Department of Civil Engineering, George Washington University, Washington 6, D. C. (1960–1962)

1. *Vortex Tank Tunnel.* An 8″ diameter cylindrical plastic tank is rotated about its axis in a vertical position by a variable speed mixer motor. A thrust bearing supports the weight of the tank and its liquid contents. An overhead horizontal runner with a vertical probe permits plotting of the liquid surface on a vertical plane through the axis. The approximate cost is $250-$300.

2. *Visual Pipe Network.* A rectangular acrylic plastic manifold with a baffle plate has a threaded hole at one end to receive a variety of short en-

trances and smooth or artificially roughened plastic tubes. Roughness is produced by internal threading. Simple static pressure head and flow rate measurements permit calculation of entrance loss coefficients and friction factors. Reynold's experiment can also be performed. The approximate cost is $250-$300.

3. *Dynamic Model.* An elastic model of a simplified rigid frame is set into lateral vibration by a modified loudspeaker unit with a variable-frequency vibration driver. The amplitude of response at selected points is measured by a movable dial indicator used as a feeler gauge. An electrical signal proportional to the response, obtained from resistance strain gauges attached to the model, may be displayed on the screen of a cathode ray oscilloscope. Phase relations and damping constant may be obtained and such phenomena as beating near resonance displayed. The assembly of the model and its driving coil on a wooden base and backboard is inexpensive. The electronic apparatus for producing the driving power and for amplifying, displaying, or photographing the response signal is expensive but generally available in university laboratories.

4. *Portable Vibration Simulator.* This portable, inexpensive device is capable of simulating passive mechanical systems and coupled mechanical systems with one, two, or three degrees of freedom. Continuously variable resistors, decade capacitors, and decade inductors simulate damping, inertia, and spring constant, respectively. A transformer is used to simulate coupling of mechanical systems. Flexibility in simulation is provided by the use of patch cords to connect various elements as desired. The system is designed for use with standard input and output equipment such as voltage generators and oscilloscopes which can be inserted at any point in the network. The unit costs under $100, owing to use of non-precision components which limit the equipment to qualitative study of systems of interest.

**Sources of Further Information:**

A report is in preparation. Complete information can be obtained from the project director.

**54. TRANSPARENT FLEXIBLE MODELS FOR OBSERVATION AND DEMONSTRATION OF INTERNAL DEFORMATION PATTERNS.** Raymond J. Stith, Department of Civil Engineering, University of Dayton, Dayton, Ohio. (1960–1963)

Transparent flexible models having internal planes are being developed so that the instructor can demonstrate and the student can visually observe internal deformation patterns within particular types of members under various conditions of loading. The models will have a maximum cross-sectional dimension of 1″ to 2″ and an overall length of about 10″. They are intended primarily for use in courses in elementary mechanics of materials to demonstrate conditions under which "plane sections remain plane," a basic assumption in the derivation of common elementary solutions. Likewise, the models will demonstrate that plane sections sometimes warp, as in the torsion of non-circular sections. Models having circular, square, and rectangular cross sections are being developed.

**Sources of Further Information:**

Negotiations for commercial production are under way. Further information can be obtained from the project director.

**55. DEMONSTRATION EQUIPMENT FOR STRUCTURAL ENGINEERING.** *(College, Graduate School)* E. H. Gaylord, Department of Civil Engineering, University of Illinois, Urbana, Illinois. (1961–1963)

A series of small-scale structural members and joints which will simulate both elastic and elasto-plastic behavior is planned. The elements are to be readily assembled and disassembled so that particular members and/or joints in simple frames, multiple-span frames, trussed frameworks, etc., can readily be replaced to demonstrate a number of predictable behavior patterns with the same framework. Because of the proposed elasto-plastic properties, it will be possible to demonstrate elastic behavior, inelastic behavior, and buckling. It is also intended to make some of the models capable of being used in quantitative work with reasonably simple instrumentation. A major effort is planned to produce equipment which can be used to demonstrate behavior of various slab, plate, and shell phenomena such as buckling, anticlastic curvature, and others.

**Sources of Further Information:**

A report is in preparation. Further information can be obtained from the project director.

**56. MODELING TECHNIQUES FOR STRUCTURAL DESIGN.** Robert J. Hansen, Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology, Cambridge 39, Massachusetts. (1961–1963)

This project will develop techniques of fabrication and testing of models of structures to assist in the teaching of structural engineering. In order to evaluate complex, yet functionally desirable and esthetically pleasing structural arrangements (for example, warped surface shells) without undertaking laborious analytical solutions, methods are needed to develop a new group of engineers and architects capable of conceiving and evaluating structural shapes best suited to solve enclosure problems. The principle underlying this development is the evolution of a rapid, yet inexpensive technique for the fabrication of structural models, probably revolving around the use of molded plastics. The equipment being developed will include a machine for copying a warped-surface mold to produce a die, and a vacuum press for the preparation of molds. The estimated cost of the equipment will be under $2,500.

**Sources of Further Information:**

Further information can be obtained from the project director.

**57. PNEUMATIC LOADING DEVICE FOR PURE DEVIATORIC LOADING OF SOILS.** *(College, Graduate School)* YEHUDA KLAUSNER, Department of Civil Engineering, Wayne State University, Detroit 2, Michigan. (1961–1963)

The device is being designed to provide controlled constant rates of deviatoric stress loading under constant isotropic pressures. It will permit investigation of the shear strength of soils under a constant state of consolidation and of such effects as dilatancy and irreversibility of the loading processes. The conventional loadings, cell test, constant pure deviatoric loading, and, eventually, constant rate of strain will be other features. The unit will be compact, with controls of the pneumatic type and with a main driving power of 100 to 120 psi pressure. The estimated cost is approximately $1,000.

**Sources of Further Information:**

Further information can be obtained from the project director.

**58. UNSTEADY FLOW IN A PIPE.** M. R. CARSTENS, Department of Civil Engineering, Georgia Institute of Technology, Atlanta 13, Georgia. (1962–1963)

A device for the study of unsteady flow in a pipe is being designed, fabricated, and tested. In the basic equipment, the test section is the middle portion of a straight piece of pipe in which the liquid is oscillated harmonically by means of a piston. Pressure measuring devices are to be located in the test section. With the velocity, acceleration, and pressure gradient being measured, the linear-momentum equation and work-energy equation can be employed to determine the boundary drag and heat dissipation, respectively. The equipment can readily be modified for more complex studies.

**Sources of Further Information:**

Further information can be obtained from the project director.

**59. EXPERIMENTAL STRESS ANALYSIS DEMONSTRATIONS.** AUGUST J. DURELLI, Department of Civil Engineering, Catholic University of America, Washington 17, D. C. (1962–1964)

Experimental techniques will be used to help students and designers in the understanding and visualization of stress and strain distribution phenomena. Correlations between the mathematical developments and experimental results will be presented using photoelasticity, mechanical and electrical strain gauges, moire patterns, and grids. It is planned to build a large field polariscope, structural models to be demonstrated in the polariscope, large scale electrical analog models, metal and plastic structural models with moire grids, embedded grid models, and devices with electrical strain gauges.

**Sources of Further Information:**

Further information can be obtained from the project director.

**60. STABILITY OF EQUILIBRIUM IN STRUCTURAL MECHANICS.** *(College, Graduate School)* GEORGE HERRMANN and JOHN F. FLEMING, Department of Civil Engineering, Northwestern University, Evanston, Illinois. (1963–1964)

The objective is to design and construct a comprehensive group of permanent models which demonstrate the instability of equilibrium of structures of various shapes under a number of different loading conditions. Each model will be designed to demonstrate clearly a specific type of buckling behavior and to show the effect of changing any of the variables involved, among them the stiffness of the structure or the support conditions. The usefulness of the models will be investigated by employing them for demonstrations in appropriate undergraduate and graduate classes in structural mechanics.

**Sources of Further Information:**

Further information can be obtained from the project directors.

**61. DIMENSIONAL ANALYSIS—ITS APPLICATION IN SOIL MECHANICS.** *(College, Graduate School)* ROBERT L. KONDNER and JORJ O. OSTERBERG, Department of Civil Engineering, Northwestern University, Evanston, Illinois. (1963–1964)

The objective is to conceive and design experiments and construct the equipment to illustrate the scientific merits of dimensional analysis as a basic tool of science applicable to studies of some aspects of load-deformation, stress distribution, and stability phenomena in the rheology of soil-foundation systems. The experiments and apparatus will be useful at both undergraduate and graduate levels.

**Sources of Further Information:**

Further information can be obtained from the project directors.

***Other projects related to projects 52-61:***

**40. EQUIPMENT FOR PHOTOELASTIC STRESS ANALYSIS OF STRUCTURAL GEOLOGY PROBLEMS**

**46. LECTURE DEMONSTRATIONS IN AERODYNAMICS**

**83. TRANSPARENT OVERLAY VISUAL AIDS FOR ENGINEERING GRAPHICS**

**91. ANALOG MATERIALS FOR STUDYING THE PLASTIC FLOW OF METALS**

## Electrical Engineering

**62. LABORATORY AIDS FOR ELECTRICAL ENGINEERING.** CLIFFORD M. SIEGEL, Department of Electrical Engineering, University of Virginia, Charlottesville, Virginia. (1960–1961)

Three instruments have been developed to demonstrate an extensive array of electrical devices and phenomena. The devices are mounted on standard instrument racks for operation by students outside of regularly scheduled classes and without supervision. One instrument provides a cathode-ray tube display of the current-vs-voltage characteristics of about thirty electron tubes, photo devices, resistors, and semiconductor devices, which are mounted in clear view behind a glass window. The student has access to certain controls for selecting the device for study and to others for manually varying such parameters as temperature, grid voltages, emitter currents, and light intensity, as desired. Another instrument demonstrates voltmeters responding to eight different properties associated with each of eight different waveforms of voltage. The third demonstrates a variety of single-phase and polyphase transformer connections, rectifier circuits, and filter circuits. It displays on the oscilloscope waveforms of nineteen currents and a great number of potential differences. Each instrument requires about $300 for parts and about two weeks' construction time; each weighs 20-30 pounds.

**Sources of Further Information:**

One report provides a description of all three instruments. Each is described further by a separate report containing, typically, 15 pages of detailed instructions for construction, an explanation of operation of the instrument, five to ten pages of schematic diagrams, and ten full-scale pictorial layout and wiring diagrams. The reports can be obtained by writing to the project director.

**63. MAGNETIC MEMORY OSCILLOSCOPE.** WALLACE L. CASSELL, Department of Electrical Engineering, Iowa State University, Ames, Iowa. (1961–1962)

This device is a single unit to be used with a conventional oscilloscope to make possible the continuous presentation of a transient. The memory is a frequency-modulated recording and play-back system with a magnetic memory element in the form of a 12″ closed loop of 1/4″ magnetic tape run at 15″ per second on a conventional tape recorder. A single recording head is used for both recording and playback and the electronic circuitry is completely transistorized. The device presents transients over a frequency range from 0 to 1000 cycles per second.

**Sources of Further Information:**

Copies of the project report, *A Small Magnetic Memory for Display of Transients*, are available from the Engineering Experiment Station, Iowa State University.

**64. DIGITAL-ANALOG CONTROLLER FOR SAMPLED DATA SYSTEMS.** *(College, Graduate School)* PAUL M. DERUSSO, Department of Electrical Engineering, Rensselaer Polytechnic Institute, Troy, New York. (1961–1962)

A special purpose combined analog and digital computer has been developed which performs the discrete data processing necessary in systems operating on sampled data. The computer samples a signal to form a sequence of numbers at its input, processes this sequence in accordance with a logical program and applies the resultant sequence to the system. It is designed for use in classroom demonstrations, laboratory experiments, and undergraduate and graduate experimentation. The unit is portable and highly flexible as to choice of sampling rate, logical programs, etc. The intention is to give students a physical experience which will clarify the mathematics of the discrete data systems which they have studied.

**Sources of Further Information:**

Further information can be obtained from the project director.

**65. DEVICE FOR DISPLAYING PHASORS AS DIRECTED LINES ON AN OSCILLOSCOPE SCREEN.** GEORGE B. HOADLEY, Department of Electrical Engineering, North Carolina State College, Raleigh, North Carolina. (1961–1962)

The device being developed will be used with an ordinary cathode ray oscilloscope to give a direct presentation of a phasor quantity as a directed line segment. The length of the line is proportional to the magnitude, and its angle with respect to a reference line is the phase angle. The instrument should be as easy to use as an ordinary vacuum-tube voltmeter and give twice as much information with each measurement. It is anticipated that its accuracy in magnitude and angle will be on the order of a few percent over a frequency range of 1 to 1,000 cps. Simple electronic techniques are employed. It is estimated that the device can be manufacturd and sold commercially for about $200.

**Sources of Further Information:**

Earlier efforts to develop an instrument of this kind are described by E. A. Walker, A. H. Waynick, and P. G. Sulyer, "Polar Vector Indicator," *Transactions of the American Institute of Electrical Engineers* 68, Part I, 154 (1949), and *Electrical Engineering* 68, 489 (1949).

Further information can be obtained from the project director.

**66. INEXPENSIVE DIGITAL-TO-ANALOG CONVERTER FOR CURVE PLOTTING WITH SMALL DIGITAL COMPUTERS.** GEORGE W. HUGHES, Department of Electrical Engineering, Purdue University, Lafayette, Indiana. (1961–1963)

The equipment takes the numerical output of a digital computer, reduces it to a binary paper tape using the normal punching facilities of the computer, then converts this tape to an electrical signal for use in plotting the data point, either on a common camera-equipped oscilloscope or on an available plotting table. The equipment incorporates relays, a low-speed tape reader, and an analog plotting device (such as an oscilloscope) which is assumed to be already available in the laboratory. Cost of the equipment for converting the paper tape signal to an analog signal is approximately $750, if the equipment is made in the institution's own shops.

**Sources of Further Information:**

A report on the project can be obtained from the project director.

**67. PROTOTYPE SYSTEMS LABORATORY EMPLOYING ELECTROHYDRAULIC, HYDRAULIC, AND HYDROMECHANICAL COMPONENTS.** *(College, Graduate School)* H. E. KOENIG and H. R. MARTENS, Department of Electrical Engineering, Michigan State University, East Lansing, Michigan. (1961–1962)

The specific objective is to expand the facilities of an existing electromechanical systems laboratory (see first reference below) by including components as they are commonly encountered in a typical hydraulic control system and by providing for the study of mixed electrical-mechanical-hydraulic systems made up of these components. Provision is made in the design of the connections and the instrumentation for efficient and effective measurement of the complete dynamic characteristics of (1) the devices as multiterminal components and (2) the performance characteristics of any system composed of a collection of mechanical, hydraulic, and electrical components. One of the main features of the laboratory is that all components are completely compatible. Provision is made for maximum flexibility in their interconnection to form a wide variety of systems.

Typical equipment includes: 1. *Components*, i.e., power supply—variable pressure and flow, electrohydraulic servo valves with matching amplifier, hydraulic hoses and connectors, rotary actuators—axial and radial pumps and motors, translational actuators — hydraulic rams, mechanical two- and three-terminal components, springs, dashpots, and inertias—rotational and translational; 2. *Instruments for* differential and gauge pressure measurements, flow measurements, force measurements, displacement measurements—rotational and translational, torque measurements; 3. *Read-out Devices,* i.e., X-Y plotter, time base recorder, visual measurements and calibrators.

**Sources of Further Information:**

W. A. Blackwell and H. E. Koenig, "A Combined Machinery and Control Systems Laboratory," *Institute of Radio Engineers Transactions on Education* E-2, No. 4 (1959). Copies are available from the authors on request.

H. E. Koenig and W. A. Blackwell, *Electromechanical System Theory,* McGraw-Hill Book Company, Inc., New York, New York, 1961.

Copies of a 125-page report describing the facility and its objective in the educational program are available on request from the Division of Engineering Research, College of Engineering, Michigan State University. The report includes: (1) a complete description of the facility, with a list of equipment, sources of supply or detail drawings, and approximate cost; (2) techniques and procedures for establishing mathematical models, both linear and nonlinear, of the various system components provided in the facility, including the actual mathematical models of several components; (3) examples of analyses of a typical linear electromechanical and a typical nonlinear electrohydraulic system showing, respectively, a comparison between analog and digital solutions and actual system performance; (4) a representative sampling of laboratory problems usable in an undergraduate educational program.

**68. MAGNETIC NETWORK DEMONSTRATOR.** NEAL A. SMITH, Department of Electrical Engineering, The Ohio State University, Columbus 10, Ohio. (1961–1962)

This project has developed a group of magnetic circuit parts, such as coils and cores, which can be used to demonstrate the physical significance of each element of a general magnetic network and to show how it appears in the equivalent electrical circuit. The experiments can be performed with instruments usually found in well-equipped laboratories, but watt meters with rather small full-scale readings are also required. A set of laboratory experiments using the developed equipment has been written.

**Sources of Further Information:**

The final report, available from the project director, includes all information necessary to duplicate the equipment developed. Copies of lecture notes and laboratory experiments are also included.

**69. DEMONSTRATION EQUIPMENT FOR THEORY OF ELECTROMAGNETIC FIELDS AND WAVES.** DENYS O. AKHURST, Department of Electrical Engineering, University of Arkansas, Fayetteville, Arkansas. (1962–1964)

Some 50 three-dimensional models are being designed and built to illustrate the properties of electromagnetic fields and waves. The models will show the strength and direction of the fields, direction being indicated by the direction of the field lines, and field strength by density or number of field lines. Time-varying fields will be represented by dynamic models illustrating the phasing, reversing, and coupling properties of such fields. The models are designed so that, after they have been introduced, they may be passed around the class by hand.

**Sources of Further Information:**

Further information can be obtained from the project director.

**70. SOLID STATE PULSE-CODE MODULATION SYSTEM.** ELLIS F. KING and RICHARD C. MACKEY, Department of Engineering, University of California, Los Angeles 24, California. (1962–1964)

The purpose of this project is to design and construct a pulse-code system of modulation (PCM) wherein analog signals are periodically sampled, quantized, and coded in a binary system for transmission. It is to be used as a lecture demonstration aid and as laboratory apparatus for experimental work where its properties may be exploited in a quantitative study of the principles involved.

**Sources of Further Information:**

Further information can be obtained from the project directors.

**71. FORCES AND TORQUES DEVELOPED BY CURRENT-CARRYING CONDUCTORS IN MAGNETIC FIELDS.** J. F. LAMB and J. R. TUDOR, Department of Electrical Engineering, University of Missouri, Columbia, Missouri. (1962–1963)

The equipment being developed is primarily for electrical engineering courses concerned with the basic principles of electromagnetic devices or rotating machines. A laminated, two-pole stator provided with interchangeable salient pole and cylindrical rotors will enable students to make static torque measurements in different rotor positions to study the fundamental principles of torque development for such different kinds of rotary transducers as meter movements, rotating machines, etc. The equipment will permit measurement of the magnetic flux distribution in the air gap between rotor and stator. Another device will demonstrate the force on a single conductor carrying current in a magnetic field in the presence of iron. Different geometries of iron and conductor arrangements will be provided for. The equipment will be tested in undergraduate student laboratories.

**Sources of Further Information:**

Much of the underlying theory of operation of the equipment is covered in the book, *Electric Machinery*, edited by A. E. Fitzgerald and C. Kingsley, 2nd Edition, McGraw-Hill Book Company, Inc., New York, New York, 1961, pp. 57–61. Further information can be obtained from the project directors.

**72. APPARATUS AND EXPERIMENTS FOR A MODERN COMMUNICATIONS LABORATORY.** *(College, Graduate School)* H. B. VOELCKER, JR., Department of Electrical Engineering, University of Rochester, Rochester 20, New York. (1962–1964)

The special apparatus being developed includes a Fourier synthesizer, a real-time spectrum analyzer, a panoramic display unit, and a pulse-code modulator and statistical analyzer. They are designed to assist in teaching modern communication theory to senior undergraduate and postgraduate students in electrical engineering.

**Sources of Further Information:**

*Experiments in Signal Analysis and Coding*, July 1961, available in limited quantities from Professor E. C. Cherry, Department of Electrical Engineering, Imperial College of Science and Technology, Exhibition Road, London S.W.7, England.

Further information can be obtained from the project director.

**73. AUTOMATIC PLOTTING OF PHASE, GAIN, AND ROOT LOCUS FROM POLE-ZERO CONSTELLATIONS.** BROTHER C. ALBERT WELSH, Department of Electrical Engineering, Manhattan College, New York 71, New York. (1962–1964)

The apparatus will give a direct plot of gain vs. frequency and phase vs. frequency on a dual beam oscilloscope from an $s$ plane plot of the poles and zeros of any transfer function. An alternative form of this apparatus will give the root locus directly and automatically. The design will be refined so that faculties and students at other institutions can build the apparatus.

**Sources of Further Information:**

R. E. Scott, "Network Synthesis by the Use of Potential Analogs," *Proceedings of the Institute of Radio Engineers* 40(7), 970 (1952).

W. H. Huggins, "The Potential Analogue in Network Synthesis and Analysis," *Air Force Cambridge Research Laboratories*, E5066 (March 1951).

S. Darlington, "The Potential Analogue Method of Network Synthesis," *Bell System Technical Journal* 30, 315 (1951).

W. W. Hansen and O. C. Lundstrom, "Experimental Determination of Impedance Functions by the Use of an Electrolytic Tank," *Proceedings of the Institute of Radio Engineers* 33(7), 528 (1945).

A. R. Boothroyd and J. H. Westcott, "The Application of the Electrolytic Tank to Servo-Mechanism Design," Cranfield Conference, 1951.

L. Malavard, "The Use of Rheolectrical Analogies in Aerodynamics," AGARDograph No. 18 (1956).

Further information can be obtained from the project director.

**74. EQUIPMENT AND EXPERIMENTS FOR A SEMICONDUCTOR DEVICE LABORATORY.** ALWYN SCOTT, Department of Electrical Engineering, University of Wisconsin, Madison, Wisconsin. (1963–1964)

Equipment for short-cycle dot alloying and epitaxial growth is to be developed. The former will incorporate several quick-heating molybdenum strip heaters and a simple thermocouple-transistor-microammeter circuit for direct reading of temperatures, while the latter will involve an open tube setup with emphasis on simple variation and control of the dopant. Experiments on the measurement of current and capacitance vs. voltage and comparison with theoretical relations as well as observation of avalanche breakdown and micro-plasma formation will be designed to be performed with the semiconductor devices produced with this equipment.

**Sources of Further Information:**

Further information can be obtained from the project director.

*Other projects related to projects 62-74:*

47. EQUIPMENT FOR ADVANCED CONTROL AND PROCESS DYNAMICS
52. ELECTRONIC ANALOG TEACHING AID FOR MATHEMATICS, SCIENCE, AND ENGINEERING

## Industrial Engineering

**75. WAITING-LINE SIMULATOR.** *(College, Graduate School)* SCOTT TABOR POAGE, Oklahoma State University, Engineering Research Division, Stillwater, Oklahoma. (Present address: Industrial Engineering Department, Arlington State College, Arlington, Texas.) (1960–1962)

This is a device to demonstrate the action of queues (waiting lines) and to enable the student of queuing theory to apply that theory by the analysis of data from the electromechanical demonstrator.

**Sources of Further Information:**

Further information can be obtained from the project director.

**76. PUNCHED-TAPE NUMERICALLY CONTROLLED MACHINE TOOL.** *(College, Technical School)* FRANK W. TIPPITT, Department of Industrial Engineering, Southern Methodist University, Dallas, Texas. (1960–1961)

The machine tool system consists of a seven-channel punched-tape reader, logic and control units, a three-axis work table, and a display panel. It is compatible with any electromechanical punched-tape reader known to be available. Some photoelectric tape readers may require a simple buffer-amplifier stage to be compatible. The instruction code is generated separately by a digital computer which punches seven-channel tape to be used by the machine tool system. The three-axis work platform moves in relation to a fixed cutting tool. A heavy-duty drill press or a vertical milling machine can be converted to numerical control by fastening the base of the work platform to the base of the machine tool. Orientation and alignment of the work platform requires only that the vertical spindle be perpendicular to the work platform. The work platform is moved by bidirectional digital motors energized by power transistor gates. The logic and control unit has been designed for both chassis-socket and printed circuit construction. Semiconductors are used throughout. The condition of the logical elements is displayed on the console panel. The circuitry uses some synchronous and some asynchronous techniques. The increase in cost is easily justified by the greater teaching value. Several clock modes are provided for synchronous circuits. Expansion of the system to a larger scale is possible. At present, simultaneous motion by two axes is not provided but can be installed with simple duplication of circuit designs used.

**Sources of Further Information:**

A final report is available from project director.

**77. PORTABLE FORCE-PLATFORM FOR MEASURING BODILY MOVEMENTS.** J. W. BARANY, Department of Industrial Engineering, Purdue University, Lafayette, Indiana. (1961–1962)

The force-platform is suitable for studying the forces and human effort required to perform various types of muscular work. The device measures human forces in three components. It is portable, inexpensive to build, and suitable for laboratory demonstrations and experiments for undergraduate courses in work methods and measurement, human engineering, and job design. Among the types of experiments that might be performed with this equipment are the following: (1) detection of differences in work methods, (2) indication of the optimum arrangement of controls and displays in man-machine systems, (3) classification of jobs by physiological costs, and (4) demonstration of the effects of individual differences on job performance. Standard recorders of the Sanborn type are used with the platform to obtain force traces.

**Sources of Further Information:**

J. H. Greene, "The Design and Initial Evaluation of a Force-Platform for Measuring Human Work," unpublished doctoral dissertation, State University of Iowa (1957).

J. H. Greene and W. H. M. Morris, "The Design of a Force-Platform for Work Measurement," *Journal of Industrial Engineering* **10,** 312 (1959).

Lucien Lauru, "Physiological Study of Motions," *Advanced Management* 22, 19 (1957), translated by Lucien Brouha.

James W. Barany and James H. Greene, "The Force-Platform: An Instrument for Selecting and Training Employees," *American Journal of Psychology* 74, 121 (1961).

An abstract of the final report is available from the project director.

**78. AUGMENTED QUEUING SYSTEM SIMULATOR.** *(College, Graduate School)* PAUL E. TORGERSEN, School of Industrial Engineering and Management, Oklahoma State University, Stillwater, Oklahoma. (1963–1964)

An existing single facility queuing simulator will be modified to simulate arrivals and services from exponential and normal distributions as well as to control the average rates of arrivals and services and the standard deviation of arrivals and services. Several of these single facility systems will then be combined through an interconnecting device to give an augmented system which will permit simulation of complex series and parallel operations. The equipment will be useful in both undergraduate and graduate courses in operations research and queuing theory.

**Sources of Further Information:**

Further information can be obtained from the project director.

*Other projects related to projects 75-78:*
*106.* MEMO-ACTIVITY CAMERA
*109.* DEVICES FOR SAMPLING STATISTICS

## Materials Engineering

**79. ATOMIC AND MOLECULAR RELATIONSHIPS IN THE STUDY OF PROPERTIES OF ENGINEERING MATERIALS.**

GEORGE N. BEAUMARIAGE, JR., Department of Engineering, Sacramento State College, Sacramento 19, California. (1960–1963)

1. Special overlays for use with an overhead projector have been made to teach phase diagrams. These 8″ x 10″ overlay sets, each with approximately eight sheets, are available at cost for the following diagrams: Fe–C, $Na_2O$–$SiO_2$, Fe–O, CaO–$Al_2O_3$–$SiO_2$, SAE 4130 steel; others are being prepared. Sets of 35 mm slides for illustrating phase diagrams are also being developed.

2. Special small heat-treating furnaces (range 0° to 2200°F) have been built for heat-treating small samples. Attached control and indicating devices can be adjusted by students working on instructional problems. Sample shapes are at present limited to small wafers or strips. A major value of these furnaces is the ease and speed with which the required heat-treating temperatures can be reached.

3. Atomic models of proportional atomic sizes or models to illustrate structural (atomic) characteristics are under development.

4. A new electric radiation-type furnace has been designed to accomodate large samples under a new range of conditions.

**Sources of Further Information:**

Further information can be obtained from the project director.

**80. PROJECTION SLIDES FOR MATERIALS SCIENCE.** JOHN C. SHYNE, Department of Materials Science, Stanford University, Stanford, California. (1961–1963)

The aim of this program is to develop a set of about 200 projection slides demonstrating metallurgical microstructures. The slides will illustrate important aspects of the subject matter taught in undergraduate level physical metallurgy courses. Sets of the photomicrographs in the form of projection slides (either 35 mm or 3¼″ x 4″) can be made up for distribution to interested institutions.

**Sources of Further Information:**

Further information can be obtained from the project director.

**81. LECTURE DEMONSTRATION EQUIPMENT FOR MATERIALS SCIENCE.** JOHN E. DORN, EARL R. PARKER, and JACK WASHBURN, Department of Mineral Technology, University of California, Berkeley 4, California. (1962–1963)

It is the purpose of this project to develop lecture-demonstration models that illustrate the scientific principles on the basis of which the useful properties of materials are correlated with atomic crystal and microstructure.

**Sources of Further Information:**

Further information may be obtained from the project directors.

**82. MICROSCOPY IN TEACHING THE SCIENCE OF SOLIDS.** *(Secondary, College)* KENNETH E. ROSE, Department of Metallurgy and Materials Engineering, University of Kansas, Lawrence, Kansas. (1962–1964)

The objective is to prepare a set of working outlines which will enable students and teachers to demonstrate and observe, by means of a microscope or microprojector, the formation and growth of crystals, the behavior of single and multiple component systems, plastic deformation, recrystallization, and polymorphic transformations. A distinct feature of the demonstrations is the small amount of time required; since most of them can be completed in five or ten minutes, they help to identify the phenomena as dynamic events involving phase changes and movement of atoms. Simple, readily available apparatus and non-hazardous reagents will be employed. Most of the demonstrations may be carried out with a low-power microscope or a microprojector with a polarizing attachment, glass microscope slides, an alcohol lamp or gas burner, and tweezers.

**Sources of Further Information:**

Basic techniques are described in E. M. Chamot and C. W. Mason, *Handbook of Chemical Microscopy*, John Wiley & Sons, Inc., New York, New York, 1951. Further information can be obtained from the project director.

*Other projects related to projects 79-82:*
87. MULTI-FUNCTIONAL MACHINE FOR MATERIALS TESTING AND PROCESSING EXPERIMENTS
91. ANALOG MATERIALS FOR STUDYING THE PLASTIC FLOW OF METALS
92. EXPERIMENTS AND DEMONSTRATION APPARATUS FOR DYNAMIC SYSTEMS, AUTOMATIC CONTROL, AND MATERIALS COURSES
98. EQUIPMENT FOR A NEW STRENGTH OF MATERIALS LABORATORY

## Mechanical Engineering

**83. TRANSPARENT OVERLAY VISUAL AIDS FOR ENGINEERING GRAPHICS.** H. M. NEELY, Department of Mechanical Engineering, Kansas State University, Manhattan, Kansas. (1959–1960)

Two series of transparent overlay visual aids were designed, developed, and used in engineering graphics at Kansas State University. The transparencies were developed conforming to the idea of presenting basic principles of graphics rather than showing solutions to specific problems.

**Sources of Further Information:**

Copies of the final report are available from the project director.

**84. SMALL HYPERSONIC WIND TUNNEL FOR STUDY OF HYPERSONIC GAS DYNAMICS.** JOHN A. FOX, Department of Mechanical Engineering, University of Rochester, Rochester 20, New York. (1960–1963) (Original grantee: Pennsylvania State University.)

The tunnel, a small hypersonic wind tunnel, uses an electric arc for gas heating purposes. The design Mach numbers are approximately 5 and up. The upper limit of velocity will depend upon the power, air supply, and/or vacuum available. The present area ratio corresponds approximately to Mach 6 (depending on the state of the gas) with air as the working medium. The test section is 1½″ in diameter. The physical test section size is 4″ in diameter and nozzles of this size compatible with boundary layer growth could be used. The present arc is provided by a modified rectifier-type arc welding unit with a maximum power output of 40 kv; it is anticipated that approximately one-half of this will be realized in the heat content of the gas (air). The unit is to operate as a push, pull, or push-pull device for which a variable geometry diffuser has been constructed and is part of the unit. Approximate costs for the configuration are as follows: welding unit, $3,200; materials, about $1,000. Other costs will depend upon gas storage, pumping and vacuum equipment available, etc. Machining time will require about 700 hours. Exact requirements for the configuration will be better known after reinstallation and evaluation.

**Sources of Further Information:**

Further information can be obtained from the project director.

**85. ENERGY CONVERSION DEVICES.** H. DEAN BAKER, Department of Mechanical Engineering, Columbia University, New York 27, New York. (Former director, ROBERT A. GROSS.) (1961–1963)

Two energy conversion devices are being built for use in undergraduate engineering laboratory instruction:

1. *A solar solid-state electric energy converter.* Commercial silicon cells (p-n junctions) will be employed to convert radiant energy to useful electrical energy which in turn will do simple work tasks such as heating a fluid, turning a wheel, or operating a simple transistor circuit. Principles of radiant energy measurement, irreversible thermodynamics, elementary solid-state theory, and the laws of thermodynamics will be illustrated.

2. *A plasma-diode energy device.* A simple plasma diode will be built to illustrate some basic properties of hot, radiating surfaces, ionization at surfaces, space charge neutralization, and some simple properties of a plasma.

The project also includes the development of a thermoelectric cooler, a fuel cell ($H_2$-$O_2$), and a supersonic propulsion nozzle.

**Sources of Further Information:**

Reports on the first two items are available from the project director.

**86. APPARATUS AND EXPERIMENTS IN MAGNETOGASDYNAMICS.** *(College, Graduate School)* ALI BULENT CAMBEL and THOMAS P. ANDERSON, Department of Mechanical Engineering and Gas Dynamics Laboratory, Northwestern University, Evanston, Illinois. (1961–1965)

Two instructional facilities are being developed: (1) a steady flow plasma arc jet, and (2) an electromagnetic shock tube having a conical discharge. Experiments relating to the spectroscopic determination of physico-chemical composition and the electron temperature are being modified. An analog computer solution of the Abel integral equation has been developed for both Pace (medium size) and Donner (table model) computing equipment. A special computer estimated to cost $1,000 is being designed and built to solve the necessary equations. A magnetohydrodynamic power generator operating on combustion gases seeded with alkali metals to increase the electrical conductivity is also being developed. The electrically conducting stream of hot gases (simulating the armature of a conventional dynamo) is passed between two pole pieces of an electromagnet (simulating the field) and electrodes (simulating the brushes) are used to draw out the power. The current experiments use recessed wall flame holders and a simple aspiration type seeding mechanism. Voltages up to 200 mv have been produced using relatively weak magnetic fields. Considerable work has also been done with electromagnetic shock tubes. A simple T-type electromagnetic shock tube has been designed and is being used to demonstrate thrust and action on an impeller. Electromagnetic shock tube studies will be continued so as to develop suitable inexpensive instrumentation for the analysis of the shock phenomena and ionization reactions as well as momentum and thrust measurements. In particular, a detailed study of the various techniques for measuring shock velocity will be made. Measurement techniques for determining the electrical conductivity of dense plasmas will also be studied. For this purpose a seeded flame unit will be built. This device will consist of a seeding unit of the aspirator type and a laminar burner. Various geometries for the burner will be considered since it is anticipated that the best configuration for an experiment may depend upon the particular measuring technique being employed. Provisions will be made to vary the seeding rate and thus the conductivity.

**Sources of Further Information:**

R. W. Porter, "Analog Computer Solution of the Abel Integral Equation and Applications to Plasma Temperature Measurement," Master's thesis in mechanical engineering, Northwestern University (August 1962).

C. F. Knopp, C. Gottschlich, and Ali Bulent Cambel, "The Spectroscopic Measurement of Temperature in Transparent Argon Plasmas," *Journal of Quantitative Spectroscopy and Radiative Transfer* (in press).

*Magnetohydrodynamics*, 16 mm sound film (available on request).

*The Influence of a Magnetic Field on Mercury Surface Waves*, 16 mm silent film (available on request).

Ali Bulent Cambel, "Magneto-Gasdynamics: Its Science and Technology," Sigma Xi National Lecture, *American Scientist* 50, 375 (1962).

Further information can be obtained from the project directors.

**87. MULTI-FUNCTIONAL MACHINE FOR MATERIALS TESTING AND PROCESSING EXPERIMENTS.** NATHAN H. COOK, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge 39, Massachusetts. (1961–1962)

This device is a bench-size machine, instrumented to measure the forces involved in turning, milling, drilling, reaming, and tapping. It is also suitable for tension, torsion, and compressive tests, combined tension-torsion tests, hardness tests, fatigue tests, wire drawing, punching, deep drawing, and bending. Materials tests can be carried out at temperatures to 1300°F. A strain gauge amplifier-recorder is used to record forces and torques. A micro-voltmeter is used to measure cutting temperatures.

**Sources of Further Information:**

A final report is available from the project director.

**88. EQUIPMENT FOR OBTAINING CONTOURS OF A FLUID MEMBRANE BY USE OF MONOSCOPIC PHOTOGRAMMETRIC TECHNIQUE.** *(College, Graduate School)* ALPHIA E. KNAPP, Department of Mechanical Engineering, University of Illinois, Urbana, Illinois, and FRANK J. MCCORMICK, Department of Applied Mechanics, Kansas State University, Manhattan, Kansas. (Grantee: Kansas State University, Manhattan, Kansas.) (1961–1963)

This equipment is designed to be used with presentations of Prandtl's membrane analogy. It consists of an I-beam base with a slide arrangement on one end on which is mounted a pressure chamber, a grid, and a 4 x 5 view camera, with a concentrated source of light mounted on the other end. The pressure chamber is mounted in line with the camera with the template perpenducular to the optical axis. The template with the desired section, secured by screws to the pressure chamber, is held in a vertical plane, thus eliminating the weight error of the soap film. The grid is placed directly in front of and parallel to the template and consists of parallel nylon filaments spaced 0.125″ apart. The light is located directly above the camera and both the light and the template are positioned correctly to ± 0.005″ from the camera lens by verniers mounted on the I-beam base on the camera support rod. The light is beamed through the parallel grid onto an opaque soap film drawn over the template section. The shadows on the soap film are distorted, owing to the distension of the soap film from the plane. The membrane is photographed, and an instantaneous recording of the soap film is made. The negative is read, using photogrammetric procedures, and the contours of the soap film are recorded. The slope and the volume of the soap film can be taken from these contours; Prandtl's analogy can then be applied. The negative can be read by a coordinate measuring microscope or by projection. Accuracy of elevation can easily be determined to ± 0.001″; with extreme care as to selection of the photographic plate and the template, an elevation accuracy of ± 0.0001″ should be possible.

This equipment will permit completion of a membrane analogy experiment in two three-hour laboratory periods.

**Sources of Further Information:**

A. E. Knapp, "A Monoscopic Photogrammetric Method for Obtaining Contours of a Fluid Membrane," Master of Science thesis, Kansas State University, Manhattan, Kansas (1960).

**89. COMBINED SHOCK TUBE, SHOCK TUNNEL, LIGHT GAS GUN, AND HOT SHOT WIND TUNNEL APPARATUS.** *(College, Graduate School)* E. K. PARKS and R. E. PETERSEN, Department of Mechanical Engineering, University of Arizona, Tucson, Arizona. (1961–1963)

The apparatus will consist of a shock tube of small cross section (approximately 4″ x 4″) composed of five or six sections having a total length of about 20′. One of the sections will be provided with windows for optical viewing. An arc chamber, a launch tube, and a de Laval nozzle will also be used in conjunction with certain sections of the basic shock tube to adapt the apparatus to use as a shock tunnel, light gas gun, or hot shot wind tunnel. The cost of the partially instrumented apparatus is estimated at $2,000, if fabricated by the university. Additional instrumentation (e.g., piezo pressure, temperature, etc.) could increase the cost by $3,000.

**Sources of Further Information:**

Glass, Martin, and Patterson, "A Theoretical and Experimental Study of the Shock Tube," *Report No. 2*, University of Toronto, Institute of Aerophysics.

David Kohlman, "A Theoretical and Experimental Investigation of a High Speed Light Gas Gun," Master's thesis, University of Kansas (1960).

Further information can be obtained from the project directors.

**90. MULTI-PURPOSE TESTER FOR DEMONSTRATIONS AND INVESTIGATIONS OF SHOCK AND VIBRATION PHENOMENA.** *(College, Graduate School)* ALI SEIREG, Department of Theoretical and Applied Mechanics, Marquette University, Milwaukee 3, Wisconsin. (1961–1962)

A portable two-mass system has been devised capable of illustrating most phenomena of shock and vibration, separately or combined. It also provides a versatile mechanical model for investigating these phenomena on different levels. The equipment can be briefly described as a two-mass system with leaf-spring suspension for the main and the secondary masses. The spring supports have straight sides for linear stiffness and different types of profiles for non-linear stiffness. Variable speed exciters are mounted on the two masses to induce disturbance of different amplitude and frequencies. The motions of the two masses are damped by three adjustable dampers, two of which are connected between each mass and the frame and the third between the two masses to dampen their relative motion. A frictional shell assembly, including a variable speed motor and a wedged table, is designed to apply different frictional forces on the main mass. Impacts are provided on both the main or the secondary masses by a dual suspension pendulum with exchangeable hammers of different shapes and materials. Instrumentation for measuring strains, displacements, velocities, and acceleration is utilized.

**Sources of Further Information:**

A final report can be obtained from the project director. A sound film showing the capabilities of the tester will be available in early 1963.

**91. ANALOG MATERIALS FOR STUDYING THE PLASTIC FLOW OF METALS.** *(College, Graduate School)* MILTON C. SHAW, Department of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh 13, Pennsylvania. (1961–1963)

A number of experiments are being designed and apparatus assembled to illustrate the main features of the plastic flow of materials when subjected to large plastic strains. By using plasticine and wax as analog materials for metals, it is possible to reduce the forces the equipment must withstand by about three orders of magnitude. Apparatus is being constructed from wood, plastics, and wire to demonstrate not only the fundamental laws of plasticity, but the major working processes as well, including rolling, extrusion, drawing, forging, cutting, and power spinning. Simple methods of applying grids for flow studies and of measuring forces and energy are being devised. The apparatus is being designed to be as inexpensive as possible so that each student may be supplied with his own kit.

**Sources of Further Information:**

Further information can be obtained from the project director.

**92. EXPERIMENTS AND DEMONSTRATION APPARATUS FOR DYNAMIC SYSTEMS, AUTOMATIC CONTROL, AND MATERIALS COURSES.** J. L. SHEARER, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge 39, Massachusetts. (1961–1963)

Experiments and apparatus are being developed for use in courses of the following types:

1. A new dynamic systems course (second year) dealing with the analysis and response of a wide range of physical systems (mechanical, electrical, thermal, hydraulic, etc.) involving the unsteady flow of matter, energy, and information. Early emphasis has been placed on such classroom teaching aids as models of simple systems and analogies, computers, and graphical models.

2. An elective course for seniors in mechanical engineering called *Introduction to Automatic Control*. Typical planned demonstrations include: (a) pneumatic position servomechanism operating from compressed air bottle, (b) attitude control of a dummy satellite or space vehicle, (c) temperature control of a simple process, (d) demonstration of inversion principle by use of feedback around high gain amplifier, (e) development of a simple portable solid-state analog computer for classroom and direct student use, and (f) demonstration of root locus concept through the use of a simple electromechanical angle computer. To date the following apparatus has been developed: (1) an electromechanical angle computer for demonstration of the root locus concept, (2) a "closed loop" pneumatic function generator, (3) a servocontrolled inverted pendulum, and (4) a pneumatic power amplifier with no moving mechanical parts for possible use with a demonstration of a reaction jet attitude control system.

3. Undergraduate courses in materials in which the use of automatically controlled testing machines is of growing importance. For instance, the yield point of mild steel, the possible relation between creep and relaxation, and the beginning of fracture in the neck of a test specimen can all be readily observed and studied when the testing machine is automatically controlled and the data are recorded automatically and continuously. An exhaustive study has revealed that it is not feasible at this time to develop a universal controller because of the great differences in the characteristics of various testing machines and the apparent need to modify individual machines in order to achieve suitable control.

**Sources of Further Information:**

An interim report and various supplementary reports on individual parts of this project are available from the project director.

**93. CONTROL SYSTEM ANALOG FOR TEACHING CLOSED-LOOP CONTROL THEORY.** LESLIE M. ZOSS, Department of Mechanical Engineering, Valparaiso University, Valparaiso, Indiana. (1961–1964)

The purpose has been to develop a control system analog for use in teaching the fundamentals of closed-loop control theory. The equipment may be used for both demonstration and experimentation. This analog helps in teaching such fundamental control concepts as controller selection, controller adjustment, control loop stability, rise time, overshoot, offset, and the effect of a disturbance and load change. Numerous easily changed experiments and experimental conditions are possible as a result of component construction. Commercially available components have been used, and thus the control system analog can be constructed in school shops by semi-skilled personnel. Basic theory of closed-loop control may be explained using only this single piece of equipment. The cost is approximately $2,000 plus labor for construction.

**Sources of Further Information:**

Copies of the final report on the equipment are available from the project director. Experiments to cover a semester's work are being prepared. These will include student instruction sheets, detailed reports on actual experiments, and instructor's notes for experiments fundamental to research on closed-loop control theory.

**94. TAKE-HOME KITS FOR EXPERIMENTATION IN ENGINEERING.** WALTON FORSTALL, Department of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh 13, Pennsylvania. (1962–1963)

The objective is to develop take-home experiments which include fluid mechanics, statics and dynamics, strength of materials, experimental stress analysis, vibrations, mechanical design, and materials engineering. Five or six kits will be made up using simple and readily available materials. A descriptive pamphlet will be written for each kit. By assigning homework experiments, it will be possible to incorporate more laboratory work in the curriculum of undergraduate engineering students.

**Sources of Further Information:**

Further information can be obtained from the project director.

**95. MICROPNEUMATIC BREADBOARDS FOR FLUID MECHANICS AND CONTROL LABORATORIES.** *(Secondary, College)* JOSEPH MODREY (Present address: Mechanical Engineering Department, City and Guilds College, London, S.W.7, England.) and W. A. AUBREY, Department of Mechanical Engineering, Union College, Schenectady 8, New York. (1962–1963)

Pocket-size models are being developed to replace to some degree the massive plumbing system typifying present fluid mechanics laboratories. Instead of pipes, etc., passages will be made by cutting grooves in illustration board or metal. Orifices, restrictors, plenums, etc., will be formed by silhouetted channels about 1/16" deep and to scales 1/10 to 1/100 of present laboratory equipment. These channels will be sandwiched between lucite plates. Pressure taps in cover plates will communicate with vital sectors of the passage. Using only a microscope and razor blade, students will be able to create pneumatic RCL circuits. It is hoped that this program will also be able to evolve methods of making pneumatic relays and triodes. Because of low cost and ease of modification of models, students should enjoy more freedom for personal explorations. The contemplated models will be most useful at the junior and senior levels of fluid mechanics, vibration, design, and control courses. One or two experiments may also be designed for high school science courses. The program will investigate the best techniques for making models, develop some experiments, and outline general rules of mechanics particularly suited to miniaturized and transient systems.

**Sources of Further Information:**

Further information can be obtained from the project directors.

**96. EQUIPMENT FOR TEACHING DYNAMIC ANALYSIS.** JOSEPH E. SHIGLEY, Department of Mechanical Engineering, The University of Michigan, Ann Arbor, Michigan. (1962–1963).

Two economical, versatile, and small items of laboratory equipment are to be developed. They consist of a bench-type machine for demonstrating and teaching the meaning of dynamic unbalance in machinery, and a bench-type cam and follower mechanism in which the follower has both mass and elasticity so that at full operating speeds the follower motion will not conform to the command machined into the cam. Both of these items of equipment are to be instrumented with appropriate, reasonably priced transducers so that such interesting quantities as displacement, velocity, force, torque, etc., can be displayed on an oscilloscope or fed into an electrical analog computer for various operations.

**Sources of Further Information:**

*The Mechanical Analysis Laboratory of the Department of Mechanical Engineering at the University of Michigan, Ann Arbor*, by Herbert H. Alvord. This report describes comparable equipment and teaching procedures. It is not part of the present project, but can be obtained from the Department.

Further information can be obtained from the project director.

**97. EXPERIMENTS ON COUPLED FLOWS IN DIRECT CONVERSION DEVICES.** STANLEY W. ANGRIST, Department of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh 13, Pennsylvania. (1963–1964)

The objective is to formulate experiments using solid state devices, which allow the student to determine for himself the important roles played by several independent variables. In addition, the experiments will permit study of those solid-state parameters which are important in direct conversion devices. The experiments will be graded in difficulty, starting the student off with the study of a simple thermoelectric generator and concluding with the study of a so-called magnetothermoelectric generator.

**Sources of Further Information:**

Further information can be obtained from the project director.

**98. EQUIPMENT FOR A NEW STRENGTH OF MATERIALS LABORATORY.** SAMUEL V. CLARK, Department of Engineering Mechanics, University of Michigan, Ann Arbor, Michigan. (1963–1964)

The objective is to modify a commercial hand-operated testing machine to make it suitable for torsion and tension tests. The equipment is to be relatively inexpensive to make it possible for the individual student to perform bench-scale experiments and develop his own ideas for extension of assigned work. The machine will have a load capacity of 10,000 pounds.

**Sources of Further Information:**

Further information can be obtained from the project director.

**99. PRELIMINARY DESIGN OF AN EDUCATIONAL COMBUSTION REACTOR.** C. R. GRAFLY DOUGHERTY, Department of Mechanical Engineering, Rutgers University, New Brunswick, New Jersey. (1963–1964)

The objective is to complete, including construction of an experimental model, the preliminary design of a combustion reactor suitable for student operation. The equipment will be capable of measuring heat release, reaction rates, blowout data, and efficiencies as a function of the fuel-oxidizer mixture ratio. This represents the first phase of a program for the complete design, construction, test, and development of an educational combustion reactor.

**Sources of Further Information:**

Further information can be obtained from the project director.

**100. ELECTRICAL ANALOG FOR FLUID AND HEAT FLOW AND DIFFUSIONAL PROCESSES.** PANAGIOTIS RAZELOS, Department of Mechanical Engineering, Columbia University, New York 27, New York. (1963)

The objective is to design and develop an inexpensive three-dimensional analog device employing a liquid ionic conductor. The dimensions of the device will be easily modifiable to suit different requirements. The apparatus will be useful in studying both steady state and transient phenomena.

**Sources of Further Information:**

Further information can be obtained from the project director.

*Other projects related to projects 83-100:*

40. EQUIPMENT FOR PHOTOELASTIC STRESS ANALYSIS OF STRUCTURAL GEOLOGY PROBLEMS
46. LECTURE DEMONSTRATIONS IN AERODYNAMICS
49. OPTICAL ANALOG OF AUTOMATIC X-RAY MONITOR AND CONTROL SYSTEMS
60. STABILITY OF EQUILIBRIUM IN STRUCTURAL MECHANICS
61. DIMENSIONAL ANALYSIS—ITS APPLICATION IN SOIL MECHANICS
67. PROTOTYPE SYSTEMS LABORATORY EMPLOYING ELECTRO-HYDRAULIC, HYDRAULIC, AND HYDROMECHANICAL COMPONENTS

## Nuclear Engineering

**101. PILE OSCILLATOR FOR UNIVERSITY NUCLEAR TRAINING REACTORS.** *(Graduate School)* ALBERT L. BABB and WILLIAM E. WILSON, JR., Nuclear Reactor Laboratories, University of Washington, Seattle 5, Washington. (1961–1963)

The oscillator is a novel device for introducing sinusoidally varying reactivity into a nuclear reactor for use in performing reactor kinetics experiments. It achieves reactivity control by varying the neutron absorption rate in a small sample of cadmium inserted into the core or reflector of a reactor. A sinusoidal variation in the neutron absorption rate will cause a sinusoidal variation in reactivity and reactor power at the same frequency. The magnitude of the reactivity oscillations is controlled by the amplitude of the sinusoidal variations.

The pile oscillator incorporates the following features that make it an excellent instrument for educational purposes: (1) simple construction, so that fabrication can be accomplished in an average college or university shop; (2) utilization of a neutron detection chamber in a conventional reactor instrumentation system; (3) use of commercial components wherever feasible; (4) simplified and graphic presentation of data employing a dual beam oscilloscope and low-frequency oscillator which will provide the student with a large amount of information—simply, rapidly, and directly; (5) remote pile oscillator frequency control; (6)

simple operation and maintenance; and (7) versatility, so that the pile oscillator may be utilized in nuclear engineering laboratory courses at any of the existing teaching reactors on university and college campuses.

**Sources of Further Information:**

*Report of the U. S. Atomic Energy Commission Education Assistance Activities*, Division of Reactor Development, Education and Training Branch, April 1960.

R. M. Cordy, "Measurement of the KEWB Reactor Transfer Function by Modulation Techniques," *Transactions of American Nuclear Society*, June 1960.

G. Smiley, "Ultra-Low Frequency, Three Phase Oscillator," *Proceedings of the Institute of Radio Engineers* 42, 670 (1954).

An interim report can be obtained from Dr. Babb.

# F. General

**102. OVERHEAD PROJECTION SERIES OF LECTURE EXPERIMENTS IN THE SCIENCES.** *(Secondary, College)* HUBERT N. ALYEA, Department of Chemistry, Princeton University, Princeton, New Jersey. (1960–1964)

The purpose is to develop several thousand lecture experiments to be carried out on the vertical and horizontal stages of an overhead projector. Material has been prepared in the following areas:

1. *Biology*. A series of filmstrips and overlay transparencies covering unit topics in biology and photo-micrographed biological dissections. Accompanying manuals.

2. *Chemistry*. Use of vertical stage projector only. Transparent plastic or glass cells used to show: acid-base indicator color changes; titrations; other chemical reactions; formation of crystals, precipitates, gases, etc.; electrolysis and other electrical effects; timing devices, i.e., clock reactions; temperature measurements; various heating devices; and such operations as evaporation, distillation, filtration, adsorption, etc. About 2,000 of the experiments described in the *Tested Demonstrations* series *(Journal of Chemical Education*, 1956–60) are being adapted to overhead projection techniques.

3. *Physics*. Use of both horizontal and vertical stages of the projector. Many of the experiments are suitable for treatment of magnetism, heat, electricity, mechanics, etc., in physics courses.

**Sources of Further Information:**

Details of this project as it relates to chemistry are being published monthly in the *Journal of Chemical Education*. The first article in this series, entitled TOPS *(Tested Overhead Projection Series)*, appeared in the January, 1962, issue. Another series was initiated in the February, 1962, issue of *The Science Teacher*. When material for biology becomes available, announcement will be made in appropriate journals.

Further information can be obtained from the project director.

**103. LECTURE TABLE THERMOMETER AND VOLTMETER.** *(Secondary, College)* F. B. DUTTON, Science and Mathematics Teaching Center, Michigan State University, East Lansing, Michigan. (1961–1963)

The thermometer-voltmeter is provided with a 4′ scale placed in front of a fluorescent lamp. The sensing elements for temperature measurement are thermocouples and thermistors. Output from the sensing elements is opposed by a fixed EMF and the difference fed to a unit which controls a motor. The motor drives a balancing potentiometer and the indicator. With appropriate settings of the controls, temperature ranges of 5°, 100°, or 1200°C and EMF of 0-2 volts may be spread across the scale.

**Sources of Further Information:**

A report will be available from the project director in 1963.

**104. EQUIPMENT FOR PRODUCING STEREOGRAMS.** *(Secondary, College)* DAVID D. DONALDSON, Howe Laboratory of Ophthalmology, Harvard University Medical School, Boston 14, Massachusetts. (1961–1963)

An instrument is being built which can automaticaly reproduce in diagrammatic form a pair of stereoscopic drawings of an object. The drawings thus produced can be presented to the student either by means of the stereoscopic viewer or by stereoscopic projection. The equipment will consist of (1) a scanner which will determine the contours and shape of the object, (2) an equation solver or analog computer which will analyze the data, and (3) a plotter which will record the final data in the form of three-dimensional drawings.

**Sources of Further Information:**

Further information can be obtained from the project director.

**105. METERLESS POTENTIOMETER NULL-POINT INDICATORS.** *(Secondary)* HERBERT HORKY. Association of Laboratory Teachers, 68 Trinity Place, New York 7, New York. (1961)

The indicators developed consist of two circuits, each employing a 6E5 radio tube which has a green fluorescent screen and a V-shaped shadow. The simpler of the two, a one-tube circuit, is sensitive to a potential difference of 0.5 volt. It is useful for student laboratory experiments and teacher demonstrations as a voltage detector. The second circuit uses a 6C6 and a 6E5. It is sensitive to a potential difference of 0.005 volt and therefore can be used in situations requiring a greater degree of sensitivity, as in pH measurements. The novel feature of these null-point indicators is that they dispense with costly and fragile meters in experiments requiring the detection of small or zero potential differences. The cost of the one-tube circuit is $8; the two-tube circuit costs $17.

**Sources of Further Information:**

Further information can be obtained from the project director.

**106. MEMO-ACTIVITY CAMERA.** H. G. THUESEN, School of Industrial Engineering and Management, Oklahoma State University, Stillwater, Oklahoma. (1961–1962)

The memo-activity camera has been designed to obtain sequenced photographs of situations to be studied. The camera, through an interval timer and mechanism, records on each exposed 16 mm frame the absolute time at which the event occurred. Frames may be exposed at intervals of 0.005 min., 0.04 min., 0.2 min., 1.0 min., 2.0 min., or at random intervals. The camera should be useful in both instruction and research, particularly in industrial engineering and management, as well as in areas such as microbiology, traffic and highway engineering, statistical analysis, psychology, sociology, and business administration.

**Sources of Further Information:**

Copies of the final report are available from the project director.

# G. Mathematical Sciences

**107. TEACHING AID FOR ANALOG COMPUTER INSTRUCTION.** KARL KAMMERMEYER and JAMES O. OSBURN, Department of Chemical Engineering, State University of Iowa, Iowa City, Iowa. (1959–1960)

The teaching aid is a plugboard similar in appearance to the board of a Heathkit analog computer, but containing only four amplifiers. The plugboard is connected to the amplifiers on the computer by plugs and jacks. In an analog computer laboratory, each student gets a plugboard and a collection of resistors, capacitors, and connectors. He then proceeds to build his program independently of the computer. When this has been finished correctly, the board is plugged into the computer and the solution is obtained in a short time. In this way, the use of the computer and the time of the instructor are extended. The plugboards are built from standard electronics parts at a cost of about $20, plus fifteen hours of construction time. The extensive use of the board in computer laboratory instruction during the last two years has shown that it is a versatile and eminently practical accessory.

**Sources of Further Information:**

James O. Osburn, "Analog Computer Instruction. A Plugboard Teaching Aid," *Journal of Chemical Education* 38, 492 (1961).

**108. INEXPENSIVE DIGITAL COMPUTERS AND LOGICAL BUILDING BLOCKS.** *(Secondary, College)* ALLEN L. FULMER, Department of Science and Mathematics, Oregon College of Education, Monmouth, Oregon. (1960–1963)

1. *SPEDTAC* (Stored Program Educational Digital Transistorized Automatic Computer). SPEDTAC is a serial, single address, fixed point, binary-type internally stored program digital computer designed specifically as a classroom and laboratory tool to aid in teaching mathematics and engineering courses. The computer's list of sixteen basic instructions is short enough to master quickly, yet diversified enough to permit the handling of a wide variety of arithmetical and logical problems. The computer features a nonvolatile magnetic disc memory with a capacity of 256 thirteen-bit words, and an average access time of 8.3 msec. The logic is implemented with diode-transistor Nand type building blocks con-

tained on plug-in printed circuit cards for ease of maintenance. Manual input and visual output are provided for all registers. Logic is included to permit the addition of a standard commercial paper type reader to facilitate faster input and provide additional storage capacity if desired. Other types of input-output equipment may also be added. The computer occupies a minimum of floor space, and there are no special cooling or power requirements. A prototype version is now in operation at Oregon College of Education, and final modifications are under way.

2. *Relay-type Logical Building Blocks.* Typical building blocks consist of flip-flops, full adders, clocks, etc. The individual building blocks may be interconnected by means of patch cords to form counters, shift registers, and simple arithmetic and logic units. No special auxiliary apparatus is required for use other than a simple low voltage DC power supply. Hand tools are sufficient for construction, and a minimum of facilities is required. Estimated component cost ranges from $5 to $20 per building block. Schematic diagrams and photographs will be available.

**Sources of Further Information:**

Further information can be obtained from the project director.

**109. DEVICES FOR SAMPLING STATISTICS.** ROBERT W. HEATH, Department of Systems Engineering, University of Arizona, Tucson, Arizona. (Present address: Educational Testing Service, Princeton, New Jersey.) (1960)

Two devices have been developed that sample from an arbitrary population distribution and present the observation to the operator. The electromechanical device developed under the present project employs a motor-driven arm that rotates a sensing unit over a circular pattern of contacts divided into sectors, the length of each sector being proportional to the area under the normal curve. When the arm stops, the observation is presented to the operator by an indicator light representing one of thirteen score values. The electronic unit uses an oscillator to drive counting tubes that are gated by means of selector switches. Through these switches, any shape of distribution can be set in the device. When the operator takes a reading, the counting is interrupted and the observation is presented to the operator by a Nixie read-out tube. The parts for the electromechanical device cost less than $100, and the components for the electronic apparatus were purchased for about $350. The electromechanical device could be assembled in any workshop; the electronic sampling unit requires more work but could be constructed by an electronic technician.

**Sources of Further Information:**

Further information concerning construction details and wiring diagrams can be obtained from Albert E. Bartz, Department of Psychology, Concordia College, Moorhead, Minnesota.

**110. MECHANICAL ANALOG OF BINARY ADDER FOR DIGITAL COMPUTERS.** *(Secondary, College)* SCOTT TABOR POAGE, Engineering Research Division, Oklahoma State University, Stillwater, Oklahoma. (Present address: Industrial Engineering Department, Arlington State College, Arlington, Texas.) (1960)

The device is a mechanical analog of the binary adder circuit of digital computers. It is made of string and pulleys and represents a normally closed switch, two normally open switches in parallel, and two normally open switches in series. In addition to demonstrating the functioning of the binary adder at a very slow speed with visible motion, the device can also be used to demonstrate various ideas and circuits relating to Boolean algebra, binary arithmetic, and the theory of switching circuits. The device is relatively simple to construct and low in cost (approximately $10 for new materials). Its construction could be a worthwhile project for a high school student interested in model-building.

**Sources of Further Information:**

A limited supply of copies of plans for the device is available from the Engineering Research Division, Oklahoma State University.

**111. FORMAL DEDUCTIVE AND SYMBOLIC LOGIC TEACHING EQUIPMENT.** *(Secondary, College)* STANLEY J. BEZUSZKA, S.J., Department of Mathematics, Boston College, Chestnut Hill 67, Massachusetts. (1961–1963)

1. *Classical Formal Deductive Logic Machine.* The basic circuit of the machine, which can be duplicated from the circuit diagram by a high school junior or senior, consists of 6v relays and rotary switches. Two boxes (one about 24″ x 18″ x 9″, the other 12″ x 12″ x 9″) will hold the machine. Construction requires no special equipment or facilities. Assembly time will vary, but should not take over two months. Attempts to develop a more compact and conveniently port-

able demonstration device will be made by use of transistors and replacement of relays with rotary switches.

2. *Symbolic Logic Device.* Experimental circuits have been devised and set up for the propositional calculus of symbolic logic for four distinct elements. On the basis of these circuits, a demonstration model of a symbolic logic machine will be built which will yield the truth value of a proposition that is a combination of propositions.

3. *Power Sets.* Simple circuits have been designed to exhibit the power set of a set A with two elements and three elements. The machine will yield the intersection, the union of any two sets, and the complement of each of the subsets in the power set of set A.

4. *Base Converters.* The circuit for base converters using stepping relays has been drawn. A more feasible approach seems to be a circuit using resistances and a bridge (null) circuit. Conversion from one base to another should be possible for approximately ten different bases.

5. *Relations.* A preliminary circuit designed to determine the properties of relations (reflexivity, symmetry, transistivity) on a set A with three elements has been extended to a set A with four and five elements. A model is being built with the additional feature that the types of orderings of the individual relations will also be displayed on the panel.

6. *Addition and Multiplication Devices.* The addition and multiplication devices are by-products of previous circuits and are simple drill machines suitable for the elementary grades.

7. *Graphing Machines.* Experimentation with graphings of simple linear equations indicates that a display panel suitable for class demonstration is quite possible. At present, either the slope of the line or the coordinates of several points satisfying the equation can be fed into the device. The circuit will be extended to include graphs of some of the conics.

**Sources of Further Information:**

Further information can be obtained from the project director.

**112. MATERIALS FOR TEACHING ARITHMETIC.** *(Elementary)* JOSEPH N. PAYNE, University School and School of Education, The University of Michigan, Ann Arbor, Michigan. (1961–1963)

Development work has been done on six items:

1. *Strips.* A set of sixty strips made of brown tempered hardboard ½″ x ¼″. Lengths are in multiples of ½″ units from ½″ through 5″. All strips more than 2½″ long have a groove on one of the ½″ sides marking each 2½″ interval. Strips over 2½″ long are a different shade of brown from the strips 2½″ and under. Each set contains twenty ½″ strips, ten 1″ strips, seven 1½″ strips, five 2″ strips, four 2½″ strips, three 3″ strips, three 3½″ strips, two 4″ strips, two 4½″ strips, and four 5″ strips. The estimated cost is $1.25 per set.

2. *Bead Frame and Abacus.* A 10″ wire, with 20 nylon beads of alternating colors by sets of five beads. The ends of the wire are bent at 90° angles and are inserted in a 1″ x 1¾″ block of tongue-and-groove mahogany wood. Two or more of the bead wires can be joined for use as an abacus. The estimated cost is $0.38 each.

3. *Hundred Chart.* A printed hundred chart, 10″ x 10″, with numerals 1 to 100 on one side and 100 circles, grouped by fives, on the other side. The estimated cost is $0.10 each.

4. *Number Line.* A printed number line 200″ long with numerals 0 to 100. The estimated cost is $0.25 each.

5. *Circle Line.* A printed strip 200″ long with 100 circles, alternating colors every five circles. Marks after each circle can be lined up with points for the numerals in the number line. The estimated cost is $0.25 each.

6. *Monograph.* A monograph in preparation contains results of experimental uses of the manipulative aids and suggestions for their classroom adaptation.

For commercial production of the manipulative aids, two additional items are being suggested: (a) squared paper 10″ x 10″ with 1″ squares and 5″ x 5″ with ½″ squares and (b) felt strips for teachers that are enlarged models of the strips described in Item 1.

**Sources of Further Information:**

Further information can be obtained from the project director.

**113. EDUCATIONAL COMPUTER KIT.** *(Secondary)* ARNOLD H. KOSCHMANN, Department of Electrical Engineering, University of New Mexico, Albuquerque, New Mexico. (Former director, R. K. MOORE.) (1959–1963)

The University of New Mexico Educational Computer is a digital computer with an internally stored program; it includes the basic features of modern high-speed digital computers. The memory has a capacity of 384 words consisting of fifteen binary digits plus sign bit. The unique memory consists of a circulating loop of magnetic tape with standard quarter-track audio heads for reading and writing. The computer operates in the binary number system, with provision for octal input and output. Machine speed is severely limited by using manual input and output and by the slow speed of the memory. The major purpose of the machine is to serve as a vehicle for teaching certain topics in mathematics and physics, as well as for teaching the principles of modern computer operation and programing. Use of the computer makes topics such as number systems, binary numbers, Boolean algebra, arithmetic operations, and numerical computation much more exciting and much more realistic for students. Because of its slow speed, the computer is well adapted to educational use but is not well suited to lengthy computation. By making the computer available in kit form, it is anticipated that the cost can be held at $1,000 to $1,500.

**Sources of Further Information:**

Further information can be obtained from the project director.

*Other projects related to projects* **107-113:**

52. ELECTRONIC ANALOG TEACHING AID FOR MATHEMATICS, SCIENCE, AND ENGINEERING
66. INEXPENSIVE DIGITAL-TO-ANALOG CONVERTER FOR CURVE PLOTTING WITH SMALL DIGITAL COMPUTERS
73. AUTOMATIC PLOTTING OF PHASE, GAIN, AND ROOT LOCUS FROM POLE-ZERO CONSTELLATIONS

# H. Meteorology

**114. LABORATORY AND DEMONSTRATION EQUIPMENT FOR METEOROLOGY.** *(Secondary, College)* FRANK R. BELLAIRE, Department of Engineering Mechanics, Meteorological Laboratories, The University of Michigan, Ann Arbor, Michigan. (1961–1962)

Apparatus has been constructed for demonstrating:

1. The radiation characteristics of the atmosphere by utilizing and combining the radiation experiments of physics. The absorption of energy of different wave lengths by atmospheres of varying composition and temperature is shown.

2. The characteristics of atmospheric vortices. The device consists of a vortex chamber which can be altered in dimensions to demonstrate various scales of atmospheric vortices. It is instrumented to indicate temperature and wind speed differences within and surrounding the vortex and to show the direction of flow at various locations within the vortex chamber.

3. The hemispherical flow of the atmosphere. The apparatus simulates wave and vortex motion of large-scale atmospheric systems in a rotating liquid with superimposed zonal flow induced by a heat source and a heat sink.

4. Atmospheric flow with Schlieren or shadow techniques. The apparatus consists of a tank in which different types of fluid flow are simulated in gases and liquids to demonstrate convection, fronts, and other atmospheric phenomena.

**Sources of Further Information:**

A final report can be obtained from the project director.

**115. MANUAL OF LECTURE DEMONSTRATIONS, LABORATORY EXPERIMENTS, AND OBSERVATIONAL EQUIPMENT FOR ELEMENTARY METEOROLOGY.** *(Secondary, College)* HANS NEUBERGER, Department of Meteorology, The Pennsylvania State University, University Park, Pennsylvania. (1961–1962)

Fifty meteorological demonstrations, experiments, and observations are described. Illustrated directions for the construction of the necessary equipment are given. For this equipment, only simple tools and inexpensive materials are used, usually those found in an average household, including discarded tin cans, aluminum foil, glass jars, etc. In addition to detailed construction drawings, photographs of completed apparatus are included. Each section contains questions for students to answer, a list of needed materials, and the approximate cost of the apparatus (usually amounting to less than $1.00).

**Sources of Further Information:**

The manual and further information can be obtained from the project director.

*Other projects related to projects* **114-115:**

12. TRANSISTORIZED CIRCUITS FOR INTEGRATION OF SOLAR RADIATION, TEMPERATURE, AND HUMIDITY

# I. Physics

**116. NEW TYPES OF CHRISTIANSEN FILTERS.** *(Secondary, College)* LOUIS AUERBACH, Science Department, Newtown High School, Elmhurst 73, New York. (Grantee: New York University, New York 3, New York.) (1959–1960)

Christiansen filters are generally mixtures of a solid and a liquid whose dispersion curves intersect at a definite wavelength. They are optically homogeneous for this one wavelength and scatter all others. They are, therefore, simple, cheap, narrow band-pass filters. Such filters should be useful for teaching purposes in college and high school courses. The project was designed to produce new types free of the major disadvantage of extreme temperature sensitivity and the practical disadvantage of a liquid component. Plastic-glass filter mixtures were examined for this purpose.

**Sources of Further Information:**

Louis Auerbach, "More Christiansen Filters," *American Journal of Physics* 28, 743 (1960).

Further information can be obtained from the project director.

**117. OVERHEAD PROJECTOR DEMONSTRATIONS IN PHYSICS.** WALTER EPPENSTEIN, Department of Physics, Rensselaer Polytechnic Institute, Troy, New York. (1959–1961)

Four groups of accessories for overhead projectors have been designed and constructed for use in physics lectures presented to large groups of students.

1. *Overlays.* A series of overlays has been prepared consisting of single transparencies, colored overlays (usually four to six per transparency), movable overlays, and "technamated" overlays for use with a polaroid spinner. The transparencies are diazotype reproductions from an ammonia-developing process.

2. *Models.* Motorized and non-motorized models made of lucite include: demonstrations of simple harmonic motion, wave phenomena and superposition, cyclotron model, AC generator, primary and secondary coils, kinetic theory, vector addition, and probability board. Collision and scattering phenomena are demonstrated by rolling steel balls dipped in colored inks across the projector, leaving visible tracks of various colors. Rutherford scattering and the Compton effect can also be demonstrated with these devices.

3. *Breadboards for Electrical Connections.* A transparent breadboard has been constructed for electrical connections. On this flexible board, many circuits have been set up using miniature batteries, switches, etc. Actual current and voltage measurements are made by projection meters mounted on the overhead projector. A circuit diagram is projected first; the actual circuit is then superimposed. This technique has been used in discussion of electrical circuits involving resistors as well as themistors, using DC and AC. When a permanent magnet is included, the Hall effect can be demonstrated directly on the overhead projector. The time constant for the charge and discharge of a capacitor can also be measured easily. This project was awarded first prize at the Apparatus Competition of the American Association of Physics Teachers in New York, February 1961.

4. *X-Y Plotter.* An X-Y plotter and associated circuits have been completed. This recorder plots on the stage of an overhead projector any signal from suitable amplifiers, analog computers, etc.

**Sources of Further Information:**

Walter Eppenstein, "Use of an Overhead Projector in Demonstrations before Large Groups," *American Journal of Physics* 27, 443 (1959).

Walter Eppenstein, "More Visual Aids in the Physics Lecture," *Ibid.* 29, 134 (1961).

Walter Eppenstein, *Toward More Effective Teaching at Rensselaer*, Office for Institutional Research, Rensselaer Polytechnic Institute, No. 5, p. 6; No. 7, p. 2; and No. 8, p. 2.

A detailed report of the whole project is available from the project director.

**118. APPARATUS DRAWINGS PROJECT.** W. C. KELLY and R. G. MARCLEY, American Institute of Physics and American Association of Physics Teachers, 335 East 45th Street, New York 17, New York. (1959–1960)

The AIP-AAPT Apparatus Drawings Project has prepared complete shop drawings of thirty pieces of apparatus for laboratory work and lecture demonstrations in college physics. Approximately 25 colleges and universities were visited, and notes and sketches of apparatus were collected. The shop drawings were prepared by professional draftsmen. The drawings and notes have been published in slightly abbreviated form in the *American Journal of Physics* and separately as a portfolio and bound volume of complete full-scale drawings. The drawings and notes enable physics departments to decide whether apparatus developed elsewhere would be useful in their teaching and, if so, to provide their shops with adequate information for constructing the apparatus. Care has been taken in the notes to describe special techniques so that students can help in making the equipment.

The thirty pieces of apparatus described in the series include: a Balmer series spectrum tube, apparatus for the magnetic field of a circular coil, air suspension gyroscope, resolution of forces apparatus, mass spectrometers, Bragg diffraction apparatus, linear oscillator, simple kinetic theory demonstration, air suspended pucks for momentum experiments, Classen's method for e/m of electrons, Hall effect magnet, large electromagnet, omegatron for determination of e/m of the proton, acceleration carts and track, nuclear magnetic resonance by absorption technique, Rutherford scattering of alpha particles by thin metal foils, electron paramagnetic resonance, small X-ray tube ionization source for Millikan oil drop experiment, versatile electric timer control system, ionization chamber, proportional counter, impulse driven torsional mechanical oscillator, platinum-wedge black body, whirligig, a conical pendulum for centripetal force experiments, vertical-circle apparatus, apparatus for investigating the properties of sound waves, versatile X-Y projector plotter, accessory apparatus for large electromagnet, and atomic beam apparatus for mean free path.

**Sources of Further Information:**

W. C. Kelly, "Introduction to Apparatus Drawings," *American Journal of Physics* 28, 33 (1960), and subsequent articles in this journal.

*Survey of Teaching Apparatus in Physics*, W. C. Kelly, ed., American Institute of Physics and American Association of Physics Teachers, 1961.

*AIP Educational Newsletter V* (February 28, 1962)..

Information on the Apparatus Drawings Project may be obtained from the American Institute of Physics. The portfolio and bound book of 30 sets of drawings and notes are available from Plenum Press, Inc., New York, New York.

**119. COLOR MOTION PICTURES ILLUSTRATING SATELLITE MOTION, GRAVITATION, AND CELESTIAL MECHANICS.** *(Secondary, College)* HARRY F. MEINERS, Department of Physics, Rensselaer Polytechnic Institute, Troy, New York. (1959–1961)

Two films have been made using an electronic planetarium, with the aid of an optical multiplexing apparatus which allows the camera to record simultaneously the image of the orbit of a satellite produced by an electromechanical Fourier computer and the image of a rotating colored relief model of the earth. The two images were synchronized so that an accurate time scale between the speed of the satellite and the rotating earth was obtained.

*Satellite Orbits* contains (1) a discussion of the six orbital elements of a satellite, (2) an analysis of the theory of gravitation, including a derivation of Kepler's third law and a discussion of Kepler's first and second laws, (3) a demonstration of the increase at perigee and the decrease at apogee of the speed of a typical satellite, (4) an analysis of the regression of a typical orbit, and (5) actual scale orbits of Vanguard I, Sputnik III, Explorer IV, and Discoverer V moving simultaneously around the rotating earth.

*Satellite Lifetime* (1) displays the three phases of orbital decay—elliptical, circular, and final burn-out, (2) discusses the exponential decrease in density of the atmosphere above the earth and how it varies with the seasons, (3) explains how satellites can be used as probes to estimate atmospheric density, and (4) demonstrates how an extension of the principle of the conservation of energy to a space laboratory allows estimates to be made of the lifetimes of satellites. The film also shows models of Vanguard I and II in orbit around the rotating earth. An actual spherical satellite disintegrating as it enters the earth's atmosphere is shown.

**Sources of Further Information:**

Harry F. Meiners and Guy Huse, "A Projection Oscilloscope," *American Journal of Physics* 27, 445 (1959).

Harry F. Meiners. Alan S. Meltzer, Charles C. Werberig, and Guy Huse, "Satellite Orbits in an Electronic Planetarium," *Ibid.* 28, 592 (1960).

The films can be obtained from the Office of Institutional Research, Rensselaer Polytechnic Institute.

*Satellite Orbits*, 20 minutes, sound-color, $150—two-week delivery.

*Satellite Lifetime*, 24 minutes, sound-color, $175—two-week delivery.

Preview prints are available.

**120. LABORATORY DEMONSTRATIONS AND EXPERIMENTS IN OPTICS.** JOHN STRONG, Laboratory of Astrophysics and Physical Meteorology, Johns Hopkins University, Baltimore 18, Maryland. (1959–1963)

A manual describing suitable student experiments in optics has been prepared to satisfy the needs of both the small colleges and the larger institutions.

**Sources of Further Information:**

The published optics laboratory manual *Optics: Experiments and Demonstrations*, by C. Harvey Palmer, The Johns Hopkins Press, Baltimore, Maryland, 1962, contains fifty-nine numbered experiments described under the general headings of (1) Ray Optics, (2) Wave Optics, (3) Polarization and Crystal Optics, and (4) Spectroscopy. Each of the experiments in the manual contains references, some theory, drawings and a description of the apparatus set-up, and procedures. A copy of the manual has been sent, free of charge, to the physics departments of all colleges and junior colleges in the United States. Additional copies can be purchased from The Johns Hopkins Press. A supplement containing additional experiments is being prepared.

Further information can be obtained from the project director.

**121. RIPPLE-TANK ANALOG FOR QUANTITATIVE RADIATION STUDIES.** *(College, Graduate School)* NELSON L. WALBRIDGE, Department of Physics, University of Vermont, Burlington, Vermont. (1959–1960)

The ripple tank is a glass-bottom tray containing 1″ of water. Ripples with amplitudes of about 0.01 mm are produced by wax buttons touching the surface. The buttons, mounted on rods, are driven at 60 cycles by magnetic cutting heads. Various radiation problems can be simulated by two or more buttons suitably spaced, with individual amplitude and phase control. Reflectors may also be used. Wet, sloping ground-glass beaches prevent reflections from the walls. A zirconium arc is mounted on the floor. Light is passed up through the tray and a 1.2 diopter lens, reflected through 90°, and intercepted by a ground-glass screen mounted on an optical bench. The light is strobed at 60 cycles by a slotted disc driven by a synchronous motor so that a steady pattern appears on the screen. The screen is moved until the outside of one of the images touches the next. At this adjustment, the amplitude can be calculated from $A = \frac{4.60}{k^2F(n\text{-}1)} - \frac{0.51\ (J/p)}{k(n\text{-}1)}$ where k = 2 pi/wave length; J is the width of the light source; p is the distance from source to ripple; and F = qh/(q-h), q being the distance from the water surface to the image of the source, and h the distance from the ripple to the position where the adjacent images touch. Measurements over a range of 20 db can be made with an accuracy of 5%.

**Sources of Further Information:**

Available on request from the project director are copies of "The Optics of Ripple Tanks" and "The Design of a Quantitative Ripple Tank." Similar work is described in a report by L. A. Woodward, N. L. Walbridge, and H. Smith, "Ripple Tank Simulated Radar Waves," *Research Reviews*, Office of Naval Research (September 1954), and in *Guidance*, Arthur S. Locke, D. Van Nostrand Company, Princeton, New Jersey, 1961.

**122. APPARATUS FOR DEMONSTRATING SIMPLE HARMONIC, CIRCULAR, AND VIBRATORY MOTION.** *(Secondary, College)* MORRIS B. ABRAMSON, Physical Science Department, Flushing High School, Flushing 54, New York. (Grantee: Queens College, Flushing 67, New York.) (1960–1961)

The apparatus consists of three units which can be used separately or in combination with one another: a device to produce simple harmonic motion, a recording unit, and a spring unit. The first unit uses a low-speed motor to rotate a radius of variable length. By means of sliding components, vertical motion is produced in a horizontal cross member. A pointer shows the rotational motion, while two indicators produce harmonic motion alongside. A front plate is graduated in degrees and in linear displacements. The recording unit has a roll of paper 12″ wide, which is unwound from one cylinder onto another at slow speed. A marking pen operated by the first unit and moving horizontally draws a large sine curve on the paper. Adjustments can be made to illustrate changes in frequency, amplitude, and length of wave. In the spring unit, a large spring is made to vibrate vertically. By careful control of the speed of the first unit, the motion of the spring is shown to be identical with simple harmonic motion. In addition, the spring can be coupled to the indicator and by varying the frequency, resonance can be demonstrated. Additional accessories can be added to illustrate, but not to produce, AC voltages. Construction of this equipment requires a lathe, drill press, and tools found in metal and woodworking shops of most secondary schools. Costs are estimated at $150-$200.

**Sources of Further Information:**

Further information can be obtained from the project director.

**123. THE FLUORESCENT LAMP AS A TEACHING DEVICE.** *(Secondary, College)* ISIDOR AUERBACH, John Jay High School, Brooklyn 15, New York. (Grantee: New York University, New York 3, New York.) (1960–1961)

The fluorescent lamp with its associated ballast and starter, which costs about $8 to build, can be used to develop the concepts of inductive reactance and phase angle. The phase angle can be measured and demonstrated visually with the aid of an electronic switch and an oscilloscope. The comparison between the negative resistance characteristic of the fluorescent lamp and that of a normal resistor can also be demonstrated. Transient oscillations can be observed as well as parallel and series resonance for 60-cycle current. The Q of the ballast coil can be measured, and the variation in frequency with resistance in a resonant circuit can be demonstrated.

**Sources of Further Information:**

Isidor Auerbach, "Fluorescent Lamp. A Teaching Device," *American Journal of Physics* 29, 546 (1961)

**124. BASIC MASS SPECTROMETER.** *(Secondary, College)* JOHN W. DEWDNEY, Department of Physics, Dartmouth College, Hanover, New Hampshire. (1960–1962)

A small mass spectrometer has been developed which can be made primarily from simple parts available in hardware and drug stores. The vacuum system is made from standard plumbing parts and rubber stoppers. Vacuum-tight electrical leads are made by inserting darning needles through the rubber stoppers. The filament of an automobile head lamp is used in the ion source. Slits are made from washers and razor blades. The magnetic field is provided by a permanent magnet fitted with homemade circular pole pieces. Auxiliary pieces of electrical equipment needed are commonplace laboratory items such as a power supply, audio amplifier, oscilloscope, etc. A mechanical vacuum pump is needed, but, if it is a good one, a diffusion pump is not necessary. The cost of the raw materials, including the magnet (but not including electrical and vacuum equipment) is about $25.

**Sources of Further Information:**

John W. Dewdney, "Undergraduate Mass Spectrometer," *American Journal of Physics* 28, 452 (1960).

Robert G. Marcley, "Versatile Mass Spectrometer," *Ibid.* 28, 418 (1960).

Further information can be obtained from the project director.

**125. EQUIPMENT FOR UNDERGRADUATE PHYSICS EXPERIMENTS.** E. M. HAFNER, Department of Physics and Astronomy, University of Rochester, Rochester 20, New York. (1960–1961)

A number of pieces of equipment and directions for their use are being prepared to make possible new demonstrations and laboratory experiments for undergraduate physics instruction. New pieces of apparatus will be described for experiments in the areas of mechanics, wave motion, statistics and kinetic theory, electromagnetism, and atomic physics.

**Sources of Further Information:**

Further information can be obtained from the project director.

**126. EXPERIMENTS ON MOMENTUM: (A) LOSS OF ENERGY IN CAPTIVE COLLISIONS, (B) FALLING SAND ON SCALE.** *(Secondary, College)* T. N. HATFIELD, Department of Physics, University of Houston, Houston, Texas. (1960–1962)

A. Rotary motion and conservation of angular momentum are employed in order to keep frictional forces small. A 30 cm rigid beam is mounted on a ball bearing at the center, allowing rotation in a vertical plane. Masses $m$ are attached to each end of the beam. A third mass $m$ (steel ball) is dropped from height $h$ so as to collide with the mass at one end of the beam while the beam is at rest in a horizontal position. The mechanism causes capture on collision, thus giving inelastic collision of mass $m$ with mass $2m$. Energy loss is measured by determining minimum value of $h$ to cause a complete revolution. The rigid beam is then replaced by a flexible beam of spring steel so that inelastic collision is mass $m$ with mass $m$, giving a smaller loss of energy. The relation between the energy of vibration and potential energy becomes an interesting problem, but the value of $h$ required is less than with the rigid beam.

B. The apparatus to show momentum principles involved in sand falling on a scale is somewhat like that demonstrated by Dr. Paul Whiting in the apparatus contest at the 1961 AAPT meeting. However, the apparatus described here shows the transient as well as the steady state. A "high impedance" scale with a natural frequency of about twenty cycles per second has been developed. A high mechanical-optical magnification of the change of force produces a vertical motion of a focused beam on a screen or wall for lecture demonstration. Simultaneous rotation about a vertical axis gives a horizontal motion of the spot of light with time. The apparatus is completely mechanical-optical, except for a magnetic trap door for dropping the sand. A zirconium arc light is used as a point light source.

**Sources of Further Information:**

A complete report, containing detailed descriptions, drawings, and photographs of the apparatus, can be obtained from the project director.

**127. ATOMIC AND NUCLEAR EXPERIMENTS FOR UNDERGRADUATE LABORATORIES.** GEORGE E. BRADLEY and JACOB DEWITT, Department of Physics, Western Michigan University, Kalamazoo, Michigan. (1961–1963)

Several experiments are being developed for use in the area of atomic and nuclear physics. One experiment involves the alignment of sodium or rubidium atoms by resonance absorption of circularly polarized D-line radiation (optical pumping), and the measurement of nuclear magnetic moments. The aligned atoms in vapor state are excited by a radio-frequency magnetic field. When the frequency corresponding to a Zeeman transition is applied, the orientation is destroyed and transmission of the algning light is reduced. Necessary equipment will be designed for the experiment.

Another experiment involves basic absorption and scattering studies with alpha, beta, and gamma radiation. The equipment will include the use of small Geiger tubes to measure scattering. Studies of ions in magnetic fields at low pressures will also be made.

**Sources of Further Information:**

Robert L. deZafra, "Optical Pumping," *American Journal of Physics* 28, 646 (1960).

Further information can be obtained from Dr. Bradley.

**128. AN ELECTRON-OPTICAL BENCH FOR STUDENT EXPERIMENTS.** HENRY E. BREED, Department of Physics, Rensselaer Polytechnic Institute, Troy, New York. (1961–1963)

The purpose of the project is to design and develop an electron-optical bench which can be assembled by students and teachers from readily adaptable components. A minimum number of pieces will need to be made in school machine shops. Once assembled, the equipment will be suitable for individual student laboratories and lecture demonstrations. In laboratory sections, students will be encouraged to make electron lenses and field probes and to prepare crystals for diffraction. This equipment should be useful in teaching the wave nature of matter and illustrating the wave-particle duality.

**Sources of Further Information:**

Upon completion of the work, reports, with full blueprints, will be available on request from the project director.

**129. APPARATUS FOR MEASURING RELATIVISTIC VARIATION IN MASS OF ELECTRONS.** JOHN W. DEWDNEY, Department of Physics, Dartmouth College, Hanover, New Hampshire. (1961–1963)

Apparatus is being developed which, it is hoped, will make possible the measurement of the relativistic increase in mass of electrons accelerated to energies up to 50 kev. The electrons are deflected in a transverse electrostatic field whose magnitude is made proportional to the accelerating field. A change in the deflection as the accelerating voltage is increased is a measure of the *difference* between relativistic behavior and non-relativistic behavior.

**Sources of Further Information:**

Further information can be obtained from the project director.

**130. MÖSSBAUER-EFFECT EXPERIMENTS FOR ADVANCED PHYSICS LABORATORIES.** J. RICHARD HASKINS, Department of Physics, Gettysburg College, Gettysburg, Pennsylvania. (1961–1962)

Equipment demonstrating the Mössbauer effect has been developed for use by students in advanced undergraduate laboratory courses in modern physics. One experiment used $Fe^{57}$ as source and absorber, and a loudspeaker with audio oscillator and oscilloscope as detector. The second experiment utilizes a toy train car on a slightly inclined track driven by a micrometer screw, which in turn is driven by a small DC motor. Sources can be prepared by evaporating $Co^{57}$ on copper and iron foils and annealing in vacuum at about 920°C. A small commercial furnace may be used for this source preparation. The initial investment for the furnace seems well worthwhi' since it allows for preparation of many sources under a variety of conditions for about the same cost as having just one source prepared commercially. The student experiments use an enriched absorber foil which is available commercially, as are all the items needed for these experiments. No AEC license is required to purchase $Co^{57}$. To be in a position to perform the Mössbauer experiments outlined requires expenditures of $650 to $1,050.

**Sources of Further Information:**

A final report can be obtained from the project director.

**131. OPTICAL MASER DEMONSTRATIONS OF PROPERTIES OF LIGHT.** WILLIAM A. BUTLER, ROBERT J. KOLENKOW, and ROBERT A. REITZ, Department of Physics, Carleton College, Northfield, Minnesota. (1962–1963)

An optical maser incorporating a ruby crystal and activated by a bank of flash tubes will be constructed. The light source will have application in the large scale demonstration of interference and diffraction phenomena.

**Sources of Further Information:**

Further information can be obtained from the project directors.

**132. APPARATUS FOR MEASURING RELATIVISTIC CHANGE OF MASS AND MOMENTUM SPECTRA OF ELECTRONS FROM BETA RAY SOURCES.** MALCOLM CORRELL and ALBERT A. BARTLETT, Department of Physics, University of Colorado, Boulder, Colorado. (1962–1963)

It is proposed to design and construct an iron pillbox spectrometer whose mass will be approximately 50 kg. A coil mounted coaxially within the iron cylinder will produce an inside-out electromagnet whose field will constitute both the bending impulse for a beta particle momentum spectrometer and the magnetic force for a velocity selector. A vacuum wall, mounted coaxially within the coil, together with the iron pillbox end plates will constitute the vacuum chamber within which a 180° beta particle spectrograph with velocity selector and solid state detector will be located. Various radioactive beta sources will be used: $Cs^{137}$ will supply electrons with energies ranging from zero to 0.625 Mev, corresponding to variations of $m/m_o$ from unity to 2.23. These measurements will require magnetic fields up to 340 gauss and electric fields up to 10 kv/mm. The project will give ample attention to practicable cost in associated equipment and will investigate the pedagogic applicability of the new apparatus.

**Sources of Further Information:**

Full publication of results is planned. Further information can be obtained from the project directors.

**133. MICROWAVE SPECTROSCOPY EXPERIMENT.** JOHN J. FARIS, Department of Physics, Colorado State University, Fort Collins, Colorado. (1962–1964)

The apparatus when completed will consist of an absorption cell and allied equipment designed to operate at 23-25 kmc. The cell will be designed for Stark modulation at approximately 100 kc and will provide a simple method of obtaining rather high sensitivity.

**Sources of Further Information:**

Further information can be obtained from the project director.

**134. INTERFERENCE STUDIES WITH OPTICAL MASERS.** ROBERT E. HOPKINS and M. PARKER GIVENS, College of Engineering, University of Rochester, Rochester 20, New York. (1962–1963)

A set of optics experiments will be designed which make use of the ruby rod maser light source. The experiments to be described include (1) the aperture diffraction and aberration effects in lens systems, (2) the Abbé theory of the microscope and the illustration of phase contrast, (3) a simple type of interferometer (using microscope objectives) which enable one to test lenses of almost any size, and (4) demonstrations of properties of the ruby rod maser itself.

**Sources of Further Information:**

Further information can be obtained from the project directors.

**135. SEMICONDUCTOR PARTICLE DETECTORS IN MAGNETIC-DEFLECTION BETA-PARTICLE SPECTROMETERS.** DONALD E. OLSON, Department of Physics, University of Minnesota, Duluth 12, Minnesota. (1962–1963)

This is a project to develop the use of semiconductor particle detectors as the detectors in magnetic deflection type beta-particle spectrometers. A study of internal conversion groups and the photoelectrons from gamma rays acting on thin converters will be made. A preamplifier will be designed for use with the conventional scalers of 25 mv input sensitivity. This work will greatly extend the usefulness of permanent-magnet beta-particle spectrometers which have been built using surplus magnetron magnets.

**Sources of Further Information:**

Further information can be obtained from the project director.

**136. SPARK CHAMBER.** ALLAN M. SACHS, Department of Physics, Columbia University, New York 27, New York. (1962–1963)

A simplified spark chamber for operation with high energy particles will be designed for construction by the physics department of a small college or production by a commercial manufacturer at a reasonable price. The spark chamber will consist of 6 to 12 flat metallic plates spaced approximately 1/4" apart. When a cosmic ray particle passes through the chamber, it is detected by two scintillation counters, and alternate plates of the chambers are pulsed to a high potential. Discharges occur in each gap along the path of ionized gas molecules which remain after the passage of the charged cosmic ray particles. The resultant sparks are very bright and can be observed by students in a large lecture room. Experiments using the spark chamber will be devised.

**Sources of Further Information:**

Further information can be obtained from the project director.

**137. EXPERIMENTS AND DEMONSTRATIONS FOR GENERAL PHYSICS.** GUENTER SCHWARZ, Department of Physics, Florida State University, Tallahassee, Florida. (1962–1964)

Demonstrations being developed include (1) Rowland's experiment on the magnetic equivalence of a current and a moving charge, and (2) the energy distribution of electrons from a hot wire. Experiments will be concerned primarily with the development of the two demonstrations and some such individual experiments as a nuclear scattering analog, the conservation of mechanical energy in a non-linear system, and equipment for describing Newton's second law for linear and circular motion.

**Sources of Further Information:**

Further information can be obtained from the project director.

**138. VERSATILE NUCLEAR COINCIDENCE APPARATUS FOR UNDERGRADUATE USE.** E. JOHN WINHOLD, Department of Physics, Rensselaer Polytechnic Institute, Troy, New York. (1962–1963)

The objective is to design and develop a prototype nuclear coincidence apparatus which will be versatile, simple to operate, and modest in cost. The apparatus is intended for use in advanced undergraduate physics laboratories. It will utilize scintillation counters together with transistor electronics embodying simplified circuitry and construction. Differential pulse height analysis is to be provided in both counter channels. The apparatus is intended to be directly applicable to a study of such topics as gamma ray scintillation, spectrometry measurements, positron annihilation, angular correlation measurements, lifetime of isomeric states, and the Compton effect.

**Sources of Further Information:**

Further information can be obtained from the project director.

**139. OPTICAL PUMPING APPARATUS FOR HYPERFINE ZEEMAN TRANSITIONS.** REUBEN BENUMOF, Mathematics-Science Department, Staten Island Community College, Staten Island 1, New York. (1963–1964)

The purpose of this project is to develop optical pumping apparatus and experiments for the study of hyperfine Zeeman transitions. The equipment is intended for use in undergraduate courses in atomic physics and undergraduate intermediate laboratory courses. An attempt will be made to devise less expensive methods of producing the desired effects. Suitable experiments will be developed and tested in the classroom.

**Sources of Further Information:**

A general description of research done in this field is given by A. L. Bloom in an article entitled "Optical Pumping," *Scientific American*, October 1960.

Further information can be obtained from the project director.

**140. APPARATUS FOR THE STERN-GERLACH EXPERIMENT.** MELVIN D. DAYBELL, Department of Physics, New Mexico State University, University Park, New Mexico. (1963–1964)

The objective is to design an inexpensive apparatus for performing the Stern-Gerlach experiment in undergraduate physics laboratories. The design will utilize parts of existing units of apparatus developed by the Apparatus Drawings Project of the AIP and AAPT, as well as components built specifically for the apparatus under development. The apparatus will be useful in demonstrating a quantization effect directly, and will also be of value for teaching the elements of atomic and molecular beam technique. If produced on a commercial basis in kit form, the apparatus should cost under $200, exclusive of electromagnet, magnet power supply, and a source of high vacuum.

**Sources of Further Information:**

Further information can be obtained from the project director.

**141. VACUUM CHAMBERS FOR NUCLEAR PHYSICS EXPERIMENTS.** ARTHUR W. WALTNER, School of Physical Sciences and Applied Mathematics, North Carolina State College, Raleigh, North Carolina. (1963–1965)

The objective is to design and construct suitable vacuum chambers for performing experiments in alpha- and beta-particle spectrometry and nuclear reactions. Experiments utilizing these chambers will be devised and tested.

**Sources of Further Information:**

Further information can be obtained from the project director.

**142. APPARATUS FOR ADVANCED UNDERGRADUATE PHYSICS LABORATORY.** THOMAS H. WOOD, Department of Physics, University of Pennsylvania, Philadelphia 4, Pennsylvania. (1963–1964)

The objective is to design and develop experiments and the necessary equipment to provide the advanced undergraduate with a direct measurement of the black-body distribution law and an illustration of the physical nature of optical resonance which will permit a rough determination of atomic half-lives of excited states of several alkali metals. Use will be made, where possible, of available, reasonably priced instrumentation. The apparatus to be constructed includes a simple infrared spectrometer and radiant energy sources for the black-body experiment and for exciting and observing optical resonance.

**Sources of Further Information:**

Further information can be obtained from the project director.

*Other projects related to projects 116-142:*

9. X-RAY CIRCUIT MODEL FOR STUDYING X-RAY CIRCUIT PARAMETERS
24. NEW ATOMIC, MOLECULAR, AND CRYSTAL MODELS
25. INTEGRATED SET OF ANALYTICAL INSTRUMENT BUILDING BLOCKS
26. COMPONENTS FOR STUDENT-BUILT INSTRUMENTS FOR INSTRUMENTAL ANALYSIS
28. EQUIPMENT AND EXPERIMENTS FOR TEACHING INSTRUMENTAL ANALYSIS
29. MULTI-PURPOSE INSTRUMENT FOR QUANTITATIVE CHEMICAL MEASUREMENT
31. MODELS OF CRYSTALLOGRAPHIC SPACE GROUPS
32. QUANTITATIVE MOLECULAR MODELS REPRESENTING THE MOLECULAR CHARGE DISTRIBUTION
38. EQUIPMENT FOR DEMONSTRATING MAGNETIC SUSCEPTIBILITY AND ABSORPTION EMISSION SPECTRA
42. SIMPLE OPTICAL TWO-CIRCLE GONIOMETER
69. DEMONSTRATION EQUIPMENT FOR THEORY OF ELECTROMAGNETIC FIELDS AND WAVES
71. FORCES AND TORQUES DEVELOPED BY CURRENT-CARRYING CONDUCTORS IN MAGNETIC FIELDS
74. EQUIPMENT AND EXPERIMENTS FOR A SEMICONDUCTOR DEVICE LABORATORY
101. PILE OSCILLATOR FOR UNIVERSITY NUCLEAR TRAINING REACTORS
102. OVERHEAD PROJECTION SERIES OF LECTURE EXPERIMENTS IN THE SCIENCES

# J. Psychology

**143. INEXPENSIVE TIMERS, MEMORY DRUM, AND PSYCHOGALVANOMETER.** *(Secondary, College)* SISTER MARY JOHN CATHERINE, Department of Psychology, Clarke College, Dubuque, Iowa. (1959)

The psychogalvanometer that has been developed consists of a Wheatstone bridge which can be made more sensitive by means of a transistorized amplifier. Changes in skin resistance are indicated on the sensitive galvanometer of the bridge. Cost: $35.

Two types of timers have been constructed. These use such interchangeable components as relays, electrolytic capacitors, fixed and variable resistors. The first kind of timer can be used to control the length of time of application of a single stimulus. The second kind turns a stimulus on and off continually. Intervals in the range of several hundredths of a second up to about three seconds can be controlled. Cost: $20.

The memory drums consists of a tin can that can be made to rotate by means of a stepping relay which is controlled by the second kind of timer described above. Cost: $30.

**Sources of Further Information:**

Information on construction, circuit diagrams, cost, and sources of parts is available from the project director. Additional descriptions given in the prepared booklet deal with the construction of the following: power supplies, a light discrimination apparatus, a reaction timer, a stop-clock for short intervals, and a color wheel.

**144. INEXPENSIVE DEVICE FOR DEMONSTRATIONS AND LABORATORY MEASUREMENTS IN AUDITION.** NEIL R. BARTLETT, Department of Psychology, University of Arizona, Tucson, Arizona. (1961)

The device is intended for use in college courses in beginning psychology and physiology. Through appropriate matching of an audio oscillator, audio amplifier, speakers, and switches, the device performs throughout the audible frequency range at amplitudes from –10 to 50 db. Both frequency and amplitude are continuously variable. In addition, the usual step switches for frequency and amplitude and dual air conduction earphones are included so that the device can be used as a clinical audiometer for testing hearing. In this capacity, the device can be used in student research projects in beginning physiological and experimental psychology courses. The unit is housed in an attractive, sloping panel, metal cabinet with output jacks for the earphones and speakers. The speakers and crossover network are contained in a separate wooden enclosure. The entire unit is expected to cost under $200 and may be constructed by anyone with previous circuit wiring experience.

**Sources of Further Information:**

A final report with construction details and wiring diagrams can be obtained from Dr. Albert E. Bartz, Department of Psychology, Concordia College, Moorhead, Minnesota.

**145. PSYCHO-BIOLOGICAL APPARATUS FOR DEMONSTRATION AND STUDENT RESEARCH.** *(Secondary, College)* D. K. CANDLAND, Department of Psychology, Bucknell University, Lewisburg, Pennsylvania. (1961–1962)

The apparatus is designed to provide compact, inexpensive, and flexible units for classroom demonstration and student research. All units may be built with household tools from materials purchased for under $5. The units include: (1) a galvanometer for measuring the galvanic skin response, (2) an algesiometer, (3) a techistoscope, (4) a light source for the demonstration of visual phenomena and psychophysical methods, (5) mirror tracing, (6) non-electric maze, (7) rotating trapezoid, (8) small animal test chamber, and (9) human maze or problem solving apparatus.

**Sources of Further Information:**

A brochure containing descriptions and plans of the apparatus has been prepared, but is now out of print. Information on similar apparatus can be obtained from Louis Snellgrove Union University, Jackson, Tennessee.

**146. PROJECTION COLOR-MIXER.** *(Secondary, College)* LORRIN A. RIGGS, Department of Psychology, Brown University, Providence 12, Rhode Island. (1961–1962)

A portable instrument for projecting color test patterns on a screen has been constructed from standard, commercially available equipment. The device is suitable for group use in classes at the high school or college level to demonstrate the principal facts of color mixing. In addition, it can be used as an anomaloscope to detect, measure the severity, and classify the various types of color blindness. A pilot model of the device costs $85; a model using somewhat more powerful projectors costs $135.

**Sources of Further Information:**

A final report detailing construction and use can be obtained from the project director.

**147. EXPERIMENTS ON ANIMAL BEHAVIOR.** RICHARD M. KLEIN, Department of Psychology, Adelphi College, Garden City, Long Island, New York. (1962–1963)

The purpose of this project is to develop some fifteen experiments on fish behavior to illustrate principles of learning and motivation. The experiments can be performed by undergraduate psycology or biology students as part of a demonstration program on learning. The experiments will be suitable for courses on the psychology of learning and motivation. To be illustrated are such principles as acquisition, extinction, reinforcement magnitude, partial reinforcement, secondary reinforcement, chaining, escape, avoidance, drive, generalization, discrimination, delay of reinforcement, conflict, classical conditioning, and probability learning. The apparatus will consist of various maze types (for discrete trials) and manipulanda set-ups.

**Sources of Further Information:**

Further information can be obtained from the project director.

*Other projects related to projects 143-147:*

22. STUDENT LABORATORY EQUIPMENT IN VISUAL SCIENCE
106. MEMO-ACTIVITY CAMERA