HOW TO BUILD YOUR OWN TEACHING APPARATUS

The following report is a brief review of the joint AAPT-AIP Apparatus Drawings Project which was responsible for the compilation of shop drawings and detailed information for constructing some thirty different pieces of physics teaching apparatus.

An AIP Staff Report

DO-IT-YOURSELF apparatus for better physics teaching is now within the reach of many small departments. Developed at a dozen leading colleges and universities,[1] the apparatus ranges in scope from a simple kinetic-theory demonstration to a student-model mass spectrometer. All of the items can be built with the facilities of an average departmental shop. This opportunity for local construction of apparatus is offered through the Apparatus Drawings Project, sponsored jointly by the American Association of Physics Teachers and the American Institute of Physics. The recent publication by Plenum Press of a 162-sheet portfolio and a 289-page bound volume [2] of shop drawings and construction notes on thirty pieces of apparatus brings to completion the project which was undertaken in 1959 with support from the National Science Foundation.

The idea for the Apparatus Drawings Project evolved from the Study of Apparatus for the Teaching of Physics, conducted in 1956–57 by the AAPT Committee on Apparatus for Educational Institutions. During the study, a number of pieces of interesting original apparatus were discovered in institutions in various parts of the country. The Committee believed that other novel apparatus existed in colleges and universities that had not been visited in the study. Yet in many physics departments new apparatus was evidently needed for use in student laboratories and lecture rooms—particularly for training in areas of importance to contemporary physics. The Apparatus Drawings Project was launched to meet this situation. The purpose of the project was to provide information in detailed form so that apparatus already developed and built by physics departments, but not commercially available, could be duplicated by other departments having average shop facilities.

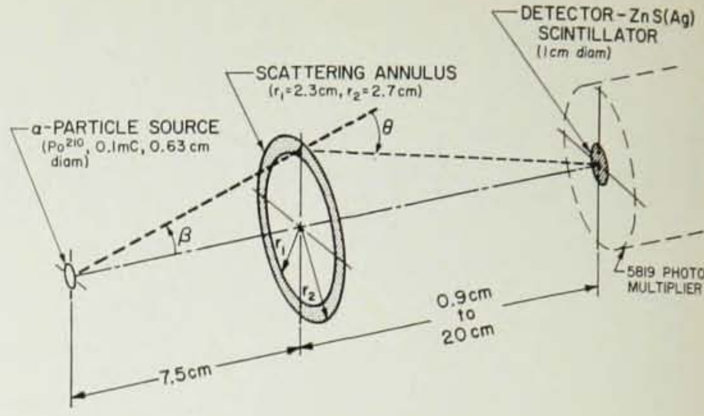
Selecting a qualified project leader was a prime consideration. Essentially, the work to be accomplished required a person well informed about the construction and maintenance of physics-teaching equipment and with a wide knowledge of the sources of commercial apparatus, components, and materials; preferably, he should be a person with recent experience in a college or university physics laboratory who could work closely and harmoniously with the Apparatus Committee and other physicists in the institutions at which the apparatus was developed; finally, he should be capable of presenting accurate and detailed drawings and descriptions of pieces of apparatus that would enable shop personnel to construct them. The project leader chosen was Robert G. Marcley.[3] He came to the project from the Massachusetts Institute of Technology, where he had held a key position as a technician in the freshman and sophomore physics laboratories for eleven years and had participated in an extensive revision of the laboratory work. In the opinion of those who worked with Mr. Marcley in this project, he possessed the qualifications mentioned above completely and almost uniquely.

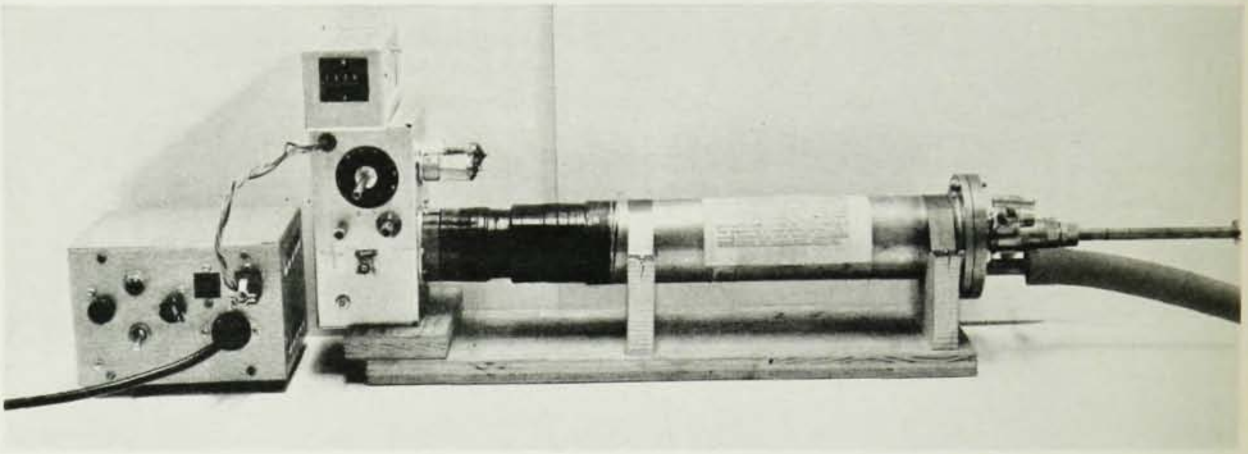
The Committee on Apparatus acted as the Advisory Committee for the project, and much valuable advice and guidance were contributed by its members, including Sanborn C. Brown (Massachusetts Institute of Technology), Vernet E. Eaton (Wesleyan University),

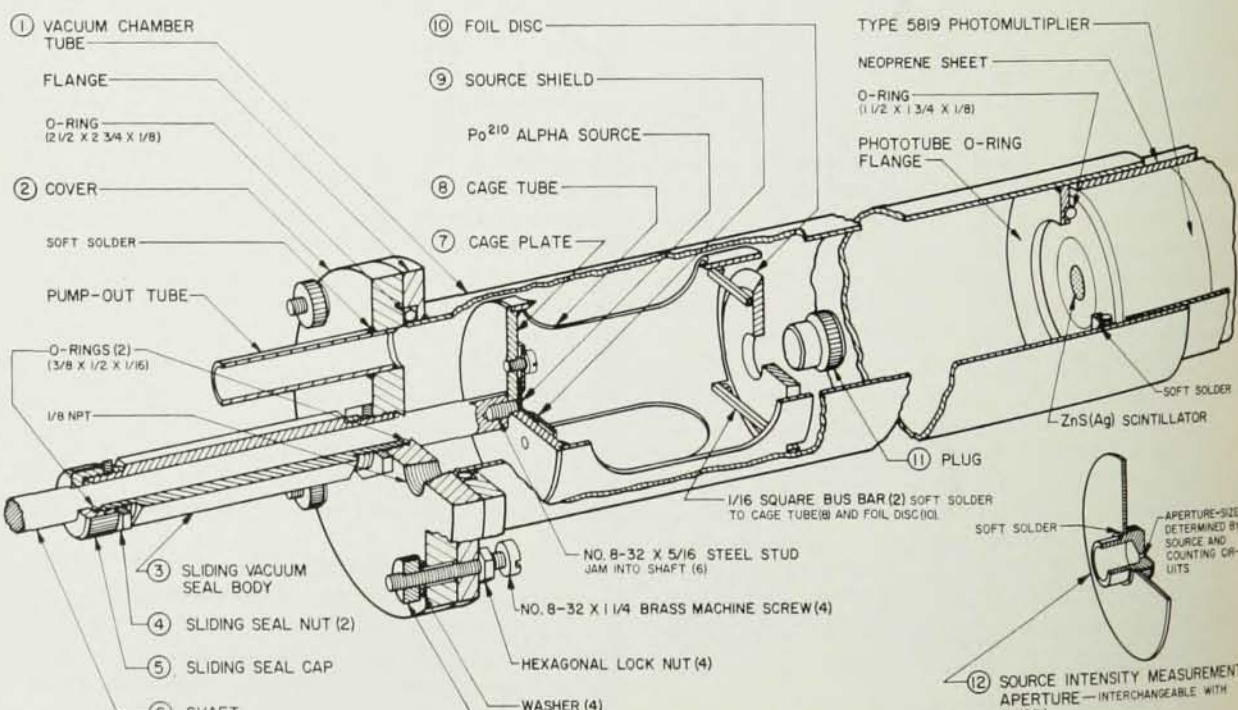
[1] Listed in the Appendix to this article.
[2] Apparatus Drawings Project (ADP), Plenum Press, Inc., 227 West 17 Street, New York City 11, 1962 ($40 for the complete portfolio and bound volume.)

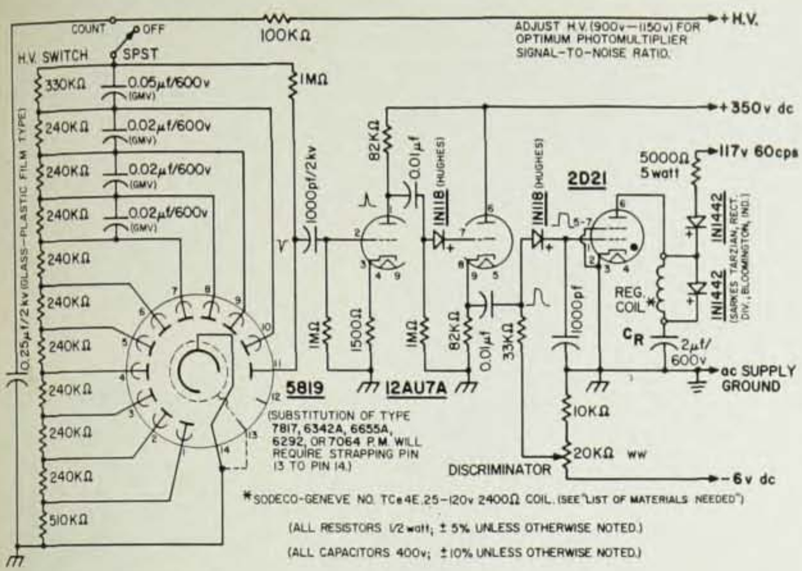
[3] Present address: Norman Bridge Laboratory of Physics, California Institute of Technology, Pasadena, Calif.

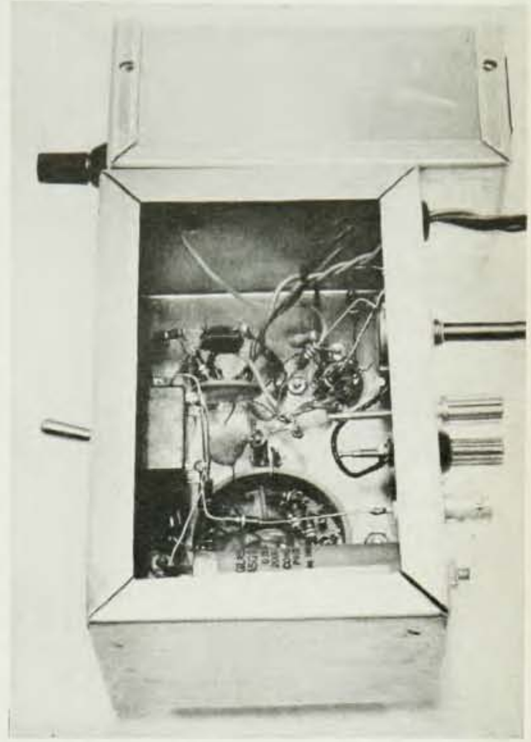
One of the examples of the apparatus included in the published collection is this setup for measuring the Rutherford scattering of alpha particles by thin metal foils, which was developed at the Massachusetts Institute of Technology for use in a large sophomore physics laboratory. Figures shown here are the schematic representation of the experimental arrangement (right) and the assembled apparatus and cutaway drawing of the vacuum chamber (below). Several additional shop drawings give details on construction of component parts of the apparatus.











The illustrations of the MIT scattering apparatus also include the above diagram of the counting circuits and a photograph showing an internal view of the counting-circuit chassis to indicate the layout of parts and the wiring techniques that have been employed.

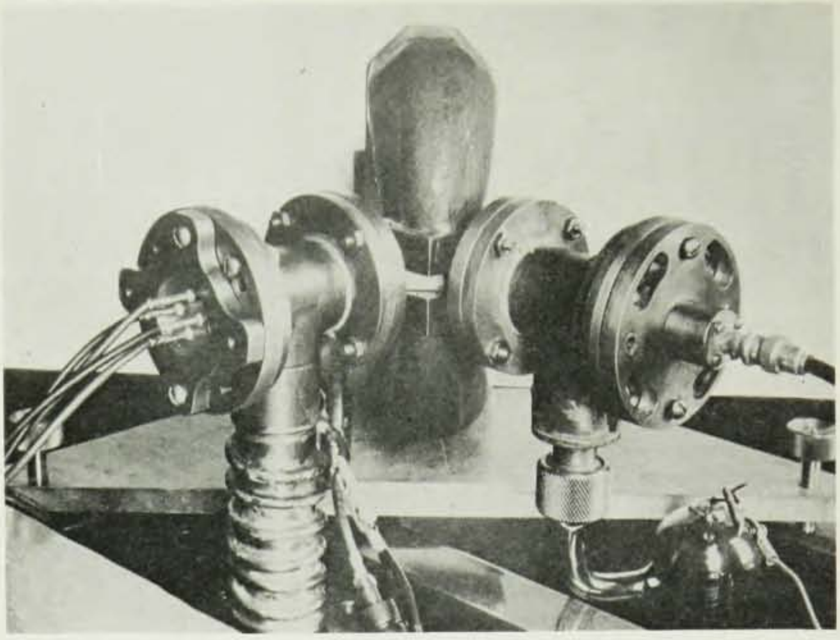
Gerald Holton (Harvard University), Harald C. Jensen (Lake Forest College), William C. Kelly (American Institute of Physics), Harry F. Meiners (Rensselaer Polytechnic Institute), Thomas D. Miner (Garden City High School), H. Victor Neher (California Institute of Technology), Howard A. Robinson (Adelphi College), Allan M. Sachs (Columbia University), and Howard P. Stabler (Williams College). Harris M. Sullivan of the Johnson Service Company joined the Advisory Committee early in 1959, bringing to it his many years of experience in the apparatus manufacturing field. During the course of the project, Professors C. J. Overbeck, F. W. Sears, L. O. Olsen, Malcolm Correll, and Frank Verbrugge served successively as presidents of the American Association of Physics Teachers. The project was carried out in the Education and Manpower Department of the AIP.

Although the earlier AAPT study provided an initial source of information on the existence and location of some items, Mr. Marcley personally visited twenty-four colleges and universities throughout the country to locate apparatus and to make an on-the-spot inspection of possibilities. He received full and enthusiastic co-operation. In all, one hundred and fifty pieces of useful and potentially suitable apparatus were considered. After inspection and review, thirty pieces were selected for the reports.

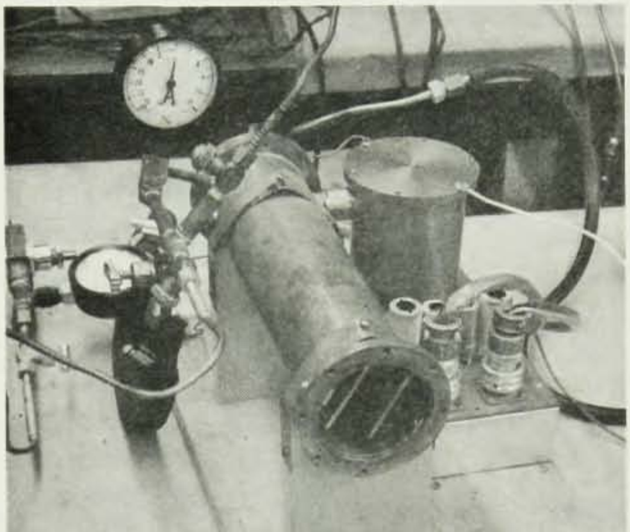
The emphasis in the project was on apparatus for demonstrations and experiments in areas of importance to modern physics, but the fields represented by the apparatus that was selected range from classical mechanics to quantum physics. No attempt was made to choose specific pieces of apparatus to meet the needs of a "recommended course". Rather, the criteria for final selection of a piece of apparatus were the following: (a) the apparatus was of importance to contemporary physics teaching, (b) it was unavailable in any form from commercial suppliers or it represented a fundamental improvement over an existing commercial piece, (c) it could be constructed by a department with only average shop facilities, (d) the cost of materials and labor was reasonable, (e) it was reliable and sufficiently tested in the student laboratory or lecture room. Automatically, these criteria weeded out many examples of interesting and novel apparatus. Others that fulfilled the requirements could not be included in the final group selected for the report because of the limitations of time.

In this "do-it-yourself" approach to the construction of teaching apparatus, physics teachers are encouraged to use the drawings to duplicate the apparatus in their shops and they are free to do so. Commercial rights, of course, are retained by the institution or individual responsible for the development of the apparatus.

Each report follows the same general format. The apparatus is described in complete detail. The text is supplemented by sketches and photographs. Ancillary equipment and services are discussed, necessary materials and shop equipment are listed, sources of commercial supply for critical or "exotic" items are named,



Developed for the Department of Physics at Dartmouth College, the mass spectrometer shown at left is described as being suitable for use in an undergraduate laboratory and also as being sufficiently versatile for simple research experiments. Major sections of the vacuum chamber are constructed from fittings commonly used for home water systems, and other components are conventional and inexpensive.



Simple parallel-plate ionization chamber, developed for the University of Minnesota's Modern Physics Laboratory, was designed for undergraduate studies of the effects of ionizing radiation on a gas under the influence of a relatively small electric field. Ancillary apparatus needed includes a potential source, a sensitive electrometer, and a small mechanical vacuum pump.

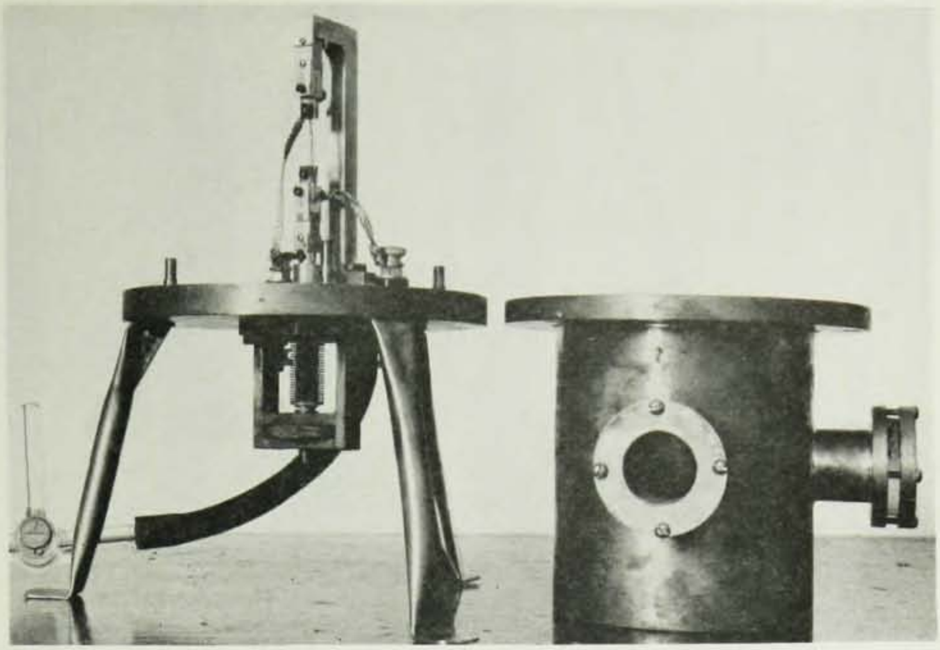
and experimental techniques (silver soldering, glass-blowing, etc.) are described in detail where it was felt this would be helpful.

Shop drawings accompany each report. They were prepared by professional draftsmen and provide the details necessary for a qualified machine-shop man or a commercial job shop to duplicate the apparatus. The style of the text, however, was chosen to enable advanced undergraduate or graduate students to understand the construction process. Before publication, each set of drawings and notes was checked by several physicists, including the developer of the apparatus, and by a machinist so that the highest possible standard of accuracy would be maintained. After the portfolio of drawings for the first ten reports had been published, a survey was made among purchasers, and the consensus of returns indicated that the reports were sufficiently detailed for the purposes intended.

The principal aim of the project was to provide information for physics departments to duplicate apparatus for use in physics teaching, and reports from users indicate that this objective has been satisfactorily met. However, the reports are also serving in other ways. Some departments have found the construction processes described to be a useful method for helping students to acquire manual skills and experimental techniques. Other departments have found the Bibliography and the section of each report entitled "List of Materials Needed" a helpful general reference on experimental techniques and sources of supply.

During the three-year span of the Project, the thirty reports were published, as they were completed, in abbreviated form in the *American Journal of Physics*. Three additional pieces of simpler apparatus are described in similar fashion by T. Walley Williams in

Platinum-wedge apparatus for use as a source of both blackbody and nonblackbody radiation was developed for use in the sophomore physics laboratory at the University of Washington. It is employed primarily for testing the validity of the Stefan-Boltzmann law and for studying the principles of optical pyrometry—or, more specifically, for measuring the apparent temperature of a nonblackbody (platinum) by comparing its radiation to that obtained from an accurate physical approximation of a blackbody.



other issues of the *Journal,* but the shop drawings and text of these will not be published separately.

Although the reports provide information for constructing apparatus, some physics departments lack the shop facilities to carry out the machining operations required. It was a timely and significant result of the project, therefore, that apparatus manufacturers have now produced some of the pieces of apparatus included in the reports, and others are considering various items for commercial production. Another interesting development has been the production by one company of kits of components and materials for assembling a number of pieces of apparatus.

The direct value of the Apparatus Drawings Project might be measured in terms of the number of physics departments that have actually constructed one or more of the pieces of apparatus. But over and above the number of units built is the value of the project in making institutions aware of what is happening in physics teaching at other institutions. This exchange of information and ideas stimulates improved physics teaching at the college and university level.

Appendix

1.	Balmer Series Spectrum Tube	Massachusetts Institute of Technology
2.	Magnetic Field of a Circular Coil	Rensselaer Polytechnic Institute
3.	Air Suspension Gyroscope	Massachusetts Institute of Technology
4.	Air Suspension Apparatus for Measuring the Resolution of Forces	Massachusetts Institute of Technology
5.	Small Mass Spectrometer	Swarthmore College
6.	Bragg Diffraction Apparatus	Rensselaer Polytechnic Institute
7.	Versatile Mass Spectrometer	Dartmouth College
8.	Driven Linear Mechanical Oscillator	Bryn Mawr College
9.	Simple Kinetic Theory Demonstration	Princeton University
10.	Air-Suspended Pucks for Momentum Experiments	Massachusetts Institute of Technology
11.	Classen's Method e/m of Electrons Apparatus	University of Minnesota
12.	Hall-Effect Magnet	Purdue University
13.	Large Electromagnet	California Institute of Technology
14.	Omegatron for Undergraduate Laboratory Determination of the Ratio e/m of the Proton	Swarthmore College
15.	Acceleration Carts and Track	Princeton University
16.	Apparatus for Measuring the Rutherford Scattering of Alpha Particles by Thin Metal Foils	Massachusetts Institute of Technology
17.	Small X-Ray Tube	University of Washington
18.	Nuclear Magnetic Resonance Absorption Apparatus	Swarthmore College
19.	Apparatus for Electron Paramagnetic Resonance at Low Fields	Swarthmore College
20.	Versatile Electric Stop Clock Control System	Princeton University
21.	Ionization Chamber	University of Minnesota
22.	Proportional Counter	University of Minnesota
23.	Impulse-Driven Torsional Mechanical Oscillator	Massachusetts Institute of Technology
24.	Platinum Wedge Blackbody	University of Washington
25.	Whirlygig: a Conical Pendulum for Centripetal Force Experiments	University of Minnesota
26.	Vertical Circle Apparatus	Rensselaer Polytechnic Institute
27.	Apparatus for Investigating the Properties of Sound Waves	Massachusetts Institute of Technology
28.	Versatile X-Y Projector Plotter	Rensselaer Polytechnic Institute
29.	Accessory Apparatus for Large Electromagnet	California Institute of Technology
30.	Atomic Beam Apparatus for Determining the Mean Free Paths of Potassium Atoms in Argon	Massachusetts Institute of Technology
30A.	Versatile RC-Filtered Low-Voltage Power Supply and a Direct-Coupled Amplifier	Massachusetts Institute of Technology