AN INEXPENSIVE UNIVERSAL KIT FOR TEACHING SECONDARY SCHOOL PHYSICS

by

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ABSTRACT

From a historical survey of the trends in the teaching of physics, it is evident that there has been more and more stress on the experimental approach. Demonstrations and experiments are increasingly becoming an indispensable part of physics instruction. The role played by experimentation is justified and demanded on the basis of psychological discoveries, philosophical principles, and the characteristics of science itself.

Although experimentation is essential in the teaching of physics, some schools are obliged to do without it because equipment is unavailable, or, if available, far too expensive. This situation demands the construction of a kit which consists of simple, inexpensive materials that are available anywhere. This kit, not only overcomes financial and practical obstacles but it can be shown to have many educational advantages over standard manufactured teaching equipment.

A set of principles has been established for selecting the topics, sequence of topics, materials, procedures, and kinds of experiences for which the kit is used. Suggestions as to the general techniques

for demonstrations and individual laboratory experiences are furnished.

According to these principles and techniques, a teacher's guide for the construction and use of the kit has been worked out. This guide includes detailed practical suggestions, and consideration of the educational issues involved.

A list of materials, and a guide to the assembly of the kit appear in Appendixes I and II. Appendix III contains a list of sources of free material.

The proposed kit makes it easy and inexpensive for the teacher to bring back into physics its natural aspect: experimentation. At the same time, it helps the teacher to accelerate the learning process, to make his course more meaningful, and to insure that his class will be more stimulated and interested.

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INTRODUCTION

The Need for an Inexpensive Universal Kit

Physics teachers as well as administrators are becoming more and more convinced of the importance of laboratory work and demonstrations in their teaching of physics. This may be the result of an inner conviction based on examined educational principles, or it may be only a wave of imitation of what is going on in schools of advanced countries like the United States of America.

Such a desire for experimentation is usually thwarted by the lack of equipment in local markets. In underdeveloped countries, one rarely finds a shop that sells scientific equipment. In many cases if the teacher overcomes this obstacle and decides to order equipment from abroad, he is faced with another impediment. The costs of pieces of equipment are very high. Equipment is priced according to the standards of living of advanced countries. In most cases the schools find it impossible to order such equipment because they cannot afford to pay for it.

Such difficulties more often cause physics instruction in underdeveloped countries to be restricted to the lecture and discussion methods, with very little, or no, demonstration work. Poor schools in relatively advanced countries often face the same situation.

A solution to this dilemma may be achieved through the construction of the special type of kit to be described in part II of this thesis. This kit is to be constructed from simple, ready-available materials. The materials must be available anywhere so that its advantages are not restricted to particular countries or regions.

The guide to the construction of this kit will help a teacher anywhere to build basic equipment with very little money. Thus he will overcome the problem of availability and cost of equipment.

Although this kit serves such purposes, as mentioned above, its educational advantages are more superior than the financial and practical ones, In comparison with the standard manufactured teaching equipment, it is more interesting, instructive and demonstrative. Moreover it fulfills the nature of science and meets the philosophical and psychological demands in physics instruction more than the standard equipment. Thus, using such a kit, the teacher does not solve his financial problems only, but he adds effectiveness, interest, and fun to his method of instruction.

PART I

PRINCIPLES AND TECHNIQUES

CHAPTER I

A SURVEY OF TRENDS IN PHYSICS TEACHING

Early Trends[1]

Physics has been one of the subjects taught in European universities almost from their foundation. If we apply today's definition of physics to such courses, they may not be called physics by the modern scientist. In the middle age, Aristotles speculations were memorized with disputations of hair splitting and their implications. It was not until the time of Galiles (1594-1643), that "modern physics" was introduced

Physics in the high schools is not as old as it is in the universities. One cannot state when it was introduced into the school curriculum, but there is evidence that as early as 1729 it was taught in Northampton, England. Many textbooks were published for school use. The most interesting of these is that of James Ferguson, which was published in 1750. It was revised in 1805 by sir David Brewster, and

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[1]A great deal of the information in this section is compiled from:
L. Riborg Mann, The Teaching of Physics, (New York: the Macmillan Co., 1925).

brought into America in 1806 by Robert Petterson of the University of Pennsylvania. In his introduction to Ferguson's book, Sir David Brewster says:"The chief object of Mr. Ferguson's labors was to give a familiar view of physical science."[1]

Physics at that time was known in Europe and America as "Natural philosophy." From its name one can easily deduce the way it was taught. It was highly theoretical and speculative, just as philosophy is, with little or no experimentation.

With the rise of industrial development, different books were introduced to cope with the new trend. The titles of these books were very similar like: The Principles of Mechanics, Acoustics, Optics Are Familiarly Explained. The causes of Many Daily Occuring Natural Phenomena Are Familiarly explained.

Although Mann[2] claims that "Natural Philosophy disappeared from the curricula of the schools about the year 1872" one cannot state so strictly the disappearance of natural philosophy and the emergence of physics. It must have

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[1]Woodhull, "The Teaching of Physical Science," Teachers College Record, XI (Jan., 1910), 18.

[2]Mann, op. cit., p. 41.

been that from around that time physics began to appear as a separate branch considered worthy to be included in the curriculum.

In 1884 the first compiled American syllabus of physics was issued by the United States Bureau of Education. The syllabus required only a qualitative description of natural phenomena, along the lines of "natural philosophy". It did not contain laws, like Newton's laws, which were known even in the eighteenth century. No mention was made of the principle of conservation of energy, which was established around 1850[1], of the atomic theory formulated in 1810[2], of molecules introduced in 1858[3], or of the kinetic theory of matter published in 1827[4],

Although the syllabus did not include laws and theories already established, it included a list of qualitative, descriptive experiments to be performed in the teaching of physics. In spite of that, it took some time before the physics teacher made any use of the laboratory even on the college level. Charles Eliot , who was a student in 1846, describes the situation:

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[1]W.C. Dampier, A History of Science (New York: The Macmillan Company, 1946), p. 246.

[2]*Ibid.*, p. 227.

[3]*Ibid.*, p. 229

[4]*Ibid.*, p. 248.

When I was a student in the Harvard College there was not a single laboratory open to the students on any subject, either chemistry, physics or biology. I was the first student who ever had the chance to work in the laboratory in Harvard College and that was entirely due to the personal friendship of Professor J.P. Cook, who fitted up a laboratory in the basement of University Hall, entirely at his own expense. That was the situation of the colleges in the country- for Harvard was by no means peculiar in this respect- only sixty years ago.[1]

Trends in Clearer Shape

From the time physics entered the secondary school curriculum, it, like all other components of the program of studies, has been subjected to repeated surveys, reforms,or scrutiny both by individuals and by committees representing various organizations. A large number of these organizations was formed in the United States of America.

The first comprehensive survey of the physics program in the United States was carried out the Committee of Ten.[2] The report recommends[3] that physics be taught by a combination of laboratory work, textbook and thoroughly didactic instruction." It recommends also that the laboratory experiments

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[1]Charles W. Eliot, "Laboratory Teaching," School Science and Mathmatics, VI (Nov., 1906), 703-707.

[2]Report of the Committee of Ten of the National Educational Association, (New York: America Book Co., 1894), pp. 117-127.

[3]Ibid., p. 119.

be mainly quantitative.

The laws that were missing from first physics syllabus were introduced by the Committee on College Entrance Requirements. This committee was appointed in 1895 to investigate into the physics curriculum of the high school. The report, presented in 1899, recommends that physics include a large amount of laboratory work; that the course also include instruction by textbook and lecture, all "to the end that the pupil may gain, not merely empirical knowledge, but, as far as this may be practicable, a comprehensive and connected view of the most important facts and laws of elementary physics."[1]

Moreover the Committee gave a list of experiments[2] to be performed. The selection of subject matter was left to the textbook authors. This arrangement led the New York State Department, the College Entrance Examination Board, and other organizations to put forward topical syllabi.

In this period, i.e., before 1910, the disciplinary value of science teaching came to be generally accepted. The

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[1]Mann, op.cit., p.

[2]These experiments appear in: Smith and Hull, The Teaching of Chemistry and Physics in Secondary Schools, (New York: Longmans, Green, and Co., 1902), pp. xiii- 337.

main aim of physics teaching was "to develop the faculties of reasoning, observation, concentration, sensory training, and the like."[1] It was believed that this disciplinary value is mainly achieved in the laboratory. Thus laboratory instruction became very popular during this period.

Reorganization of Physics Teaching

With the rise of the abandonment of the faculty psychology, the discoveries of modern physics, and the findings of modern psychology, new trends had to emerge in the teaching of physics.

With the development of the junior high school "came the development of science instruction that would help pupils interpret their environment."[2]

As a result, a course in general science was initiated between 1910-1915. By 1930 it was taught in most schools in the United States.

In spite of the factors that demand new practices in

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[1]Arthur G. Hoff, Secondary-School Science Teaching, (Philadelphia: The Blakiston Compaxy, 1947), p.8.

[2]Ibid., p.10.

the physics teaching, these practices were introduced very slowly. In 1932 Wilbur Beuchamp made a comprehensive survey of the stutus of science teaching. He found out that the courses in chemistry and physics still followed the line of the old mental disciplinary theory. Very few schools were utilizing new trends.[1]

These new trends were summarized by the National Society for the study of Education in 1932. Some of them are[2]:

> 1. An attempt at redefinement, better description, and definition of science demonstrations as teaching devices.
> 2. An attempt at redefinement, better limitation, and description of laboratory instruction, with attempts at evaluation of laboratory instruction as a means of producing certain definite outcomes in pupils.
> 3. A market swing toward a unit organization of subject matter and instructional techniques in all high school sciences.
> 4. A movement for the diagnosis of pupil difficulties in the learning of science materials.
> 5. A revival of interest in simple, homely, and home-made laboratory demonstration apparatus.
> 6. A beginning of experimental investigation of the value of visual aids ... in instruction.
> 7. A general and spreading interest in the use of free and inexpensive supplementary material draw into the school from outside commercial sources.

These trends developed more and more with the years until some of them became an orgamic part of the physics curriculum.

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[1] Ibid., pp. 12-13

[2] National Society for the Study of Education, Thirty - first Yearbook, (Bloomington: Public School Publishing Co., 1932), p. 269.

A change in the methods of instruction does not satisfy all the changing factors of this age. Physics itself is changing; it has advaced very rapidly. "Despite this progress, little attention has been given to revising the introductory teaching of basic ideas in the light of modern developments. Simply updating existing course structures may result, especially for a student who is not going on to specialize in the field, in a disjointed collection of ideas which falls short of giving an accurate perceptive of the nature and the role of physics in today's world."[1]

This existing state of secondary school physics led to a wave of general dissatisfaction among university physicists in more than one state of America." This dissatisfaction stemmed from many sources. College professors were discovering that students came to them with grossly inadequate secondary school preparation; others, with their children of high school age, were uneasy at the type of science training that was being made available to them; the place of science in the genral culture fell far short of representing its value and its importance."[2]

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[1]Physical Science Study Committee, P.S.S.C. Physics: Teacher's Resource Book and Guide, part one, (Boston: D.C. Heath and Co., 1961), p. iv.

[2]First Annual Report of the Physical Science Study Committee, (Recording and Statistical Corp., n.d.), p.3.

As a result of these conditions, the Physical Science Study Committee (refered to as PSSC) was formed in Boston in 1956. The Committee directly started studying the existing physics textbooks. Its conclusions were[1]:

> 1. Textbooks in general reflected a scientific outlook that dated back half a century and was no longer representative of the scientific community.
> 2. Genuine attempts to remain abreast of scientific developments had given even the best textbooks a patchwork quality in which the unity of physics disappeared.
> 3. The sheer mass of material in the textbooks had become so great that it could no longer be reasonably taught in an academic year or two years.
> 4. With the increasing application of science in the everyday environment, physics textbooks had given over more and more of their attention to technology, thus further overloading the course and further minimizing the concepts of science itself, and its unity.

Concerning laboratory manuals and audiovisual aids the Committee's opinion was[2]:

> Laboratory manuals dated back in concept and in excution to an era that had long since passed; the polentialities of audio-visual aids were not being adequately exploited.

To meet this need, a new trend in the teaching of physics represented by the P.S.S.C. and other organizations developed so rapidly that it became an influential element in physics instruction. In many places there is a strong tendency to adopt this trend without change, while in other cases

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[1] _Ibid._, p.3.

[2] _Ibid._, p.3.

it is adapted to the facilities of the localities. But in all cases its impetus is undeniable. The main characteristics[1] of this new trend are:

1. Physical science should be taught in one body with interrelated units. The student must see this unity. But Newtonian physics can no longer serve as the unifying factor. With the postulation of quantum theory, relativity, and wave mechanics, a syllabus has to be constructed to represent a continuing process of unveiling the laws of the physical world.[2]
2. In establishing physical laws many arguments should be used, mainly derived from the laboratory work and demonstrations, Another main source is the past ordinary experience of the student.
3. After the laws are established, many physical conclusions can be derived from them. These deductions from the laws show their power and scope.

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[1]The characteristics are derived from
a. Elbert P. Little, "From These Beginning", The Science Teacher. xxiv, No.7 (Nov. 1957).
b. "Physical Science Study Committee", Physics Today, x, No.3 (March 1957), 28-39.
c. First Annual Report.., op.cit.

[2]For a textbook following this system see:
Physical Science Study Committee, Physics, (Boston: D.C. Heath and Co., 1960).

4. Although physical laws are established experimentally it must be emphasized that they have limitations. The range in which a certain law holds must be specified.
5. Experiments should be performed wherever needed. They should not be routine collection of data to fit into a certain result, but rather a contribution of information to help in understanding the course. Moreover laboratory work should be "open-ended" so that the sudent is stimulated to pursue more experiments along the lines of the ones performed in the lavoratory.
6. The apparatus used for experiments is to be simple, and wherever possible, constructed by the student.

Although the new trend in the teaching of physics has its roots deep in a long history of physics intruction, it stands distinct in its characteristics. Its significance lies in the remarkable changes that its implementation will bring about. Its strength lies in its logic and completeness. Its power lies in the piles of experimental data[1] which show that it is sound and teachable.

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[1]See Physical Science Study Committee, 1959 Progress Report, (Watertown: Educational Services Inc., 1960), pp. 6-8, 29-32.

CHAPTER II

THE ROLE OF EXPERIMENTS IN TEACHING PHYSICS

It is evident from the survey of the traditional and modern trends of physics teaching (chapter II) that there is a tendency to include more experiments in the physics course. Moreover, it is not only a matter of increasing the number of experiments but rather it is the emphasis and importance given to experimental approach. New textbook are centering their exposition of the material on observations and data collected from experiments[1]. Even the educational systems that are known for treating physics as an intellectual activity are remodeling their methods to base them on an experimental approach[2]. Moreover, teachers and administrators, in both developed and underdeveloped countries are anxious to obtain laboratory equipment and supplies to use in demonstrations.

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[1]See:
a. Charles E. Dull et al., Modern Physics, (New York: Holt, Rinchart and Winston, Inc., 1960),
b. PSSC, Physics, op. cit.

[2]The new tendency in French books is toward experimentation. See:
a. Jean Cessac and George Treherne, Physique, (Paris: Fermand Nathan, 1957).
b. R. Faucher, Physique, (Paris: Librarie A. Hatier, 1959).

Although there is not much argument as to the indespensible role of experiments and demonstrations, it is worth stating some of the reasons for including experiments in the teaching of physics. This theoretical background will help to indentify the types of experiments that will meet needs.

The call for the implementation of the experimental approach comes from three field;

Psychology

Many of the traditional practices in the teaching of physics have their roots in the old theory:faculty psychology. This theory held that the mind is made of a set of faculties that can be strengthened by exercise just as the physical muscle is strengthened. In application to this theory physics was taught as an intellectual activity. The harder it is the better it serves as a means of formal discipline.

With the march of modern psychology, the old theory of formal discipline became obselete. Hence great changes had to follow in applications and techniques in the methods of teaching. Modern psychology assigned an essential role to experiments in the learning process based upon its descoveries in four main areas:

1. Law of interest:

Since learning is no longer regarded as an act of the mind, but of the whole organism, the interest of the individual must be aroused to accelerate the learning process[1]. Demonstrations and experiments will start the learner off to acquire new behavior. During the learning process experiments will attract his attention and increase its span. Interest is greatest in things which the learner sees, handles and acts with, especially if these things are concrete[2]. This applies very well to the apparatus in experiments.

2. Concept formation[3]

If a concept is adopted, ready-made, by memorization, it will be meaningless to the students. Concepts must be formed rather than adopted. A concept, to be formed, demands the observation of qualities and relationship in many expe-

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[1]William C. Morse and G. Max Wingo, Psychology and Teaching, (Chicago: Scott, Foresman and Company, 1955), p. 183.

[2]David F. Miller and Glenn W. Blaydes, Methods and Materials for Teaching Biological Sciences, (New York: McGraw-Hill Book Company, Inc., 1938), p. 99.

[3]Condensed from:
a. Morse and Wingo, op. cit., pp. 249-251.
b. Miller and Blaydes, op. cit., pp. 99-100.

riences as seen by the learner. This principle demands the presence of concrete objects to build concepts from. Secondly, it lays stress on first - hand experiences of the learner. If a concept of real images, for example, is to be taught, a real image must be presented as a concrete object, then the student must have an experience with it. The roots of such a concept will enter deep into the student and will serve as a basis for the formation of further concepts and generalizations.

Thus the nature of concept-formation demands the implementation of demonstrations and experiments done by the students themselves.

3. Meaningful learning

"The learner must see the relation of current learnin to his life and must be able to recognize situations where the new understanding or skill is appropriate. This means that ... what he learns must be meaningful to him."[1] Learning can be meaningful if it insures relationship in the material and to the learner. In this case, experiments can be built in a sequential developmental scheme to point

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[1]Morse and Wingo, op.cit., p.239.

out the relationships within the material. They can also be chosen to bear a relationship to things familiar to the student, to explain new experiences in terms of past ones. In this case experiments can make learning more meaningful.

4. Transfer of learning.

Transfer of learning depends partly on the similarity of stimulus conditions.[1] If a transfer of learning is desired in the teaching of physics, then there must be a similarity between the physics experiences in schools and what the child is expected to face in life. Thus environment must be "brought into" the class. The student should be faced with experiment derived from his every-day life- Such a type of experiments will facilitate the transfer of learning.

Philosophy

We have seen that the new theories of modern psychology demand the presence of the experimental side in the teaching of physics. Does philosophy support or undermine psychology in this issue?

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[1]For a detailed discussion of this topic see:
a. Arthur J. Gates et al., Educational Psychology, (New York: Macmillan Co., 1954), pp. 491-501.
b. Morse and Wingo, op. cit., pp. 414-415

It is interesting to see that the main philosophies imply the use of experiments in physics teaching, (or science teaching in general).

Idealism to start with, although it stresses the absoluteness of things, believes that "nature... is the medium through which the absolute progressively reveals itself in external form."[1] The learner's knowledge of this nature depends upon the way he apprehends it. Consequently it is not sufficient to have laws and concepts in nature. The learner must be brought in contact with them. This contact must be in the right way so that his apprehension will correspond to the ultimate reality present there. What can satisfy such conditions more than experimental work which, according to the idealist, will reveal the absolute in external form and make the learner acquire knowledge about it?

Naturalistic philosophy stresses nature much more than the idealists do. Nature is governed by laws, and the aim of education is to uncover these laws through intimate contact with nature. Experimentation, in this case, becomes essential for the acquiring of knowledge.

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[1] John S. Brubacher, Modern Philosophies of Education, (New York: McGraw-Hill Book Company, Inc., 1950), p. 311.

Further more, Naturalism builds on the premise that the child is by nature self-active. Thus when the student engages in learning, he must be fundamentally active . He must do himself. "The teacher can teach him but, to put it ungrammatically, he cannot 'learn' him."[1] Thus, naturalism calls for the participation of the student in the experimental work.

Similarly the pragmatist believes in "learning by doing". But his premises are different. When the learner is confronted with a problem he does not know the solution until he acts on one or more. Thus learning is experimental both in the classroom and in the laboratory. In fact it is experimental anywhere the learning process takes place. Thus the pragmatic justification for experimentation is epistomological.

In conclusion, the experimental approach in teaching physics is supported philosophically on metaphysical, ontological and epistomological bases.

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[1] Ibid., p.85.

Nature of Science

Science, as Conant defined it,[1] is a series of conceptual schemes arising out of observation and experiment, and giving rise to further observation and experiment. Thus science by its nature includes experiments, just as the English language includes words and phrases and cannot be taught without them.

If the aim of the science teacher is to"acquaint his pupils with the broad lines of great scientific principles, and with the ways in which these are examplified in familiar phenomena and applied in the service of man",[2] then experiments must be inevitably included in the program. He must show them the sources from which the concepts of science developed, and how they developed, by using demonstrations and concrete experimentation.

But that is not the sole objective of the science teacher. He aims "to get pupils" to reason about things they have observed and to develop their power of weighing and interpreting evidence"[3]. In other words, the teacher wants

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[1]James B. Conant, On Understanding Science, (New Haven: Yale University Press, 1947).

[2]John Brown, Teaching Science in Schools (London: University of Candan Press, Ltd., 1943), p.11.

[3]Ibid., p.11.

to help the sudents use the scientific method. This method can be summarized in five step:[1]

1. Definition of the problem
2. Accumulation of facts pertaining to the problem
3. Setting a hypothesis
4. Testing the contributory material
5. Experimentation .

There is no way to teach the students how to collect data, plot them against "control", variation of conditions and conclusions except by letting the student undergo the process himself.

In addition, physics teachers aim to apply the scientific method to help students acquire scientific attitudes. Such attitudes include accuracy, intellectual honesty, open-mindedness, suspended judgement and the habit of criticism.[2] How can such attitudes be inculcated?

One of the early studies on scientific attitudes was reported by Curtis.[3] The author concludes from his experiment that:

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[1]Miller and Btaydes, op.cit., p. 16.
Harrinoton Wells, Secondary Science education, (New York: McGran-Hill Book Company, Inc., 1952), pp. 58-59.

[2]Victor H. Noll, The Teaching of Science in Elementary and Secondary Schools, (New York: Longmans, Green and Co., 1942), p.25.

[3]Francis D. Curtis, Some Values derived from extensive reading in general science, (New York: Bureau of Publication, Columbia University, 1924).

> Extensive training in scientific subject matter even when joined with superior intelligence and maturity does not in itself insure the degree of possession of scientific attitudes which may be secured with definite training toward this end.

This "definite training" can be only achieved through letting the student live the situation in practical experiments. In other words, scientific attitudes, "the ways of the scientist ... are caught, not taught."[1]

In other words, the nature of physics, supported by the aims of teaching it, makes the role of experiments indispensible. With experiments, the student will no more learn _about_ physics, but will learn _physics_.

The theoretical justification of the experimental work is widely supported by studies that compare the conventional and experimental methods.

According to the study of Carpenter[2], learning is more meaningful if the laboratory is used rather than rote learning. He concluded that "manipulation and sensory learning continues to demonstrate superiority over verbal learning."

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[1]Paul F. Brandwein _et al_., _A Book of Methods_, (NewYork: Harcourt, Brace and World, Inc., 1958), p. 36.

[2]Finley Carpenter, "The Effect of Different Learning Methods on Concept formation," _Science Education_, XL (October 1959), 282-285.

Abrahamson[1] made a study comparing the traditional teaching and the experimental teaching in the field of mechanics. Experimental teaching included the use of visual aids and demonstrations. The experimental group was made of less able students. After two months the two goups were at the same level. Some time later, significant gain was reported by the experimental group.

Scott also compared the textbook approach and the inductive method in teaching physical science. The inductive method included experiments. Scott's major findings were:

1. The experimental group made higher scores than did the control group.
2. According to the average scores, the gain of the experimental group over that of the control group was very significant.
3. The percentage of members of the experimental group who correctly answered those questions which required the application of principles was higher than the percentage of members of the control group who so answered.[2]

These experimental results are in good harmony with the theoretical demands for the inclusion of demonstrations and laboratory work in the teaching of secondary school physics.

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[1]Bernard Abrahamson, "Comparison of two Methods of Teaching Mechanics in High School," Science Education, XXXVI (March,1952), 96-106.

[2]Ellesworth S. Obourn and Clarence H. Boeck, "Sixth Annual Review of Research in Science Teaching," Science Education, XLIV (Dec., 1960), 381.

CHAPTER III

ADVANTAGES OF AN INEXPENSIVE UNIVERSAL KIT

It has been established beyond doubt that the role of experiments and demonstrations in teaching of physics is very important. The experimental approach became an integrated part of the instruction in physics. The next question to be discussed: "How can the role of experiments be achieved? What are the means that bring forth this achievement?"

With the advances of technology in this age, and the production of big machines and beautiful equipment, one is tempted to look for such equipment for his laboratory use. Administrators like to include huge pieces of apparatus to boast about, and teachers find it easier to take a catalogue of equipment, mark the needed items and send an order. But is this the best way to proceed in attempting to obtain maximum benefit from experiments in the teaching of physics?

It was pointed out earlier[1] that standard manufactured teaching equipment cannot be found

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[1] <u>Supra</u>, p.1.

everywhere. To meet the need for equipment, an easily-made universal and inexpensive kit has been suggested. Does this sacrifice the benefits of standard equipment? In other words, is it being suggested that the cost of inexpensive simple material is a loss of the instrumental value of standard manufactured equipment?

In fact, the suggested kit is justified not only on the basis of its availability and practicality, but also because it can discharge the role of experiments more efficiently and thoroughly than can be done with standard equipment. Thus the kit is not only an answer to the physical and financial needs of the schools in under-developed countries, but also an answer to an educational need in all schools that teach secondary school physics.

The educational advantages of the kit over standard manufactured equipment may be summarized as follows:

1. More Interesting

It was pointed out earlier[1] that one of the functions of experiments is to arouse the interest of the student. In the case of the kit, the student can

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[1]Supra, p. 18.

help in its construction. Any piece that a student builds and operates successfully will bring him satisfaction and will increase his interest in the course. "Nothing succeeds like success." Since interest depends upon the involvement of the individual, this kit can make the student a partner in the teaching process. Moreover, the interest of the student is proved when he feels the interest of the teacher as he sees him busy in constructing the apparatus.

2. More Instructive

The psychological pattern of concept formation is from the concrete to the abstract. New experiences depend a great deal on past experiences. In this respect, the kit is formed of ordinary available materials which form an integral part of the past experiences of the students. In the case of standard manufactured equipment, there is no link with the past, on which further concepts may readily be built. Manufactured equipment is new to the student, and demands some time to be understood. In other words, a certain learning process must precede its use. Simple materials, on the other hand, can be the first stones in the conceptual scheme.

For example, if a standard calorimeter is introduced, the student wonders why such an apparatus is used. The same thing applies to electroscopes, balances, pendulums, different meters, and most other standard manufactured equipment. In other words, it does not serve as a primary, concrete starting-point. Some learning must precede their use. In the case of equipment constructed from simple material, the student feels at home from the beginning, and can see the principle in a concrete form.

Moreover, the use of standard equipment creates the impression that the laws of physics hold only with such elaborate and shiny-looking pieces of apparatus. Such materials strongly suggest that a gap exists between physics and daily life. Simple apparatus bridges the misleading gap automatically, and shows the laws of physics as facts derivable from simple ordinary material found around the learner. Such a process accelerates the transfer of learning because the student does not find much difference between classroom experiences and everyday life experiences.

3. More Demonstrative

One of the main aims of the equipment used in physics teaching is to demonstrate physics laws and phenomena. In some cases this purpose is defeated by the use of standard manufactured equipment. The student sees boxes, colors, and well-made pieces of apparatus, but cannot see exactly how they function. The learner sees a motor, running, a galvanometer deviating, a telescope bringing the building nearer, a hydrometer floating, a battery supplying current. What do these mean to him? He understands them, if at all, in terms of their function rather than in terms of the principles according to which they function.

In this realm the simple kit provides a much greater opportunity to demonstrate principles and laws of physics. With the use of the suggested kit a motor is comprehended in its parts and principles (E-31). Nothing is hidden in the galvanometer (E-32). The telescope becomes very simple (L-33), the hydrometer entirely convincing (M-53) and the battery perfectly clear (E-11 to E-14).

In the case of the simple kit, the teacher is not afraid to let the students play with the apparatus. It is cheap! And if they construct it together, no doubt the student will learn its details by doing. In addition, no irrelevant complications, housings, or protective sceens are attracting the attention of the student away from the principles the equipment is designed to show.

This does not mean that simple kit has no disadvantages. There is the possibility that while someone is using such an approach he may over-simplify the laws of physics which will give a wrong impression to the learner. It must be made clear to the student that more accurate equipment might lead to a more reliable form of a certain law (although the essence of the law is the same.) In other words, the limitations of this kind of apparatus must be pointed out.

Moreover some of the phenomena that are related to complicated manufactured apparatus and that could be discovered only through the use of such equipment cannot be demonstrated with such a kit. Examples on these would be the wave properties of electrons, properties of radioactive materials, oscilloscopes etc.

Finally, if such a kit is to be used exclusively, it may have a negative influence on students that will enter college. In higher physics courses such students are faced with a good deal of manufactured equipment. They will find that they lack experience with such equipment and might find it hard to bridge the gap between the two types of apparatus. To overcome such a possible disadvantage it is advisable to introduce some standard equipment, whenever possible, side by side with the simple kit, to acquaint students with it. Neverthless, it must be said that exposure to the simple kit will do a great deal more for the college-bound student than no exposure to equipment at all, and this latter is perhaps all-too-often the actual truth of the situation.

Disadvantages such as these can be safeguarded against if the teacher is aware of them. The universal inexpensive kit can clearly be a valuable tool in the hands of the physics teacher who aims to achieve great things with a small capital investment.

CHAPTER IV

GUIDING PRINCIPLES IN THE SELECTION OF MATERIALS AND EXPERIENCES

There have been many attempts to compile a satisfactory set of experiments to be performed in the secondary school physics course. The extent to which such sets of experiments were used depended on the influence and authority of the organization that issued them. Educational research has not indicated in a straight forward manner what kinds of experiences are to be included in a secondary school physics program. Thus it is pertinent to derive a system of guiding principles to aid in the selection of these experiences.

A set of such principles was followed in the selection of the experiences and materials for the kit described in this thesis. These principles will be discussed in connection with the fields in which they served as guides.

Selection of Topics

The kinds of experiences that are described in the "guide" (Part II) depended upon three factors:

1. High school requirements

A study of some of the books used in high schools has shown that these textbooks agree on a large number of topics. A number of experiences and demonstrations were designed to cover these topics.

2. College requirements

Although only a small percentage of high school students go on to college,[1] college requirements were taken into consideration. Experiences are selected in such a way as to bear a similarily to laboratory experiments on the college level. Such a similarity can help transfer of learning. Some of these topics are :

Resolution of forces	(M-4)[2]
Force and Motion	(M-20)
Circular motion	(M-36)
Radiation	(H-20 and H-25)
Convex lenses	(L-24)
Concave lenses	(L-26)
Ripple tank	(L-36)
Wheatstone Bridge	(E-22)

[1]In the U.S.A. about 25%. In Lebanon about 5%

[2]M stands for mechanics, and 4 for the numbers of the experiment in the unit on mechanics. All experiments are numbered this way depending upon the unit and their places in it.

Potentiometer (E-23)

Terrestrial Magnetism(MG-12)

When such topies are included, the student does not feel that he is in a completely new situation. Such experiences will serve as a link between his high school and college physics.

3. PSSC materials

The Physical science study committee has issued its recommendations on the basis of some studies and investigations. Consequently some of the PSSC recommendations were accepted as determinants for the selection of some experiences.

According to the philosophy of the PSSC,[1] experiments like the following were included:

Measurements	(G-8 - G-10)
Size of a molecule	(G-11)
Wave theory of light	(L-21 ...)
Static electricity	(E-1 to E-7)

The first three topics are not included in most high school physics courses. The last topic, although included in most physics textbooks, it is not given as the PSSC gives it.

[1]PSSC, Physics, op.cit.

Selection of Sequence

The sequence followed in the organization of the demonstrations and experiments depended upon two principles:

1. Nature of the material

Since concept - formation depends upon the past experience of the child, the demonstrations that clearly have some connection with the past experience of the child have been put before others. Moreover, the ones that deal with issues that are facing the child every day were put before issues that he must be made conscious of. According to this principle, mechanics was discussed before the other units. Although light comes first in the PSSC's textbook[1], it is placed after mechanics and heat in this thesis, because it includes wave-motion. This concept, related to light, is not an urgent issue in the mind of the student because he is not conscious of the wave properties of light in his daily life.

2. Conceptual scheme

The experiences were arranged so that when the learner acquires a concept through one experience he uses it as a

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[1] *Ibid.*, pp. 179-307

basis to acquire further concepts. For example, the concept of beams in L-2 and L-3 is used in L-5, L-8, L-10 etc.

Another illustration is taken from the unit on magnetism. Magnetic forces are discussed in MG-6. Once acquired, this experiment serves as a basis for the determination of pole strength (MG-7). This experiment, in turn, together with MG-12, furnishes a background for experiment MG-13. In such a case the sequence can not be reversed. One cannot start with MG-13, because not enough concepts are available for the performance of this experiment.

Selection of Material

In general, the material depends upon the experiences selected. But since the purpose of this kit is to have it universal and inexpensive there are many limitations upon the selection of materials. It follows that in many cases the selection of experiences depended upon the type of materials needed for such experiences. The principles followed in the selection of materials were three:

1. Availability

As was stated in the introduction and in chapter III, one of the advantages of the kit is its universality. Therefore, only the materials that are assumed to be available anywhere were included. This principle excluded the use of mercury, many chemicals, rubber stoppers, glass tubing, pulleys, graduated cylinders, accurate balances, and many other things which seem so ordinary in advanced countries. This principle also excluded the use of standard galvanometers, ammeters and voltmeters which restricted many of the experiments on electricity, and deprived them of any truly quantitative aspect. In addition, the experiments on sound were limited, because sound detectors like a gas flame or a microphone are not widely available.

2. Inexpensiveness

What is true about availability in terms of objectives is also true about inexpensiveness. The selected materials had to be cheap. Consequently many of the suggested pieces of equipment included tin cans, bottles, metal strips, pieces of wood, strings, potato, salt etc. Such items are cheap because they are not specifically designed for the laboratory. A great part of the material is collected after it has fulfilled its original purpose like the medicine bottles and cans. Other pieces are produced on a large scale for industry, like wood and metal, and consequently are cheap.

This selection principle adds to the first principle to exclude some more experiments like the ones on atomic and electronic physics. If we assume that the equipment is available it is expensive. As a result such experiments were not included .

3. Portability

Many schools suffer from lack of space. As a result, very few can set aside a separate room as a physics laboratory. Still fewer can afford to have a special storeroom for equipment adjacent to the physics laboratory or classroom. In such a situation it is essential to have a portable kit that does not take much space. It can be carried to the classroom at any time and with much ease.

This kit is designed to be, portable. Consequently each of the materials used was selected could be a part of many different experiments. Thus duplication is avoided. Throughout the guide, one can notice the frequent use of materials that were used in previous experiments. For example, the same board is used in five or six experiments. The trolley is used in a similar number of experiments. The same is true of glass tumblers, cans, weights, pulleys and many other items. This wide use of the same pieces is not accidental; the experiences were deliberately designed with this economy of space and material in mind.

Selection of Experiences

Although the selection of topics and materials had a great influence upon the selection of experience, these are not the only factors. The guiding principles in the selection of experiences are far more important than the restrictions demanded by the kind of materials used. Some of these principles are:

1. The experience should be real.

The experiments suggested in the guide are not mere models of real things. The student can see the required phenomenon or law directly in the experiment or demonstration. Wherever models are used they are directly followed by realistic experiments. The wave theory, for example, (L-34 ...) although established by the use of a ripple tank (L-36), is preceded and followed by "real" experiences. Waves in strings (L-35) and diffraction patterns (L-37) and interference (L-38) reinforce the wave theory in a realistic way. Similarly the way properties of sound are manifested in a realistic demonstration in S - 6.

2. The experiences should be convincing.

The abstract concept that the learner is not familiar with must be supported by strong convincing experiences.

Such experiences must demonstrate the principle in a direct way, or must help the student, through the analysis of the data, to reach the desired conclusions.

Some concepts seem contradictory to the common sense of the learner. In such cases convincing demonstrations and experiments are essential. Examples of such concepts are: the independence of vertical and horizontal motion (M-22, M-23), Weightlessness (M-24), pressure in all directions (M-48), real images (L-12), refraction of sound (S-7).

3. The experiences must be easy to comprehend.

Demonstrations should not require a lecture to be understood. They should help the learner comprehend the difficult concepts. Similarly laboratory experiences should make learning more efficient than it can be without them.

To fulfill these objectives, demonstrations and experiments should be simple, showing one concept at a time; direct, giving the student the chance to catch the idea behind them; and organized, helping the student not lose the track.

This point can be illustrated by many examples. The concept of inertia could be put together with motion and acceleration. But it was intentionally discussed separately to make it simple (M-11). The same is true of the screw

(M-32). gears (M-33), surface tension (M-39), magnetic poles MG-4) etc.

4. The experiences must be interesting

The factor of interest is important in maximizing the opportunities of the teaching process. Consequently, many experiments and demonstrations are oriented in such a way to arouse the interest of the student. If the experience is real, convincing and comprehensible it will doubtless be interesting to the learner, but in addition to that, the experience must stimulate the learner and satisfy his curiosity.[1]

Many of the demonstrations are designed with this principle in mind. Examples of such demonstrations are: resolution of forces (M-5), a pencil entering the bottle (M-6), relative motion (M-21), dramatic demonstration (M-55), expansion (H-3), Hot-air wheel (H-19), drop of water lens (L-23), electric motor (E-31).

Selection of Procedure

Many laboratory manuals leave little or no room for the student to think. Like wise many demonstrations do not

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[1]Miller and Blaydes, op.cit., p. 104.

Such a procedure can be detected very clearly in most of the experiments on light and most of the students experiments in other fields, like M-20 (force and motion), and M-38 (pendulum).

The same approach is used with the teacher also. In the guide, the teacher is frequently asked to notice what happens in the demonstration without giving him the result. This procedure will stimulate the teacher to try the demonstration beforehand.

Conclusion

In conclusion, the guiding principles that were set restricted the selection of topics, sequence, materials, experiences and procedure, to a certain pattern. These principles were derived from the objectives of the kit, the educational needs, and the latest discoveries in educational psychology. The set of experiments designed, guided by these principles, enrich the teaching of physics and help the students acquire scientific attitudes and conceptual knowledge.

CHAPTER V

TECHNIQUES OF DEMONSTRATIONS AND LABORATORY EXPERIENCES

Teachers sometimes wonder when to use demonstrations and when to let the students work individual experiments in the laboratory. Some go farther to wonder which method is more efficient?

No doubt each method has its importance and place in the teaching of physics. Many studies have been done comparing the lecture-demonstration and individual laboratory work. Conclusions of different studies[1] have shown that no method is superior to the other although some investigators have shown that laboratory work produces some results that are not produced by the demonstration. Consequently one should not discard either of the two methods because each one has a function in the teaching-learning process.

Accordingly both demonstrations and individual experiments have been included in the guide for the use of the kit. The experiments designed to be done by the student are marked with an asterisk (*). Below are some

[1]See items 2, 20 and 40 in the bibliography.

general techniques helpful both in the performance of demonstrations and in individual laboratory work.

Demonstrations

Although demonstrations are mainly thought of as experiments performed by the teacher, this does not mean he should monopolize this right. However, during teacher demonstration, the assistance of the students is helpful, because it keeps them attentive and directly involved.

Some of the simple demonstrations that are suggested in the "Guide" can be carried out by the student and demonstrated to the class. They can also be prepared by a group of the class. But if the demonstration is meant to introduce a concept or a clear-out scientific principle, it must be performed by the teacher. Burnett writes in this respect:

> (The teacher) has a mature understanding of the principle or phenomenon, whereas the student is at the learning stage where there are many hazy aspects. The teacher is experienced in handling the equipment and in interpreting and explaining it to others, whereas the student tends to be inept and confused about the best means of clarifying for others points of difficulty or ambiguity. It is for these reasons that every science class should have the opportunity of observing many clear-out, clear demonstrations by the teacher[1].

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[1]R. Will Burnett, Teaching Science in the Secondary School, (New York: Rinehart and Co., 1957), p. 200.

The techniques for a good demonstration are[1]:

1. A demonstration should be preplanned and tried.

Materials and equipment should be prepared and the demonstration should be tried beforehand to discover its techniques and tricks. This is essential because if the demonstration fails, it has a negative result on the students. Planning of the time is also important. The teacher should find out the best time for a demonstration to be introduced. This must be planned in the light of the purpose of the demonstration. Many hints are given as to the timing of the demonstration in the "guide" (Part II).

2. The demonstration should be clear.

The students must understand the apparatus used, what to look for, and what the demonstration illustrates. Clarifying explanations are usually helpful.

3. The demonstration should be visible.

Sometimes the teacher appears to perform a demonstration exclusively for himself. A demonstration should be put in a place seen by everybody. If it is

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[1]Condensed from:
a. Richardson and Cahoon, op. cit., p. 20.
b. Hoff, op. cit., p. 189.
c. Miller and Blaydes, op. cit., p. 47.

touchable, let the students touch it also. If the class is large the teacher may need to perform the demonstration in two separate places in the room.

4. The demonstration should be presented as a problem.

Demonstrations should not be like pictures, with a passive character. They should not always be given to the class as an illustration of what is learned. A demonstration should present a challenge to the student to search for a new knowledge. For example, you could explain the law of inertia and then show the students the demonstration on the pencil and ring[1] telling them that it is an illustration of inertia. You could, in a much better way, show them the same demonstration and ask them to find a way to explain what they have observed.

Similarly, after the students have had accelerated motion you could show them the demonstration on "weightlessness[2]" not as an example of the concept but as a phenomenon that they are required to explain.

In this way the demonstration ceases to be a "diluting" element in the lecture method. It becomes an important part of the learning process.

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[1]*Infra*, M-6.

[2]*Infra*, M-24.

Individual Laboratory Work

The practical techniques for use of laboratory work are:

1. Although it is called "individual" work, it does not mean that every student should work alone with a seperate set of equipments. It is advisable that the laboratory work be performed by groups of two or more. In this case not as many pieces of equipment are needed. In the second place "attitudes and habits of cooperation are encouraged by the type of laboratory experience in which the students are associated with others[1]". However such an arrangement might lead some students to rely on their partners. Therefore a continuous shift of partners as well as occasional individual work is highly advisable.

2. The experiments marked with an asterisk (*), are designed especially for the student to perform. A teacher can mimeograph these experiments, whenever possible, and give them to the student. If mimeographing is not available, the teacher can dictate the instructions to the students.

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[1]Richardson and Cahoon, op. cit., p. 29.

When the sheets and the apparatus are distributed to the students, the job of the teacher is not over. His guidance and help is needed. The sheets are designed in an inductive-deductive way in which the student has to think and reason for himself. If the teacher furnishes him with the answers at the beginning of the laboratory session, he has defeated the purpose of the experiments[1]. So the teacher must urge the students to <u>think</u>, and help them conclude <u>for themselves</u>.

3. Reports on the experiments do not have to be of a certain special pattern. However neatness and accuracy must be required to train students for advanced laboratory work. No special method of reporting can be considered superior. Bail conducted an experiment on different methods of reporting and concluded that "the important element is not by what method the experiment is recorded, but how well it is recorded by whatever method is used".[2]

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[1]For the principles underlying the experiments see Chapter IV.

[2]Noll, <u>op. cit.</u>, p. 50.

PART II

A TEACHER'S GUIDE TO THE CONSTRUCTION AND USE OF THE KIT

(Experiments market with an asterisk(*) are for individual laboratory work. The teacher can mimeograph the instructions and pass them to the students.)

CHAPTER VI

GENERAL DEVICES AND
MEASUREMENT

G-1. Measurement of Angles.

If a protractor is not available, take a piece of gelatin or glass and cut it in a circle of the same dimension as the one shown in fig. G-1. Put it in such a way to coincide with the circle in the diagram and copy the details of it using graphite paint, or china ink, or any permanent paint. Thus you have a graduated circle which can be used as a protractor also. Anyhow a protractor can be obtained by using a semicircle only.

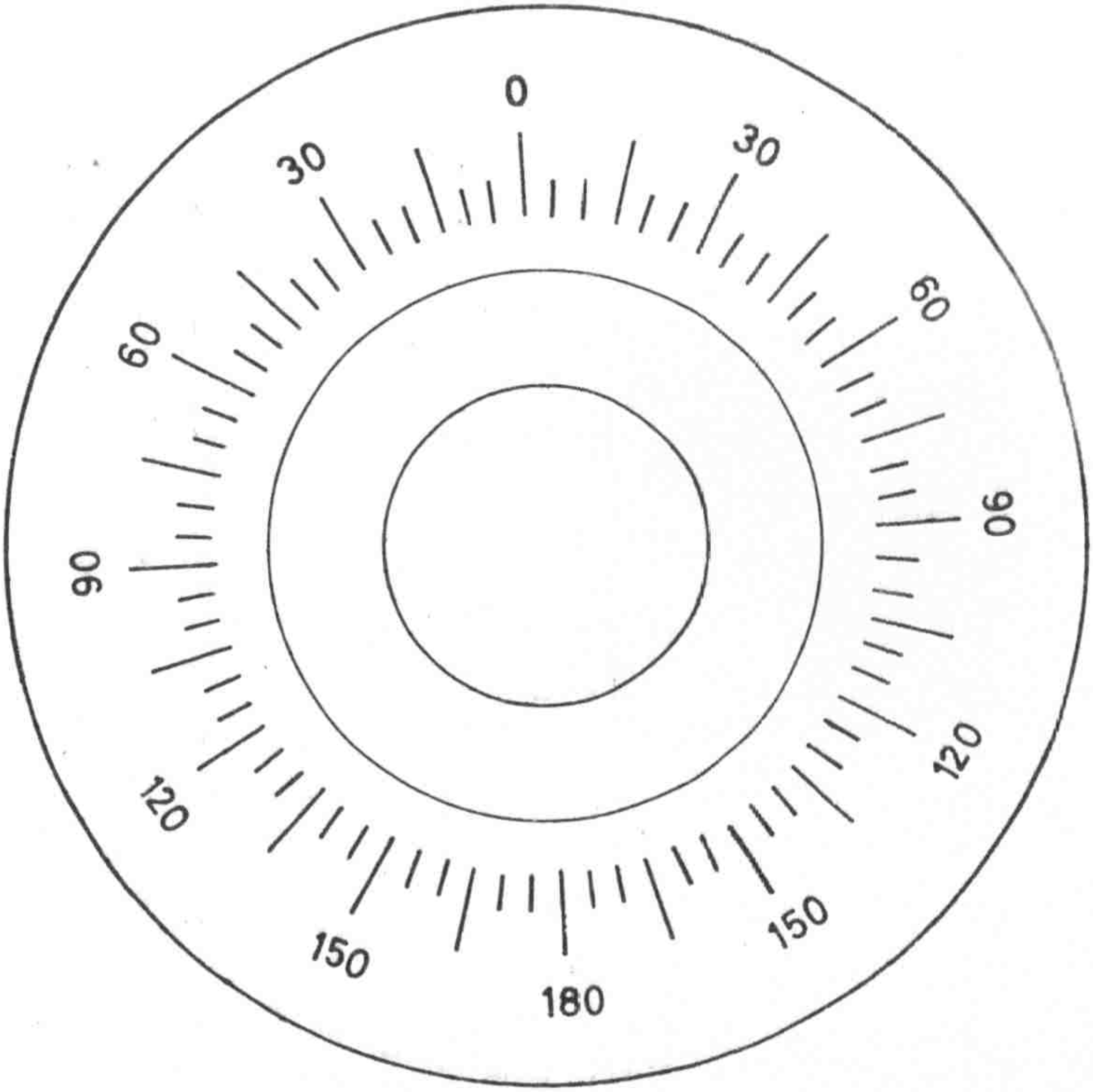

Fig. G-1

G-2. Compressed Air

When-ever compressed air is needed, you can use a bicycle pump.

G-3. Partial Evacuation

Whenever partial evacuation is needed on a small scale, you can boil a small quantity of water in a container. Seal it with wax on a stopper and pour cold water on it. Partial vacuum is produced.

G-4. Evacuation

Take the bicycle pump used in G-2. Open it, remove the piston and take out the leather washers. Turn them over and put them back on the piston. Insert the piston into the cylinder and you get a vacuum pump.[1]

G-4. Stand.

Take a piece of wood about 15cm. long 10cm. wide and 2cm. thick. Near one end of it drill a hole and insert a metallic

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[1]UNESCO, UNESCO Sourcebook for Science Teaching, (Amsterdam: UNESCO, 1956), p. 80.

rod about 40cm. long and 1cm. in diameter. (Make two of these stands.)

Clamp. Obtain block of wood with an edge 4 cm. long. About one cm. from one face drill a hole so that the rod in the stand enters freely in it. Drive a screw in the nearest face and perpendicular to the hole, to hold the rod in position.

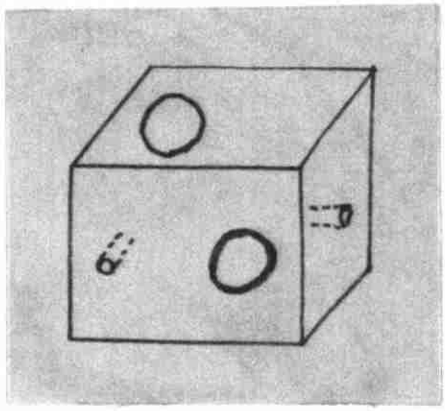


Fig. G-4a

Through the other two faces drill another hole 3/4cm. in diameter. Pass a rod intonthis hole about 15cm. long. Insert a screw to hold the rod in position.

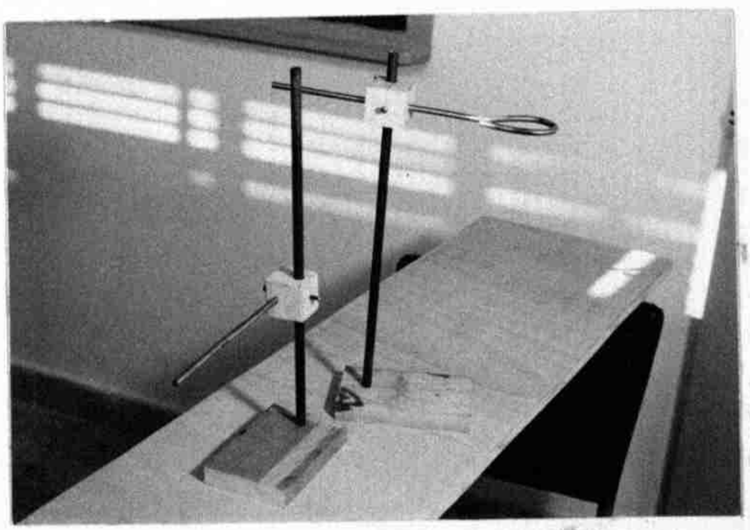


Fig. G-4b

Construct another clamp as described above. Let its rod be about 40cm. long. Bend about 20cm. of it into a ring to support objects on it.

G-5. Graduated Cylinder.

If a graduated cylinder cannot be obtained commercially one can easily construct one.

If a large cylinder is required, obtain a large glass tube or bottle. Make sure it has a uniform diameter of cros-section. Weigh a quantity ofwater of about the capacity of the container. Mark it in tens (eg. 60, 70, 100 gr. etc.) This will be the same quantity in cubic centimeters. Pour the water into the container. Measure the height and compare it with the volume. Establish a scale on a piece of paper and stick it to the side of the container. (A transparent paper is prefered)

If a small cylinder is required, select a glass tube like the ones used for drugs. Then follow the same procedure.

G-6. Balance

Usually balances are commercially available in the market. A balance that measures to the tenth of a gram is recommended, because such accuracy is needed in the experiments.

However if such a balance is not available one can construct one.

Take a piece of wood about 35 x 4 cm. to serve as the base. The support of the balance is made of a piece of wood about 15 x 2 x 2 cm. To two opposite sides stick two pieces of thin wood about 20cm. long. Drill a hole in each about 3cm. from the top. (see fig G-6a)

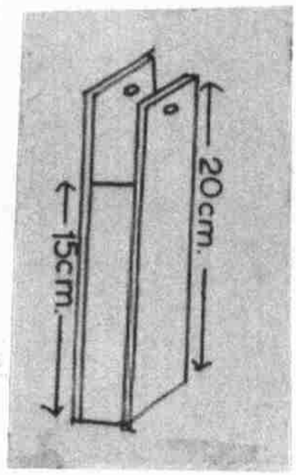


Fig. G-6a

The arm is constructed as follows: Cut a piece of wood about 40cm. long, 2cm. wide and a bit less than 2cm. in thickness. Insert one hooke near one end of the rod. At exactly 10cm. from the hooke drill a hole enough to pass a nail freely through it.

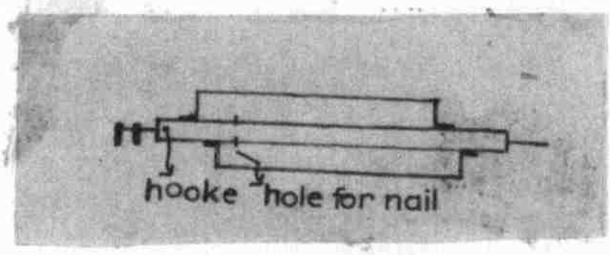


Fig. G-6b

Cut two metal strips about 26 cm. long and 1cm. wide and bend them as shown in fig. G-6c.

Fix them to two opposite faces of the arm. (Keep one end of one of the strips unscrewed to make it possible to pass a nail through the hole as mentioned above).

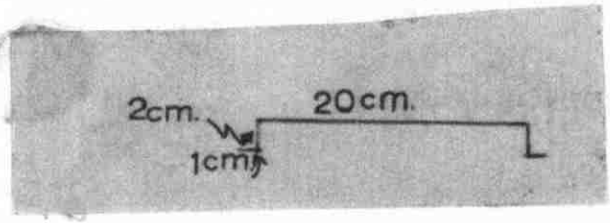


Fig. G-6c

In one end of the arm insert a screw with two nuts for fine adjustment of the balance. On the other end insert a nail to serve as a pointer.

Take a tin can cover to use as a pan. Suspend it with three pieces of wire or string each of about 10cm. long. To find the places of the holes to which the wires must be connected, place the can on the graduated circle (G-1) and concentric with it. One hole would be at angle 0 the other at 120° and the third at the other 120°.

Take a weight of 200gr. (obtained from the market), and another one of 10gr. If the 10gr. weight is not commercially available you can go to a pharmacy and use the balance to cut a piece of metal of 10gr.

Now fix the support to the base at a distance of about 15cm. from one end. Fix the arm to the support by passing a nail into the three holes. Screw the free end of the metal strip. Suspend the pan to the hooke. Hang the weights each to one metal strip. Put the 10gr. weight on one end on the strip nearest to the pan and move the 200gr. weight to get a horizontal position of the arm. This is the zero point of the two weights. On the side of the 10gr. weight make a scale of 20cm. This can be done either by obtaining such a scale from meter-strips used by tailors or by copying the scale on a paper and pasting it on the metal strip. This scale will read one gram to every one centimeter.

On the other strip make grooves 1cm. apart. Each position will be equivalent to an increase of 20gr.

Now that the balance is calibrated, you can add a vertical wood strip near the pointer on the arm to make balancing easier. Draw a line on this strip for the horizontal position then draw few more lines, equally spaced for comparison. You can add two screws to this strip about 2cm. above and below the horizontal position to limit the oscillation of the arm.

Before using this balance, check the zero reading by adjusting the bolts on the screw near the pan.

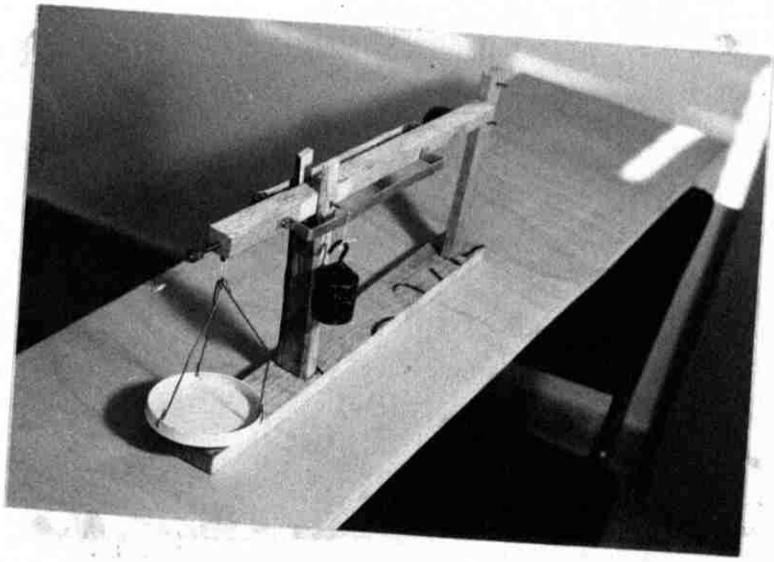


Fig. G-6d

G-7. Stroboscope

Construction:

Cut a disc of a cardboard of a diameter of 25cm. Draw consecutive angles of 30^o each on it, by the help of the graduated circle. Along these radii cut slots 5cm. long from the circumference and about 4mm. wide. Cut a circular hole about 1.5 cm. in diameter and about 2 cm. from the center. Fix the disc to a piece of wood of the thickness of the thumb in such a way that while holding the wood the disc can rotate freely. Paint disc black.

Suppose there is a rotating or vibrating body. If you look it with a stroboscope with one slit and you rotate the disk with the same frequency as that of the rotating body, you see the body at rest. As the body moves, you see a certain part of the rotating body through the slit. The body moves and you follow it with the slit. So you see the same part. Thus the body seems to be at rest. If the stroboscope has 2 slits, then you need to rotate it with a frequency half of that of the body to see it at rest. The same is true of 3, 4 ... 12 slits.

Now in the case of the stroboscope with 12 slits, if you see a vibrating body stop, then its frequency is 12 times that of the stroscope. So you can find the frequency of an object vibrating with a high speed by means of such a device as the stroboscope.

Fig. G-7

G-8. Micro Balance

This demonstration aims to help the students understand the concept of small weights. A very sensitive balance can be made as follows:

Take a small rectangular cardboard box and cut it as shown in fig. G-8 you need also a soda-straw (If it is not available cut a thin piece of wood of the length of a soda straw. Insert into one end a string loop narrow enough to pass through it a screw. If available you can use a natural straw instead.)

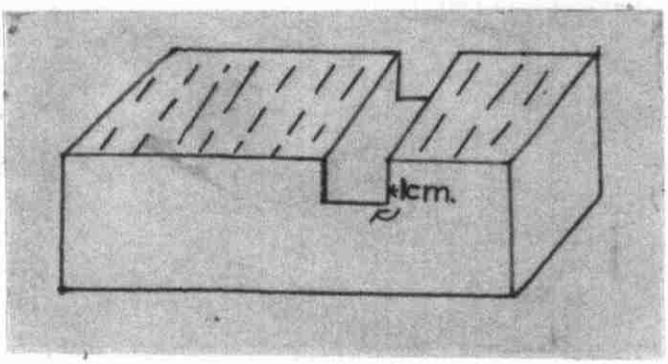


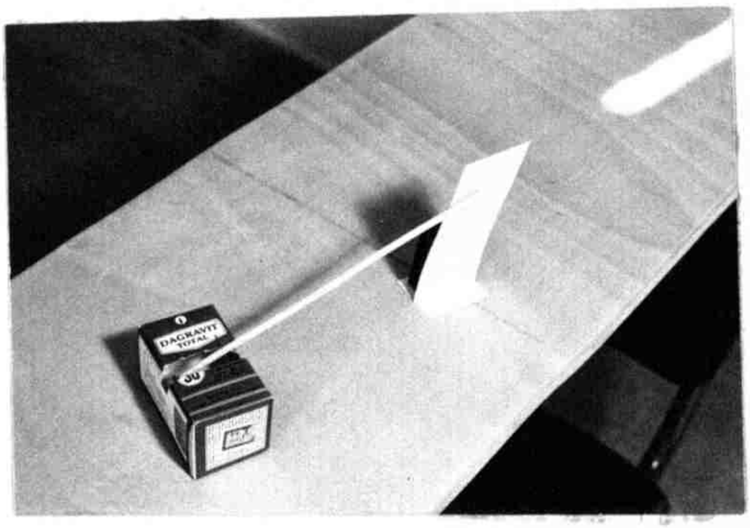
FIG. G-8a

Take the straw, or the piece of wood, and insert a screw that fits in tightly. At about 2cm. from that end drive a pin or needle into the straw to serve as an axis and place it across the opening in the box. Flatten the other end of the straw to hold weights. Now the balance can be adjusted by the screw.

To calibrate the balance cut a piece of cardboard about 15cm. long and 1.5cm. wide. Hold it vertically near the flattened end of the straw by means of a clothespin. Take a thread 1 meter long and weigh it. Cut few pieces ½ cm. long and add one at a time on the flattened edge. Knowing their weight you can mark on the cardboard paper such weights. Extend the scale according to the few values you got.

After you have a scale you can weigh a piece of hair or string or any small object.[1]

Fig. G-8b



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[1]Condensed from: Freshmen Laboratory sheets, Physics Department, American University of Beirut.

G-9. Optical Micrometer

Take a piece of wood about 6 x 4 x 2 cm. At one corner cut a slice 1 x 1 x 2cms. Fasten it to the end of a wooder board. 30 x 12cm.

Cut two pieces of ordinary glass 6 x 2cm. Paint one with graphite or any black paint and paste it or hold it to the upper part of the block by means of rubber bands. Towards one end of the glass slide fasten a needle vertically by means of a rubber band and drive it a bit into the board.Place the second glass plate over the first and hold it with a rubber band at the edge near the needle.

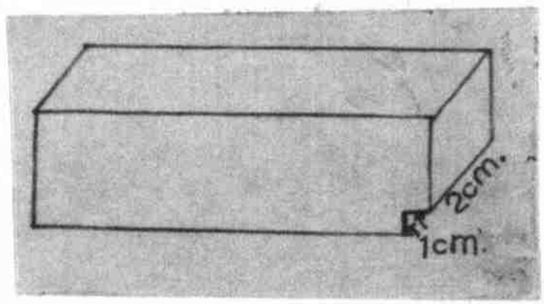

Fig. G-9a

To calibrate the instrument,paste a piece of paper to the free side of the board and tie a thread to the needle about 40cm. long. Drive a pin or nail into one side of the block and about 10cms. from it. Align the image of the pin with the needle, and mark this on the paper. Then take a pad of paper, measure its thickness and divide by the number of pieces to find the thickness to each piece. Start inserting these pieces between the two slides and again align the image of the pin with the needle and mark this on the paper. After a few trials you get a scale.

Now you can measure the thickness of a hair or razor or any other thin object.[1]

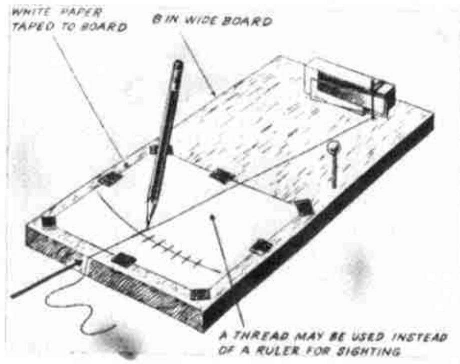

Fig. G-9b

G-10 Parallax Viewer

(Before such an experiment is done by the student or with them the meaning of parallax should be made clear to them)

---

[1]Adapted from:
A. Joseph et al., A Sourcebook for the Physical Sciences, (New York: Harcourt Brace & World, Inc., 1961), p. 25.

Take a meterstick and prepare a piece of wood to slide freely on it. Drive two nails or pins in the slide with a distance of 1 centimeter between them (This distance must be accurate.)

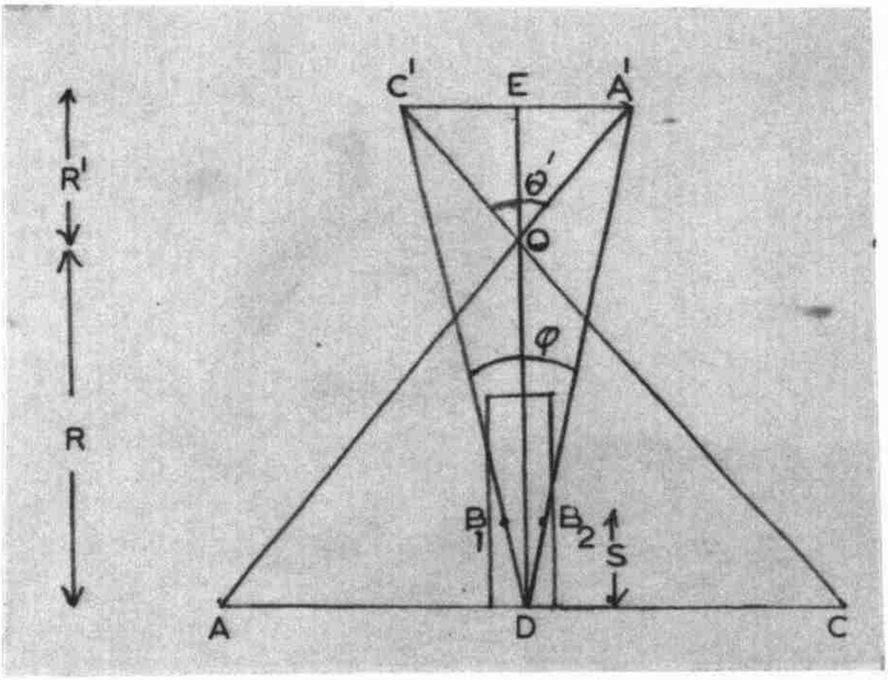

Fig. G-10

Select an object O which you want to find its distance. Choose an object that has a back ground like a wall. More about 1 meter from D and locate point C' (you can use a student carrying a stick to represent C').Similarly locate A' from A. Now go back to D and point the meter stick to O. Move the slide until B_1 coincides with C' and B_2 with A'.

It is clear from trigonometry that

$$\frac{AC}{OD} = \frac{A'C'}{OE}$$

$$\frac{A'C'}{DE} = \frac{B_1B_2}{S}$$

But $$\frac{DE}{A'C'} = \frac{D\ O}{A'C'} - \frac{OE}{A'C'}$$

$\frac{DO}{A'C'}$ is very small and can be neglected

$$\frac{AC}{OD} = \frac{B_1B_2}{S}$$

Whence $$OD = \frac{AC\ .\ S}{B_1B_2}$$

The quantities to the right can be measured and consequently OD can be found.[1]

[1]Condensed from:
Joseph *et al.*, *op.cit.*, p.27.

G-11 Size of the Molecule

Since molecules are too small to be measured by a direct method, an indirect method is deviced. The dimensions of the molecule will give the student an idea about its size.

If a drop of oil is poured on a tray of water, the oil spreads and forms a thin film. The thickness of the film cannot be less than the width of a single molecule. If we can get the thinnest possible layer then we can obtain the thickness of the molecule.

Since a drop of oil covers a large area, then we must have a volume of oil less than one drop.

1. Add 5 c.c. of olive oil to 95 cc. of alcohol (use graduated cylinders discussed in exp. G-5). Then take 5 c.c. of the mixture and add to it 45c.c. of alcohol.
2. Calculate how much oil exists in one c.c. of the final mixture.
3. Find how many drops of the mixture make one cubic centimeter. (Use a medicine dropper.) Thus find the volume of oil in one drop of the mixture.
4. Pour water to depth of 1cm. into the tray used for the ripple tank in exp. L- 36. Lightly put chalk dust on the surface of water.

5. To make sure that alcohol has no permanent effect on the surface of water, put a drop of pure alcohol on the dust. What do you observe?

6. Put one drop of the final mixture on the chalk dust. The oil film will be terminated by the dust particles. Find the area of the film.

7. Try two drops. Is the area doubled? What can you conclude about the thickness of the film?

8. Find the thickness of the oil film.

9. Roughly, how many molecules of oil are present in one drop?

10. Find the density of oil and thus find the mass of one drop. Calculate the mass of one molecule of oil.

11. What assumptions have we made as to the shape of the molecule of oil. Is this a clever assumption?

What are the sources of error in this experiment?[1]

---

[1]Adapted from:
Freshman laboratory sheets, Physics Department, American University of Beirut.

CHAPTER VII

M E C H A N I C S

A. FORCE

M-1. Force Table

Cut a disk from a piece of wood or thick carton paper. Let the diameter of the disk be between 20 and 25 cm.

Copy the graduated circle that appears in (G-1), and fixit on the one side of the disk and concentric with it.

Now you need pulleys to be clamped at any position on the circumference of the table. If they are not available in the market, you can substitute the following for them.

Take three piece of aluminum (or any smooth metal available to you) of about 10 cm. long and 3 cm. wide. Shape each one as in figure M-1.

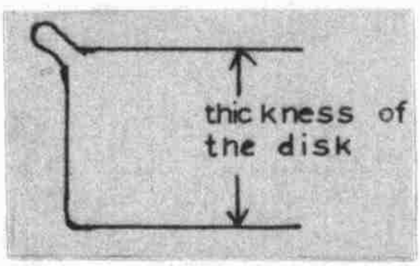

Fig. M-1

Adjust it in such a way to enter easily and slide on the circumference of the disk.

This table with a metallic ring, few weights of different values, and about 100 cm. of a thread with be sufficient apparatus for the next experiment to be done by your students. (See Fig. M-2)

* M-2. Composition of forces

1. Support the disk on a book or a block of wood like the one used in M-22. Adjust two of the "pulleys" on fixed places on the turn - table and leave the third for further adjustment.

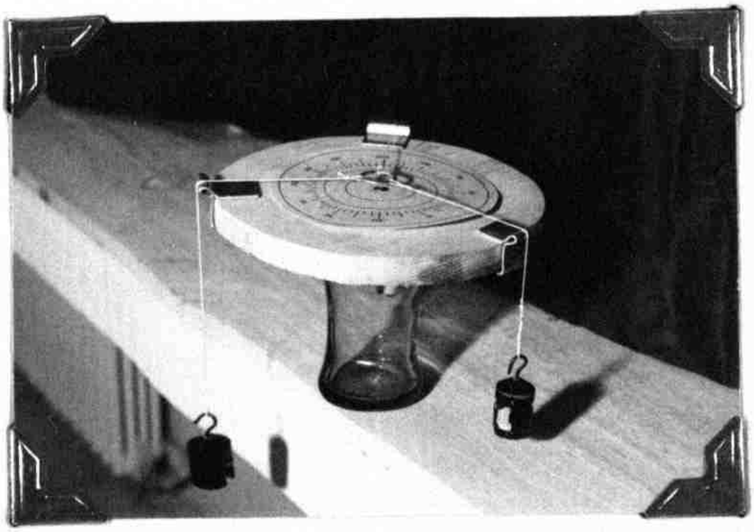

Fig. M-2

2. Cut three strings each of about 30cm. long. Attach them to a ring about 2cm. in diameter. Attach two weights to

the other ends of two strings.

3. Holding the third string in your hand,pass the strings over the pulleys. By trial - and - error find the magnitude of the weight you must attach to the third string for different positions of the pulley. This will be the anti- parallel of the resultant of other two forces (the "equilibrant")

4. Knowing the angle between the first two forces, by means of the graduated circle, find graphically the resultant force. Compare with the magnitude and direction of the anti- equilibrant .(Find the "resultant")

M-3. Composition of forces

The concept shown in experiment M-2 can be demonstrated by the following experiment.

Take a broad of wood about 40 x 40 cm. or use the back of the inclined plane used in M-16. Drive two nails into it at about 10 cm. from each edge. Do not put the nails on the same level. Have two spools roll over the nails to minimize friction. Take about 50 cm. of string and attach weights to its two ends and

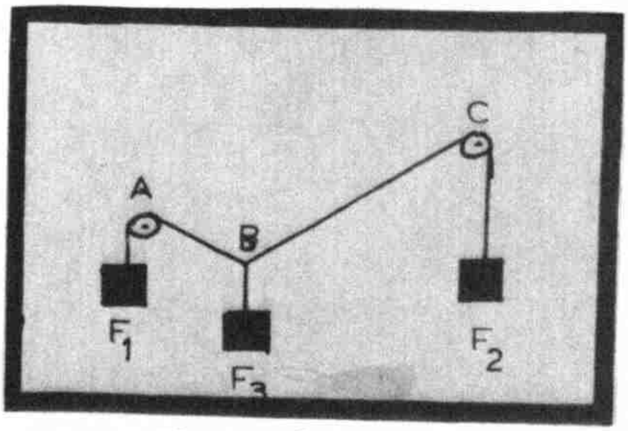

Fig. M-3

pass it over the spools. Some place in between hang a convenient weight to get something like figure M-3.

By means of a protractor (see G-1) measure the angles about point B. Compute graphically the resultant of the forces F, and F_2. Compare with F_3.

* M-4 Resolution of forces.

Use the same board that you used in M-3

Hang two weights W and W' as shown in Fig. M-4

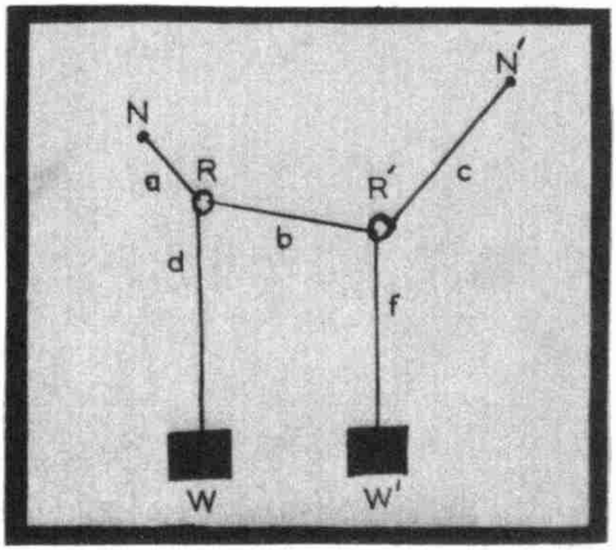

Fig. M-4

The forces around points R and R' are the same as the ones demonstrated in previous experiments, W is a known weight while you are required to find W'.

1. W is the anti- equilibrant of the two forces of tension in a and b, knowing the angles between a,b and d Draw a diagram representing these forces. Find graphically the value of the forces in a and b.

2. Draw a similar diagram representing the direction of the forces in b,c and f. Knowing the force in b find graphically

pass it over the spools. Some place in between hang a convenient weight to get something like figure M-3.

By means of a protractor (see G-1) measure the angles about point B. Compute graphically the resultant of the forces F_1 and F_2. Compare with F_3.

* M-4 Resolution of forces.

Use the same board that you used in M-3

Hang two weights W and W' as shown in Fig. M-4

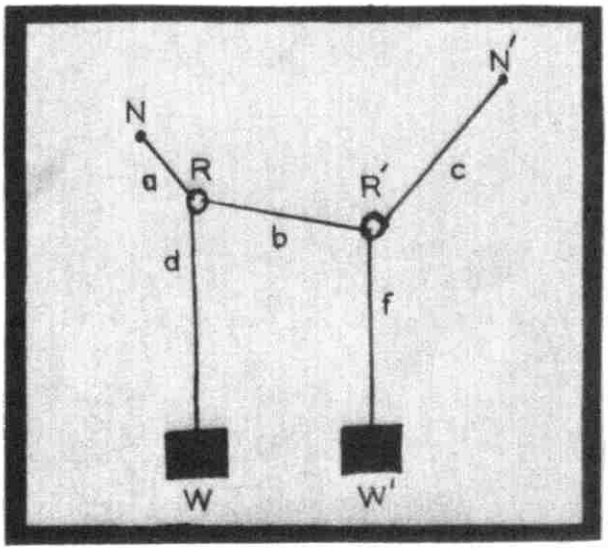

Fig. M-4

The forces around points R and R' are the same as the ones demonstrated in previous experiments, W is a known weight while you are required to find W'.

1. W is the anti- equilibrant of the two forces of tension in a and b, knowing the angles between a,b and d Draw a diagram representing these forces. Find graphically the value of the forces in a and b.

2. Draw a similar diagram representing the direction of the forces in b,c and f, Knowing the force in b find graphically

the resultant of the forces in b and c. Consequently find W'.

3. Follow the same procedure again to find W', but use analytic method of resolving forces rather than the graphical method. Do you results agree with the accepted value of W'? If not what are most probably the sources of error?

M-5. Resolution of Forces.

This experiment[1] demonstrates the resolution of a vertical force into forces at an angle with the vertical thus having vertical and horizontal compoments.

Take a carton tube of about 1.5cm. in diameter (the dimension is arbitrary). If a tube can not be obtained, take a carton paper, wind in a cylindrical form and fix it by means of an adhesive tape. Attach over one end of the tube a piece of tissue paper with a rubber band or a string. Fill the tube carefully with fine dry sand to a height of about 5 or 6 cm. Introduce a wooden dowel or a thick pencil with a diameter nearly equal to the inner diameter of the tube. Exert a force on the dowel by means of

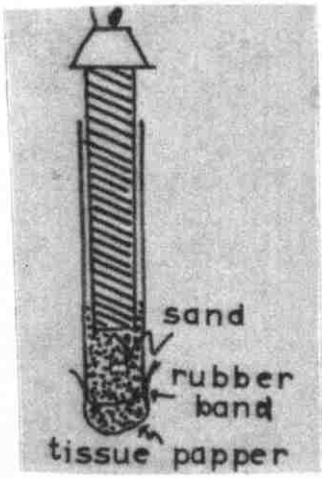

Fig. M-5

[1] R.M. Sutton, Demonstration Experiments in Physics, (New York: Mc Graw-Hill Book Co., Inc., 1938), p.17.

a weight see how much weight can be applied before the tissue breakes.

Try the same thing without sand; you see that the tissue breaks with less weight.

B. INERTIA

M-6. A Pencil Entering a Bottle.

You can introduce inertia by showing the following demonstration, leaving the explanation for the next session to let the students think of it.

Construct a wooden ring as follows: Take a thin piece of wood about 70 cm. long, 1cm. wide and few mm. thick. Bend in a circle and fix the ends by means of a stabler, if availabl . If not use adhesive tape, or cement can be used.

Support the wooden ring vertically on the mouth of a soda bottle. Let a pencil stand on its botton on the upper part of the ring. (see Fg.M-6)

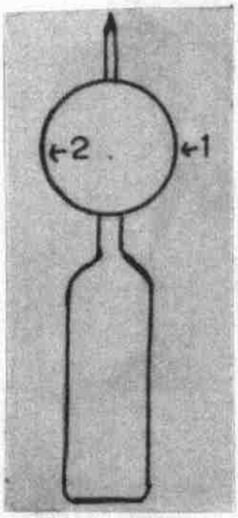

Fig. M-6

If you hit the ring from the outside (position"1") with your finger, the pencil will not fall into the bottle. If you hit the ring from the inside (position "2") the pencil will fall into the bottle.

When you hit the ring from the outside, it forms an ellipse with the longer axis in the vertical direction. Thus it will exert a force on the pencil before it moves from under it. While if you hit it from inside, it will squeeze under the pencil without changing its position, thus the pencil falls straight into the bottle .

M-7. Breaking a String by inertia

Take the trolley used in exp. M-12 or a book or a heavy object and tie it with a thread from both ends. Support one thread to d stand.

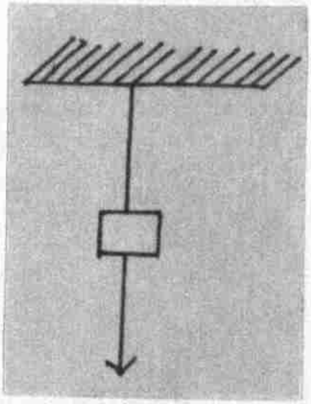

Fig. M-7

1. Hold the end of the other thread and pull slowly. The upper thread will break, because there is the force applied plus the weight of the body exerted on the thread.

2. Repeat the same arrangement. Pull quickly and the lower thread will break because of the inertia of the body.

M-8. Falling Spool.

Make two circular wooden discs of about 5cm. in diameter. Drive a nail through their center leaving them about 5mm. apart. (Before you drive the nail into the second disc tie around it the end of a 50cm. long string.) Now wind the string around the nail between the discs. Hold the end with your hand and leave the spool to fall down. Before the string unwinds completely give it an upward jerk and the spool will climb up. This is due to inertia of the motion of the spool.

(In some places this is a toy available in toy shops and known as Yo-Yo.)

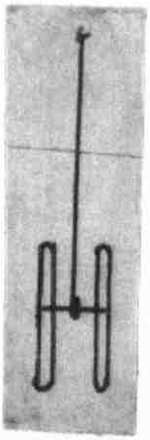

Fig. M-8a

Fig. M-8b

M-9. Spinning Wood.

The same concept, shown in M-8, can be demonstrated as follows.

Take a piece of metal about 5.5cm. long and 2cm. wide. Bend it in a U- form (see fig. M-9a)

Drill 3 holes in the three sides. Pass a nail in the two opposite holes and drive it into a block of wood about 5x3x1.5 cm.

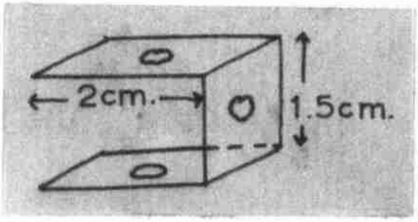

Fig. M-9a

Tie a string to the nail and pass it through the side hole. Spin the wood to wind the string on the nail. Hold the metal with your finger and pull the string. The block will spin. Before the string unwinds completely feed it in again. It will wind around the nail. Pull; and the process repeats itself. Again the inertia of the block of wood makes this continnous spinning.

Fig. M-9b

M-10. Spinning Button.

A third simple demonstration of inertia can be very easily repeated by students at home .

Take a large button about 2 or 3cm. in diameter pass a string through one hole and back through a second (opposite) hole. Tie the ends of the strings together. Hold the loop in your fingers with the button in between. Swing the button in a circle so that the string will wind on itself.. Pull the string with your fingers and feed periodically and at convenient time, and you will obtain a continnous rotation of the button, which alternates in opposite direction.

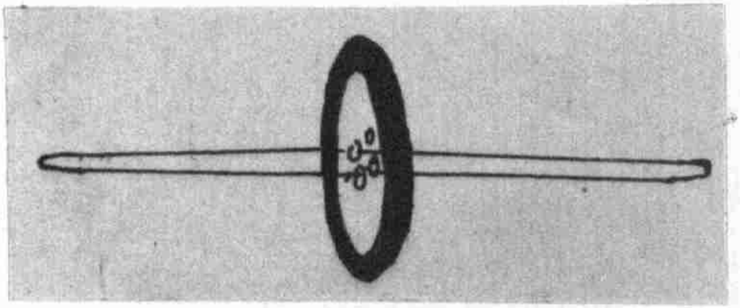

Fig. M-10a

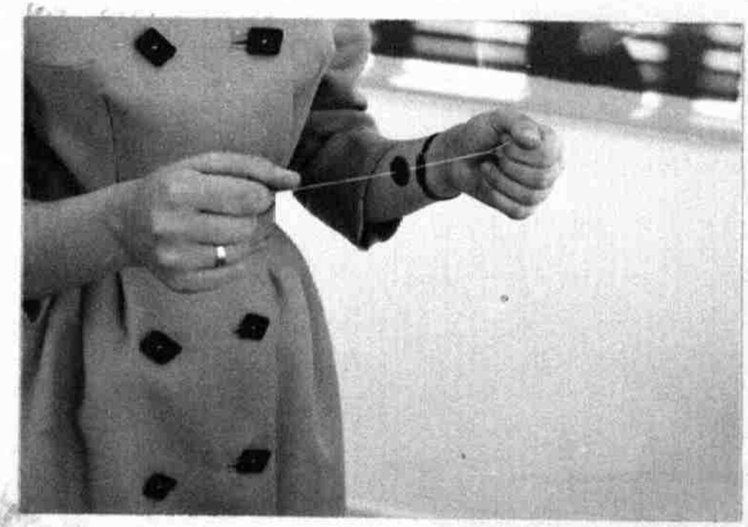

Fig. M-10b

C. REACTION

M-11. Reaction Balloon

Fill a balloon with air and release it. It will move by the action of a jet of air escaping from its mouth. Let the students observe that it is moving opposite to the direction of the jet. (The teacher might say here few words about rockets and jet planes)

M-12 Reaction Car

Build a car as follows (It will be used in further experiments)

Cut a piece of wood about 30cm x 10cm. Use it as a base and build around wooden walls about 8cm. high. Cover only 2/3 of the top with a piece of wood screwed to the walls. (Some times one can find such a box already made).

Obtain wheels from old toy cars. If not available cut wooden or metallic wheels in a workshop. Drill a hole at the center and attach them to the cart by means of nails.

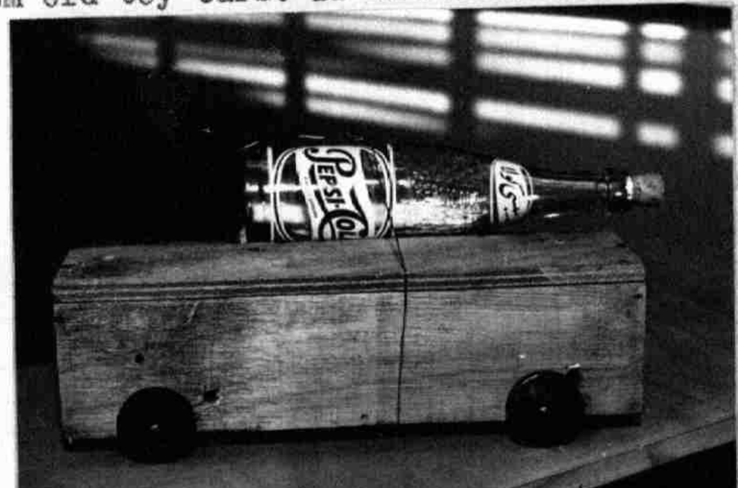

Fig. M-12

Take a few grams of baking soda and wrap? them with a tissue paper or a piece of cloth. Insert in a bottle, pour vinegar or lemon juice over them, and close the bottle lightly with a cork stopper. Attach the bottle horizontally on the cart by means of rubber string. After some time the gas will force the stopper out and the cart will move in the opposite direction.

M-13. Reaction Wheel[1]

Take a tin can and make holes near its bottom by means of a nail driven in it sidewise (not through the axis of the cylinder) and parallel to the plane of the bottom (see Fig. M-13). Suspend the can by means of a string and fill it with water. As the water jets out of the holes, the can will move in the opposite diredtion.

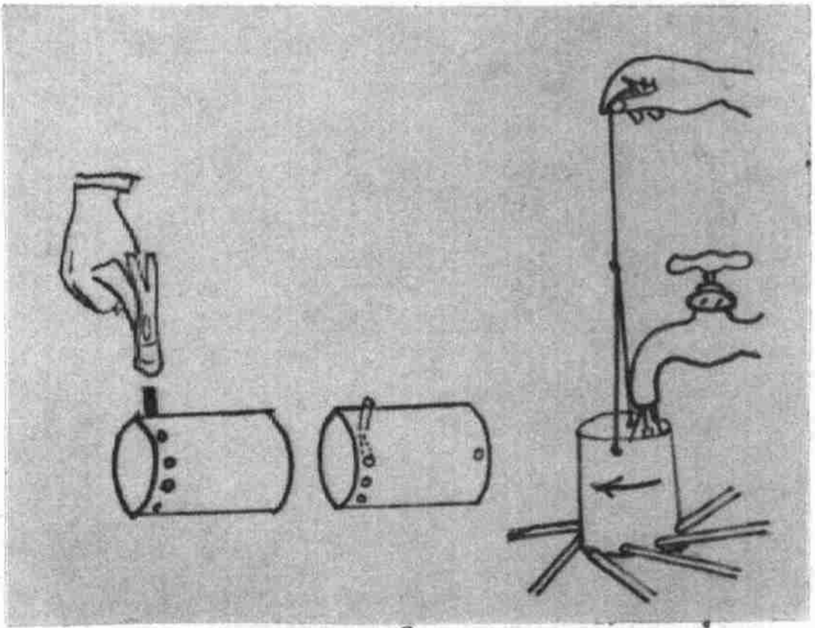

Fig. M-13[2]

[1]Richarson and Cahoon, op.cit., p.200.

[2]C.J. Lynde, Science Experiences with Home Equipment, (New York: D. Van Nostrand Co., Inc., 1949), p.65.

D.FRICTION

M-14. Amount of Friction.

Friction can be introduced by taking two similar blocks of wood, one is coated with wax and one is not. Push them on the table. One stops before the other.

M-15. Fluid Friction.

Friction can also be introduced by catching the attention of students by the following demonstration.

Take two eggs: one raw and one hard boiled. Spin them on the table. The boiled one will spin more readily than the raw egg which has internal friction. If you stop the raw egg by your finger it may resume rotation when released due to inertia.[1]

* M-16. Coefficient of Friction.

Take a plane about 1 meter long and 20cm. wide, Incline it by means of a support. (You can use the cover of the kit box for this purpose)[2]

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[1] Sutton, op.cit., p. 33.

2 See Appendix II

1. Show (theoretically) that if an object slides with a constant speed on an inclined plane then the coefficient of friction equals the tangent of the angle of inclination of the plane

$$u = \tan \emptyset$$

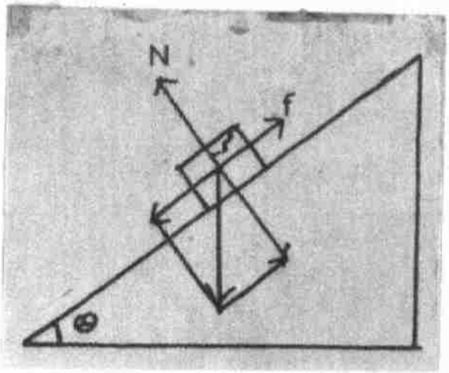

Fig. M-16

2. Adjust the plane so that a piece of wood slides with no acceleration. Find u.
3. Find u after you coat one surface of the block with wax. Compare with the result in (2)
4. Rolling Friction

   Adjust the plane so that a cart (the one used in experiment M-12) rolls with no acceleration on the plane. Compute u. Compare with the sliding coefficient of friction.
5. Pass a rubber band around the two pairs of wheels of the cart so that they do not turn. Slide the cart and find u. Compare it with your result in (4).

M-17. Friction and Pressure

Support a meter stick on your index fingers such that one is on the 10cm. mark and the other on the 70cm. mark. Ask the class on which side the stick will fall as the two fingers are brought together. Bring the fingers slowly together and you see that they will meet at the middle of the stick, with the stick in equilibrium.[1]

Let the class explain such unexpected result. You can leave your explanation for the following session.

E. MOMENT

* M-18. Torque

After the students acquire some knowledge of moments they can perform the following experiment.

1. Support a meter stick on a knife edge.(This can be provided by taking a carton box and cutting it like a prism to get a wedge) Hang a weight on the right by means of a string. Choose another weight and hang it to some place to the left to obtain equilibrium. What is the torque produced by each weight around

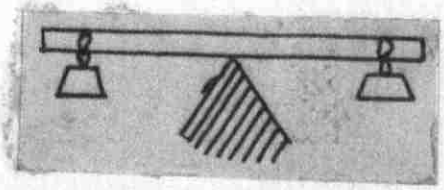

Fig. M-18a

[1]Sutton, op.cit., p. 31.

the center? Is it as expected?

2. What are the forces acting upon the meter stick? Take any point, and compute the torque around it produced by these weights. Is it as expected?

3. Support the meterstick by the help of some weights at the 30cm. mark. Compure the torque around any point produced by the forces acting upon the stick. (Do not forget the weight of the stick).

4. Choose the weights to balance the stick as follows:

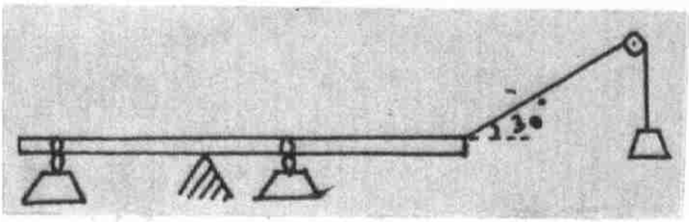

Fig. M-18b

(To make an angle of 30° pass the string over an iron rod on a stand, or use the pulley as of experiment M-28.) Compute the torque around the edge of the stick. Is it as expected?

Question: What can you say about the condition for a point to be in equilibrium?

M-19. Balance

Insert a pencil into a piece of potato or cork. Drive a fork into the potato piece at an angle with the horizontal. Support the end of the pencil at the edge of the table. Give the other end a push and it will oscillate. You can stick to the end of the pencil a toy man to make the experiment more interesting.[1]

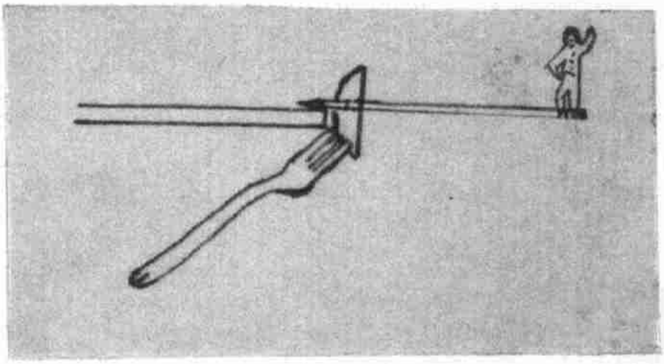

Fig. M-19

F. NOTION

* M-20. Force and Motion[2]

Use for this experiment the inclined plane used in M-16 the trolley of M-12 and the pulley discussed in M-28

Support the inclined plane by means of a stand and a rod under the upper edge of the plane. Attach to the upper

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[1]Lynde, Science Experiences with Home Equipment, op.cit., p.144.

[2]Adapted from: Freshmen Laboratory sheets, Physics Department, American University of Beirut.

end of the plane a wooden rod about 15 cm. high. To it attach a metallic strip about 30cm. long 1cm. wide and few mm. thick, parallel to the plane, At the end of the rod fix a brush by means of a rubber band. At the lower end of the plane fix a pulley.

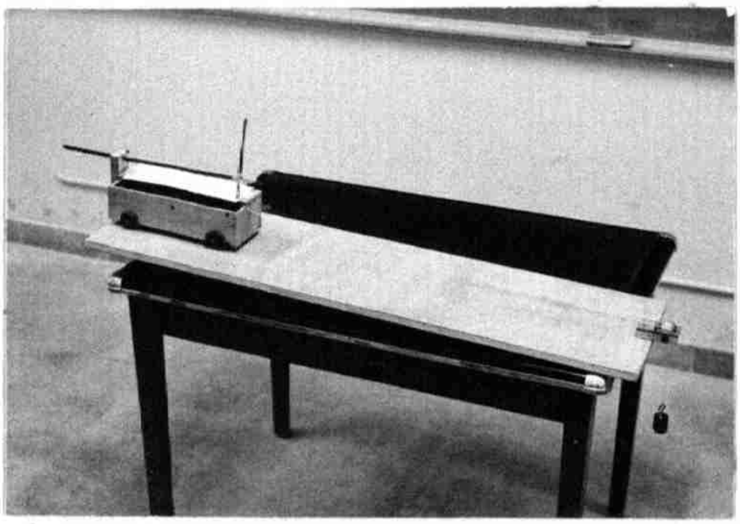


Fig. M-20a

Cut a strip of paper and fix it to the top of the trolley by means of rubber bands or adhesire tape, connect a string to the front of it and pass over the pulley. Hang a 100gr. weight at its end.

As the trolley is released the metallic rod is vibrated and the brush leaves a track on the paper as in fig. M-20b

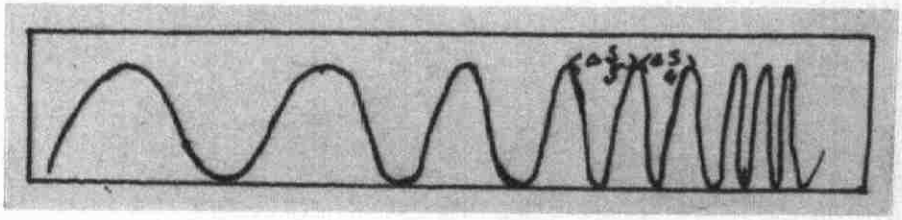


Fig. M-20b

If the unit of time taken is a period of oscillation of the brush, (call it tick) then the velocity of the trolley is

$$v_1 = \frac{\Delta s_1}{1 \text{ tick}}$$

$$v_2 = \frac{\Delta s_2}{1 \text{ tick}}$$

The acceleration will be $a = \frac{v_2 - v_1}{t} = \frac{s_2 - s_1}{1 \text{ tick}}$

1. Adjust the plane so that the trolley(without the weight) moves with no acceleration. Thus the force of friction is compensated for.
2. Connect the weight, set the strip into vibration and let the trolley accelerate. You will get an ink- track on the paper.
3. Change the paper. Make several trials using the same procedure but adding masses to the trolley.
4. Double the mass of the trolley by adding weights to it and double the hanging weight. Follow the same procedure to find the acceleration. Compare it with the case before doubling the mass and the weight.
5. <u>Data Analysis</u>

   Take the paper strips and measure Δs for each vibration. compute the velocity and the acceleration. (Find the average acceleration) Thus for every different mass you will have a value for the acceleration. How are they related?

Similarly analyze the data that you got from part (4). How does the acceleration depend upon the force?

M-21. Relative Motion

Remove the cover of the trolley used in experiment M-20. Fix to its side a wooden rod or a meter stick. At the end of the stick support a piece of wood parallel to the plane of the trolley. Attach to the end of this piece an electromagnet connected to a battery put in the trolley. The key of the circuit is two wires coming down along the sides of the trolley and bending at their end to carry a free metallic wire (see fig. M-21b)

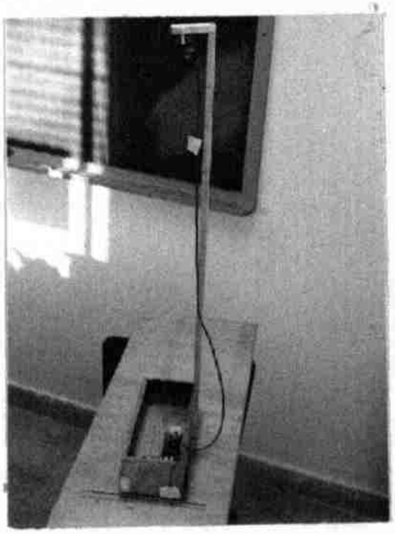


Fig. M-21a

The trolley rolls along an inclined plane with no acceleration. Some place at the middle of the plane a nail is placed so that when it hits

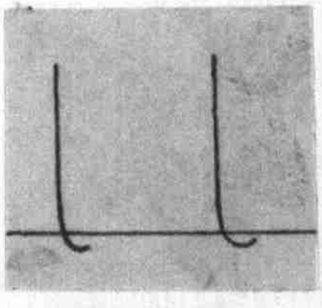


Fig. M-21b

the free wire of the key the current stops and the electromagnet releases a metallic ball to fall.

It will be noticed that the metallic ball will fall into the cart, as if it was standing, showing the relative motion of the ball with respect to the cart.

M-22. Vertical Motion in a Projectile

To show that the vertical motion of a projectile does not dpend upon its horizontal motion obtain a piece of wood about 10 x 10 x 4cm., and two metallic balls of diameters between 2 and 3 cm. Have tha balls identical in shape and mass.

Cut into the wood two rectangular grooves. (see fig. M-22) the dimensions must be in such a way to have the groove hold the ball.[1]

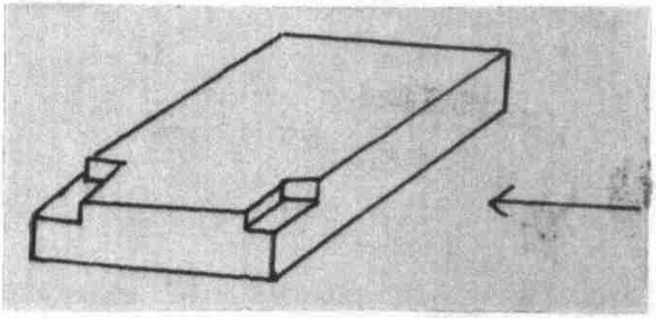


Fig. M-22

Adjust the block so that it extends about 5cm. beyond the edge of a table. Put the two balls in the groves and give a push from one side as denoted by the arrow in fig. M-22. One ball will move in a projectile and the other will fall

[1]A. Joseph et al., A Sourcebook for the Physical Science, (New York: Harcourt, Brace & World, Inc., 1961), p. 370.

freely. They reach the floor simultaneously.

The demonstration might not work for the first attempt because the free falling ball might leave the block before the other. Compensate for that by moving the other ball towards the adge and putting a small piece of wood or paper behind it. With some patience the experiment can work.

M-23. Vertical Versus Horizontal Motion

A more amusing way to demonstrate the concept mentioned in M-22 is the following experiment.

Support on a stand a glass tube or a carton tube (This can be made by taking a piece of hard paper, bending it into a cylinder and fixing it with adhesive tape. Hang on the tube two rings made from ordinary metallic wire. Let the rings be of a diameter larger than that of the tube, on the rings support a solid metallic wire with bending end just at the mouth of the tube, and some winding at the other end, (see fig. M-23a)

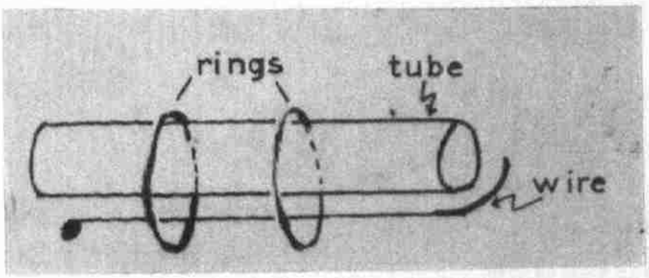


Fig. M-23a

On another stand and on the same level as the table support an electromagnet[1]. Connect the electromagnet to the rings by means of wires, including battery in the circuit.

Attach a small sheet of iron or tin to the elctro-magnet and point the tube to it, project a ball from the tube by blowing in it. As it goes in a projectile motion it hits the wire and cuts the circuit. Thus the metal sheet is released, and thus the ball hits it some place.

The distance between the stands and the blowing force can be adjusted to get the best results.

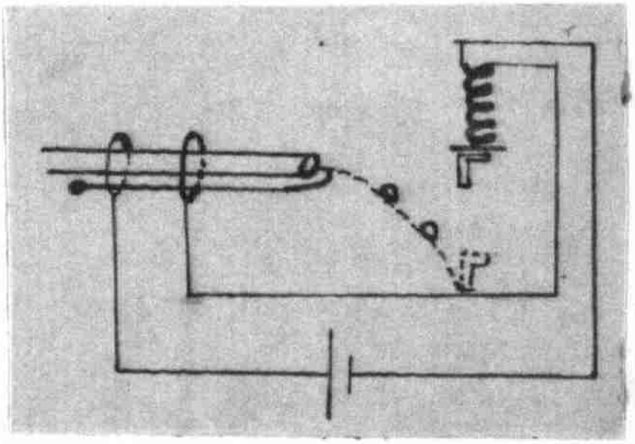
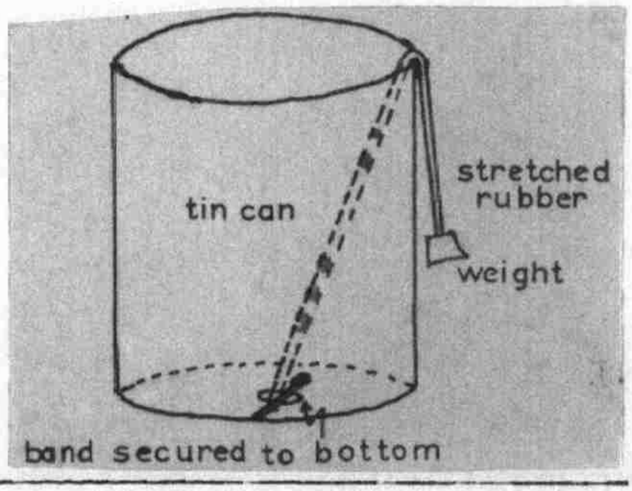


Fig. M-23b

Fig. M-23b



M-24. Weightlessness

Make a hole in the bottom of a tin can about 12cm. high and 10cm. in diameter. Pass a rubber band through the hole and hold it by means of

[1]See E-28

a nail (see fig. M-24) Stretch the rubber band and hang to it a weight of about 50gr. It keeps the band stretched.

When the can and the weight are dropped together, the weight becomes "weightless" and the rubber band, contracting, pulls the weight into the can with audible click.

G. MOMENTUN And ENERGY

M-25, Momentum

The law of conservation of momentum can be demonstrated by the following simple experiment.

Get the trolley you used in experiment L-12 with the accessories you added to hold an electromagnet. Put the trolley on a glass plate like the one used for the ripple tank (L - 36). Instead of the electromagnet connect a string and hang to it a weight a bit above the cover of the trolley. Set the pendulum into oscillation and the cart will oscillate in the opposite direction. If you are not satisfied with the amplitude of oscillation of the cart increase the value of the weight.

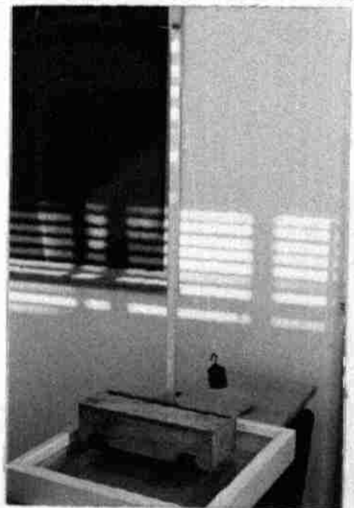


Fig. M-25

* M-26. Momentum and Collision

Construction

The apparatus for this experiment can be easily constructed as follows:

Take a piece of hard paper about 3cm. wide and 30cm. long. Turn up the long sides so as to make a path for a marble or metallic ball to move freely. At about 10 cm. from one end cut the turned-up sides for bending, as shown in figure M-26a .

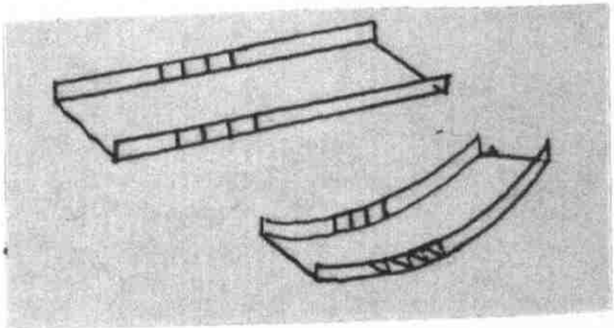


Fig. M-26a

Take a pencil and make a groove in its eraser to hold a marble.

Take two marbles of equal masses, and a third of a different mass.

1. Fix the pencil to the edge of the table by means of an adhesive tape. Let the eraser level be with the plane of the table. Support a marble ball on it.
2. Adjust the paper path in such a way that when the rolling ball leaves it hits the pencil off center.

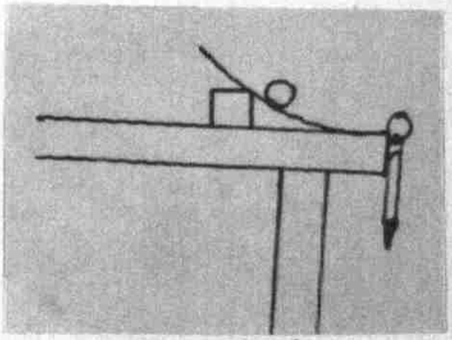


Fig. M-26b

3. Put a piece of paper on the floor so that when the ball falls it makes a mark on it.

4. Release a marble ball from a certain point on the track. It will hit the target ball at an angle. Both will fall at some distance from the table. (To find the exact place from which the target ball fell you could hang a weight with a string to the pencil) These distances represent velocity x time . But since the time is the same for all falling balls from the table (refer to exp. M-22) then the distances represent velocity vectors. If multiplied by the masses of the balls , they represent momentum vectors.

Make several trials projectiling from the same starting point.

5. Release the incident ball to roll several times without using the target ball.

6. Using vector analysis, find graphically the resultant momentum of the incident and target balls, and compare with the momentum vector of the incident ball when rolled freely. (see fig. M-26). Are the results as expected?

7. Repeat by using two different balls. Should you multiply the velocity vectors by the masses? Why? Are the results as expected?

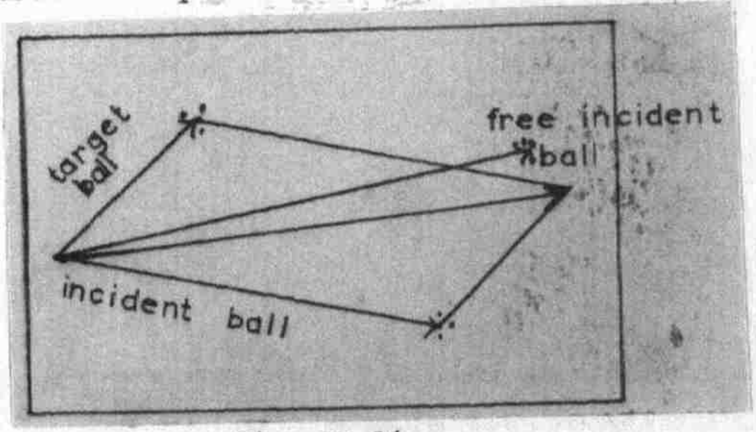


Fig. M-26c

M-27. Momentum and energy

After the students have acquired basic knowledge about the meaning of kinetic and potential energy then these experiments will establish the law of conservation of energy and momentum.

* 1. Elastic Collision

Hang two identical weights by means of two strings of equal length to the same point on a stand (see G-4) i.e. you will have two pendulums. Lift one weight (keeping the string stretched) to an amplitude of about 30°, and, release it to hit the other weight. To what height does it rise? Compare with the height of the first weight. Is energy conserved? (Consider Potential energy) Is momentum conserved?

Repeat with two different weights. Answer the same questions.

* 2. Inelastic Collision

Remove one weight and replace it by a rubber ball or a clay ball. Repeat the same experiment as above. Are momentum and kinetic energy conserved?

Conclusion: What is the difference between elastic and inelastic collision in terms of energy?

Why is it that a heavy object does not stop completely when it strikes a lighter one?

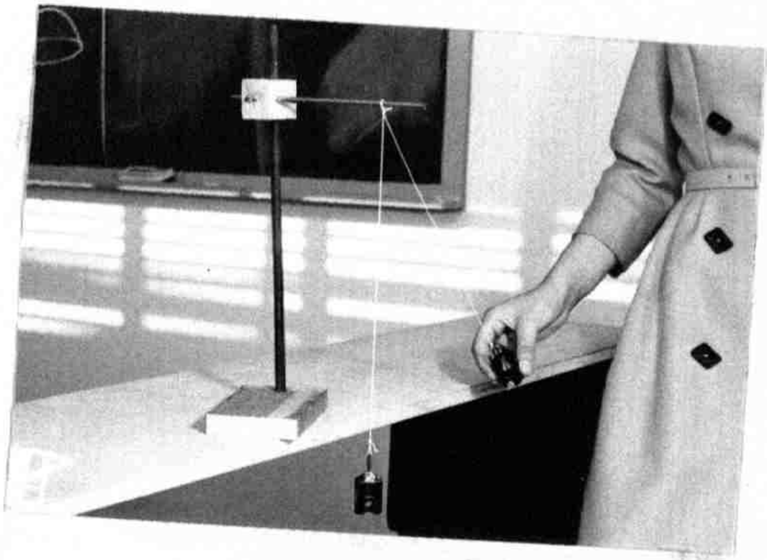


Fig. M-27

H. MACHINES

* M-28. Pulley

Construction: Take a piece of wood 3 cm. wide and bit longer than the spool you use. To its ends fix two wooden strips about 8cm. long and 2 cm. wide. Drive two holes in the extended parts of strips. Put the spool so that its hole is concurrent with the holes you made. Pass a screw and knot it. The spool will roll on the screw.

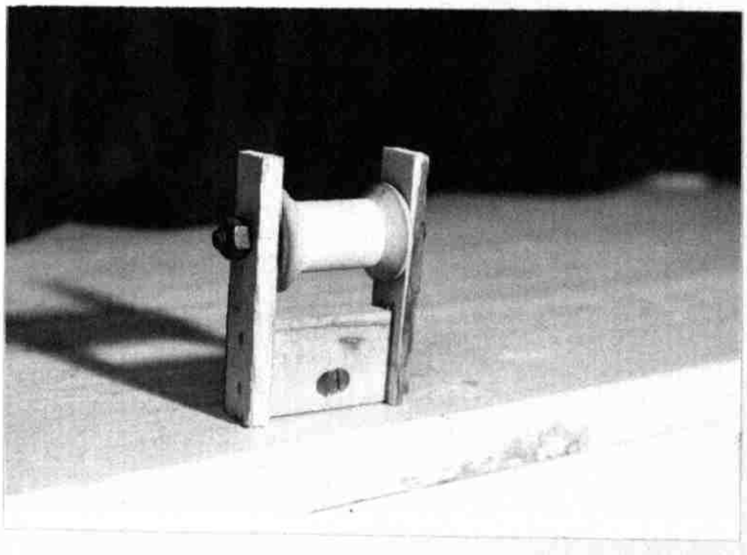


Fig. M-28

Drive a screw in the flat piece of wood to hang weights.

Experiment.

1. Tie the end of a string to a stand and pass it over the pulley. Hang a weight to the pulley. Tie the other end of the string to a spring balance if available. If not available, tie it to an arm balance (see G-6) and measure the force just as you weigh an object. Compare the reading of the balance to the value of the hanged weight.

   Find the mechanical advantage and compare it with the number of ropes supporting the weight. Establish a relation between the two quantities.

2. Measure the distance the weight travelled and the distance the balance moved. Compare. Find the efficiency of the pulley.

M-29. Lever

When discussing the lever in class the teacher can use the experiment about moment (M-18) and relate the two concepts.

M-30. Wheel and Axle

The principle of the wheel and axle can be demonstrated by taking the pulley used in experiment M-28 and winding on half the spool a long strip of paper to increase its diameter. Tie to the spool a string, turn it around few turns and hang a weight in the remaining 30 cm. say. On the wound paper wind a string in the opposite direction to the first. Fix the pulley to a stand and start trying weights on the second string to see which one will lift the first weight with nearly constant speed. Compare the two weights. Measure the diameters of the spool and paper disc. Calculate the Mechanical Advantage and the Efficiency.

M-31. Inclined plane

Adjust the inclined plane as in experiment M-16 and fix the pulley to the upper end. Connect a string to a trolley and pass it over the pulley. Find a weight that when attached to the string will raise the trolley with a constant speed. Divide the weight ofthe trolley by the suspended weight, to find the mechanical advantage. Measure the length of the plane and its height. Divide and compare with the mechanical advantage.

<u>NOTE</u>: In all of the experiments on machines the teacher can point out the concept of work and conservation of energy.

M-32. Screw

Cut a piece of paper into the shape of a right triangle. With one side along a pencil wind the whole paper. The hypotenuse will show a path of a screw. This simple demonstration reduces all work on screw to inclined planes.

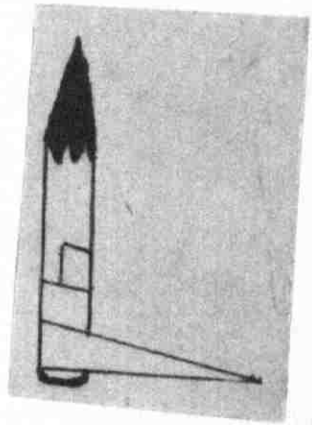


Fig. M-32

M-33. Gears

1. The comcept of gears can be illustrated by showing the inside of a watch if available.
2. Models of gears can be made by soda pop caps. Mount two such caps on a piece of wood by driving nails through their center. When you rotate one it forces the other to rotate also.

I. CIRCULAR MOTION

M-34. Whirling Backet

Although this experiment is obvious yet some of the students might not be acquainted with it. Swing a backet in a vertical circle. The water will not spill. From this demonstration the idea of centripetal force can be introduced.

M-35. Circular Motion

To link between circular motion and inertia rotate a wooden ball or to a rubber stopper or any light object tied to a string in a horizontal plane. Ask the class what happens if you let go the string. They might think that circular motion continues. After they see that the ball goes in a straight line tangent to circle you can explain to them the meaning of centripetal force and how circular motion stops when the centripetal force stops.

* M-36. Circular Motion

The apparatus is shown in Fig. M-36 Pass through a glass or carton tube a string about 150cm. long. To one end connect a harmless body like a rubber piece. To the other end hang a weight.(see fg. M-36)

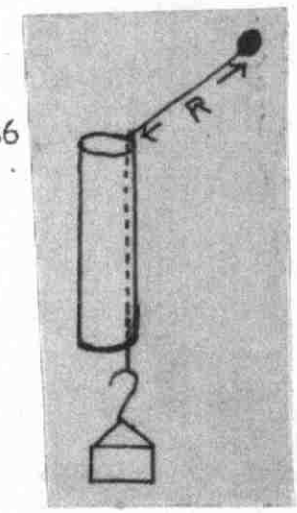


Fig. M-36

When you rotate the ball the period of rotation can be measured by finding the time it takes to rotate many turns and calculating the time needed for one turn.

1. Keep R constant and vary W. How does T (period) change? What does that mean about the velocity ?

2. Keep W constant. How does T vary with R ?

3. Keeping W and R constant, how does T vary with the mass?

Can you establish a proportionality relation between V,R,W and m? Is it as expected ?

J. HARMONIC MOTION

* M-37. Oscillating Spring

1. Hang a spring to a stand. Hang weights to it and measure displacements. Plot a graph of the two quantities and find if the spring follows Hooke's law. Find Hooke's constant from the slope of the graph.
2. Hang a load from the spring and set it into vibration . Measure the period of oscillation for different amplitudes. Does the period depend upon amplitude? If not then the motion is called isochronous. (The period can be found by measuring the time for a number of oscillations and dividing by that number).
3. How does the period agree with the expected value

$$T = 2\pi \sqrt{m/K}$$

Should m include the mass of the spring?

* M-38. Pendulum

Tie one end of a string to a weight and the other end to a bar on a stand. You get a pendulum. The period can be calculated by measuring time needed for many oscillations.

A complete oscillations means, that the weight should move from A to B to C and back to A.

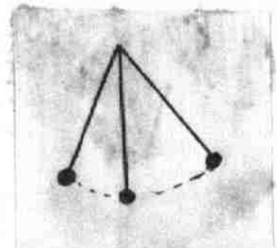


Fig. M-38

1. Keeping the mass of the object, and the length constant, vary the amplitude. The amplitude can be measured in terms of the angle the string makes with the vertical. This can be measured by means of a protractor or graduated circle. (see section G-1)

   How does the period vary with amplitude?

2. Keeping the amplitude and the length constant how does the period vary with the mass?

3. Keeping the mass and amplitude constant, how does the period vary with the length?

   Plot the results of this part on a graph. Choose the type of function to get a straight line. (Try T vs $\sqrt{l}$ or l vs T^2)

Knowing that T is inversely proportional to $\sqrt{g}$ establish a formula to find T in terms of the variables of this experiment.

K. SURFACE TENSION

M-39. Needle on Water

The concept of surface tension can be introduced by floating a razor or steel sewing needle on the surface of water. Break the surface and the razor blade or needle will sink.

M-40. Alcohol Boat

Take a hollow can about 3 x 3 x 0.5cm. (like the ones used for drug pills) and fill it partially with alcohol. Place the can carefully on water in a trough. If a large container is desired use the can designed for ripple tank. Put a light cotton wick, or a scrap of cloth, in the boat, pass it over the edge and let it touch the water. As the alchohol moves down the wick and spreads over the water the boat starts moving. The reason is that the force of adhesion between the can and alcohol is less than that between the can and water. So the adhesive force of water pulls the boat.

M-41. A reduced boat

A simpler way to illustrate the concept demonstrated in the previous experiment (M-40) is to take a match stick and rub one end of it with a piece of soap. Place it on the surface of water and it will move for the same reasons.

M-42. Capillary Action[1]

Take two glass plates aboat 20 x 30 cm. Clamp together one end by means of paper clips or clothes pins. Clamp the other end after you insert between them a thread or wire, Dip the plates in a trough of colored water and you will get what is shown in Fig. M-42

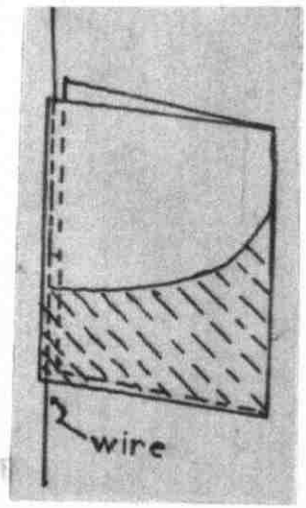


Fig. M-42

M-43 Cohesion

Forces of cohesion are responsible for the formation of water drops. Run a stream of drops from a faucet and observe them by means of stroboscope (see G-7). If a fancet is not available use with a small hole in a can.

M-44. Equidensity Drops.

Prepare a layer of salt water at the bottom of a glass tumbler, full of water. Place a drop of oil on the surface of the water. On this drop add 1 or 2 mm of colored salt solution by means of an eye dropper. The oil coats

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[1]Sutton, op.cit., p. 94.

the solution and a large drop is formed. Because of its density it sinks slowly to the bottom of the beaker until it reaches a layer of its density. It remains there for several hours, to demonstrate the action of the forces of cohesion.[1]

NOTE: A layer of salt solution canbe formed by putting salt in the tumbler and introducing water slowly waiting for it to dissolve without shaking it. A large quantity of salt will give a much better result.

L. DIFFUSION and OSMOSIS

M-45. Diffusion.

1. The experiment that was just mentioned illustrates the concept of diffusion. Salt molecules diffuse among water molecules.
2. Open a bottle which contains a liquid with strong smell like euax de cologne. You can also use hydrogen sulfide (H_2S)[2], ammonia (NH_3)[3] or chlorine (cl_2)[4]. Ask the

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[1] Sutton. op.cit., p. 101.

[2] If chemical are available, H_2 S canb e prepared by fes- HCL $FeCl_2$ - H_2S.

[3] For NH_3 use the familiar bottle of pungent cleaning fluid la-beled ammonia or ammonia water.

[4] Chlorine is liberated by adding hydrochloric acid to magnanize dioxide.

students to raise their hands when they smell it. You will observe that the oder moves gradually to the back of the class. This demonstrates diffusion in gases.

M-46. Osmosis

You can introduce osmosis by the following experiment. Take a piece of potato or carrot and take the off outer crest carve a wide groove in, keeping only a thin layer. (see fig.M-46). Fill about half the hole with a saturated solution of salt or sugar. Then place the piece of potato or carrot in a beaker of fresh water. After some time you will notice that the level of the solution in the hole has risen. Molecules of water have moved into the hole through the membrane. This is osmosis.

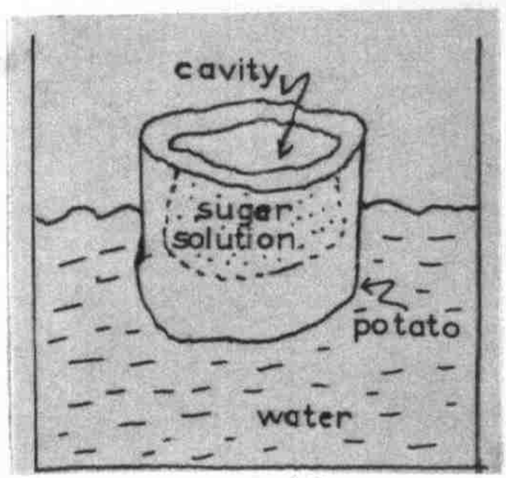

Fig. M-46

M. MECHANICS of LIQUIDS

M-47. Pressure and Height

To demonstrate that pressure due to a liquid depends upon its height take a tin can and make two holes in it at different heights using a nail of 1 or 2 mm. in diameter . Fill the can with water and you will observe that the water from the lower hole reaches a longer range than that from the above one.

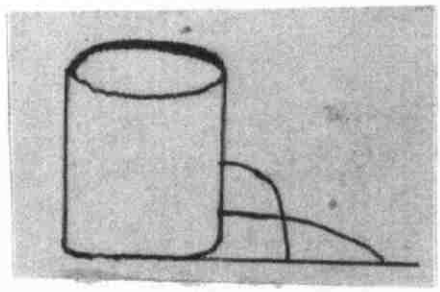

Fig. M-47

M-48. Pressure in All Directions.

Take a tin can similar to the one you used in the previous experiment. Drill two holes of equal diameter in it. One hole should be in the botton but very near to the side, the other in the side but very near to the bottom. Close the holes with your finger or with clay. Fill the can with water and provide two graduated cylinders to catch the water from the holes. Let the water flow. After a certain time you will find that the volume of the water in the two cylinders

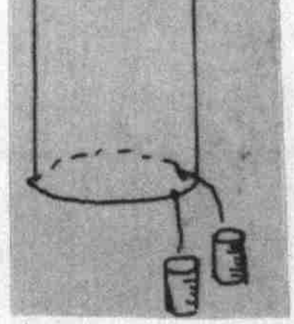

Fig. M-49

is the same.[1] (For the construction of graduated cylinders refer to G - 5)

M-48. Cartesian Diver

Invert a small tube, bottle, or a medicine dropper into a large glass bottle or tumbler full of water. Let the medicine dropper float just emerged by introducing some water into it. Cover the large bottle with a piece of ballon rubber and press it in. You can see the water level in the diver rises as its air is compressed, Consequently it sinks. When the pressure on the rubber is released the diver rises up.

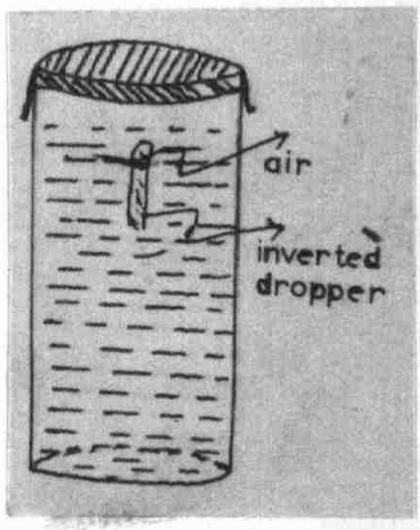

Fig. M-48

M-49. "Force" Pump

Take a piece of hollow cane with one knot in it. Into the knot drive a nail to make a hole.

Take a piece of wood or a part of a branch of a tree. Choose it to be straight, and a bit longer that the piece

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[1]Richardson and Cahoon, op. cit., p.266.

of cane. Make using a knife, two perpendicular cuts into one end of the wood .

Cut strips of cloth about 5cm. long and 1cm. wide. Force enough of them evenly into the two grooves you made in the dowel, until it fits tightly into the cane.

Dip the cane in a trough of water and pull the piston. Remove the pump from the wat water, push the piston, and water is forced out.

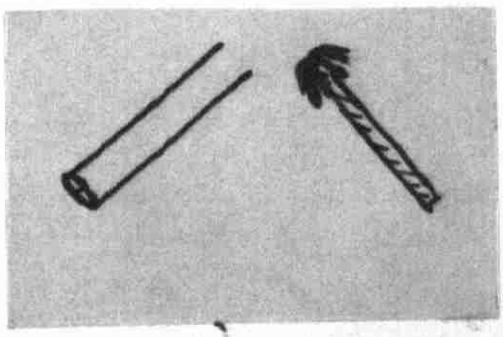


Fig. M-49

M-50. Lift Pump.

Take a glass or plastic tube (like ones used for drug pills) Cut one end of it by means of a glass cutter(in a glass shop) If the glass is thin an appropriate file will do. Take a piece of cork or potato. (or any similar vegetable) and cut it in a "frustum of a cone" manner to fit tightly into the tube. Make a hole in it by means of a nail and pass a natural straw or soda straw through the hole. On one end of the hole and to the inside of the tube , put a small rectangular piece of rubber (from a balloon) and fix one side of it to the cork or potato with two pins.

Cut another piece of cork or potato to pass tightly into the tube. Pass through its center a long screw. Near the center make a hole and fix to it a piece of rubber just as in the previous case.

The pump will look something like Fig. M-50 (The rubber valves can be replaced by marbles which fall into "valve seats").

Insert the straw under water and lift the piston with the srew. After some strokes up and down, water will over-flow up the tube. You can make a hole near the top of the tube with another straw in it and you can collect water.

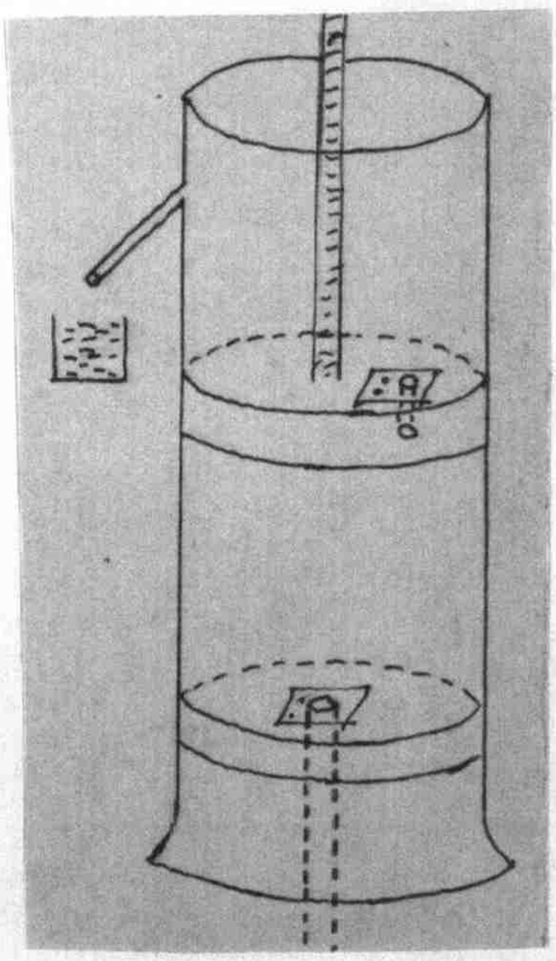


Fig. M-50

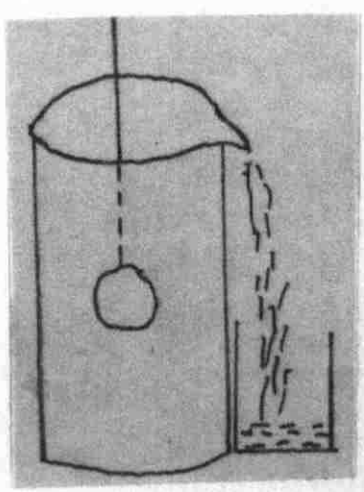
M-51. Archimedes' Principle

After the students have a clear idea about buoyancy in liquids, they can benefit from this experiment.

1. Weigh a piece of metal in air. (If a balance is not available you can construct one as described in G-6) Weigh the same piece in water by suspending it with a string connected to the balance. In this case the balance should be lifted on few books. You can weigh the object in water by using the principle of torque described in exp. M - 18 . Find the buoyancy force.
2. Take a tin can, make a bend in the top edge to set as a pouring spow for overflow. Fill it with water to the point of overflow and provide a cylinder (see G-7) to catch the water. Immerse the piece of metal and find the volume of the water it displaced. What is the weight of water, Compare with the loss of weight.

   What do you conclude?
3. Find the specific gravity of the matal.

Fig.M-51



M-52. Specific Gravity of a liquid

1. Weigh an object such as a metallic ball in air and then weigh it in water (For procedure see exp.M-51) Find the loss in weight. This is the weight of dip-laced water according to Archimedes' principle.
2. Weigh the same object in the given liquid. Find also the loss of weight. This is equal to the weight of displaced liquid.
3. Since the volumes of the displaced liquids are the same in parts 1 and 2, the specific gravity of the liquid is the value of the weight in (2) over that in (1).

M-53. Hydrometer

According to the principles that were demonstrated in the previous two experiments one can build an instrument to measure the density of a liquid directly. This is called a hydrometer.

If a body floats in a liquid its weight is balanced by the upward buoyant force. The upward force equals the weight of water displaced. If a regular cylinder floats vertically in a liquid to a depth of m cm. then the volume it displaces is mxs, where s is its cross-sectional area. Its weight is mxs xd, where d, is the density of the fluid.

If the same cylinder immerses in another fluid to a depth of n cms, the weight of the fluid it displaces is

$n \times s \times d_2$ where d_2 is the density of the second fluid. This weight is equal to its weight. Thus

$$m \times s \times d_1 = n \times s \times d_2$$

If the first fluid is water then

$$d_2 = \frac{m}{n}$$

<u>Construction</u>

Take a long glass or plastic tube about 15 or 20 cm. like the one used for medicine pills. (It can be made of any other material provided the crossection is constant). On a small strip of paper copy the centimeter scale up to the length of the tube. Instead of numbering it 1,2,3, etc. number it 10/1 (= 10), 10/2 (= 5), 10/3,... 10/5 (= 2)... 1o/7,... 10/10 (= 1) etc. Stick this paper to the cylinder such that the first division is on the bottom. (If the material you are using is transporent it is preferable to stick the paper to the inner side of the tube).

Insert the tube into water and start pouring fine lead shots until it floats with scale number $\frac{10}{10}$ = 1 on the surface of the water.(i.e with 10cm. under water.) Now you can see the meaning of the scale according to the formula we derived in the first part of this experiment.

You can remove the tube (now a hydrometer) put it into any other liquid, and read its density on the scale.

N. ATMOSPHERIC PRESSURE

M-54. Tumbler and water

The existance of atmospheric pressure is usually demonstrated by the old classical way of the tumbler and paper. You fill a glass tumbler with water, cover it with a piece of paper, hold the paper, invert the tumbler and remove your hand. The paper sticks to the water.

To make this demonstration more meaningful it will be wise to raise such questions as:

1. Why should the paper be held while inverting the tumbler?
2. Should the tumbler be completely full of water? (Try and see)
3. Does the experiment work for cold and warm water? (Try)
4. Does the experiment succeed with all liquids? (You might try different liquids heavier than water like salt solution).

M-55. Dramatic Demonstration

Lay a newspaper on a table. Place a ruler or a wooden strip under it with one end projecting over edge of the table. Strike sharply the projecting end of the ruler with a hammer. The ruler breaks while the paper does not lift up.

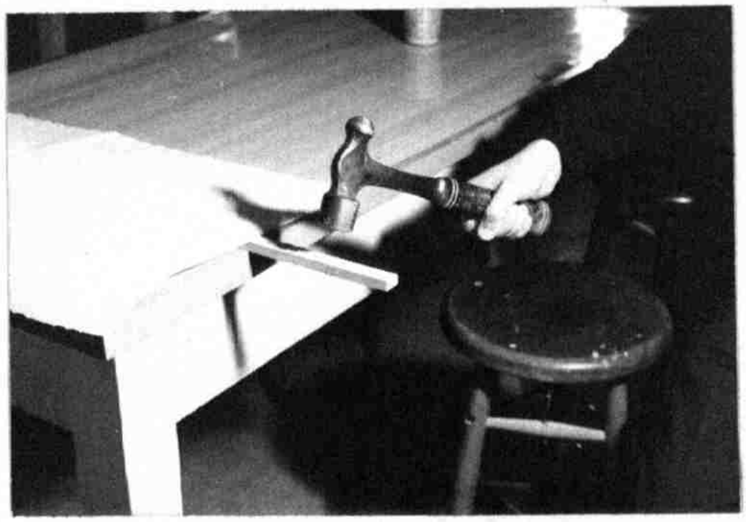


Fig. M-55

M-56. Siphon

Another demonstration of the effect of atmospheric pressure is manifested in the principle of the siphon.

Fill a tin can(or any container) with water. Fill a rubber tube also with water, close the two ends and insert one of them into the water. Lower the other end below the water level and open it. Water will flow.

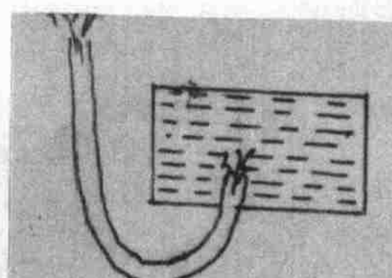


Fig. M-56

M-57. Sucking

After the previous two demonstrations are explained the students are now ready to understand a demonstration about sucking, like drinking with a soda straw. You can also repeat the previous experiment by sucking through the tube rather than filling it with water. This principle can be demonstrated by throwing a burning paper into a bottle with wide mouth. Cover it lightly with a rubber sheet(like a balloon). The rubber is sucked in (see fig. M-57)

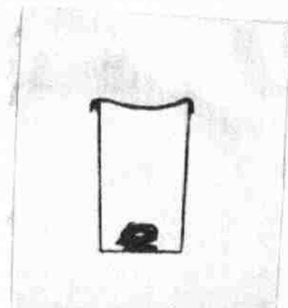


Fig. M-57

M-58. Aneroid Barometer

Cover the mouth of a glass tumbler with a stretched rubber sheet (like a piece of a ballon) Tie it with a rubber band. Glue a soda strawor wood splinter, or any carton strip to the center of the rubber sheet. As the atmospheric pressure changes, the diaphragm rises up or down causing the pointer to move. You can put a ruler to measure deviation in the pointer.

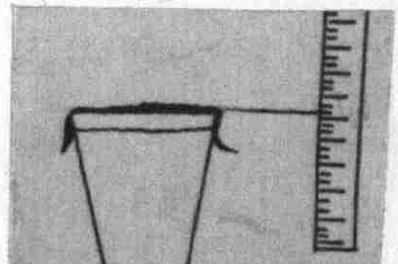


Fig. M-58

Velocity and Pressure

M-59. Hold two sheets of paper, blow between them. They are pushed together.

M-60. Suspend two Ping-pong balls. Blow a stream of air between them and note how they approach one another. If ping-pong balls are not available take two eggs, blow out their contents through pin holes, and use them instead.

M-61. Stick a pin into a card and insert it in the hole of a spool. Blow through the spool. The card will not fly away from the spool but it will stick to it.

Fig. M-61

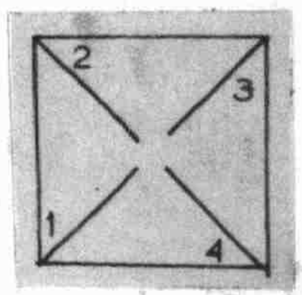


Fig. M-62a

M-62. Wind Wheel

Take a piece of paper and cut it into a square of an edge of about 15cm. Cut along the diagonals of the squares, leaving about 2 cm uncut in the center.

Take vertices 1,2,3, and 4 and glue them together. pass a pin through them and through the center of the square, serving as an axis for the wheel. Beads can be added as bearings. Connect the axis to a stick. Put the wheel out of the window or run with it and it will turn.

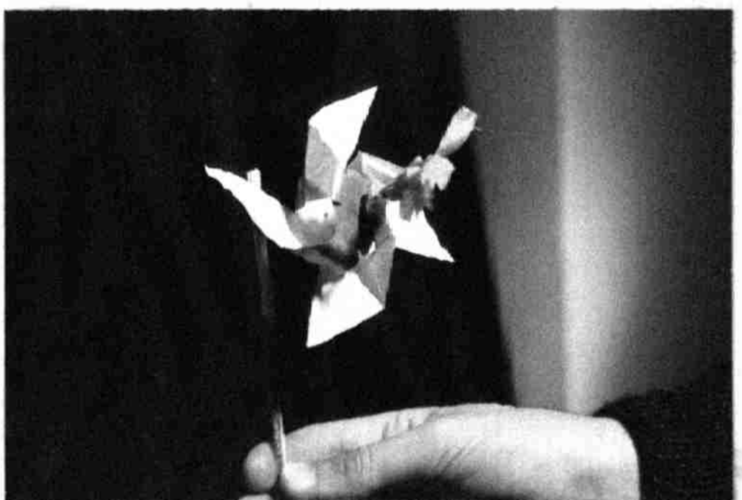


Fig. 62b

CHAPTER VIII

H E A T

H-1. Human Thermometer

Put three containers on the table. Let one contain cold water, the second lukewarm, and the third hot water. Place one hand in cold water and the other in hot water. Place both hands (or fingers) in the third container. You will feel that it is hot and cold with different hands.

With this demonstration you can point out the unreliability of human senses and the need for a more standard device of measuring temperature.

H-2 Thermometer

a. A mercury thermometer can be obtained commercially. If not locally available, it can be ordered by mail from: Macalaster Bicknell corporation, 253 Norfolk Street, Cambridge 39, Mass., U.S.A.

b. Water thermometer can be constructed as follows: Fill a bottle with colored water. Prepare a cork stopper (or a piece of potato or a similar vegetable). Make a hole in the stopper and pass a glass tube or a soda straw through the hole. Insert the stopper so that the water rises in the tube for few centimeters. As the water is heated the level in the tube rises.

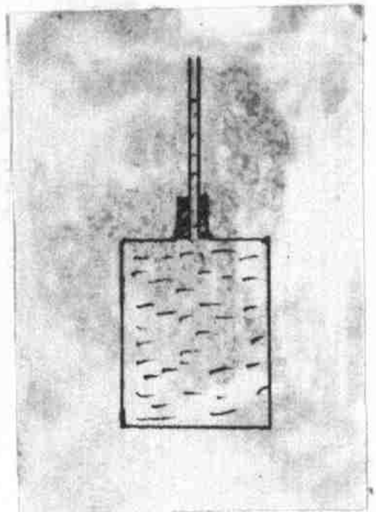


Fig. H-2

H-3. Expansion

The water thermometer introduces the phenomenon of expansion as a result of heat. A demonstration of linear expansion should be given at the beginning of a discussion on this topic.

Take a wooden bar about 50 x 5 x 2 cm. To one end fix a strong steel strip about 6 cm. long. It will serve like a spring. About 15cm. from this end, fix to the wood a piece of metal in the form of U with two holes in it as shown in Fig. H-3a. Pass a nail through the holes and solder to it a pointer like a stiff wire 20 cm. long. At the other

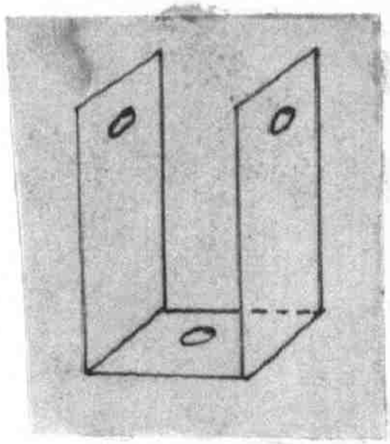
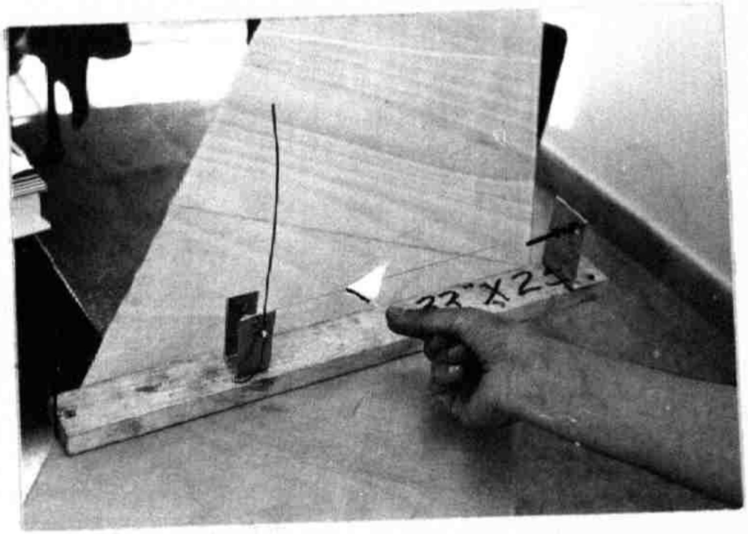


Fig. H-3a

end fix another piece of metal. Drill a hole in it and put a bolt with nut on it. Take a thin wire.(It can be obtained from normal wires that are used in electric circuits and contain many thin wires together). Solder the wire to the steel strip, wind it over the nail, and solder it to the nut while it is at the end of the screw. Now turn the screw so that the wire becomes tight. Adjust the pointer verically upward. Light a match or candle and put it under the wire. The pointer moves showing expansion of the wire.

NOTE: You can pass the wire through a short piece of wire insulator, so that when you wind it over the nail this insulator will be in between to avoid slipping.

Fig. H-3b



H-4. Expansion of a gas

Take the apparatus you used for the liquid thermometer (H-2b). Pour out the water and turn it up side down. Insert the tube into water in a tumbler. Heat the bottle and the level of water in the tube will drop down because of the expansion of air.

* H-5. Heat and Temperature[1]

1. Put about 50 c.c. of water in a beaker or can. (You can use the apparatus of H-16). Measure the temperature of water.

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[1] E.M. Rogers Physics for the Inquiring Mind, (Princeton: Princeton University Press, 1960), p. 413

2. Put few c.c. of alcohol in a metallic dish, like the capsule of a bottle. Heat the water by burning all the alcohol. Record the rise in temperature.
3. Continue heating the water with several equal "doses" of alcohol. Record the rise in temperature in each case
4. Consider each quantity of alcohol use as one unit of heat. Plot heat against rise in temperature on a graph? What kindof curve do you get? What can you conclude about the relation between heat and temperature?

* H-6. Calorimeter

Experiments H-7 - H-9 need a calorimeter. It can be easily constructed from two cans, a large one and a small one. The large one can be of 10cm. in diameter and 12 to 15 cm. in height. The other must be about 2cm. less in dimensions. Cut two cardboard discs a bit bigger than the larger can. In one of them cut a circle equal to the circumference of the smaller can to fit in it. Insert the small can into the cardboard circle, and place it in the larger one. In the other disc make a small hole to pass a thermometer through. Cover the can with it.

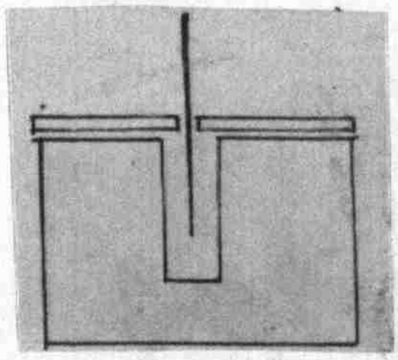

Fig. H-5

* H-7.Heat Exchange

1. Fill half the calorimeter (inner can) with water (H-6). Measure the temperature, and the mass of the water and of the calorimeter.
2. Heat about 30c.c. of water to about 60°c. and pour them into the calorimeter. Record final temperature.
3. Find the heat gained by the calorimeter. You need its specific heat. Knowing its material, look it up in your textbook (To first approximation neglect it)
4. Find the heat gained by the cold water.
5. Find the heat lost by the hot water.
6. What is the relationship between heat lost and heat gained? Is it as expected? Are there any sources of error?

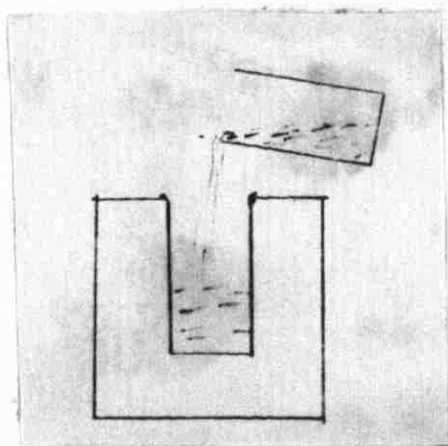

Fig. H-7

* H-8. Specific Heat.

You want to find the specific heat of an unknown metal

1. Obtain a piece of that metal, weigh it and put it in water. Heat the water over a local source of heat.
2. Prepare a calorimeter (see H-6) half full of water with a known temperature.
3. Read the temperature of the hot water (which is the temperature of the metal) and directly tranfer the metal to the calorimeter. Observe the thermometer as it rises until it becomes relativety constant. Record the temperature.
4. Find the heat gained by the calorimeter.
5. Find the heat gained by water.
6. What is the heat lost by the metal? What is the specific heat of the metal?

* H-9. Heat of Fusion

1. Fill half a thermometer with hot water. Wait for sometime and read the temperature. Masses of both calorimeter and water should be determined.
2. Directly put a piece of dried ice into the water of the calorimeter. Ice will absorb heat from the calorimeter.

and melt. The water formed by the melted ice will absorb also some heat and rise to the final temperature. Record the final temperature.

3. Determine the mass of the ice.
4. How much heat was lost by the calorimeter and the water in it?
5. How much of the heat went into warming up the water formed by the melted ice? How much heat went into melting the ice?
6. The heat of fusion is defined as the heat needed to melt one gram of ice at $0^{\circ}c$ into water at $0^{\circ}c$. What will be the heat of fusion of water? Is it as expected? Why?

H-10. Effect of Pressure on Melting Point

Secure a block of ice (special size is not essential). Support it on edges of two tables. Pass over the block a string with two weights hung over its ends. After some time the string will enter into the block because the ice melts as a result of pressure.

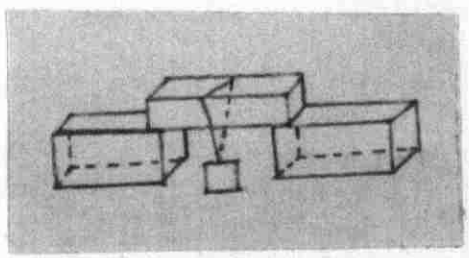

Fig. H-10

H-11. Cooling Effect of Evaporation

Put alcohol (or even water) on the skin of your hand. Leave it to evaporate. You will feel the coolness on you skin.

You can call the attention of the students to recall how they feel cold as their sweat dries on their body.

H-12. Sublimation

Take few crystals of camphor and put them in a small glass flask (like the one used for drugs).Cover the bottle with a watch glass[1] containing cold water. Heat the bottle and you will notice camphor crystals collecting on the bottom of the watch glass.(A watch glass can be replaced by a flat beaker).

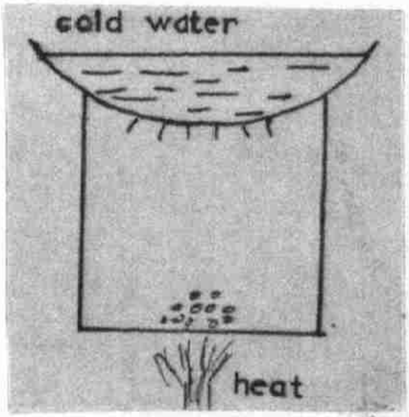

Fig. H-12

H-13. Boiling point and pressure

Half-fill a medium size bottle with water. Heat the water to boil. Remove it from the flame and close it tightly

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[1] Joseph *et al.*, *op.cit.*, p. 239.

with a cork or a piece of potato. Pour cold water over it and the water boils.

It will be more fascinating if you introduce a thermometer through the stopper to measure the temperature of the water inside the flask. You will see how it boils at a temperature less than 100°c.

You can introduce here the concept of vapor pressure and its effect on the boiling point.

H-14. Hygrometer[1]

Attach a toothpick or a small piece of wood or a knitting needle to a long human hair. Support over the pointer a heavy body like a washer. Pass the hair over the bar of a stand and fix one end to

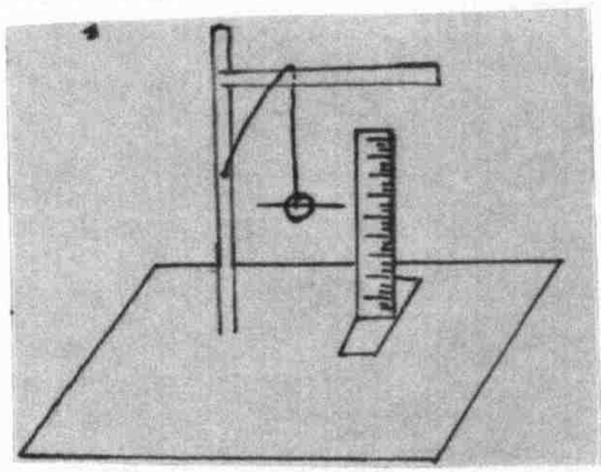

Fig. H-14

the leg of the stand by means of an adhesive tape. Since the length of the hair changes with humidity the pointer moves up and down. You can add a graduated scale made of hard paper

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[1]Joseph _et. al._, _op.cit._, p.44.

and fastened to the base of the stand.

H-15. Conduction

Conduction can be easily demonstrated by putting a metallic rod or spoon in hot water. After sometime the end of the spoon becomes hot. (Silver or copper spoon is recommended).

H-16. Conductivity of Solids

Take a tin can of about 10cm. diameter and 15 cm. in height. Solder to the bottom the can three rods of equal thickness and length, one of brass, the other of copper, and the third of steel.

A convenient length of the rods would be about 20cm. and the thickness about 3mm.

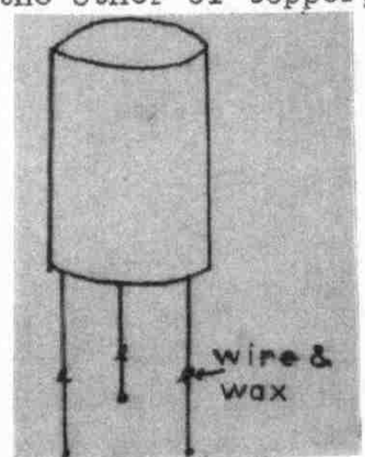

Fig. H-16

Cut 3 cm. -long pieces of a metallic wire about 1mm. in thickness. Tie them loosely to the rods and fix them at equal distances from the can by means of a drop of wax.

Support the can on a table and pour hot water into it. Observe which of the wire loops move down the rod. That rod will have the highest conductivity coeffient. Heat passed through it and melted the wax.[1]

This experiment is used to study the relative conductivities of different metals. It is advisable to show this demonstration before you give students a table of conductivity of solids.

H-17. Convection in water

Fill a small bottle with hot water. Add to it few drops of ink and close it with a cork (not tightly). Connect to the cork a string. Put the bottle in a trough and pour cold water over it. Pull the string and notice the path of the colored water.

Try the same thing with cold water in the bottle (of the same temperature as that in the trough). Notice the difference.

H-18. Convection and Pieces of Paper.

The same concept can be demonstrated by heating water in a container. Add few pieces of paper or saw dust. They

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[1]Sutton, op.cit., p. 231.

will follow the path of convection current.

H-19. Hot-air Wheel.

Convection in gases can be shown by the following demonstration:[1]

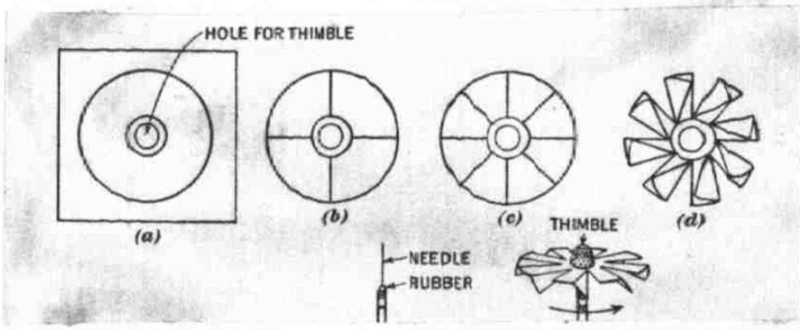

Fig. H-19

Draw on a writing paper two concentric circles one with a radius of about 10 cm. and the other of about 1.5cm.

Put a sewing thimble inside the smaller circle and trace its circumference. Cut out a circle slightly inside what you have traced to fit the thimble in.

Draw radial segments as shown in figure H-19. Cut the outer circle and cut also along the radial lines. Bend half of each slice back. Then insert the thimble .

Drive a pin to 1cm. into the eraser of a pencil. Place

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[1]Lyde, Science Experiences With Home Equipment, p.194.

the thimble and the wheel on the pin. Hold the pencil with your hand, bring it over a hot object or a lighted match. The wheel will turn.

H-20. Radiation

As an example of radiation the heat from the sun can be mentioned. In the following experiments the source of heat can be the sun or any local source of heat (like what is used for domestic purposes).

* H-21. Transmission of radiation

Expose your face to the source of heat. Insert in between a piece of paper of wood. What do you observe?

Use a sheet of glass as an obstruction. What is the difference?

Interpret your observations.

* H-22. Emission of Radiation

Take a large sheet of copper polish it on one side and paint it black on the other side. Hold it with a forceps over the fire to get hot.

Put the back of your hand or your cheek near the shiny face them near the black face. Compare your results and draw a conclusion concerning emission of radiation from black and shiny surfaces.[1]

* H-23. Absorption of Radiation

Secure a block of ice. Put over it two pieces of cloth one white and the other black. Expose the block to sunshine (or another source of heat). Does ice melt equally under the two pieces of clothe? What do you conclude?

* H-24. Expose you hand to a heater (preferably near to it) as much as you can bear it. Record the time.

Cover your hand with a thin metal foil (like the ones used in cigarette or chocolates boxes.) and press to you skin with saliva . Again expose your hand to heat. How much time can you stand the heat?

Paint the foil with graphite paint or "china ink" How much can you expose your hand to heat?

What do you conclude concerning absorption by different surfaces?[2]

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[1] Rogers, op.cit., p. 75.

[2] Ibid., p.75

* H-25. Reflection of Radiation

Take a shiny metal and put a flame near it. Put your hand in front of the sheet with a book obstructing it from the flame. Do you feel any heat?

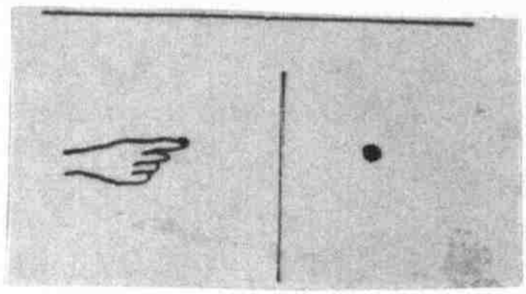

Fig. H-25

H-26. Refraction of Radiation.

Let a beam of sunlight (which includes also infrared waves) pass through a converging lens (see L- 21) Focus the beam on the back of your hand. What do you observe? Explain.

H-27. Mechanical Equivalent of Heat

It will be more scientific for the students to measure the value of Joule's constant rather than for it to be given to them. The following experiment serves as a rough method to find the mechanical equivalent of heat.

1. Take a handfull of lead shot and measure their temperature by means of a thermometer.

2. Put the lead shots into a cardboard tube about 30cm. long close it and invert it quickly so that the lead falls to the bottom of the tube. When the tube is inverted it should rest on a firm surface so that no energy is lost. Repeat the inversion of the tube about 50 times.
3. Pour the shots into a box and read the temperature.
4. Calculate the distance the shots travelled. Then find the potential energy loss. This energy is changed into kinetic energy and then into heat energy.
5. Calculate, from the change of temperature of lead the heat produced. (Specific heat of lead is 0.035)
6. A calorie is equivalent to how many joules? This is the mechanical equivalent of heat.[1]

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[1]Adapted from: Freshmen laboratory sheets, Physics department, American University of Beirut.

CHAPTER IX

LIGHT AND WAVE MOTION

A. LIGHT

L-1. Shadows

a. First show the students sharp shadows by using a flash-light (with front lens removed) in a darkned place. Anything like the body of a student or his hand will cast shadow on the wall. The size of the shadow can be derived quantitatively as a function of the distance of the object from the source.

It can be verified from this experiment that $\frac{AB}{A'B'} = \frac{oD}{oD'}$. Consequently a hint to the use of ray diagrams is established.

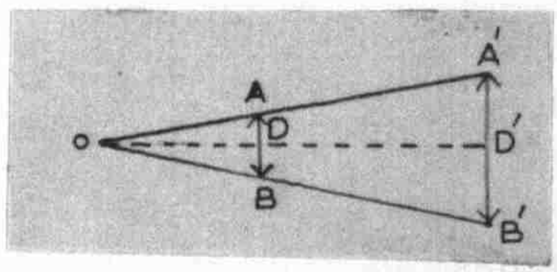
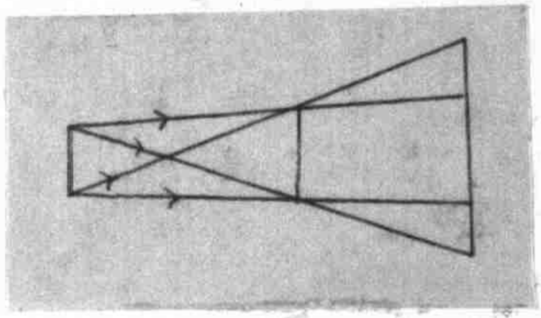


Fig. L-1a

b. Fuzzy shadow can be produced as follows: prepare a dark place. Put a lighted candle on a table. About few cm.

from it hold a piece of paper or wood about 5 x 5 cm. It will cast a shadow on the wall that has two regions as shown in fig. L-1b. After this demonstration the students can be asked to draw a ray diagram representing this case. It should look something like fig. L-1b

Fig. L-1b



L-2. Beams

Take a piece of hard paper (preferably black) about 20 x 20cm. Draw a line at the middle of it on one side of the line and starting with it cut about 5 slots 5cm. in length and about 2mm wide and about 1 cm. apart. Fold the paper along the line up to 90^o. Put it in sunshine or in front of a bulb or candle and you will see beams of light on the piece that has no slots in it.

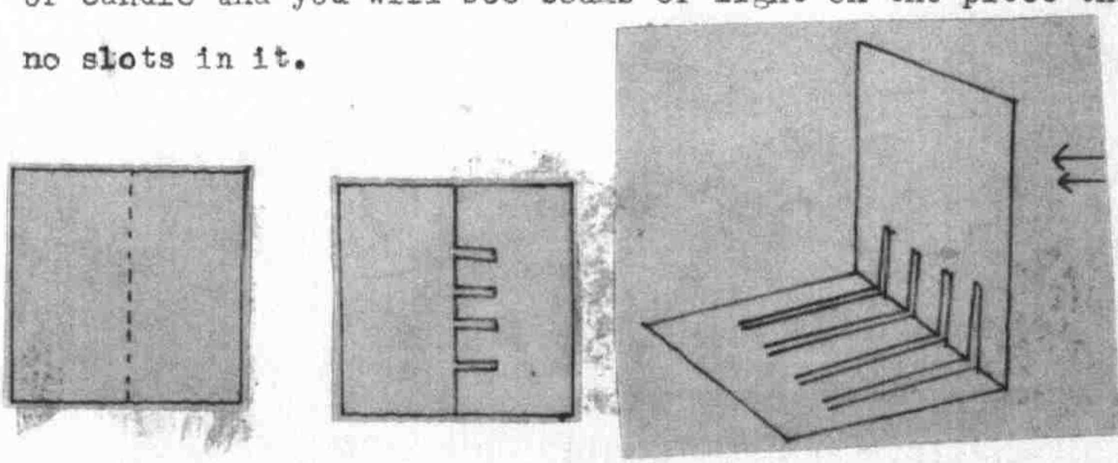


Fig. L-2

L-3 Beams with a Comb

Slots in paper can be replaced by a comb.[1] (The rest of experiment is the same as L-2)

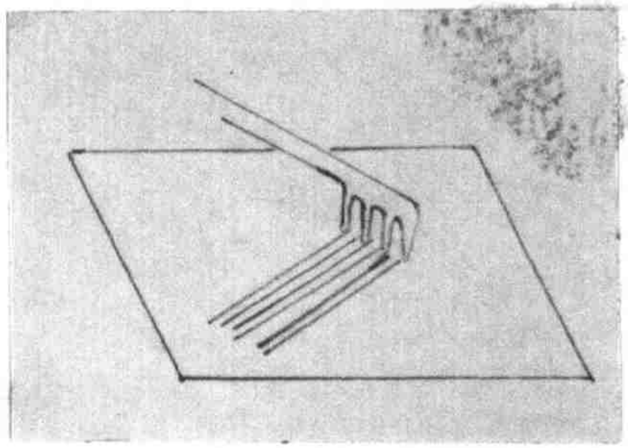


Fig. L-3

L-4. Location of Objects.[2]

Have one student hold a thin piece of wire in his hand. Have another student try to touch the end of the wire with a similar wire in his hand, Let that student close one eye and try to touch the wire. He will find that it is not as easy as with two eyes.

Fig. L-4

[1] UNESCO, UNESCO Sourcebook for Science Teaching, Amsterdam: UNESCO, 1956), p. 174.

[2] PSSC, Physics, op.cit., p. 193

L-5 Reflection by Plane Mirrors

1. Put a white paper on a table. At one edge of it put a Mirror perpendicular to it. Support it by a block of wood behind it. Point the mirror to a light coming from the sun or a strong source through the ray slot or comb (see L-2&3) Let the rays fall at the mirror at an angle. Observe the reflected rays. The angle of incidence can be measured and compared with the angle of reflection.

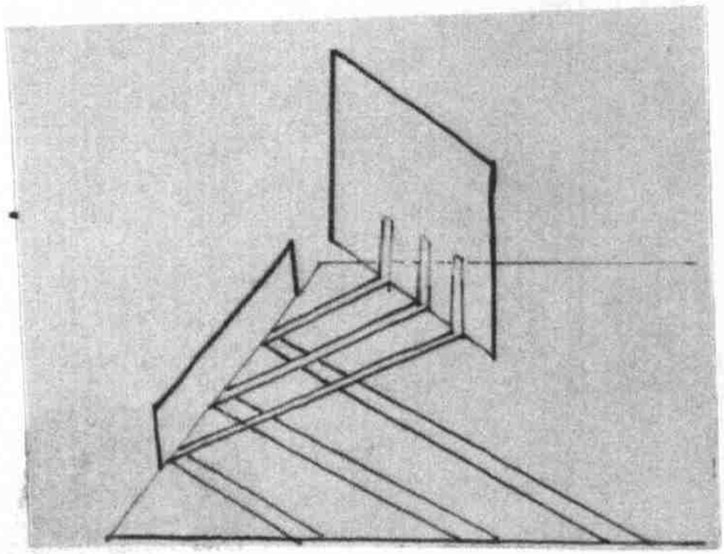


Fig. L-5

L-6 Plane Mirrors at an Angle

Take two plane mirrors of about 10 x 10cm. Support them perpendicular to the plane of the table with a right angle between them. Put a lighted candle somewhere in between and observe the images. Choose different angles like 30° and 60°. See if the students can establish a relationship between the value of the angle and the number of images.

* Reflection by Plane Mirrors

If you stick two pins vertically into a piece of wood and you look so that the nearer pin to your eye will block the other one then a ray of light coming from that pin passes to the second, to your eye. Thus you can trace the path of such a ray. This produce is going to be followed in this experiment in a slightly different way.

Reflection

1. Support a plane mirror by means of molding clay (when available) or a block of wood, vertical to the table. In front of it, place of piece of white paper about 30 x 20cm. Stick two pins on the paper along a line that is not perpendicular to the mirror (you can try later

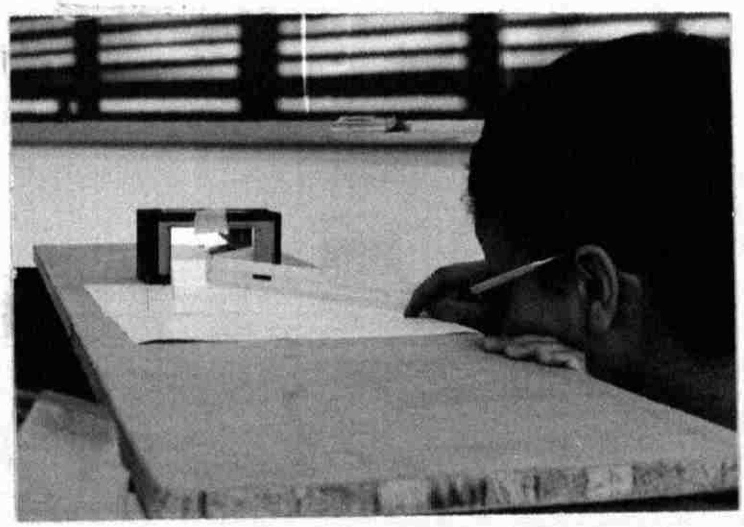


Fig. L-7

the case when the pins are along a perpendicular line to the mirror). Try to locate the images of these pins. Move your head to see the images one blocking the other. This is the path of the reflected ray.

2. Take a meterstick. Line it on its narrow edge to make one line with the images of the pin. Trace a line to meet the mirror. Draw a line joining the positions of the object pins to the mirrors. Where do the two lines meet?
3. Draw the normal to the mirror. What can you say about the angle between the normal and the incident and reflected rays?

<u>Image formation</u> (This can be a separate experiment)

1. Keep the mirror in place and remove one of the pins. Move the ruler to another position and orient it to have your line of sight to the image of the pin along it. Draw a line. Move it to a new position and draw another line
2. Move the pin from position A to another, B. Use the ruler to trace three rays "coming" from the image.
3. Remove the mirror. Put a paper beside the first one and extend the lines representing the reflected rays. Do they meet at two points A' and B'? These are the images of A and B .
4. What can you say about the distances of A and A', B and B' from the mirror?

5. Join AB and A'B'. Measure them . What do you conclude?

<u>QUESTION</u>: Does this experiment prove that light travels in straight lines?

L-8 Ellipsoidal Mirrors

Replace the plane mirror in L-5 by a very well polished spoon, once the concave side toward the light and onee the convex side. Make sure that half the spoon is below the plane of the paper.

L-9. Cancave Mirrors

a. Obtain a watchglass. Paint the convex side with graphite, or "india ink" If aluminum paint or silver paint is available you will get a better result.

b. Electric bulbs if available can replace watchglasses . The spherical portion is cut by means of a glass cutter in a glass shop. The convex side is painted as above.

L-10. Concave Mirror

In introducing the concept of spherical mirrors you can use the following demonstration:

Replace the plane mirror in L-5 by a concave mirror, As in the case of the spoon make sure the center of the mirror is in the plane of the paper.

* L-11 Concave Mirrors

1. Support a concave mirror by means of clay(if available) or a block of wood or two clothespins, in such a way that its angle with the table can be adjusted. Put a long paper 60 x 20cm. or two papers 30 x 20cm. joined by an adhesive tape, in front of the mirror.
2. Hold a pin (preferably with a big white head) in front of the mirror. Move it back until the image becomes unclear. This is relatively the focal plane. Move further back until you get an inverted image.
3. Stick the pin in the final position to the paper and, using the edge of a ruler, trace two lines of sight to the image. Choose one line to pass through the middle of the mirror. Do the lines meet. Where? What is the significance of the point of intersection? When the rays <u>actually</u> meet what do you say about the image?
4. Join the lines to the mirror, and from it to the pin. Through the middle of the mirror draw a normal to it.

What can you say about the angles of incidence and reflection?

5. From the object point and the image point drop perpendiculars to the normals. These perpendiculars can be considered as an object and its image. Measure them. Measure the distances from the feet the perpendiculars to the mirror. What relationship can you make between AB, A'B' and BP,

6. Find the focal length of the mirror by projecting the image of the sun or a far object, like a tree, on a screen. Carefully measure the distance of the screen from the mirror. This is the focal length.

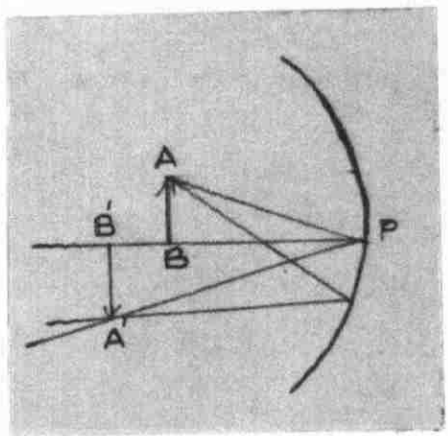


Fig. L-11

7. Find f from $\frac{1}{BP} - \frac{1}{B'P} = \frac{1}{f}$

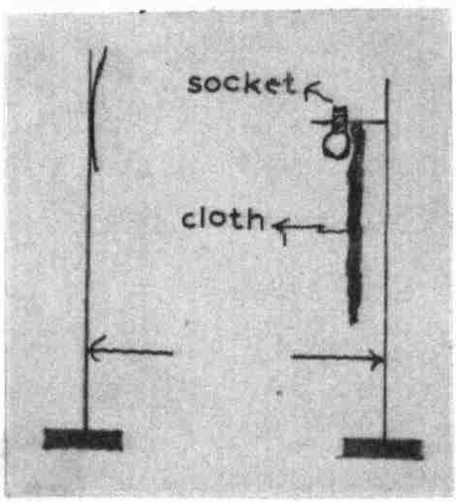
Does it agree with the result you got in (6)?

L-12. Illusion

Attach a concave mirror (relatively large) to a stand (G- 4) by means of an adhesive tape. At the focal length x 2 of it, and by means of the other stand, put the socket of a battery lamp.(This can be taken from a flash light). Below it put a lamp and connect it to a battery. Cover the lamp from all sides except the one facing the mirror by means of a black cloth . You will see a lamp in the socket.

Let students pass their fingers through the image of the lamp to make sure it is an illusion. (This demonstration must be done in a darkened place).

Fig. L-12



L-13. Convex Mirrors

a. If a shaving mirror is available bring it to class and let the students look in it to detect the nature of the image and the size.

b. Convex mirrors can be constructed by using watchglasses. Paint the cancave side as was explained in L-9.

c. Steel shiny balls can be used as convex mirrors.

d. Where available, Christmas tree balls can demonstrate the reflection from a convex mirror.

L-14. Refraction

Refraction can be introduced by putting a coin in a tumbler of water and observing the apparent depth. A pencil in the tumbler will bend.

L-15. Model of Refraction

Refraction can be explained in terms of velocity of light in different media by using the following experiment:

Take a piece of wood (see M-3) and put it on a table. Next to it, and on a paper put a layer of sand to the same level as the wood.

Take a piece of wood about 5 long and about 1 x 1 cm. Attach 2 wheels to its ends by means of nails so that the wheels can move freely independent of the wood. (The wheels of the trolley can be used). A spool can take the place of this roller. Push the wheels (or the spool) on the wood at an acute angle with the line of separation of the wood and sand. The push must be enough to make the wheel travel through the sand also. The path of the wheels demonstrate the path of rays from a rare to a dense medium.

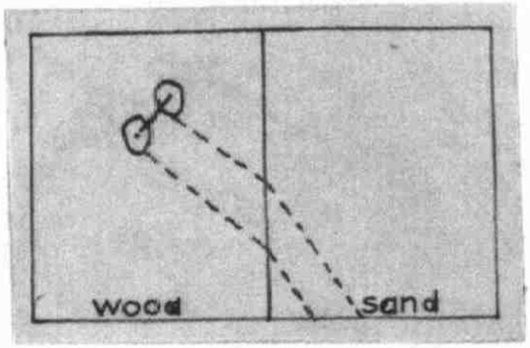


Fig. L-15

The significance of this demonstration is that if light is a pasticle- stream, then the fact of refraction is consistent with the assumption that speed of light in glass (or water..) is greater than speed in air (or vaccum). But this demonstration shows the contrary. It can be compared with wave-front demonstration L- 36)

L-16. Refraction in Water[1]

Take a piece of hard paper about 20 x 30. Bend it at 10 cm. from on end. Cut a slot in it at 5 cm. from one side with one end at the bend. The slot can be about 30 x 2 mm.

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[1]C.J. Lynde, Science Experiences with Ten-cent Store Equipment, (New york: D. Van Nostrand Co., Inc., 1950), p. 74.

Put the paper in a trough of water and let it face the sun or a strong source of light. You will see the beam bend down.

To get a clear beam add few drops of milk to the water in the trough.

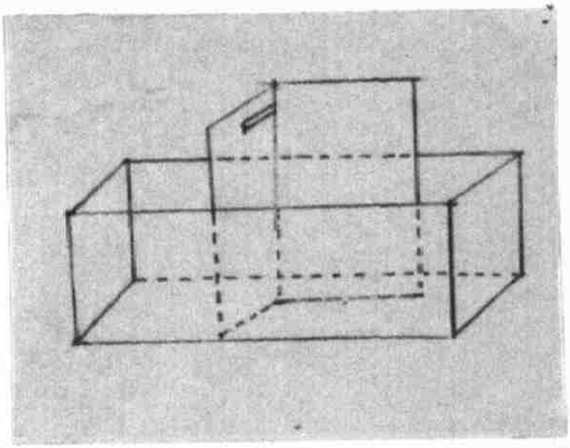


Fig. L-16

L-17. Quantitative Study of Refraction

A quantitative study of refraction can be demonstrated by using the apparatus of the previous experiment (L-16)

Stick to the side of the cardboard where there is no slot a graduated circle, by means of a pin at its center. The center of the circle must lie where the beam meets the surface of water, (Two protractors can replace the circle). Final adjustment for the position of the circle can be made by moving the board or tilting it.

The angles of incidence and refraction can be measured and snell's law can be verified .refraction of water.

(For the constraction of the graduated circle see G-1)

L-18, Plate with Parallel Faces

Use the cardboard with the slot used in section L-16

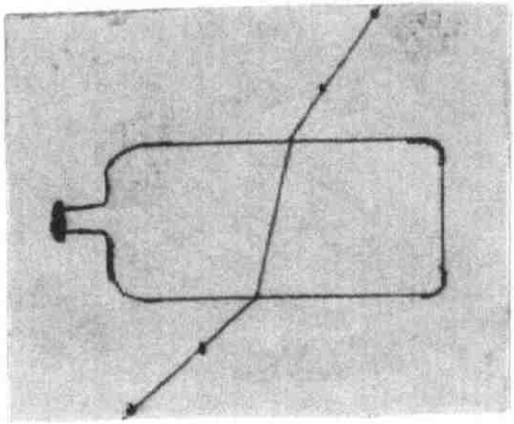
Fill a retangular bottle with water and add to it few drops of milk or any such liquid. Put it in the path of the ray coming from the slot. You will observe refraction due to the plates. (The sun can be used to provide strong light).

* L- 19. Refraction in a Plate

For a quantitative analysis, fill the bottle you used in L-18, with clear water. Close tightly and put it flat on a piece of paper. Stick vertically two pins to the paper. Look at the pins from the other side of the bottle and through it. Move your head till you see them above one another. Stick a pin on your side so as to block the others, and similarly a fourth one. These four pins represent the path of a ray (see Fig. L-19)

Trace the boundaries of bottle and the positions of the pins and remove them. Join the pin points to the boundaries of the bottle and through it as shown in Figure L-19 .

Fig. L-19



What do you observe?

Draw normals and locate angles of incidence and refraction.

What can you say about them?

L-20. Cylindrical Lenses.

Use sunlight or a strong source to produce beams in the cardboard with slots used in section L-2 . Fill a cylindrical bottle with water and put it in the path of the beam. Observe how the rays converge at one point.

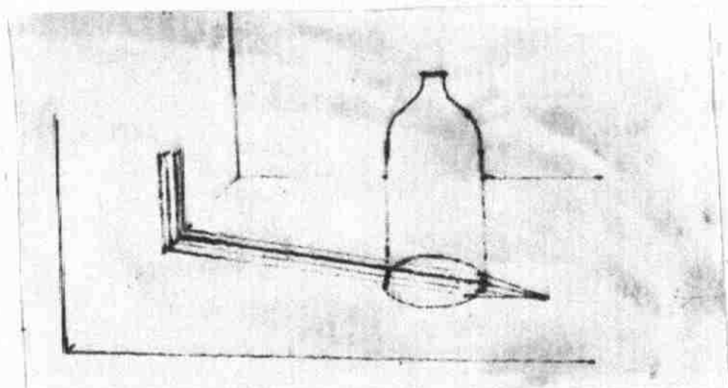


Fig. L-20

L-21. Convex Lenses.

Take two watch glasses and seal them together with wax leaving a small opening. Expose it to sunlight and try to collect an image of the sun on a screen. You will fail to get it.[1]

Fill the space between the glasses with water and seal the small opening. Now try to produce the image of the sun. You will succeed.

L-22. Reading Glasses

Usually reading lenses are available in market. These can be used to demonstrate the behavior of convex lenses. Such a lens can be passed to the class to look through it on the book and see how the image is magnified.

L-23. Drop of water Lens

Support a glass plate on a stand. From an eye-dropper release one drop of water on the plate. It will serve as a convex lenses. Put under it a printed page and you will see the letters magnified.

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[1]Richardson and Cahoon, _op_._cit_., p.241.

L-24. Convex Lenses

1. Lay a meter stick on the table. Support, near its mid-point, a converging lens by means of a clothespin, or clay (where available). You can also use for holding the lens a piece of wood into which a groove is made. A candle supported on a piece of metal, or glass serves as an object. The image can be collected on a screen made of white hard wood about 10 x 10cm. and supported by means of two clothes-pins. Another way to support the screen is to bend about 10cm. of a longer piece of paper, which serves as a base,

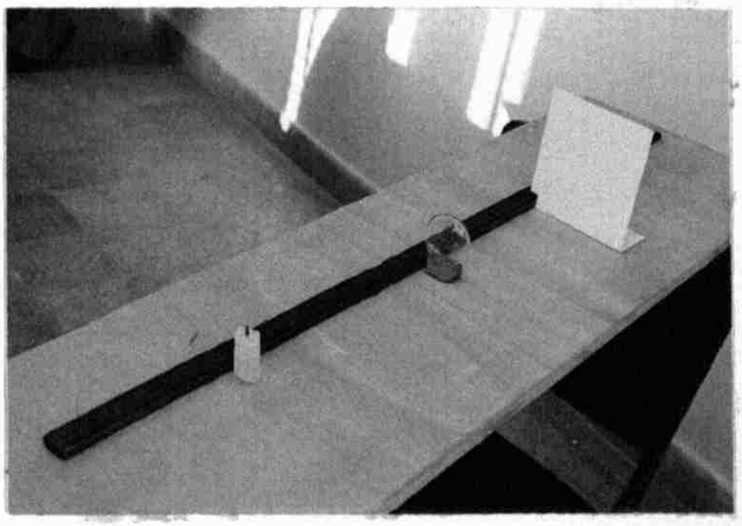


Fig. L-24

2. Starting with the object a bit far from the lens try to collect its image on a screen. What are its properties.

Records the distances of the object and image from the lens, p and p', by reading on the meterstick.

3. Take another position of the object where the image is of about the same size as the object. What do you notice about p and p'? Record their values.

4. Follow the same procedure with some other positions of the object. Observe the properties of the image and record the values of p and p'.

5. Can you establish a relationship between the distances p and p'. (Hint: it is in the form of $\frac{1}{p}$ and $\frac{1}{p'}$)

6. Remove the lens and find its focal length by locating the image of the sun or a far object. What relation does it hold to your answer in (5)? What relation does it have to p and p' in part (3)? Generalize.

7. Put the lens back in position and put the object at a distance less than a focal length from the lens. Try to collect the image on the screen. Can you?

8. Look through the lens from the opposite side of the object. Do you see an image? What are its properties? Remove the object back beyond the focal length and look again through the lens. Do you see an image?

L-25.Construction of Concave lenses

a. Concave lenses may be obtained from optician shops.

b. It not commercially available, the base of some glass tumblers serves as a concave lens. Hold such a tumbler in a horizontal position. Hold a pin behind it and look at the image through it.

c. Watchglass can be used to construct concave lenses. Take two watch glasses; hold them the convex sides toward one another. Wind around them a piece of nylon or thick cellophane and stick it to the glass with decocement or any adhesive liquid. Punch a hole in the nylon or cellophane and fill the space between the watch glasses with water. Close with a scotch tape, and you are provided with a concave lens.

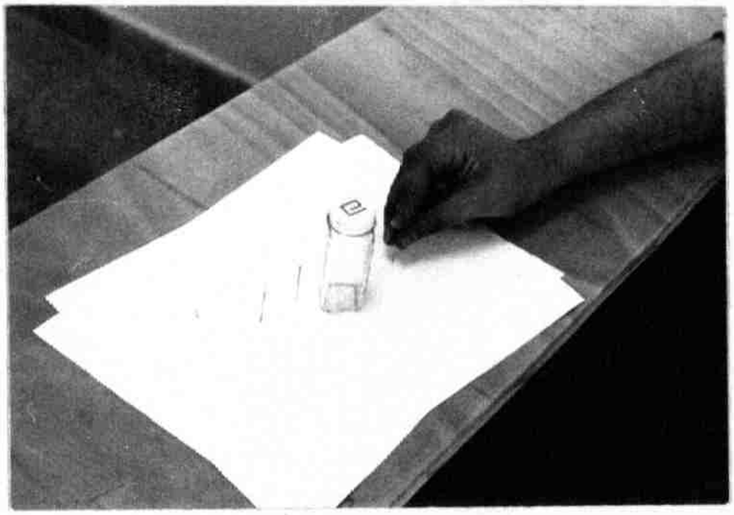
* L-26.Concave Lens.

1. Support a concave lens by means of clay or wood with a groove, at the middle of a large piece of paper.
2. On one side of the lens stick a pin to the paper. Look from the other side and you will see the image of the pin. What are its properties?

3. Orient a meterstick at its narrow edge along your line of sight to the image of the pin. Draw a line on the paper. Move your head to another position, adjust the ruler and draw a second line.
4. Take different positions of the pin and follow the same precedure by locating rays coming from it.
5. Remove the lens and extend the rays in each case. The place they meet will be the image position of the pin. Why ?
6. Measure for each case the distances of the image and the object from the lens. Is the relation between them the same as that of the convex lens?

* L-27. Prism

1. Fill a retangular bottle (like the one used in L-18) with water. Close it tightly with a piece of cork. R'est it on of paper.
2. Stick two pins near the one face and look through an adjacent one until you see the pins blocking one another. Stick two pins on your side along the same line of sight.
3. Trace the boundaries of the bottom of the bottle you were looking through. Remove the bottle and the pins.



Join the position points of the pins to the boundaries of the bottle, and join the points of intersections of these lines with the boundaries. You have the path of a ray. Why?

Fig. L-27

4. Draw normals and measure angles of incidence and refraction. Using snell's law find the index of refraction for the two surfaces. Is it the same?
5. Add the two angles of refraction. Is there anything significant in the result. Why ?

L-28. Dispersion of Light.

Use the cardboard with one slot that appeared in L-16. Rest it on the face with no slot and direct to the sun or any strong source. Put the bottle you used in L-18 such that one of its faces receives the beam at an acute angle. Collect the beam as it energes from an adjacent on a screen. You will notice many colors.

L-29. Dispersion of Light in Water

In a trough of water support a mirror by means of a block of wood at an angle with the base.

Put the trough in sunshine coming from the window . (Sunshine can be replaced by a strong source of light. If a weak source is to be used, it is preferable that the room be relatively dark.) Adjust the mirror to have the emerging rays meet the ceiling. You will see a spectrum.

Shake the surface of the water. The colors will mix and white light will appear on the ceiling.

L-30. Eye.

Bring the eye of a bull or sheep or any big animal from a butcher's shop. Disect it by means of a sharp razor blade. Show to class the different parts of the eye. Take the lens, wash it well, and use it to collect the image of the sun or a screen. This will convince the students that it is a real lens.

L-31. Image on the Retina[1]

Put a pin very near to your eye. Look through a pin hole in a card at the sky or at a strong light your will see the pin inverted . (see fig. L-31)

In fact the eye fails to produce an image of the pin because it is very near. The pin will cast a shadow on the retina in the same orientation as the pin.

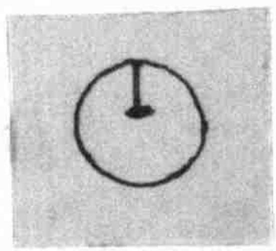


Fig. L-31

The shadow will be carried to the brain in an inverted form and thus it looks inverted.

This experiment shows that all images are inverted on the retina and thus we see them erect due to the interpretation of the brain.

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[1]Lyde, Science Experiences with Ten-cent Store Equipment, p. 131.

L-32. Mircoscope.

Put a piece of hair between two plates supported on a stand. Let a drop of water fall on the plates above the piece of hair to form a lens. Below the plates place a plane mirror at an angle so that the reflected light falls on the object.

Hold another lens in your hand above the drop of water and bring your eye near to it. Adjust its position to see the image of the piece of hair.

L-33. Telescope.

If two lenses of different focal lengths are available you can demonstrate the principle of a telescope.

Hold the two lenses in your hands the more powerful nearer to you. Look through the two at a near building Adjust the positions to see a clear image of the building.

B. WAVE MOTION

After the students are exposed to geometrical optics, they will not get complete idea of light without understanding its wave properties. Before the class moves to the wave properties of light they must be introduced to wave motion in general.

L-34. Shape of Waves

Waves can be seen in a trough of water by tipping on the surface of the liquid with the head of a pencil.

L-35. Waves in a String.

Use the board of the inclined plane with the pulley. (M-20) In place of the iron rod connect a string and hang a weight at the end of it. Strike it with your finger and you will see it vibrating. Use a stroboscope (G- 7) to see standing waves on the string

L-36. Ripple Tank

After the students get an idea about different kinds of waves the ripple tank can be used to explain the properties of light in terms of wave motion.

Construction.

Construct a wooden frame around a glass plate about 40 x 50 cm. The height of the frame does not have to be more than few centimeters. It is advisable to put wire mesh covered with bondage ganze around the plate to prevent reflection of waves. To the frame and very near to the edge fix two wooden bars about 20 cm. long with only one screw to move them up and down. Fix another bar over them to be used as a support for the wave generator.

The wave generator can be constructed as follows:

1. Take a toy electric motor from a toy shop or from a toy electric car or airoplane.[1] Insert the axis of the motor into a piece of wood or one centimeter of a pencil. Drive half a screw into the wood and perpendicular to the axis.

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[1]A toy electric motor is available by mail order from Lafayette Electronic " 165-08 Liberty Ave. Jamaica 33, New York, Catalog F - 258.

Take a piece of wood about 30 x 2 x 2 cm. Fix to it a clothespin a bit away from the midde of it. Let the clothspin hold the motor with its axis parallel to the bar.

Cut two brass or iron wires about 2mm. thick, and 5cm. long. Bend them at the middle to form a right angle. Drill two holes into the wooden bar and insert them in. Turn them up above the level of the bottom of the piece of wood.

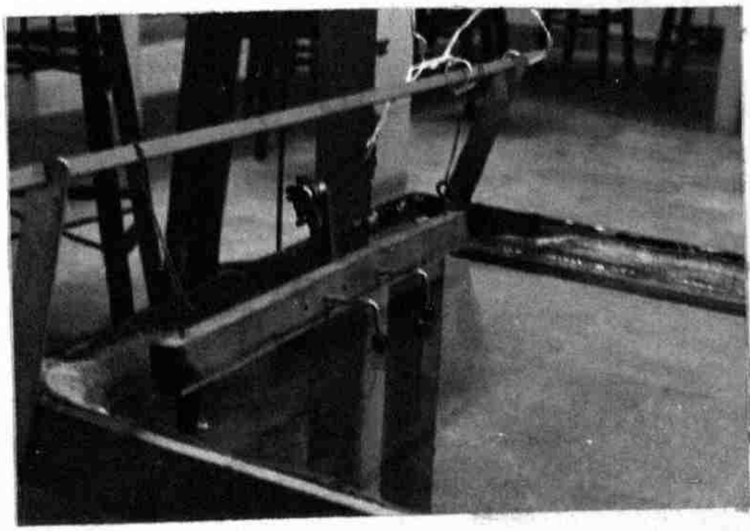

Fig. L-36a

Hang the wave generator to the support above the tank by means of rubber bands. Pass over the support wires to connect the motor to a 1,5 or 3 volt dry cell.

2. If by no means a motor could be obtained, a wave generator can be constructed as follows:

Take two pieces of thin steel about 15cm. long and 3cm. wide. Drill two holes at each end. Bend them as in fig. L-36b

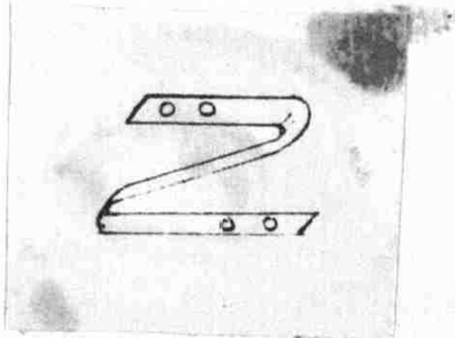

Fig. L-36b

Fix the two pieces of steel about two centimeter from the ends of a metallic or wooden bar about 30cm. long, 2 cm. wide and 2cm. thick. At the middle of the bar insert a metallic rod about 20cm. long. Into it insert a metallic or wooden block with an adjusting screw.

Fasten the ends of the steel strips to the wall of the ripple tank. When a push is given to the block on the rod the flat bar will vibrate. The frequency can be adjusted according to the position of the block.

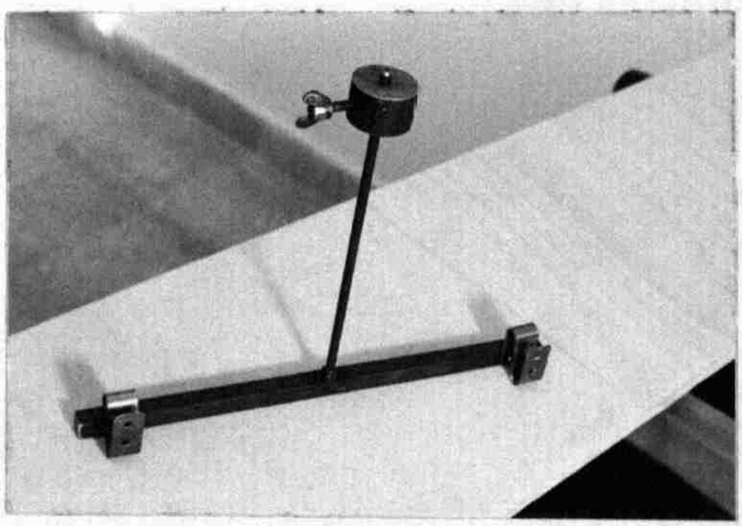

Fig. L-36c

Drill two holes in the bar to add the point sources when necessary.

Parallel Waves

Support the tank on two chairs. Put a piece of white paper between the chairs and provide yourself with a flash light or a bulb to project the wave motion on the paper. You can project the waves on the ceiling also.

Pour water into the tank to a depth of about one centimeter. Lower the wave generator to touch the surface. Set it into vibration, put on the light and parallel waves will be projected.

Reflection.

At an angle with the parallel waves insert into water a retangular piece of wood with a wax coat. You will observe the reflected waves. Angles of incidence and reflection can be measured.

Refraction.

Put a sheet of glass on the bottom of the tank (the glass sheet used for capillary action (M- 42) is good for use here) The water will be shallower in this region than in the rest of the tank. You will observe the change of direction of waves, if the glass sheet's boundary is oblique to the propagation direction of the waves.

Spherical Mirrors.

An aluminum strip about 50cm. long and 3 cm. wide can be made into the form shown in fig. L-36d

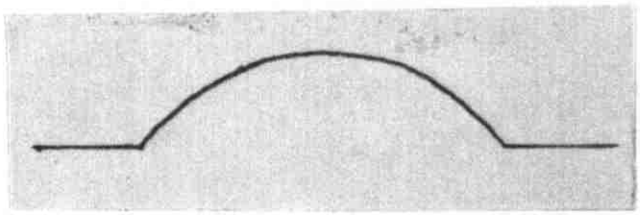

Fig. L-36d

When this piece is put in the path of waves it can be used to represent a convex or a concave mirror. You will havewaves focus at one point.

Lenses

Lenses can be presented by glass sheets in the form of the cross ection of a lens. Concave and convex shapes can be made.

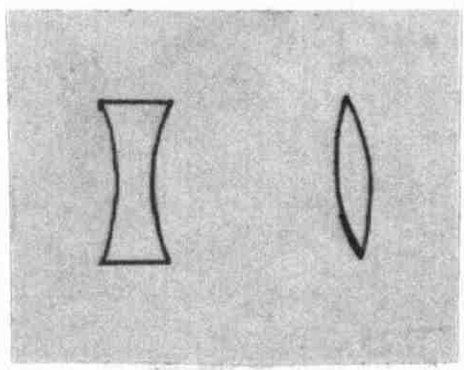

Fig. L-36e

Put the lens in the middle of the tank; obstruct the remaining path with pieces of wood and observe the path of waves .

Diffraction

Remove the lens and place a third piece of wood coated with wax, in such a way to keep a small space between it and the other blocks. Diffraction pattern is observed.

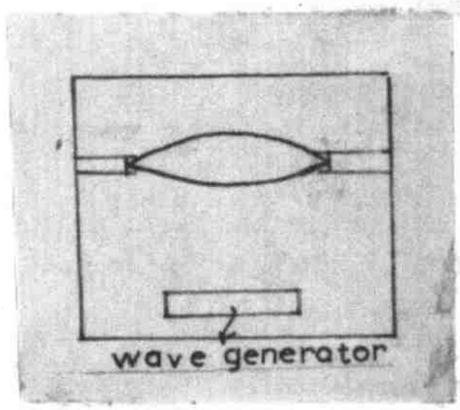

Fig. L-36f

Interference.

Add the point sources. Lift the flat bar of the generator and let the end points only touch the surface of water. Observe the interference pattern.

L-37. Diffraction Patterns

Take a fine cloth or wire mesh and look at a point source like a distant candle or a bright star. You will see two-dimensional diffraction pattern.

L- 38. Interference

a. Dip the top of a cup or tumbler in soapy water. A film is formed. Hold the cup so that the film is vertical and exposed to sunshine, or to a strong light. You will see colors.[1]

b. Put a trough of water in a strong light (not sunlight). Add to it a few c.c. of black ink. By means of an eye dropper release a drop of oil on it. You will see colors. Blow the water surface and the colors change.[2]

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[1]Lynde, Science Experiences with Ten-cent Store Equipment, op.cit., p.108.

[2]Ibid., p. 109.

CHAPTER X

S O U N D

S-1. Sources of Sound

As an introduction to sound various sources can be demonstrated which are also to be used in future experiments.

a. To show that sound is generated by the vibration of a body take an ordinary table fork and strike it against a solid object. Bring it near your ear and you hear a sound. Hold it with your fingers and sound stops.

b. Strike on a table or metal and sound is generated.

c. Whistles can be used demonstrating another source of sound.

S-2. Transmission of Sound

To show that sound needs a medium take a watch and suspend it with a rubber band to a cork which fits into the mouth of a bottle(a rubber stopper gives better results.)

Pour few c.c. of water into the bottle and heat them to evaporation. Insert the watch into the bottle and fit the cork. Pour some water over the bottle. You get partial vacuum. Listen for the sound of the watch. Move the cork to let some air enter the bottle. Note the difference in sound.

S-3. Effect of Medium

The following experiments show that sound travels in solids better than in air.

a. Stand at one end of the table. Put your ear near it and let one tip with his finger on the other end. Now put your ear on the table and note the difference.

b. Take a string about one meter long. Hang a spoon at the middle of it. Make loops at both ends, pass your fingers in them and put them in your ears. Bend forward and let the spoon strike the edge of a table. You will hear beautiful sound. Try with two spoons or forks.[1]

S-4. Transmission in Solids

a. Take two tin cans. Make a hole in the bottom of each and connect a string from one can to the other. The

[1]Lyde, Science Experiences with Ten-cent Store Equipment, op.cit., p.1.

length of the string can extend to 10meters or more. Let one student speak in one can and another student listen.

b.Tie a string about 2 meters long around a pencil. Connect the other end to a match box. Stretch tightly between two students. When the pencil is rolled against the string, sound comes out from the box.

S-5. Wave Properties of Sound.

Take a piece of wood about 15 x 15cm. with a thickness of about 2cm. Drill a circle of a diameter of about 10cm. to a depth of 1 cm. Then drill another circle concentric with the first, with a diameter of about 5cm. in the remaining thickness (see fig. S-5)

Fix to the smaller circle a cardboard cone.

If such an apparatus cannot be constrcted it can be replaced by merely a cone.

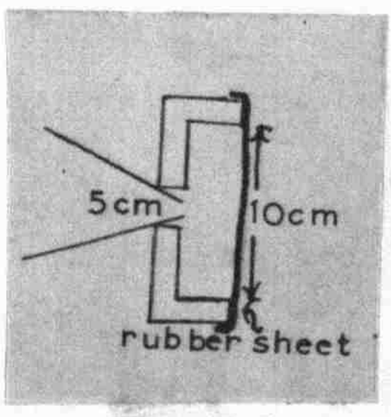

Fig. S-5

On the other circle place a piece of rubber sheet (taken from a balloon) and stick it by means of glue or a rubber band.

Speak through the cone. Feel the diaphragm and you will notice it vibrating.

Put half of the diaphragm in water in the ripple tank (see L- 36). Speak through the diaphragm and waves will be generated. You can project the wave motion as described in L-36.

S-6. Wave Properties of Sound Visualized

To the diaphragm in the previous experiment, and a bit away from the center, glue a small plane mirror.

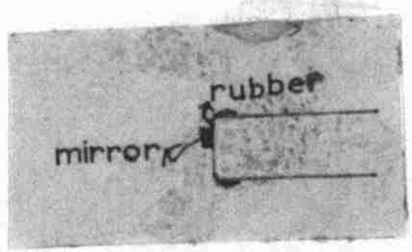

Fig. S-6

Let light be incident on it from the sun or a strong source and reflected on a wall, as a bright spot. Speak through the cone and shapes of waves are formed on the wall, due to the vibration of the diaphragm.[1]

S-7. Sound Lens.

Put some baking soda in a bottle with a narrow neck. Pour over it vinegar. Connect to the mouth of the bottle a rubber balloon. The carbon dioxide gas formed will fill the balloon. Tie the neck of the balloon with a string.

Stand at a distance from a clock, and listen to its sound. Insert the balloon in between, and notice the difference in the strength of sound. The balloon converges the sound waves, you can try several positions to get the best result.[2]

S-8. Resonance

Take two empty bottles of the same size. Glass tumbler can be used. Place a piece of light paper on one and tilt it so that the paper is about to slip off. Hum into the other bottle to obtain the resonant frequency. At this note the paper on the other bottle begins to slide off.[3]

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[1] Lynde, Science Experiences with Ten-cent Store Equipment, op.cit., p.11.

[2] Ibid., p. 35.

[3] Richardson and Cahoon, op.cit., p. 324.

S-9. Doppler Effect

You can call the attention of your students to note the sound of the horm of a car when it passes them. The pitch is high as the car approaches them. It gets lower as it passes away .

* S-10. Sonometer

Stretch a brass (piano wire) across the inclined plane used in M-16. and pass the wire over the pulley.

1. The tension in the wire is determined by hanging weights. Change the tension. How does the pitch when you strike the wire change with tension?
2. Keeping tensin constant insert a wooden wedge under the wire. How does the pitch vary with the length?
3. Now divide the length of the sonometer into 8 equal parts and place V-shaped paper riders at positions

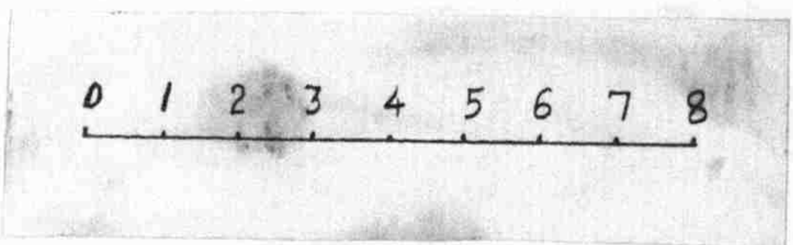

Fig. S-10

1.2.3.4. and 5 (see fig. S-10). Put a wedge at position six and bow the string at position 7. Paper riders at 1,3 and 5 will be thrown off since these are anti-nodes. What is the wavelength of the wave? Are the end positions nodes or anti-nodes ?

S-11. String instruments

Instruments like guitar or violen can be brought to class if available. The principle is demonstrated in the sonometer experiment (S-10)

S-12. Wind Instruments

a. Take a small pipe with a closed end or the cover of a fountain pen and blow across the open end. A musical note is heard.

b. To show that the note depends on the length of the column take few tumblers and fill them with water to various heights. Beat on them with a wooden rod. Different notes are generated.

c. Soda Straw Saxophone

Flaten one end of a soda straw about 1cm. Cut the corners and put about 5 cm. of this end into the mouth and blow.

When you cut a part of the straw the note changes.[1]

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[1]Lynde, Science Experiences with Ten-cent Store Equipment, op.cit., p.31.

CHAPTER XI

M A G N E T I S M

MG-1. Compass Needle

It is recommended to introduce this unit by introducing a familiar and yet fundamental device - the compass needle.

Obtain a compass needle if available in the markets (toy shops may sell it). If not available get a magnetic pin and stick it to a piece of paper or cork. If you cannot find such a pin magnetize a sewing needle and use it instead. (see MG-3). Float it in water. It will serve as a compass needle.

MG-2. Magnets

Magnets are usually available in markets. Horse-shoe magnets can be obtained from electric repair shops for cars where such magnets are taken from old dynamos.

MG-3 Making Magnets

1. Use the coil described in experiment E-26 . Place inside it a steel rod or bar, for few seconds. It becomes a magnet.

2. Obtain an iron rod or a steel sewing needle. Rub it with a magnet as shown in the fig. MG-3

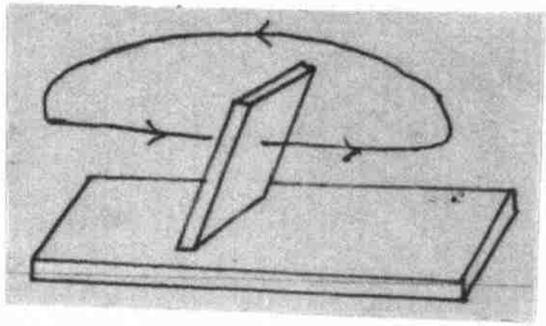

Fig. MG-3

* MG-4. Magnetic Roles.

1. Let a magnet attract a needle. Try the needle on all places of the magnet. Is it attracted with equal strength? It seems that the magnetic effect is mainly at the ends of the magnet. These are the poles.

2.(a) Float a magnetized needle on water (see MG-1). It points north - south. Label its poles.

(b) Try the same procedure with another needle.

(c) Bring the north pole of one magnet to the south pole of the other. What do you observe? Bring the two magnets north to north. What do you observe?

What do you conclude about the poles of magnets ?

MG-5. Which is Which

Give your students two pieces of iron of identical shapes. One is a magnet and one is not. Let them experiment on the two pieces to find which one is the magnet without using any compass needle or the magnetic field of the earth.

They sould try the end of one to see if it attracts the middle of the other. If it does, it is the magnet (Fig. MG-5a). If it does not, then the other is the magnet (Fig. MG-5b)

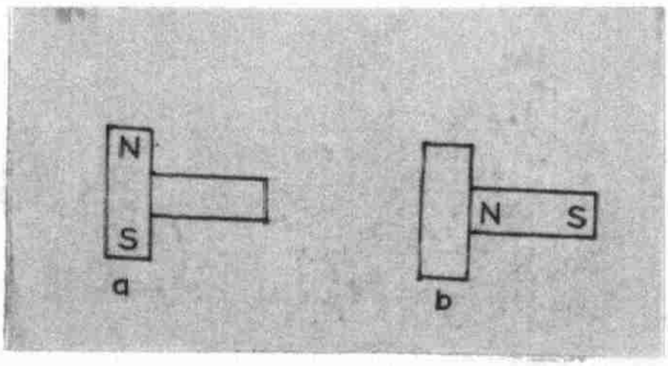

Fig. MG-5

* MG-6. Magnetic Forces

To establish the inverse square law of magnetic force, the following experiment is used. (The students must be reminded of the laws of moment to understand this experiment)

1. Support a long bar magnet on a wedge. On one side suspend a weight. Below the other side lay another bar magnet with an opposite pole. Change the position of the weight to balance the bar(i.e. to counter-balance the force of attraction)[1]

2. From the laws of moments calculate the force of attraction between the two poles.

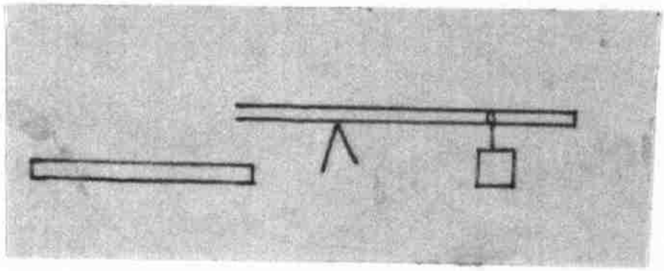

Fig. MG-6

3. Change the distance between the two poles be inserting a book under the wedge or under the bar lying on the table. Find the new position of the weight. Calculate the force of attraction.

4. Try for several different distances

5. How does the force of attraction depend upon the distance? Plot a graph of Force vs $1/(\text{distance})^2$. What kind of graph do you get ? What does it mean ?

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[1]Sutton, *op. cit.*, p. 282.

* MG-7. Determination of Pole Strength

1. Magnetize two knitting or ordinary sewing needle, or small iron rods together in a solenoid (see E- 26)
2. Suspend the needles with light threads about 25 cm. long to a stand. like poles must be adjacent. The needles will repel to a few centemeters.[1]

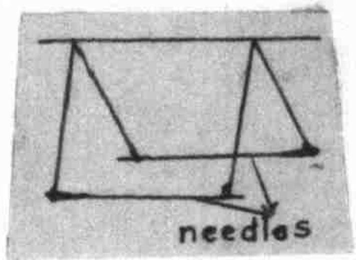

Fig. MG-7a

3. The forces acting upon each needle are those of magnetic attraction, magnetic repulsion, and gravity. The resultant is in the direction of the suspending string. Knowing angle a (half the angle between the string) and the weight of the needle, you can find graphically the resultant force acting on the needle.

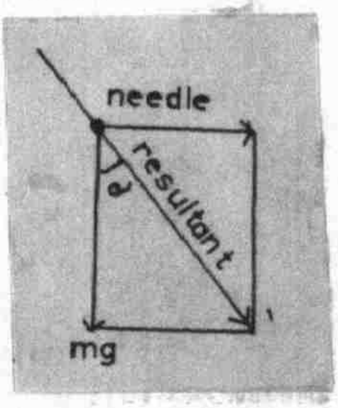

Fig. MG-7b

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[1]Sutton. op.cit., p. 283.

4. Find the horizontal componant. As can be seen from fig. MG-7c. The horizontal component is

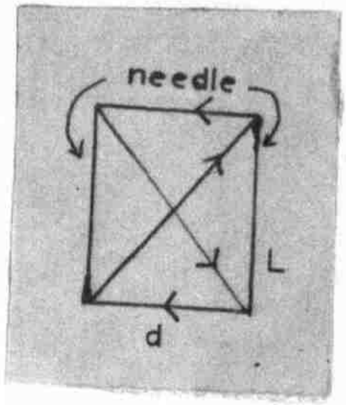


Fig. MG-7c

$$F = 2\left(k \frac{m_1 m_2}{d^2} - k \frac{m_1 m_2}{(L^2 - d^2)} \frac{d}{(L^2 - d^2)^{\frac{1}{2}}} \right)$$

Derive this formula.

($k = 10^{-7}$ if F is in newton and the distances in meter ; m will be in webers)

Assuming $m_1 = m_2$ and knowing F, d and L find m, the pole strength.

MG-8. Magnetic Induction

Let a magnet attract a piece of soft iron. Bring a pin near to, but not touching, the iron bar. It will be attracted. Remove the magnet and the pin falls.

* MG-9. Magnetic Field

A magnetic field can be traced by two methods (a) The needle of a small compass points along the magnetic field. Put a magnet on a piece of paper. Start with a compass needle near the N-pole of the magnet. Make a pencil mark in fromt of the needle. Remove the compass and place it again in such a way that the south (or the tail) is on the pencil mark. Now make a mark before the head and so on, until you trace a line of force (see fig. MG-9)

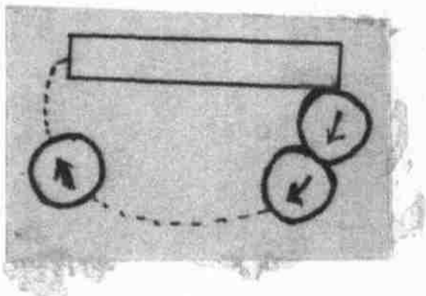
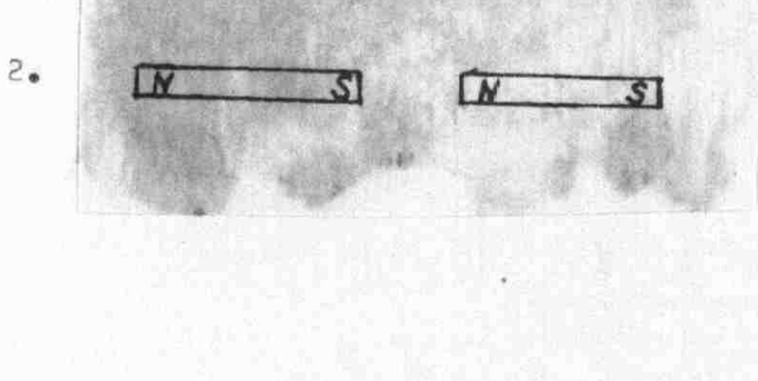


Fig. MG-9

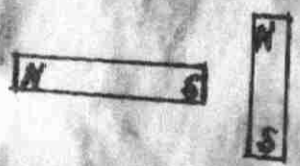
(b) Put a paper over a magnet. Sprinkle iron filings over the paper. They will arrange themselves into the shape of the magnetic field.

Find the shape of the magnetic field of the following arrangements



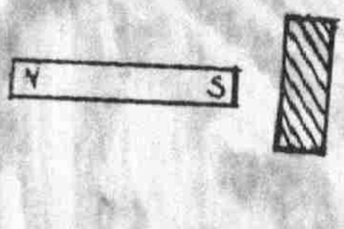
3.

4.



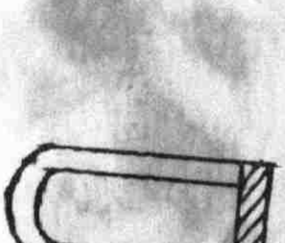
5.

6.



7.,

8.



Draw conclus$ions for each case

MG-10. Screening Effect

Tie a string to a nail or paper clip and secure to an object on the table. Let a magnet attract the clip so that it is suspended in the air without touching the magnet.

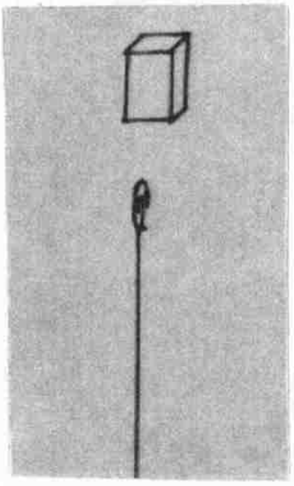


Fig. MG-10

Insert various materials like metal foils and paper and study their effect on screening.

* MG-11. Theory of Magnelization.

1. Magnetize a brittle iron rod. Check the presence of the two poles by means of iron filings.
2. Break the rod into two. Test the four ends. What do you observe about the poles.

   Put the two parts together. Do you observe any poles in the middle?

We can cut a magnet more and more and find that each piece is a magnet in itself. If these pieces are put together they form a large magnet.

Thus far we can theorize saying that a largy magnet is composed of small magnets aligned with the N- pole of one close to the S- pole of the other. On the other hand in an unmagnetized bar these small magnets - called domains - are disarranged.

Try to explain magnetization by striking (MG-3) and induction (MG-8) in terms of this theory.

3. As a result of this theory hammer a piece of iron in the magnetic field of the earth or another magnet. See if it becomes a magnet.

4. Magnetize a small pin or needle. Heat it very well. Does it loose its magnetic effect. Explain according to the theory of magnetization.

MG-12. Terrestrial Magnetism

Determine the direction of the magnetic field by using a compass needle. (See experiment MG-1)

The compass needle does not measure the vertical compoment of the magnetic field of the earth. To find the direction of the resultant magnetic field a dipping needle is used.

Take two knitting needles. Magnetize one of them by using the solenoid method (E- 26) . Insert them at right angles into a cork. Set the system on two glass tumblers with the unnagnetized needle as an axis.[1]

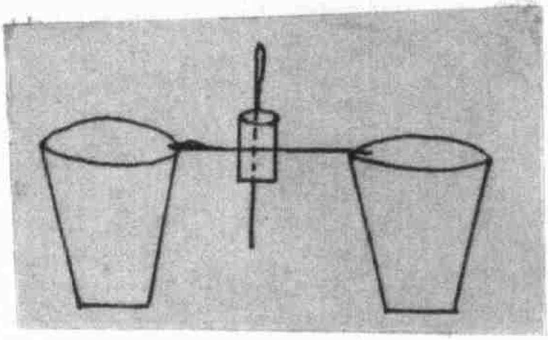


Fig. MG-12

Hold the graduated circle (G-1) parallel to the dipping needle with the axis passing through its center. Adjust the axis perpendicular to the magnetic meridian. The dip angle can be measured.

* MG-13. Strength of the Magnetic field of the Earth[2]

1. Measure the magnetic pole strength of a magnet as described in experiment MG-7. It is prefered to use the same magnet.

   Place such a magnet East West direction near a compass needle.Two forces will be acting on the needle

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[1]Joseph et al., p. 514.

[2]Adapted from Freshmen Laboratory sheets, Physics Department, American University of Beirut.

due to the magnetic field of the bar magnet and the earth. It will point in the direction of the resultant.

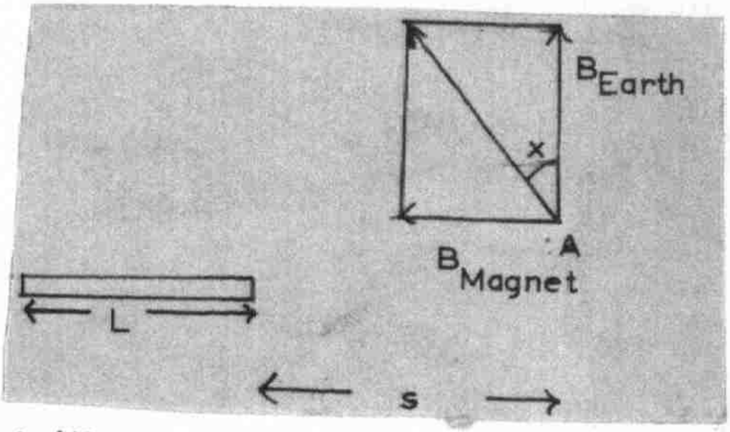

Fig. MG-13

2. The field on A (the position of the compass needle) due to the bar magnet is

$$B_m = k\frac{m}{s^2} - k\frac{m}{(s-L)^2}$$

Find B_m

3. According to the diagram calculate B_E.

4. B_E is the horizontal componant of the earth's field. Find the dip angle (see MG-12) which is the direction of the resultant field.

Find the magnitude of the resultant magnetic field of the earth. Find the vertical componant.

CHAPTER XII

E L E C T R I C I T Y

A. ELECTROSTATICS

Note The best condition for experiments of static electricity is a cold dry snappy day.

* E-1. Electrification

1. Take glass rods or glass tubes (like the ones used for medicine pills). Rub one of them with your clothes, (better with silk). Try it on bits of dust or paper. What happens?
2. Suspend the first rod. Electrify the other and bring it near to the first rod. What do you observe? What can you conclude about forces between like charges.
3. Get a rod about 20cm. long of hard rubber, lucite, or sealing wax. You might use also a comb, fountain pen,

or a ballpoint pen instead. Rub the object with fur or with your clothes if they contain wool (You can use your hair also). Does the object attract pieces of paper?

Bring the rod to the suspended glass. What do you observe. Are the two rods of the same charge? Why ?

E-2. Living Dancers

Cut men from tissue paper. Put them in a metal can and lay over it a sheet of glass. Rub the glass with silk or leather and the men will dance.[1]

E-3. Electroscope

To detect the presence of charge an electroscope is used. It must be introduced after the students are familiar with forces of attraction and repulsion between charges.

Take a wide bottle about 5 or 6cm. in diameter. Cover it with a cork of a piece of wood or hard paper. Insert through the cover a long nail reaching the middle of the bottle.

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[1] Lynde, Science Experiences with Ten-cent Store Equipment, op.cit., p. 157

Cut two strips of metal foil(like the paper used in chocolate bars or some gums or cigarette box-

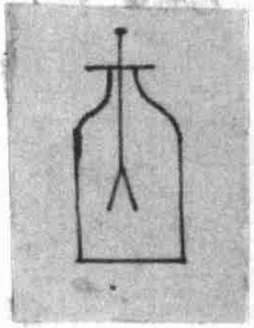

Fig. E-3

es). Make the strips about 4cm. long and ½cm. wide. Connect the strips to the end of the nail by means of an adhesive tape or glue.

Approach the head of the nail with a charged rod (see previous experiments). The leaves will repel. Touch the head with your finger and the leaves go back to their original position.

E-4. Pith Ball

Construct two pith balls as follows: Take two small pieces of cork identical in size and mass and wrap them with chocolate paper (metal foil). You can use metal foil without cork if a light ball is desired.(A ball does not have to be spherical)

* E-5. Coulomb's Law

1. Suspend two identical pith balls (see previous experiment) with strings about 10cm. long to one point in a stand.
2. Charge the two balls by contact with a charged rod (see exp. E-1) What do you notice about the behaviour of the balls.
3. Measure their masses, the distance between them and the angle. Using exp. MG-7 as a guide calculate the charge on each ball assuming they have the same charge.

E-6. Conductors and Insulators

Take several wires of different materials like copper, iron, brass etc. Take also silk, cotton and wool threads.

Connect the end of one wire to an electroscope and the other end to a piece of wood. Touch this end with a charged rod and see if the charge has been transmitted to the electroscope and deviated its leaves.

Try the same procedure with each wire and thread. Classify them into two categories: conductors and insulators.

* E-7. Induction

1. Set an electroscope with its leaves together. Approach the head of its nail with a charged rod. Do not touch it. You will notice that the leaves repel.

   What do you conclude about the charge of the leaves?

2. With the rod in place touch the nail. The leaves come together. What does that mean about the charge of the electroscope?

3. Remove your finger. Then remove the rod. What do you notice in the leaves ? Why is the electroscope charged? What charge do you think it carries? Why?

4. Check your answer in part (3) by touching the nail with a rod of the opposite predicted charge. If the leaves come together then your prediction was correct. Why?

E-8. Sparts

Scuff your shoes over a deep carpet for about 10 meters, and touch a friend. A spark will appear. Or let your clothes be brushed with rubber while you stand on 4 tumblers.[1]

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[1]Lynde, <u>Science Experiences with Ten-cent...</u>, <u>op.cit.</u>, p. 154.

B. CURRENT ELECTRICITY

E-9. Electric Circuits

When electricity is introduced no doubt that the students are anxious to know how the electric connections are made to make a bulb light. Those that have an idea about it will be building upon an established experience which makes the learning process more efficient.

Give the students a 1.5 v dry cell used in flashlights, some short wires, and a bulb. Ask them to try to make the bulb light. With this experiment it will be found that one needs a battery (power supply) and a metal wire connecting the battery to the lamp and then the other end of the lamp to the battery. The students can observe the presence of a wire in the bulb. The concept of a complete circuit must be stressed as a result of this experiment.

* E.10 Conductors and Insulators

1. Connect a bulb to a battery by means of a copper wire? Does the bulb light?

2. Try different connections like iron, aluminum, paper. (They do not have to be wires; they can be sheets or any other shape.) You can also try silk, cotton or wool threads.

Which of the above are conductors? Compare your conclusion with exp. E-6 in electrostatics.

3. Construct a circuit as shown in fig. E-10. Use any container to hold water (Do not let the wire touch the container if the latter is a metal. Why?) Connect the wires to two copper plates and dip them in water.

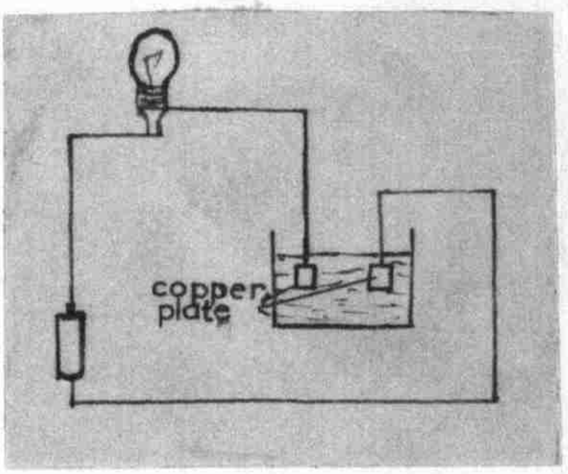


Fig. E-10

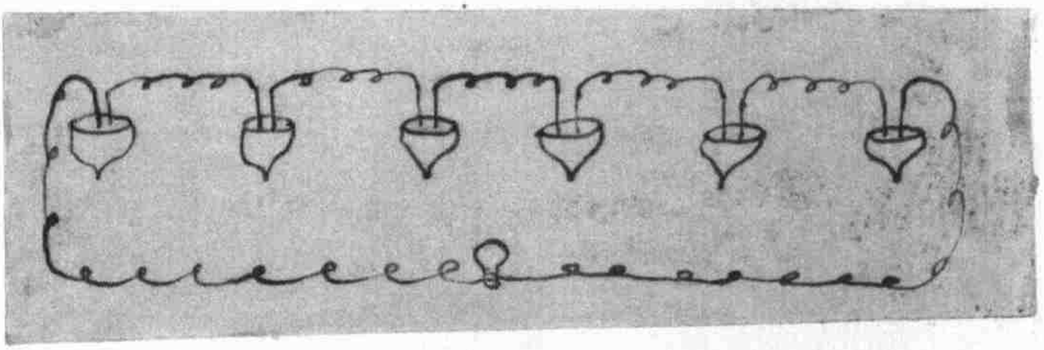
Does the bulb light? Is water therefore a conductor of electric current?

4. Add salt or lemon juice to the water. Is the solution a conductor?

E-11. Voltaic Cell of Lemon

Cut 3 or 4 lemons into half. Press in each half a copper plate and a zinc plate. Connect the copper plate in one to the zinc plate in the other. Connect the combination to a flashlight bulb.

Fig. E-11



If the bulb does not light replace it by a galvanometer. (For the construction of a galvanometer see E-32)

E-12. Voltaic Cell with Acid

If sulfuric acid is available (It can be obtained from technical shops for the electricity of cars) you can construct a different cell with the same principle. If the acid is concentrated dilute it with four parts of water to one part of the acid (Pour the acid into the water. Do not reverse the process)

Dip two electrodes of copper and zinc in the acid. (These are cut from thin rods with a length from 10 to 15cm.) Connect the electrodes to a galvanometer. It will deflect showing the existance of a current.

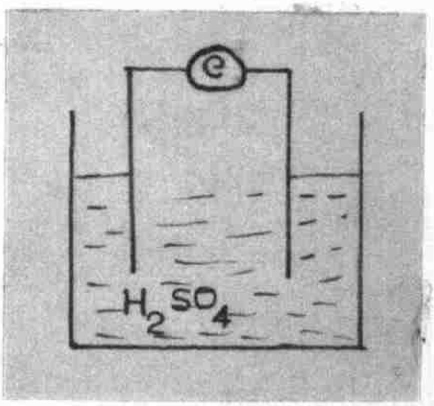


Fig. E-12

E-13. Dry Cell

Obtain an "empty" dry cell used in flashlights. Cut it in a longitudinal crosssectional way and show the parts to the students. Build your explanation on their concept of the voltaic cell.

E-14. Storage Cell

Dip two lead electrodes in a glass tumbler containing a solution 30% sulfuric acid. Connect the electrodes to two or three dry cells put in series for about 10 minutes. Disconnect the electrodes from the cells and connect them to a 1.5 volt bulb (flashlight bulb) or to a galvanometer. Current is detected.

If sulfuric acid is not available you can replace it by baking soda put in hot water.[1]

E-15. Resistance

Take a very thin wire about 1 meter long and wind it around a glass tube. Leave the ends free for connections. Coils used in experiments on electromagnetism can be also used as resistors.

The concept of resistance can be introduced as something that resists the flow of current.

Connect a lamp to a cell. You get a certain brightness. Insert into the circut a resistance. The brightness of the bulb will decrease.

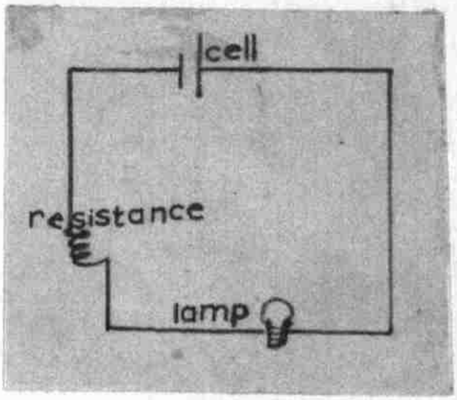


Fig E-15

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[1]Lynde, Science Experiences with Home Equipment, op.cit., p. 189.

E-16. Resistance and Temperature

Heat the resistance in the previous experiment and the lamp goes off. This shows that resistance increases with temperature. (This experiment does not work for all substances)

* E-17. Resistance and Length.

1. Stretch a thin wire over a meter stick. Connect one end in series with a galvanometer[1] and a dry cell. The other end of the circuit is free to move on the wire.

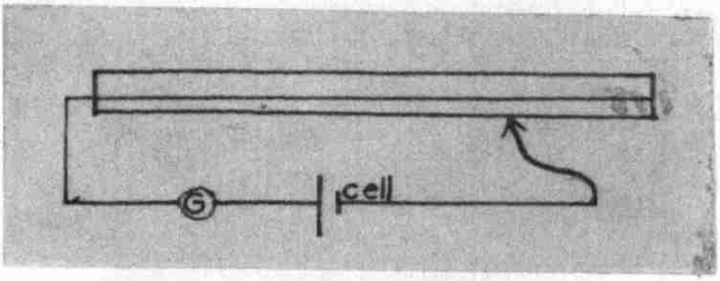

Fig.E-17

2. Start moving the free end from one end of the wire to the other end. From the deviation of the galvanometer you can tell that the resistance depends upon the length of the wire.

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[1]For the construction of a galvanometer see E-32.

3. Replace the thin wire by a thicker one. What do you notice in the deviation of the galvanometer? How does the resistance depend upon the thickness of the wire?

E-18. Rheostats

The system of wire on the meter stick in exp. E-17. serves as a rheostat. The wire between the fixed end and the point of contact with the movable wire is the resistance used. So, changing the position of the movable wire changes the value of the resistance.

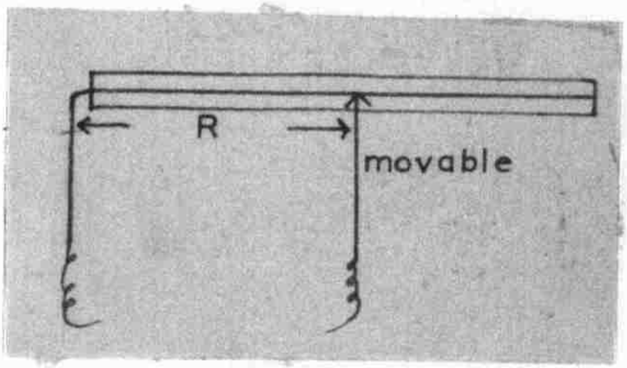


Fig. E-18

E-19. Ohm's law: Qualitatively

Arrange a circuit as shown in fig.E-19. You get a certain deflection in the galvanometer. Use a battery with a stronger voltage or use two batteries in series, you will notice that the deflection in the galvanometer is more. This shows that the current is directly proportional to the potential difference.

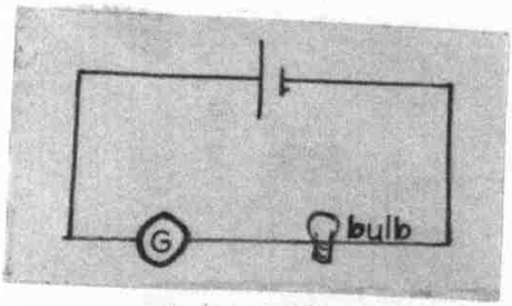


Fig. E-19

E-20. Heat Effect

This effect can be manifested by connecting a thin wire about 10cm. long and about half as thick as the carbon in a pencil to a dry cell. Feel the wire after some time . It is hot.

Connect the wire to two cells and you see that it gets hot quicker.

Connect a bulb to the cell or cells and feel it after some time. Observe the presence of light and heat together. The teacher must introduce here the principle of incandescent lamps.

* E-21 Lamps in series and Parallel

1. Connect a lamp to a 1.5 volts dry cell. Remove it and connect in its place a similar one, Is the current the same in both? Is the potential difference the same ? Why?

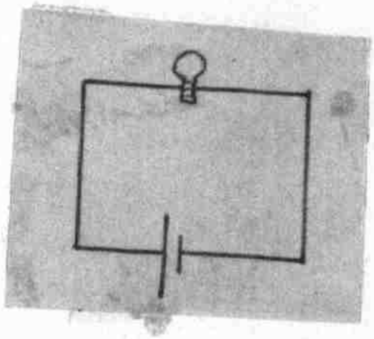


Fig. E-21a

2. Connect the two bulbs in series with the battery. What do you notice about their brightness? Is the power in each more or less than in case (1)? Is the current more or less ? What proportion? Answer the same question with respect to potential difference. What happens if you remove one bulb?

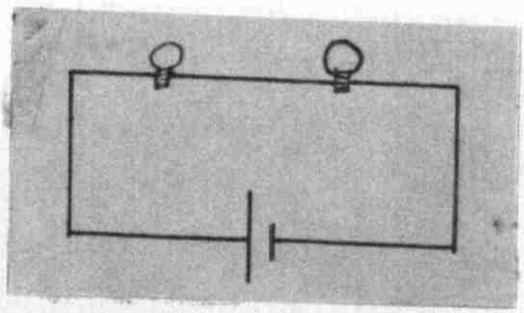


Fig. E-21b

3. Arrange the two bulbs in parallel and connect them to the cell. What do you notice about their brightness? What is the potential difference across each bulb compared with case (1)? What is the current in each ? What happens if you remove one bulb?

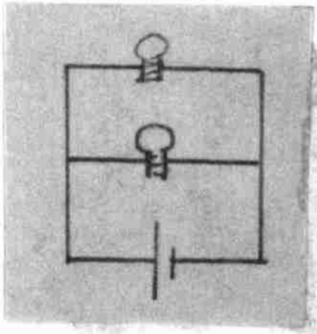
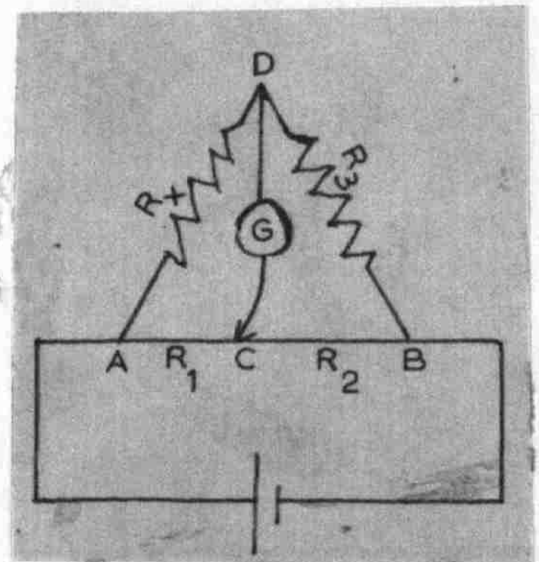


Fig. E-21c

4. According to your observations in this experiment , give reasons why bulbs are used in parallel in household circuits.

E-22. The Wheatstone Bridge

Fig. E-22



Refering to fig. E-22 an unknow resistance Rx can be balanced against the other resistances by changing R_1 and R_2 (R_3 being fixed) so that the galvanometer reads zero (no deflection).In this case

$$R_x = \frac{R_1}{R_2}$$

But it R_1 and R_2 are parts of the same wire their resistances depends upon their length, thus

$$R_x = R_3 \frac{L_1}{L_2}$$

R_1 and R_2 is a wire of the thickness of a needle stretched on a meter stick.

R_3 is a known resistance. It can be a 1.5 volt bulb. You can find its resistance by reading on it the voltage and current and dividing V by I. R_x is a resistance like the one used in exp. E-16, or it can be another bulb. G is a moving coil galvanometer constructed according to exp. E-32

Use two or three dry cells in series as a source of electricity.

To measure R_x, you slide point C until you get no deflection in the galvanometer. Then apply the formula.

Experiment.

1. Set up the circuit as described.

2. Measure the resistances of two unknow resistances one at a time.

3. Measure the resistance of the two unknown resistances when they are in series. Is the result as expected?

4. Measure the resistance of the two in parallel. Is the result as expected?

* E-23. Potentiometer

The potentiometer is a method to find the emf of a cell.

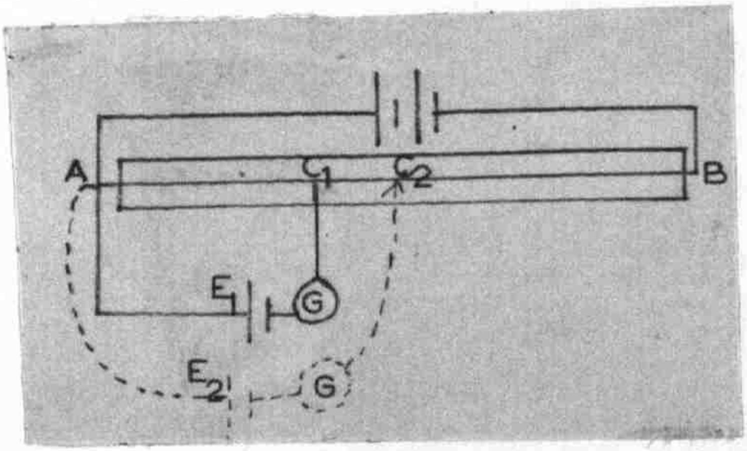


Fig. E-23

1. Set a wire along a meterstick as in previous experiment (E-22). Connect it to two cell in series. As in the fig. E-23, connect another cell with a known emf in series with a galvanometer to the first circuit.

Move the sliding point C so that there is no deflection in the galvanometer.

Find an expression relating E, to V_{AC_1}

2. Remove E, and put another cell which you want to measure its emf. Move the point C to a position C_2 so that there is no deflection in the galvanometer. What is true about E_2 and V_{AC_2} ?

3. Knowing that

$$\frac{V_{AC_1}}{V_{AC_1}} = \frac{AC_1}{AC_2}$$

You can find E_2 .

E-24. Magnetic Effect of a Current

Place a card-board on the ring of a stand or between two books or tables. Pass a thick wire vertically through it and connect it to a battery for a very short time. Detect the presence of a magnetic field by spinkling iron filings on the cardboard. Tap gently on the board and the iron filings arrange themselves in circles. You can find the direction of the field by using a compass. (See exp. MG-1)

E-25. Magnetic effect of a current in a coil

Wind loosely on a bottle or can 5cm. in diameter about 50 turns of thin insulated wire to make a coil. The wire must be about twice as thick as a human hair. Remove the coil and hold the turns with an adhesive tape or tie them together with a string or a piece of wire. Make two slots in a cardboard so that the coil can enter through them.

Connect the coil to a dry cell. Sprinkle some iron filings and tap the cardboard gently. The filings will shape themselves in the direction of the magnetic field.

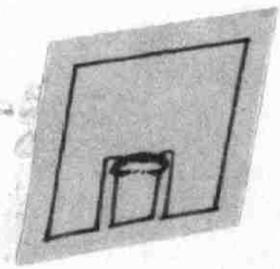


Fig. E-25

E-26. Solenoid

Take a cardboard tube about 15cm. long and 2cm. in diameter. Take two wooden disks about 10cm. in diameter. Drill in them two circles and insert the ends of the tube in them. (Fig. E- 26)

Wind about 500 turns of a thick insulated wire on the tube.

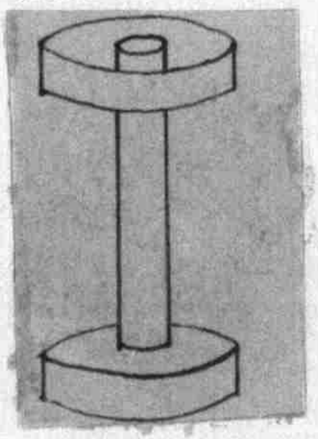


Fig. E-26

Connect the ends of then wire to 4 or 5 dry cells in series. Check the ends of the solenoid for the presence of a magnetic field.

Pass an iron rod into the tube. See if the magnetic field increases.

This solenoid is used to magnetize steel and iron rods. Put the rod in the tube for sometime, along the axis of the solenoid and it will magnetize.

E-27. Tangent Galvanometer.

The coil with the cardboard used in the previous experiment is put in the plane of the magnetic meridian. A compass needle is placed at the center of the coil (on the cardboard) When a current passes through the coil a magnetic field is produced perpendicular to that of the earth. The compass needle deflects to point in the direction of the resultant field.

E- 28 Electromagnet

Take a bolt about 5 cm. long and ½cm. thick with a knot on one side and two washers on the two sides. Wind on the screw about 5-7 layers of insulated wire of the thickness of a clothespin. Connect the ends of the wire to a dry cell and the bolt becomes a magnet. Disconnect the battery and the bolt is no more a magnet.

E-29. Telegraph

Fix the electromagnet described in the previous experiment (E-28) to a table by mean of an adhesive tape. Put nearit a book a bit higher than the electromagnet. On the book put a piece of tin or iron like a forceps or a knife so that its end is just above one pole of the electromagnet . Put a bottle or a similar object below the metal strip, but not touching it, so that when the strip vibrates, it touches the bottle before the electromagnet. Connect one end of the electromagnet to a battery and the other end to a long wire. Connect the other end of the battery to another long wire. When the ends of these wires touch the electromagnet is magnetized. It attracts the metal strip which touches the bottle and gives a noise. When the circuit is open the noise stops.

A code of short and long pulses is used to send letters in the telelegraph.

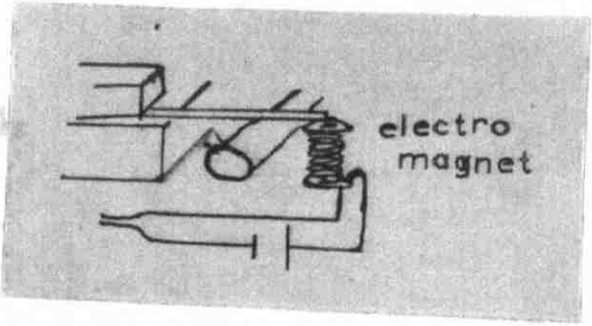


Fig. E-29

E-30. Force on a Conductor

Pass a wire between the poles of an electromagnet. Connect it to a battery. If the poles are right, the wire will jump.

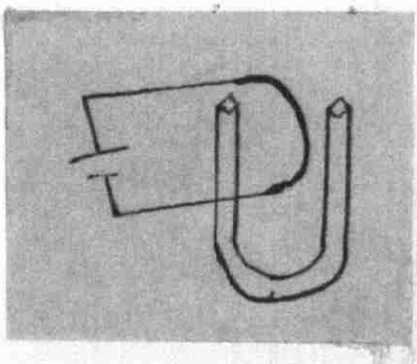


Fig. E-30

E-31. Motor

Take a bolt about 6cm. long and 3/4cm. in diameter. It would be better to get a longer bolt and cut most of the threaded part. Drill a hole midway between the two ends and pass a rod about 20cm. long and 2 or 3 mm. thick. Let the bolt rest at about 8cm. from one end. Insert a knot into the end of the bolt and two washers on both ends (from the inside.)

Take about 10 meter of insulated copper wire with a thickness of a needle or a bit more. Wind the wire on the screw into five layers. Leave about 15cm. from each end for connections.

Use a cork or spool or a rounded piece of wood for a commutator. It must be about 1cm. in diameter. Fix two thin sheets of copper to the commutator with about 2mm. space between them on both ends. Use glue, duco cement, or small nails for this purpose.

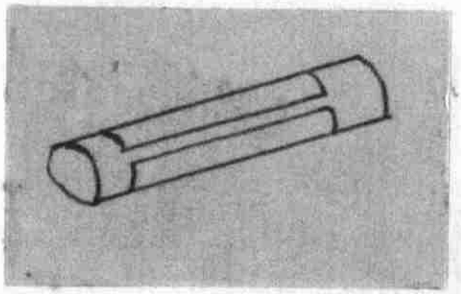


Fig. E-31

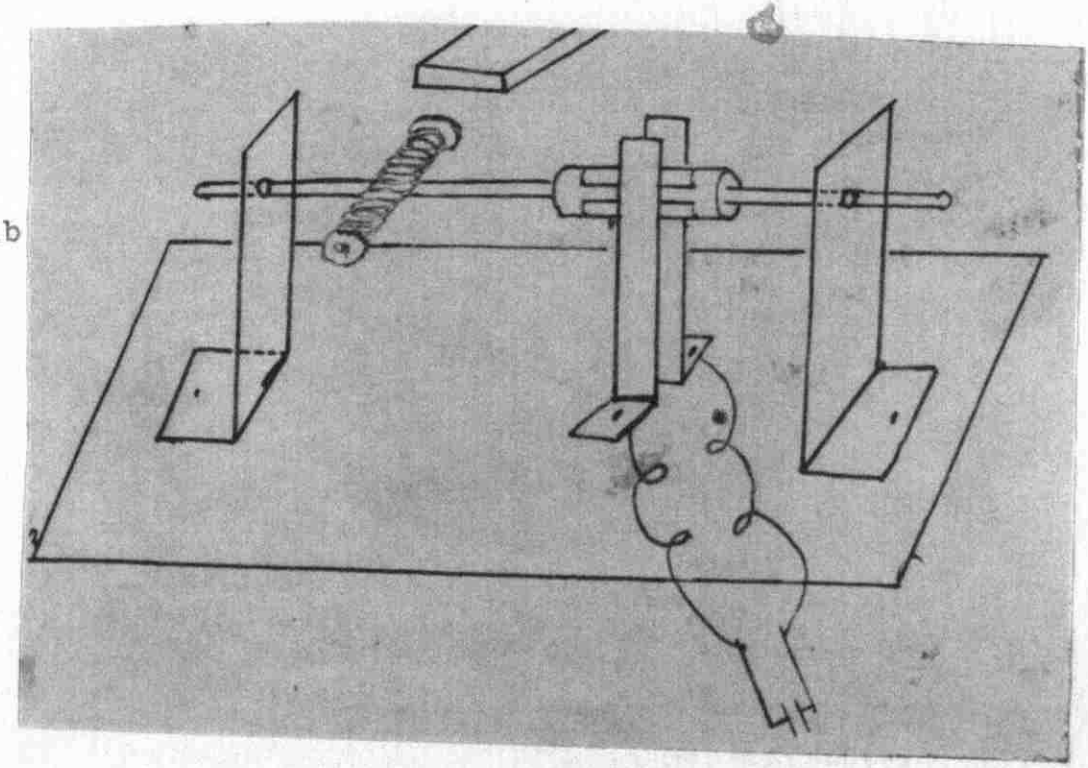
Insert the axis through the commutator until it is about 5 cm. from one end of the rod. Connect the free ends of the armature to the copper foils of the commutator. (Do not forget to remove the insulator from the wire). The spaces between the foils must be lined with the armature.

Cut two metal strips 9cm. long and 2 cm. wide. Bend them 3 cm. from one end and drill a hole in each long face 1cm. from the edge. Fix these strips along one line on a block of wood about 13cm. apart. Pass the axis of the motor through the holes.

Cut two strips of copper 9 x 1 cm. to be used as brushes. Bend 3 cm. from each and nail them to the piece of wood to touch the commutator gently but enough to conduct current. Connect the two brushes to a 1.5 or 3 volt battery.

Take a horseshoe magnet and place it such that the armature runs freely in it. If such a magnet is not available hold a strong magnet in a horizontal position near one pole of the armature.

Fig. E-31b



The motor might not turn for the first time. The brushes have to be well adjusted. When it turns, if the axis moves out of place, wind a rubber band outside the supporting posts.

E-32. Moving Coil Galvanometer[1]

Wind a thin wire(twice the thickness of a hair) into a retangular coil with 50 turns. Its size must be in such a way to move freely inside the horse-shoe magnet that you have. Wind the ends of the coil around a pencil to make a suspension spring. A soda straw is attached to the top of the coil at its center to act as a pointer.

A support is made as shown in fig. E-32b. The coil is suspended with its spring and held to the base by a string or a loose wire. A scale can be made with arbitrary units, just for comparison of currents passing through the galvanometer.

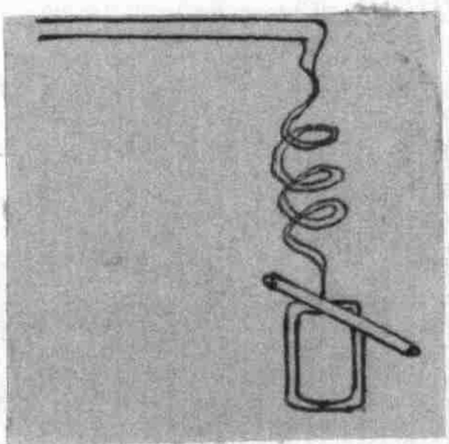
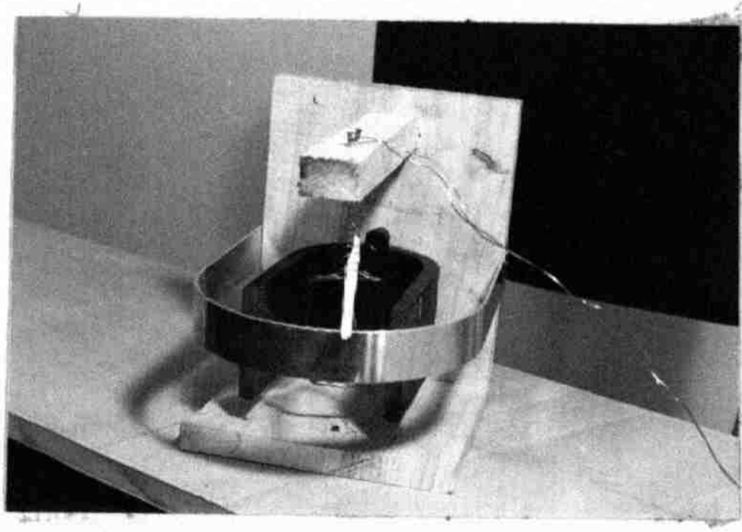


Fig. E-32a

[1]T. Miner, (ed), Physics Handbook, (Albany: The New York State Education Department, 1959), p. 160.

Fig. E-32b



E-33. Induced Current

Connect the coil used in exp. E-25 to a demonstration galvanometer like the one discussed in E-32. Pass a bar magnet through the coil. The galvanometer deflects showing the presence of an induced current.

E-34. Electric Swing

The electric swing demonstrates the principle of generator and motor at the same time.

Connect two coils (as those of exp. E-25) with two conductors over the bars of two stands. Place two magnets on blocks of wood so that their poles are on the centers of the coils. Swing one coil and you see that the second swings. Stop the first; the second stops.

As one moves an induced current is formed which flows to the other coil. Since it is in a magnetic field, it experiences a force and thus it swings.

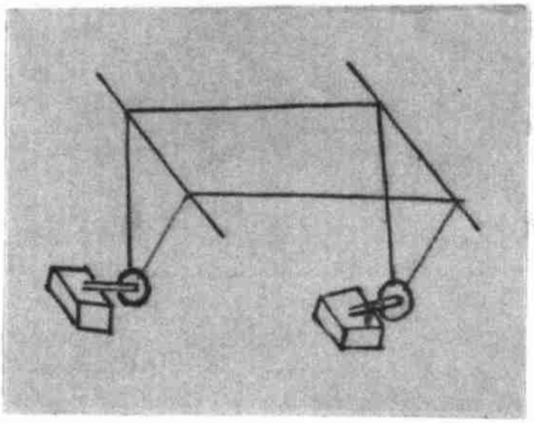


Fig. E-34

PART III

APPENDIXES

APPENDIX I

LIST OF MATERIALS USED IN THE KIT

A teacher can follow two procedures in building up the kit. He can construct the pieces experiment by experiment while he is teaching the course through the year. He can also collect the material all at one time, using the material collected he starts constructing and experimenting in the appropriate time.

If the teacher wants to follow the first procedure the "guide" (chapters VI-XII) provide him with sufficient information. If he likes to follow the second procedure, a list given below describing the kind materials needed and their quantity, will be helpful. The list is arranged in an alphabetical order.

Material	Quantity
1. Adhesive tape or glue	200 c.c.
2. Alcohol	200 c.c.
3. Aluminum	
a. Strips 1) 20 x 1 cm.	1
2) 26 x 1 cm.	1
3) 6 x 2 cm.	1
4) 50 x 2 cm.	1

Material	Quantity
5) 12 x 2 cm.	1
6) 50 x 3 cm.	1
7) 9 x 2 cm.	2
8) 10 x 3 cm.	2
b. Sheet 20 x 20cm.	1
4. Baking soda	1 packet
5. Balloon	1
6. Battery, dry	5
7. Bicycle pump	1
8. Bolt with nuts and washers	
a. 5 cm. long	3
b. 10 cm. long	1
9.Bottle	
a. 100 cc. capacity	1
b. 20 cc. capacity	1
c. c. retangular	1
d. large	1
10. Bottle caps	3-4
11. Brass rod (20cm. long- $\frac{1}{4}$cm. diameter)	1
12. Bulb (1.5 volts)	2
13. Button (diameter 2 cm.)	1

Material	Quantity
14. Campher - pieces	20 gr.
15. Candle	1
16. Cane (hollow)	1
17. Cardboard	
a. sheets 1) 25 x 25 cm.	1
2) 30 x 3 cm.	1
3) 10 x 5 cm.	2
4) 20 x 20 cm.	3
5) 20 x 20 cm.	2
b. tube (1.5cm. in diameter)	1
c. 15cm. (2cm. diameter)	1
d. cone	1
e. small box	2
18. China ink	1 bottle
19. Clay (molding)	1 block
20. Cloth	
a. sheet 20 x 20 cm.	1
b. fine cloth 10 x 10 cm.	1
d. White piece 10 x 10 cm.	1
21. Clothespin	2
22. Comb	1
23. Compass needle	1

Material	Quantity
24. Copper	
a. electrodes 10 x 2 cm.	3
b. rod 20cm x ¼cm.	1
c. strips 1) 2 x 1 cm.	1
2) 18 x 1 cm	1
d. sheet 20 x 20	1
25. Cork	5
26. Cotton	5 gr.
27. Egg.	
a. raw	1
b. hard boiled	1
28. Eye of a bull	1
29. Flashlight	1
30. Fork	1
31. Gelatin sheets 15 x 20 cm.	3
32. Glass	
a. plates 1) 6 x 2 cm.	2
2) 20 x 30cm.	2
3) 40 x 50cm.	1
b. tube 20 cm. x (1cm. diameter)	1
c. tube open on both ends - 15 x (3cm.diameter)	1

Material	Quantity
d. jar	1
e. rod	2
33. Hammer	1
34. Hair (long)	1
35. Ice	
a. cubes	3
b. block 25 x 15 x 15 cm.	1
36. Iron	
a. filings	100 gr.
b. soft rod 15 cm.	1
c. brittle rod	1
d. ring 10 cm. diameter	1
37. Knife	1
38. Lead	
a. shot	200 gr.
b. plates 15 x 2 cm	2
39. Lemon	4
40. Magnet	
a. horse-shoe	1
b. bar	2
41. Marble	2

Material	Quantity
42. Match	
a. box	1
b. stick	1
43. Medicine dropper	1
44. Metal foils from gums or chocolate bars	5
45. Metal	
a. rod 1) 40 cm. x 1 cm. diam.	2
2) 20 cm. x 3/4cm.diam.	1
3) 40 cm. x3/4cm. diam.	1
4) 30 cm. x $\frac{1}{4}$ cm. diam.	1
b. strip 30 x 1	1
c. balls (2 -3cm. diameter)	2
46. Meterstick	1
47. Milk	few drops
48. Mirror	
a. plane 10 x 7 cm.	1
b. plane 1 x 1 cm.	1
49. Motor - electric toy	1
50. Nail	
a. 15 cm. long	1
b. 4 cm. long	10
51. Needle	4
52. Oil	20 cc.

Material	Quantity
53. paper	
a. large sheet 100 x 50	1
b. legal size	10
54. Paper clip	1
55. Perfume	3c.c.
56. Pencil	
a. thick	1
b. with eraser	1
57. Pin	4
58. Potato	1
59. Razor blade	1
60. Rubber	
a. sheet 1) 3 x 3	2
2) 15 x 15	2
b. bands	6
c. tubing 50 cm. long	1
d. rods 25 cm. long	2
(can be replaced by combs)	
61. Salt	100gr.
62. Sand	500gr.
63. Screw	10
64. Sewing thimble	1

Material	Quantity
65. Silk cloth 20 x 20 (not essential)	1
66. Soup	20 gr.
67. Soda straw	5
68. Spool	2
69. Spoon (polished)	2
70. Spring 20cm. long	1
71. Steel	
a. rod 1) 15 cm. long	2
2) 20 cm. x ($\frac{1}{4}$ cm. diameter)	1
b. strip 1) 6 x 1 cm.	1
2) 60 x 1 cm.	1
72. String (strong)	25 meter
73. Sulfuric acid	1 leter
74. Thermometer	1
75. Thread	50 cm.
76. Tissue paper	2
77. Tin	
a. can cover 10 cm. diameter	1
b. can 10 cm. high x 10 cm. diameter	5
c. can 8 cm. high x 5 cm. diameter	2
d. can 3 x 2 x 0.5 cm.	1

Material	Quantity
78. Trough	1
79. Tumbler (glass)	2
80. Vinegar	300 c.c.
81. Watch glass	6
82. Weights	
a. 200 gr.	2
b. 100 gr.	2
c. 50 gr.	2
d. 10 gr.	2
Other weights are preferable bu no essential	
83. Wheel 3cm. in diameter	4
84. Whistle	1
85. Wire	
a. bare and hard	150 cm.
b. iron	50 cm.
c. brass	50 cm.
d. wire connections	11 meters
e. very thin	9 meters
f. thin (not insulated)	100 cm.
g. thick wire (thickness of needle)	20 meters
h. thicker wire	15 meters
i. wire with high coefficient of expansion	50 cm.

Material		Quantity
86. Wood		
a. sheet		
	1) 20 x 15 cm.	1
	2) 15 x 15 cm.	1
	3) 10 x 10 x 4 cm.	1
	4) 30 x 12 cm.	1
b. bar	1) 15 x 2 cm.	2
	2) 50 x 5 cm.	1
	3) 40 x 2 cm.	1
	4) 15 x 10 cm.	1
	5) 4 x 4 x 4 cm.	1
	6) 35 x 4 x 2 cm.	1
	7) 15 x 2 x 2 cm.	1
	8) 6 x 4 x 2 cm.	1
	9) 10 x 2 x 2 cm.	1
	10) 3 x 4 x 2 cm.	1
c. thin wood		
	1) 20 x 2 cm.	1
	2) 8 x 2 cm.	2
d. disk - Diameter		
	1) 10 cm.	1
	2) 25 cm.	1

Material	Quantity
3) 5 cm.	2
e. block 4 x 4 x 5	2
f. ruler	1
g. wedge	1
h. bar	110 cm.
i. dowel 6cm long x 1.5 diameter	1
j. ring (flexible) 25 cm. diameter	1
k. box 30 x 10 x 8 cm.	1
87. Yo-yo	1
88. Zinc electrodes 15 x 2 cm.	3

APPENDIX II

HOW TO ASSEMBLE THE KIT

After the kit is constructed according to the "guide" in PART II, it must be assembled in a neat way. When it is put in order, the teacher can pick up the item he wants without loss of time in searching. Moreover, when the kit is assembled in a compact form, it can be carried from one place to another without much difficulty.

In assembling the kit, one can follow two procedures. The teacher can design a wooden case specially for the kit, in which case he can use its cover for the inclined plane (M-16). The disadvantages of this procedure are that the box will be too heavy to carry around, and more expensive than the material put in it.

Following the second procedure, the teacher can buy a ready-made suitcase and add to it some constructions. The second procedure is discussed below in details.

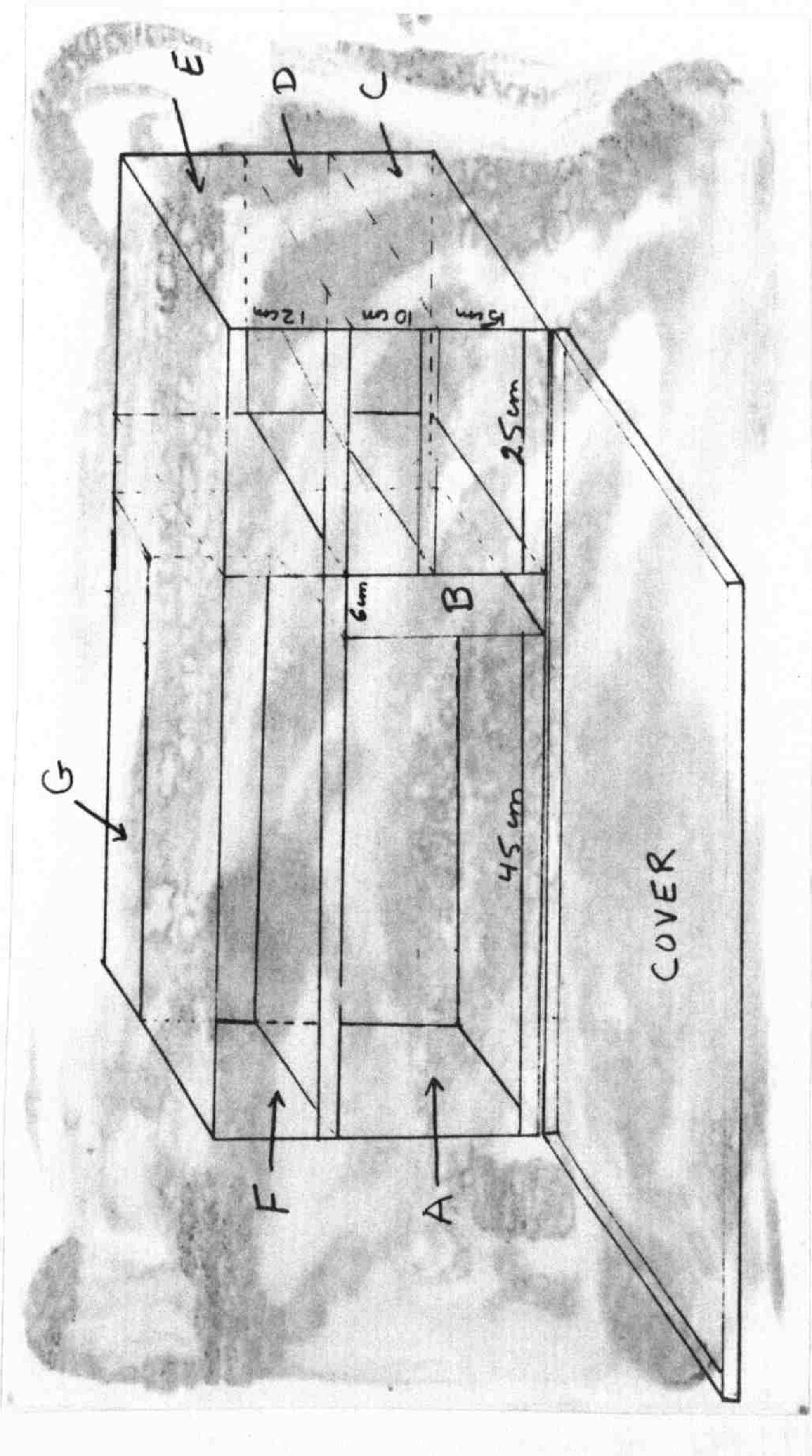


Fig. A-1.

General Construction

Buy a tin or cardboard suit case of the size of about 75 x 40 x 25 cm. (Usually the width is less than 40 cm). Cut a slot in the upper narrow face near the handle of the same dimensions as the face of the ripple tank. Divide the box into compartments as shown in figure A-1. Fix to the front edges of the shelves strips of thin wood or hard cardboard to prevent the material from falling. The width of these strips can range from 4 to 6 cm. With this arrangement, you will have seven compartments to assemble to the material in.

Assemblage of Materials

Below are lists of the materials included in every compartment. Within the compartment, the arrangement is left to the teacher.

Compartment A

Balance

Base of the micrometer

Block of wood of M-22

Cart

Expansion apparatus (H-3) - or in comp. F

Large bottle

Ring for M-6

Rubber Tubing

Weights

Compartment B

Force table

Gelatin paper

Paper (all types needed)

Sheets of copper and aluminium

Stroboscope

Tissue paper

Compartment C

Bottles and cans

Conductivity apparatus (H-16)

Sand

Support of galvanometer

Trough

Compartment D

Appratus of S-5

Batteries

Ballpoint pen

Cardboard tubes

Carton box

Coils

Comb

Cork

Dowel

Flashlight

Force pump

Handle of stroboscope

Hydrometer

Lamps and socket

Lift pump

Match box

Pencil

Potato

Spinning wood

Solenoid

Wires

Wood for parallax viewer

Wooden blocks

Wooden wedge

Yo-yo

Compartment E

Adhesive
Alcohol
Baking soda
Balloon
Button
China ink
Clay
Cloth pieces
Clothes pin
Campher
Candle
Compass needle
Dropper
Glass plates (small)
Hair
Knife
Metal foils (from gums)
Needles
Oil
Perfume
Pins
Plane mirrors
Razor blade
Rubber bands
Rubber sheets
Salt
Sewing thimble
Soap
Soda straws
Spoons
Strings
Thermometer
Vinegar
Watch glasses
Whistle

Compartment F

Balls

Bicycle pump

Bottle caps

Electrodes

Hard wire

Iron filings

Lead shots

Magnets

Marbles

Metal blocks

Metal rods

Metallic strip with base of M-20

Motor

Paper clip

Ping pong balls

Pulley

Pulleys of force table

Screws and nails

spools

Spring

Stands

Compartment G

Glass plates (large type)

Ripple Tank and its accessories

Cover

On the inside of the cover one can hang the following:

Hard paper of M-26

Hot air wheel

Inclined plane board

Meter stick

Wind wheel

Wooden ruler

APPENDIX III

SOURCES OF FREE MATERIAL[1]

American Can Co., 100 Park Ave., New York 17, N.Y.

American Cancer Society, 47 Beaver St., New York 14, N.Y.

American Dental Association, 222 E. Superior St. Chicago 11,111.

American Forest Products, 1816 N St. NW., Washington 6,D.C.

American Gas Association, Educational Service, 420 Lexington Ave., New York 17, N.Y.

American Heart Association 44E. 23rd St., New York 10, N.Y.

American Nature Association, 1214 16th St. NW., Washington 6, D.C.

American Optical Co., Instrument Division, Buffalo 15, N.Y.

American Potash Institute, 1102 16 St. N.W. Washington 6, D.C.

Bausch & Lomb Optical Co., 1635 St. Paul St. Rochester 2, N.Y.

Borden Co., Educational Service, 350 Madison Ave., New York 17, N.Y.

Bristol-Myers Co., 630 5th Ave., New York 20, N.Y.

Church and Dwight, 70 Pine St., New York, N.Y.

Cinchona Products Institute, 10 Rockefeller Plaza, New York 20, N.Y.

Corning Glass Works, Public Relations Dept., 718 5th Ave., New York 19, N.Y.

Crown Zellerbach Corp., Rincon Annex, Box 3475, San Francisco, Calif

Diamond Crystal Salt Co., St. Clair, Mich.

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[1]Nathan S. Washton, Science Teaching in the Secondary School, (New York: Harper and Brothers, 1961), p. 262.

Dow Chemical Co., Midland, Mich.

General Foods Corp., 250 Park Ave., New York 17, N.Y.

Johnson & Johnson Co., Education Dept., New Brunswick, N.J.

Metropolitan Life Insurance Co., School Service Dept., 1 Madison Ave., New York 16, N.Y.

National Audubon Society, 1130 5th Ave., New York 28, N.Y.

C. Pfizer Co., 11 Bartlett St., Brooklyn 6, N.Y.

Upjohn Co., Kalamazoo, Mich.

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